VEGETATION-SOIL RELATIONSHIPS IN SOME *ARTEMISIA* TYPES IN NORTHERN HARNEY AND LAKE COUNTIES, OREGON

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VEGETATION-SOIL RELATIONSHIPS IN SOME *ARTEMISIA* TYPES IN NORTHERN HARNEY AND LAKE COUNTIES, OREGON

INTRODUCTION

As early as 1927, Kittridge (48, p.565) recognized the need for a basic correlation between vegetation and soils. He emphasized the value of these correlations, as developed by soils men and plant ecologists, in facilitation resource inventory work as a sound basis for management.

The fact that land managers are seeking to identify and characterize the "range site"[1] demonstrates that no one has yet published a widely accepted method which will provide an understanding of the landscape and subsequently enable a widespread application of synecological knowledge to land management problems. This understanding cannot be accomplished by the study of a single species or of a single environmental factor alone; it can be attained through the study of community ecology (2, 18, 21, 27, 28, 66, 82).

A similar approach was used in this investigation. The fundamental units of the landscape were identified

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1 A range site is a "specific soil and climatic complex associated with a particular climax vegetation" (28).

and characterized by the combined study and interpretation of vegetation and soil. The soils were interpreted according to the series and phase concept (87, pp.277-284), and the vegetation was interpreted according to the poly-climax philosophy of Tansley (79). This enables subdivision of the landscape into its natural units, referred to as "habitat types"[2].

Autecological or synecological data taken and interpreted in this manner are most useful to the land manager because the information is identified with the natural ecological units of the landscape--the habitat types. In this author's opinion, such an approach provides a better basis for understanding the minimum biological units which have similar inherent capabilities and which react similarly under management practices. In like manner, research results can be most safely generalized on the habitat type basis.

The results obtained from the Squaw Butte Experiment Station near Burns, Oregon, could not be generalized in such a manner because the synecology of this area was not known in sufficient detail. It therefore seemed desirable

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2 A habitat type has been defined by Daubenmire (21) as "the collective area which one association occupies or will come to occupy as succession advances", and thus denotes an ultimate unit of the effective environment. It is synonymous with a specific ecosystem.

to identify and characterize the habitat types in the service area of this station--thus providing for the extension of results to equivalent environments and thereby increasing the value of research contributions from this station. Through this approach ecology can attain wider recognition and usefulness to the land manager.

The immediate objectives of this project were:

(1) to determine the habitat types represented in the immediate study area,

(2) to characterize the more important habitat types as to modal vegetation, soil, and physiographic features,

(3) to develop vegetation-soil guides for use in identification of each habitat type, and

(4) to determine, on a reconnaissance basis, the relative extent of the habitat types studies.

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DESCRIPTION OF STUDY AREA

The Squaw Butte Experiment Station is located about 40 miles west of Burns in Harney County in southeastern Oregon. The elevation of the area varies from 4,500 to 5,200 feet above sea level. Figure 1 shows a general landscape view in the study area.

An area of approximately three by six miles on and surrounding the station was sampled intensively and reconnaissance was conducted in an area of approximately 400 square miles around the station (Figure 2).

The sagebrush (*Artemisia* spp.) semi-desert range is predominantly a sagebrush-bunchgrass type intermixed with Juniper (*Juniperus occidentalis*). This general type of range is typical of many millions of acres of private, county, state, and federal lands in the intermountain region, southeastern Washington, and northeastern California.

History

The history of Harney County is interestingly presented by Brimlow (11). The history of the immediate study area has been briefly described by Lavell (49). Lands suitable for cultivation were homesteaded in the early 1860's. However, large-scale cattle operations did

Figure 1. General landscape view of the northern part of the study area.

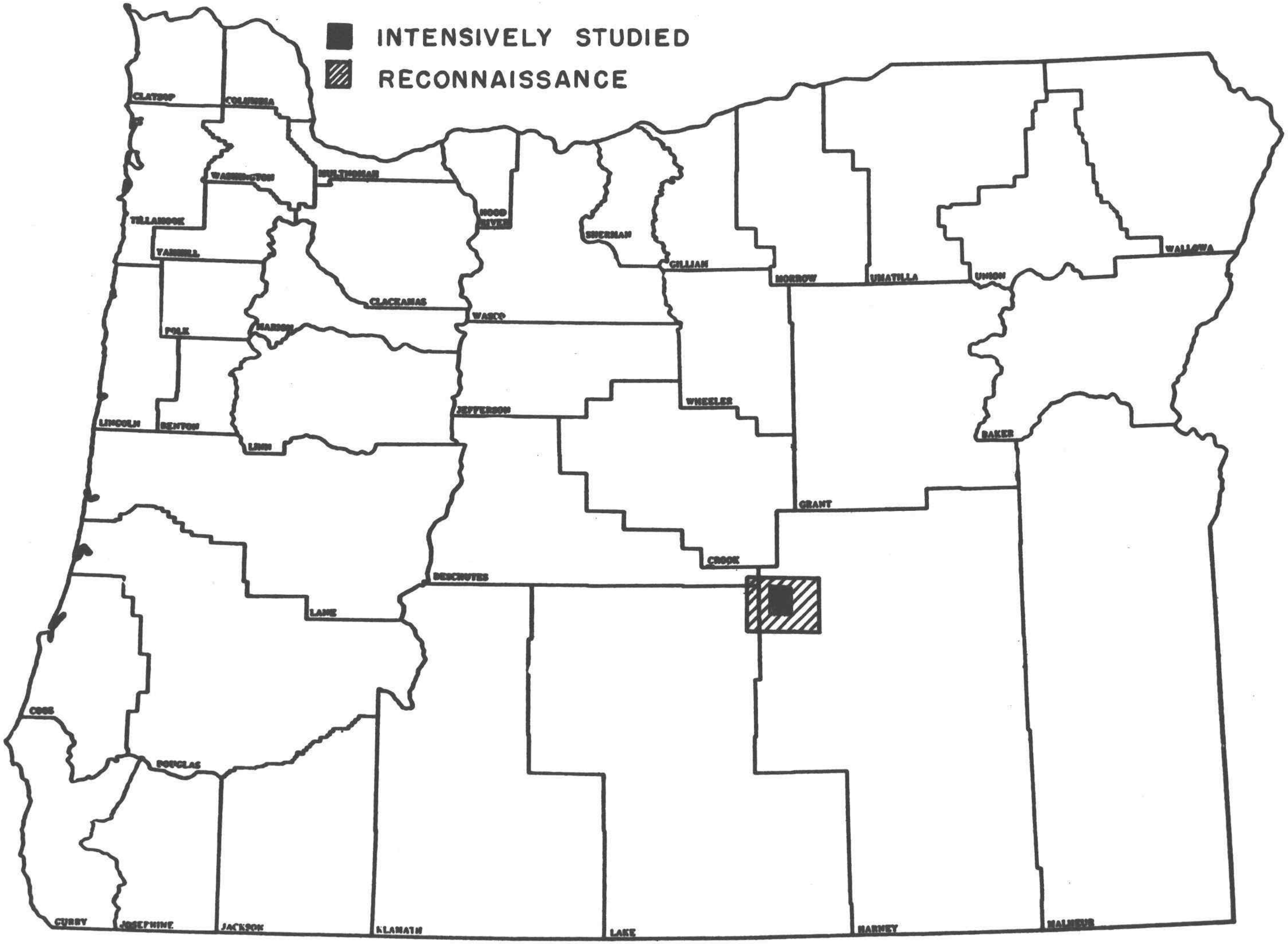


FIGURE 2. GEOGRAPHICAL LOCATION OF THE STUDY AREA.

not begin until the 1880's. Animals were turned out in the spring and spread throughout the country wherever feed and water were available. Herd numbers increased rapidly prior to 1912. In 1908 sheep bands moved into Harney County and by 1915, 12,000 head grazed throughout the study area. The subnormal precipitation from 1916 to 1938 reduced water supplies, plant vigor and growth and, together with excess numbers of livestock, resulted in a general depletion of the vegetation. This area has been marked by strife between stockmen. Range wars occurred as late as 1930 with the main issue being control of water.

Geology

The Harney section of the Columbia Plateau lies south of the Blue Mountains (75). Fenneman (29) prefers to relate the Harney section of Oregon with both the Columbia Plateau and the Great Basin Provinces. As a whole, southeastern Oregon forms a great uneven plateau region underlain by the Columbia lava. In the late Oligocene and mid-Miocene there began a series of lava flows which ultimately covered southeastern Washington and eastern Oregon (29) (Figure 3). These lavas issued from fissures and vents along the axis of the present Cascades and throughout eastern Oregon. Before the

Figure 3. Series of tilted lava flows.

outpouring of lavas the surface of the country had been carved into mountains and valleys that formed a well-developed topography. The flood of Miocene lavas buried this existing topography and filled canyons to a depth of more than 1,000 feet in places (64).

With the elevation of the Cascade Mountains in Pliocene time, earth movements disturbed this relatively level surface of the lava flows (90). In some places this table land was broken into great blocks with the long axes extending in a general north-south direction. By unequal subsistence in some places and uplift in others, these blocks were tilted and now form elevations having an escarpment on one side and a gentle slope on the other. This topography has come to be known as the basin-range type of structure. Geologists disagree as to whether southeastern Oregon should be part of the Basin Province or of the Harney section of the Columbia Plateau Province. While interior drainage is characteristic of both, this is a poor criterion for drawing boundaries. Fenneman (29) has pointed out that a belt 50 to 100 miles wide across the northern part of the Intermountain Province, chiefly in southern Oregon but overlapping somewhat into Nevada, differs in important respects from the country farther south. In general the mountains of this northern district are in the youth of their erosion cycle, whereas the mountains of the Great Basin represent older geologic structures which have undergone considerable erosion.

Walters (91), from his study of the Glass Butte region of northern Lake County, also sees this area as a northern extension of the fault block mountains of Nevada but characterized by the uneroded nature of the mountains. Smith and Packard (75) also point out that the main features of the topography resulting from the deformation during Pliocene still exist comparatively unmodified. This condition indicates that deformation could not have taken place very long ago, geologically speaking, because weathering and erosion would have worn down the slopes since precipitation was greater during the Pleistocene than now.

Five distinct stratigraphic units were reported to span the Miocene and Pliocene epochs (64). Of these, the oldest two were composed almost entirely of extrusives. These rocks are mainly basalts and basaltic tuffs, the former chiefly basalts containing basic feldspars. Rhyolite, rhyolitic tuffs, and andesites are embedded in this matrix. The youngest three include relatively thick sections of sedimentary strata. The post-Pliocene valley fill comprises alluvium, lake and playa deposits and eloian sediments, all derived largely from the volcanic rocks of the uplands.

Macroclimate

Through the study of *Pinus ponderosa* tree rings in eastern Oregon, Keen (46) has been able to arrive at an index of ancient climatic history back to the year 1268. The boundaries of the climatic zone studied were not well defined, but he considered it to cover the northern Great Basin region from the Cascades to the Rocky Mountains and including the Pitt, Klamath, Deschutes, and Snake-Columbia River drainages. The results of the study of tree ring records indicate that during the past 650 years no general trend toward drier or wetter years is apparent. If such a trend did exist it was so slight as to be obscured by other fluctuations. Average growth for the 20 year period 1900 to 1919 was found to be identical with the average growth during the past 650 years.

All tree ring measurements demonstrated a very critical subnormal growth period from 1917 to 1937. This drought was the most severe experienced in the past 650 years. This agrees with Jessup's work (44) in which Juniper tree rings were studied. According to Keen, 1931 was considered the worst year with growth about 68 per cent below normal.

The climate of southeastern Oregon is classed by

Thornthwait (80) as DC'd (semiarid, microthermal, with moisture deficiency in all seasons). Daubenmire (23) has pointed out, however, that such systems of climatic classification fail even to distinguish between such large phytosociological units as forest and grassland. Thus these systems are of questionable value in synecological studies.

The weather records from the Squaw Butte Experiment Station indicate two peaks in the seasonal precipitation pattern (Figure 4). One peak is evident during the months of November, December, January, and February and is due mainly to snow. The other in May and June is due principally to rain. The winter peak in an average year is sufficient to recharge the subsoil moisture storage of most profiles (Table 1). The May-June peak, together with favorable temperature conditions, is responsible for the maximum growth during this period. Although there is sufficient subsoil moisture in March and April, growth is very slow because of low temperatures and reduced surface moisture as a result of winds.

Average precipitation at the Station is 11.55 inches based on records for the past 19 years (88). A low of 5.41 inches was reported in 1949 and a high of 15.93 in 1941. Killing frost may occur at any time of the year but has little effect on the native species. The average

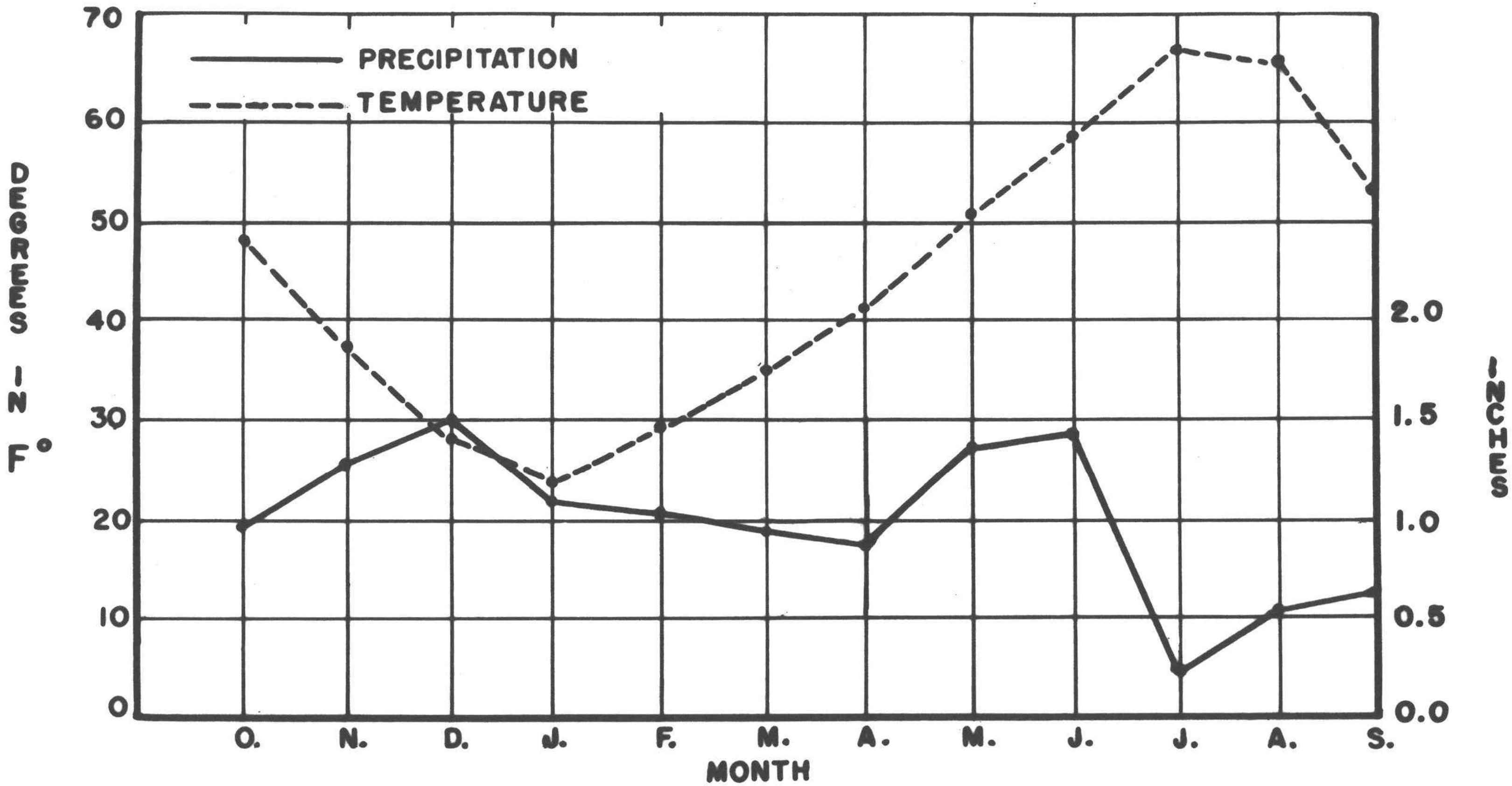


FIGURE 4. DISTRIBUTION OF THE MEAN MONTHLY PRECIPITATION AND TEMPERATURE VALUES AT THE SQUAW BUTTE EXPERIMENT STATION. (MEAN OF 19 YEARS) (88).

Table 1. Inches of total soil moisture storage capacity and available moisture above restrictive layer in selected habitat types.

Habitat Type	Profile Depth (inches)	Total Inches of Moisture Required to Wet Soil to Moisture Equivalent	Total Inches of Available Moisture
Artemisia tridentata Agropyron spicatum	23 (to dissected basalt)	11.95[1]	5.47
Artemisia tridentata Agropyron spicatum, Stipa thurberiana phase	25 (to strongly cemented pan)	6.81	3.17
Artemisia tridentata Festuca idahoensis	24 (to rubbley rhyolite)	6.69	4.22
	19 (to dissected basalt)	6.68	3.50
Artemisia arbuscula Festuca idahoensis	18 (to weakly cemented pan)	5.50	2.66
	30 (to strongly cemented pan)	12.30[1]	5.43
Artemisia arbuscula Agropyron spicatum	24 (to bedrock)	6.47	3.23
	21 (to strongly cemented pan)	8.97	3.93

Sixteen years total precipitation data are available from the Squaw Butte Experiment Station. The average for the October through May period is 8.99 inches.

1 Winter precipitation was not great enough in any year to wet these two profiles to moisture equivalent, but was great enough to wet the remaining soils to moisture equivalent in nine of the sixteen years.

frost-free period is 69 days, with the average growing season for shrubs, perennial grasses, and forbs about 180 days, from April 1 to October 1.

Soils

No intensive soil survey work has been done in the immediate study area; thus the soils are totally unknown and uncorrelated. The U. S. Department of Agriculture yearbook, Soils and Men (84 Appendix map) lists only two soil areas comprising the study area; the Portneuf-Sagemore area associated with the plains and plateaus, and the McCammon-Deschutes area associated with open Juniper woodlands. Characteristics of the Portneuf-Sagemore soils are well known only in a few localities where surveys have been made. The McCammon-Deschutes areas have for the most part never been covered by a detailed soil survey. The soils are complex as they are developed on rough topography from a variety of parent materials. Such generalized soils information as this is of no value in land management.

The early geological reports of Waring (90) made mention of the degree of alkalinity of some of the alluvial soils of playas.

Experimental work concerned with seedbed preparation on the Squaw Butte Range by Hyder and Sneva (42) has provided some soils information from one location. These data were a general profile description and determinations of bulk density, moisture equivalent, and 15 atmospheres moisture percentage. Some unpublished work by Poulton (65) has described in detail the morphological soil profile characteristics in some experimental areas on the Squaw Butte Station. These reports constitute the literature concerning the soils of the study area prior to 1956.

In 1956, Cheney et al. (16) published the most recent information on the soils of the Pacific Northwest. Their generalized soils map shows the Brown soil zone as characteristic of the study area. The authors state that Chestnut soils may occur on north-facing slopes within the Brown zone. The results obtained from this thesis problem have shown both of these statements to be correct.

Vegetation

In lower-Pliocene time the regions of southeastern Oregon supported a luxuriant mesophytic forest containing, among others, species of Acer, Picea, Abies and Pinus (15, p.229). This flora indicated a moist continental type of climate.

"With the uplift of the Cascade Mountains in Pliocene time, the climate became progressively more xerothermic due to the interception of the moist westerlies by the mountains. As the mesophytic forest disappeared during Pliocene time, desert and grassland species began to migrate into the area from the south and east where older arid regions had acted as refuges as did dry sites within the mesophytic area" (19). Daubenmire (19) hypothesized that *Pinus ponderosa*, *Pinus cembrioides*, and *Juniperus* spp. constituted the first xerophytic formation, and that by the end of the Pliocene time the desert formation had spread northward across the Great Basin and no doubt into southeastern Oregon. This was the situation at the start of the Pleistocene.

The intraglacial periods were moist and the basins of eastern Oregon were occupied by deep lakes as a result of increased precipitation and glacial runoff from nearby mountains (64). Hanson (37) divides the post-glacial time into four climatic stages. During the late Pliestocene and early post-glacial periods, forests covered a large area owing to a more moist climate. As the climate attained maximum warmth and dryness (4,000 to 8,000 years ago), these forests attained their maximum constriction. Pollen analyses show that during this period grasses, composites, and chenopods extended rapidly into the southern Oregon area. Since this period, the climate has returned to cooler and more moist conditions, with minor fluctuations, as it is today.

The present vegetation within the actual study area will be presented in a later section. A species list containing scientific names and authority for each is presented in Appendix 7.

REVIEW OF LITERATURE

The literature review will be divided into two sections: (1) early attempts in vegetation classification as exemplified by the use of plant and/or animal indicators, and (2) more recent investigations in range ecology with emphasis on vegetation and/or soils. Both types of research have been limited in the immediate study area, thus necessitating emphasis on principles developed elsewhere in the sagebrush-grass type.

Early Attempts in Vegetation Classification

The first investigations of note were those of Merriam (55, 56). His was the first major attempt to use climatic data to interpret the distribution of North American biota. According to Merriam (56) temperature and humidity were the most important causes governing the distribution of plants and animals. Using temperature, he developed the well-known "Merriams Life Zones and Crop Zones of the United States." These life zones are still being used, chiefly by zoologists, although Daubenmire (17) has summarized the various criticisms of Merriam's work. Merriam classified the study area of eastern Oregon in the upper Sonoran zone in which he includes such diverse vegetation types as *Artemisia* spp., Atriplex confertifolia, and Sarcobatus vermiculatus (56). In spite of its shortcomings, Merriam's work did stimulate interest in the cause of plant and animal distribution.

Bailey (3), using these life zones, published on the mammals and life zones of Oregon. He indicated that the eastern Oregon study area belongs to the arid subdivision of the transition zone and is characterized by Artemisia tridentata and A. arbuscula. This classification is an improvement over that of Merriam, although the subdivisions are still too large for management purposes. This is indicated by the lumping together of the two Artemisia species which indicate differences in productivity and potential.

In 1902 Griffiths (36) commented on the vegetation on the northern border of the Great Basin. Here he recognized the presence of a sagebrush type which grew on the foothills and mesas but seldom under alkaline conditions. Associated with the sagebrush was Agropyron spicatum which he claimed grew almost invariably on rocky but fertile soils. It is interesting to compare these comments with those of Fremont (31, p.174) who mentioned only the genus Festuca in south-central Oregon.

Kearney et al. (45) reported that the sharply delimited vegetation types in the Tooele Valley of Utah could hardly be attributable to climatic factors. They suggested the possibility of correlating the distribution of vegetation with the chemical and physical properties of the soil. If such a correlation could be made, it could be utilized in the classification of land with regards to its agricultural capabilities. Another significant contribution of these workers was the recognition of the plant association defined "as an assemblage of plants occurring in a relatively uniform environment, having an easily recognized appearance and physiognomy and characterized by the predominance of one or a few species." This concept allowed the vegetation mosaic to be subdivided into more or less workable units. The nomenclature used by Kearney *et al*. for the vegetational units was derived from the dominant species present.

Aldous and Shants (1) stated that "the natural vegetation is a result of all growing conditions of the area where it is produced and it is, therefore, an index or a measure of the environmental factors influencing its growth." The differences in the density of the vegetation within the same type were recognized and ascribed only to the quality of the growing conditions in the area. It was not indicated whether these variations were due to site or to use history differences. As in most of these early studies, the more important vegetation types were listed as being indicative of some soil characteristic.

In 1936, Shantz and Zon (72) divided the Northern Desert Shrub type into three rather broad groups: *Artemisia tridentata* plus associates, *Atriplex confertifolia* plus its associates, and *Atriplex nuttallii* plus its associates. He recognized the importance of gross soil characteristics in describing the types dominated by the *Artemisia tridentata*, *Artemisia nova*, and *Purshia tridentata*.

In his studies of the Uinta Basin in Utah and Colorado, Graham (35) recognized that altitudinal zones were primarily due to climatic factors. However, these zones were often divisible into smaller units due to physiographic or edaphic factors. He considered both physical and chemical characteristics of the soil to be of major importance in determining plant associations. In the interpretation of the various associations, he considered edaphic, physiographic, and climatic units as comparable ultimate units of vegetation. Using these concepts, he classified the vegetation of the area according to characteristic species in spite of minor variations in their dominance. No data are given which would help in the interpretation of these variations.

Shantz and Piemeisel (71) have pointed out that the Northern and Southern Desert Shrub types indicate gross climatic differences, but that the sub-types within each of these divisions indicate local differences in soil, either in the chemical or physical nature, or in moisture content. These workers emphasized that the most reliable indicators of soil conditions are the climax plant communities associated with each soil.

Shreve (73) described the desert vegetation of North America on the basis of physiognomy, community structure, and floristic composition. According to this author, the salient features of the vegetation of the Great Basin are characterized by simplicity of composition and fidelity of distribution with relation to belts of soil conditions. He lists *Artemisia tridentata* as one of the most widespread community dominants and states that it is the dominant plant in localities so different that they may be expected to have different vegetation. By this conclusion, he seems to have recognized site differences within his large *Artemisia tridentata* type, but he did not describe these differences.

None of these early classifications divided the vegetation mosaic into phytosociological units small enough for intensive management purposes.

More Recent Investigations In Range Ecology

Vegetation Emphasis. In 1942, Daubenmire (18) divided southeastern Washington and adjacent Idaho into three vegetation zones, each of which is characterized by a distinct climatic climax association. Within the *Artemisia-Agropyron* zone, primarily on the basis of vegetation, he recognized 12 edaphic associations, in addition to biotic and fire climaxes. He emphasized the close correlation between the vegetation zones and the previously mapped soil zones.

In 1947 Tisdale (82) described the vegetation of the grasslands of the southern interior of British Columbia. He found the same three vegetation zones as previously described by Daubenmire (18). He hypothesized that the grasslands in this area represent a northern extension of the communities common further south, i.e., eastern Washington, northeastern Oregon, Idaho, and northern Utah. The three vegetation zones which he described (the *Agropyron-Artemisia*, the *Agropyron-Poa*, and the *Agropyron-Festuca*) were found to be correlated with three great soil groups, Brown, Chestnut, and Chernozem. Within each zone the author recognized edaphic and biotic communities characterized by changes in species presence and dominance.

In 1945, Billings (4) described the plant associations of the Carson Desert region of western Nevada. He pointed out that the climatic climax, the Artemisietum, occurs on the higher hills on the valley but that the other types of climaxes occur on steep north slopes and on the lower flood plains of the rivers.

Humphrey (40) published on the common range forage types of Oregon and Washington in which he attempted to define individual communities on the basis of vegetation only. The lack of soils information may have been partially responsible for this author's not differentiating between seral and climax plant communities.

As a result of the work of Dyksterhuis, many guides have been developed for the purpose of determining range condition on the "site" basis (27). Such guides have been developed by the Soil Conservation Service in Oregon (86). In his classification of range sites, Dyksterhuis places primary emphasis on the vegetation present, with only the gross soil characteristics being described. The range site types as described may represent one habitat type, a complex of habitat types or inclusions of different habitat types.

Soil Emphasis. Dunnewald (26) and Thorp (81) were among the first investigators to place the major emphasis on soil characteristics. These two workers described the vertical zonation of soil zones in the Big Horn Mountains of Wyoming and observed distinctive plant communities associated with each. These plant communities included desert, four types of grassland, and one type of coniferous forest.

The work of Gardner and Retzer (32) points out that climate is the primary factor in determining the type of vegetation, but that within a climatic zone soils exert the strongest influence on range plants. They emphasize that the need for classifying range soils is increasing as a need for more intensive management increases, and that soils series level interpretations seem to be adequate for most purposes.

Wieslander and Storie (92) indicated the value of combined soil and vegetation classification in range management. This combined type of survey would help in the evaluation of range soils and site as a basis for improved management and development. In their approach only the broad kinds of vegetation cover are determined and the seral relationships are, for the most part, ignored. More emphasis is placed on timber than on shrubby or herbaceous vegetation. The soils classification is quite complete, with the soil series being the mapping unit.

Olson (59) published on the value of the soil profile as an aid in range management. He points out that, all too often, consideration of range improvement or management stops short at the surface of the soil. The examination of the soil profile is especially important in areas where one general range type is found overlapping several kinds of soils, each of which may have a different potential. He points out that two soil profiles alike in all details will produce, or be capable of producing, the same kind and density of plants. Conversely, unlike profiles only rarely have the same productiveness.

Retzer (67) discusses some of the methods used in making soil-vegetation surveys of wildlands. He considers the soil as the most important single factor of the site and the soil series as the most useful unit of classification for wildlands. He concludes that the soil-vegetation type of survey is best for supplying the most useful information and is less costly than separate surveys made for each kind of information.

Combined Vegetation-Soil Studies. Thus it is apparent that the third and perhaps the best way to understand the ecology of rangelands is by the combined interpretation of both vegetation and soil.

Spilsbury and Tisdale (76), working in the southern interior of British Columbia, found that within a vegetation zone, profile depth was the most important soil characteristic with respect to species dominance. _Agropyron spicatum_ was found to be dominant on practically every soil type. However, there were marked differences in density, height, and yield, depending on soil texture and depth. These writers were of the opinion that minute, as well as broad, relationships may be found between the soil and the plant cover it supports. The authors indicate that both the plant community and certain characteristic species are good indicators of the habitat.

Billings (5), working in Nevada and eastern California, divided the basin sagebrush of Clements into two zones on the basis of macro-climate and soil. Each of these zones is a vegetational mosaic consisting of edaphic climaxes within the large _Artemisia_ dominant climatic climax. These edaphic climaxes are stable plant communities determined by compensating or limiting soil factors.

Hubbard (39), working in southeastern Saskatchewan, reports that changes within a vegetation zone are usually associated with latitude, longitude, and elevation. Soil changes within a zone were due to topography, exposure, parent material, and method of deposition. According to Hubbard, vegetation, if properly interpreted, will answer many questions regarding the soil and climatic conditions of a region.

Marks (51) described the vegetation and soil relationships in the lower Colorado Desert. He found significant correlations between vegetation and salt content of the soil, and between vegetation and soil moisture-holding capacity. No correlation was found between vegetation and soil pH.

Poulton (66), working in Morrow and Umatilla Counties, Oregon, described three vegetation zones, the *Artemisia/Agropyron*, the *Agropyron/Poa*, and the *Festuca* zone, each of which is represented by one climatic climax and numerous edaphic, topographic, and topo-edaphic climaxes. Each type of climax is associated with a particular group of soil series. Within any zone it is possible to have the climatic climax and associated soils of another zone represented as an edaphic or topographic climax due to compensating factors. Using the poly-climax interpretation, these examples of habitat types represent stable plant communities whose productive capabilities are different from those of the climatic climax of the zone and which, therefore, have different management characteristics.

Anderson (2), of the Soil Conservation Service, points out an apparent principle of soil-vegetation relationship indicated by his studies in eastern Oregon. In range areas where zonal soils develop, in contrast to areas lacking soils with well-developed zonal characteristics, the vegetation units and soil units most frequently coincide and the vegetation on contrasting soils are also sharply contrasting as to composition and dominance. Anderson has been able to relate certain range sites to definite groups of soil series although he recognizes that considerable variation in climax composition is often encountered within a single range site as mapped. The work of Poulton (66) has led to the explanation of the true nature of these variations. They have been identified as the biological units of the landscape, or the habitat types, which are not practical to delineate at the mapping scale used. The proper approach in handling these variations seems to be first to recognize their basic differences and similarities. In this way, we may more clearly understand the resource which we are managing. These units may then be combined into "range sites" for management purposes as each situation warrants. The results obtained by Poulton are now being incorporated into the Soil Conservation Guides as an aid in range inventory and management in the Columbia Basin region of Oregon. This would seem to indicate that ecological interpretations based on the poly-climax philosophy and the concept of investigating vegetation and soils together will be readily used by management agencies.

Autecological Studies. During this period of combined vegetation-soils research, other studies, complementary to the above, have been carried out. These studies have attempted to explain some of the observable vegetation-soil relationships. This type of autecological research is complementary to the synecological approach if the autecological studies are stratified by habitat types.

Billings (6) has shown that plants with a high moisture requirement, i.e., *Pinus ponderosa* and *Pinus jeffreyii*, occupy soils, formed from rocks altered by hydrothermal metamorphism, far from the normal distribution of these species. The sagebrush association which is climax for the area, cannot grow on these soils from altered rocks, principally because of the lack of phosphorus and low pH. This allows the more mesic species to utilize more of the environment due to the release of sagebrush competition.

McMinn (54), working on a habitat-type basis, studied the effect of soil moisture on the distribution of plant associations on the lower slopes of the Rocky Mountains.

He concluded that the distribution of plant associations in this region was determined by the per cent of available moisture remaining in the soil during the summer drought period.

Gates (33), working in the salt desert shrub type, has shown a significant correlation between vegetation type and the following soil chemical and physical characteristics: total soluble salts, conductivity of a saturation extract, one-third atmosphere moisture percentage, exchangeable sodium, and soluble sodium. Because of the disturbed types of vegetation in his study areas, it is doubtful if his work was done on equivalent habitat types but rather on a basis of more generalized types determined primarily by a single dominant species.

This kind of research is not limited to the western United States. Wilde and Leaf (93) studied the relationships between the degree of soil podzolization and the composition of the vegetation in parts of Wisconsin. They pointed out that (1) differences in soil morphology can be correlated with soil reaction, exchange capacity, organic matter, total nitrogen, and soil moisture content; (2) the composition of the soil profiles is closely correlated with both the qualitative and quantitative aspects of ground cover vegetation; and (3) indicator species have a pronounced tendency to attain maximum density and frequency of distribution on certain genetical soil types. This type of research could have been made much more useful if the workers had stated whether they were working with climax or seral vegetation, an important principle to observe in this kind of investigation.

METHODOLOGY

Introduction

Since the purpose of this research project is to characterize and classify the ecosystems in eastern Oregon range lands, the stands selected for intensive study must be representative of the more important habitat types of the area and should be in near climax condition. Since many stands may represent vegetation complexes of the fundamental units of the vegetation, being comprised of numerous habitat types, it is necessary to stratify each stand into its component environmental units. In each of these habitat types, the vegetation and soil must be studied together if the soil-vegetation relationships are to be clarified.

The thirty-one stands studied were determined by a reconnaissance of the Squaw Butte Experiment Station and surrounding area. After a particular stand had been selected, the study plot was located within a homogeneous unit dictated mainly by uniformity of vegetation, soil, slope, aspect, and parent material. Study plots were not established unless they could be located in a suitable homogeneous location. More than one study plot was used within a stand where definite stratification of the plant cover occurred. Paired plots were used only when considerable variation occurred in a short distance. The number of study plots per habitat type should be sufficient to obtain a good representation of the variation and modal condition that exists within each ecosystem. Generally four macroplots were considered minimum in this study, but a larger number would be preferred, especially in variable communities. An effort was made to replicate study plots in widely separated stands since variation over such an area was considered to be of greater importance than variation within a particular stand, and because sampling was designed to give some measure of the lesser important variations within stands.

In developing the research methods for this cooperative regional project, a unified approach was considered desirable. From among the following previously published methods appropriate techniques were selected and modified in the field to meet the conditions under which they would be used.

1. Constancy of occurrence on macroplots of sufficient size--based on the species-area relationship--to represent the plant association (9, p.58; 13).

2. Cover and frequency data from small plot samples (18, 21, 66).

3. Basal area estimation (61).

4. Line intercept for shrub crown cover (14).

5. Belt transect for shrub density (12).

The sampling methods were required to meet the following qualifications:

1. They must be applicable to stands of widely different vegetative cover.

2. They must be relatively insensitive to fluctuating weather conditions.

3. They must be usable on grazed stands.

4. They must give a good measure of species frequency, dominance, and constancy.

5. They must give all vegetation information at one visit to a site.

6. They must have "man error" small enough to assure detection of differences among associations.

7. They must give a maximum of data per unit of time spent. Personnel from Oregon and Idaho met in the field several times to test and improve the methods employed during the first two years of this study.

Vegetation Investigation

Macroplot. The work of Poulton (66) has shown the advantage of intensive sampling within a definite macroplot which also provides constancy data. The size of this macroplot was tested on stands in Oregon and in Idaho. Species area curves from Oregon indicated that a macroplot 10 by 50 feet is adequate, while in Idaho the macroplot should be approximately 50 by 50 feet in order to give a good representation of the species present (Table 2). As a result of these trials, the investigators established the minimum macroplot size as 50 by 100 feet because of the greater ease of laying out these dimensions. These tests indicate that this size will probably exceed the minimum area for most conditions encountered in the *Artemisia* types. It also provides ample room for randomization of the transects used in the present sampling procedure and for other types of sample plots which may be established in the future.

The macroplot orientation is with the long axis running up and down slope. Only in rare instances has it been necessary to orient macroplots with their long axis along the contour. On level terrain, orientation has been north and south, mainly for convenience in relocation. The lower right hand corner of the macroplot (as one looks upslope) is designated the reference corner, and the southeast corner is so designated for macroplots located on level ground and along the contour. The reference corner of the macroplot is marked with a steel post.

Transects. Within each macroplot, four 50-foot belt

Table 2. Species-area relationship for macroplots.

Macroplot Dimensions (ft)	Macroplot Area (sq ft)	Cumulative Total Species Idaho	Cumulative Total Species Oregon	New Species Added Idaho	New Species Added Oregon
50 x 10	500	21	25		
50 x 20	1,000	24	26	3	1
50 x 30	1,500	29	26	5	0
50 x 40	2,000	30	26	1	0
50 x 50	2,500	34	27	4	1
50 x 60	3,000	34	27	0	0
50 x 70	3,500	35	28	1	1
50 x 80	4,000	36	28	1	0
50 x 90	4,500	36	28	0	0
50 x 100	5,000	37	28	1	0

transects are established. Twelve possible locations for transects 4-feet wide occur along the 50-foot base line, allowing a 1-foot border along each side of the macroplot. Four out of the twelve possible locations are randomly selected. The randomization of the distance from the base line to the starting point of the transect is restricted, so that two of the four transects originate within 0 to 24 feet from the base line and two within 25 to 50 feet. This two-way randomization adequately provides for sampling the full 100-foot length of the macroplot.

Observation Plot. Within the macroplot, small observation plots are used to estimate dominance and to determine frequency. All these sample data are taken along four transect lines. The size and shape of a suitable observation plot must have the following characteristics:

1. It must be small enough to see at a glance.

2. It must be large enough to give an adequate measure of the dominance and frequency of the more important species.

3. It should give a frequency of the more important plants between 30 and 70 per cent to enable comparisons to be made between study areas.

In Idaho, 1 by 2 and 1 by 3 foot sampling units were compared on 80 randomly located plots; and 1 by 2, 1 by 3, and 2 by 2 foot sampling units were compared on 40 randomly located plots. All these sizes provided frequency values within the acceptable range, with but few exceptions. In most cases the 1 by 2 foot plot was found adequate by the above criteria and was the most easily handled in the field. This observation plot was then further tested on 80 randomly located plots in Oregon and in Idaho, and was selected for use in taking frequency and basal area data.

Dominance and frequency observations are made with the long axis of the observation plot oriented parallel to the line transect and lying on the side of the 50-foot transect line nearest the reference corner. Ten basal area estimates and frequency observations are made at equal intervals along the transect line starting at the 1-foot point on the tape. Ten plots are used because of the ease in computation, because a total of 40 observations per macroplot were found adequate in the Columbia Basin (66) and also because this intensity appeared to provide for adequate sampling in this study (Table 3).

<u>Dominance and Frequency Determinations</u>. In the preliminary considerations, herbage cover was ruled out as an estimate of dominance because it fluctuates greatly

Table 3. Comparison of number of species encountered on macroplots and on observation plots.

Association	Macroplot (Number of species with a constancy of 50 per cent or more)	Observation Plot (total number of species)
Artemisia tridentata/ Agropyron spicatum	32	48
Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	38	52
Artemisia tridentata/ Festuca idahoensis	38	37
Artemisia arbuscula/ Festuca idahoensis	30	36
Artemisia arbuscula/ Agropyron spicatum	31	33

with yearly weather variations. Therefore it is necessary either to measure year difference or to conduct all comparisons of relative dominance on the basis of a single year. The herbage cover method necessitates visiting the study sites at a time when each group of species has obtained its maximum development. In Idaho, especially, this could not be accomplished because of the great distances between study locations. It is also impractical to use where livestock are grazing. However, after the first two years of this study in Oregon, it was noted that the sites selected for study were not grazed to the extent that herbage cover measurements would have been impractical.

Basal area estimation was selected as the method of indexing relative dominance. This type of measurement is free from the above disadvantages of herbage cover, even though it does not index dominance as well as does herbage cover. Basal area estimations are made directly in per cent. Estimates are made for all species, with the aid of two circular guides equivalent to 2 and 5 per cent of the observation plot (Figure 5). Estimations are made to the nearest 1 per cent up to 10 per cent, and to the nearest 5 per cent from 10 to 100 per cent. Plants occurring along the plot margins are counted if half or more of the plant is rooted within the plot. These

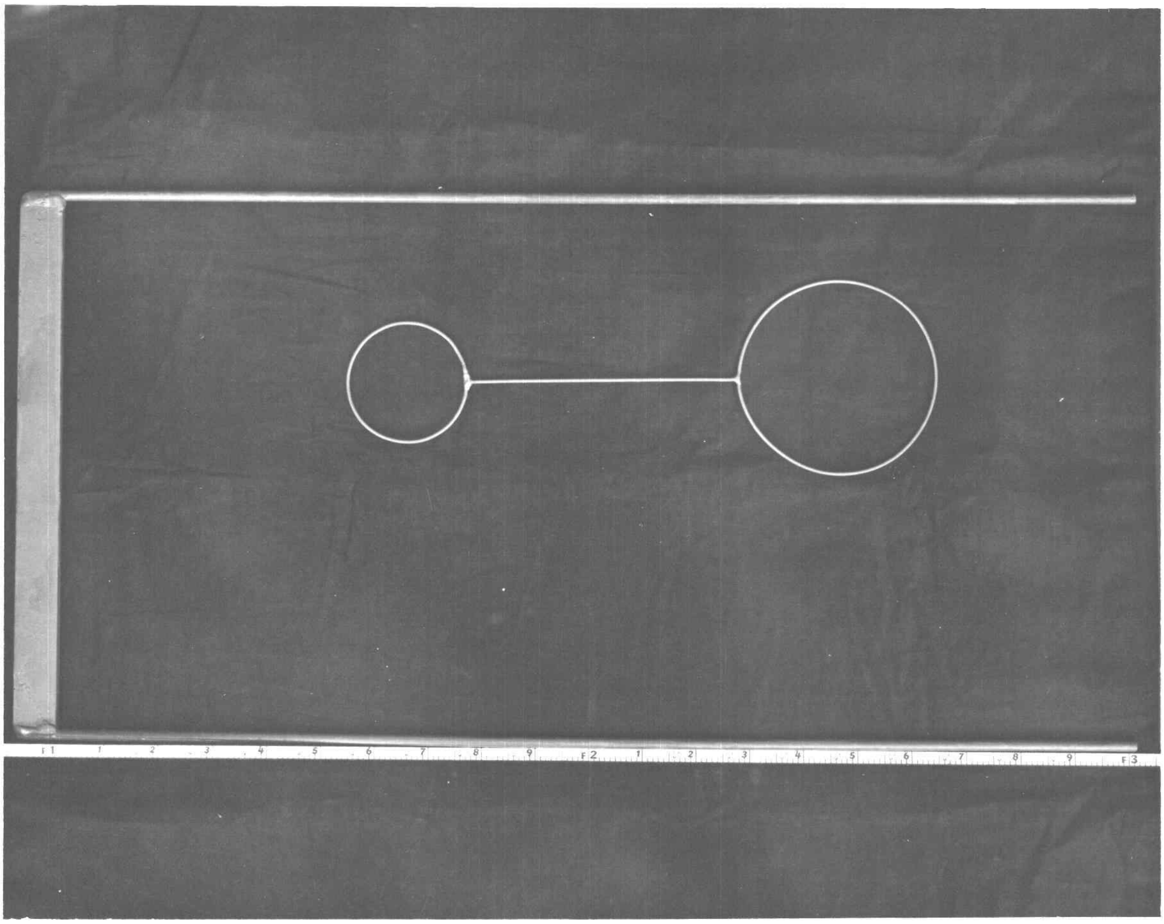


Figure 5. Observation plot and estimating rings.

techniques have resulted in minimum error among individual observers. The basal cover of mat forming plants, such as *Phlox diffusa* and *Antennaria corymbosa*, are estimated as the total area in which these plants exclude the growth of other species. Single stemmed perennials of any species are considered one plant and are estimated as such if the individual stems are no further apart than one-half inch. This same criterion applies to *Agropyron spicatum* when it grows as a very loose bunchgrass or in a rhizomatous form. Dead centers of bunchgrasses and similar growth forms are excluded from the estimate if they exceed an area greater than 1 per cent of the observation plot in an individual plant. Basal area of shrubs occurring on the observation plot, including prostrate branches or stems which exclude growth of other plants, are included in the basal area estimates.

This method is not well adapted to sampling annual species because of their small basal area. However, since the same method is used on all macroplots, the results are comparable although the relative dominance in many cases is much too high for annuals and too low for perennial forbs.

Cryptogam cover is divided into two parts, *Tortula ruralis* and epigeous cryptogams. Bare ground and stone cover are also estimated. Individual gravels greater than 1 per cent of the observation plot are estimated in stone cover. Any rock fragments smaller than 1 per cent of the observation plot area are estimated as gravel. Litter is the most difficult component of ground cover to estimate. For this reason, litter is determined as the difference between an estimate of bare ground plus litter and bare ground alone. Included in litter are leaves of shrubs, forbs, and grasses and nonliving branches of shrubs. Only shrub seedlings are counted within the observation plot. Basal area estimates by transect are made to total 100 per cent by adjusting the value of the largest non-vegetative class, usually bare ground.

Frequency of occurrence of individual species is automatically obtained by tallying the number of basal area estimates of all species, rooted in the 40 observation plots.

Shrub Density and Height. The belt transect is used to obtain shrub density. Preliminary field work in Oregon and Idaho was done using various widths of belts along transect lines 50 and 100 feet long. The results showed that the average area per shrub was the same whether the 4-foot or the 6-foot width was used (Table 4), but that the former was easier to handle in the field. The 2-foot belt was not large enough to give an adequate measure of shrub density as indicated by a

Table 4. Comparison of estimates of square feet per plant obtained by height classes on belts of various widths and lengths.

Belt Length	Belt Widths (feet) 2: 0 - 6	2: 7 - 12	2: 12+	4: 0 - 6	4: 7 - 12	4: 12+	6: 0 - 6	6: 7 - 12	6: 12+
50	6.23	100.00	26.16	7.69	100.00	18.25	7.83	87.25	16.28
100	5.89	200.00	25.00	7.55	100.00	17.40	7.68	85.75	16.66

large number of zero entries. The 100-foot line showed no distinct advantage over the 50-foot line. Based on this information a belt transect 4 feet wide and 50 feet long was selected for use in this study.

Within the 4-foot belt transect, the number of all shrubby species is tallied by height classes. The tally of dead shrubs within each belt transect is also obtained. Only those shrubs that are completely or one-half rooted within the specified area of the belt transect are recorded. Height classes are as follows: 0 - 6 inches, 7 - 12 inches, and greater than 12 inches. All height measurements are taken to the top of the tallest vegetative shoot. It has been found that a 4-foot stick marked off in 6-inch intervals works well with a minimum amount of motion. This stick can also be used to delineate the 4-foot width of the transect so that two lines four feet apart do not have to be established. Along or adjacent to the belt transects, ten measurements of maximum height are recorded to the nearest six inches for Artemisia tridentata and shrubs of similar stature. Forty such measurements per macroplot or ten per transect line are considered sufficient. Results obtained in the thesis study indicate that forty measurements give a good mean with a low standard error.

Height measurements to the nearest six inches have no significance when related to low growing shrubs such as *Artemisia arbuscula*. For this reason, fifty random measurements, to the nearest inch, were recorded for this species in addition to the density counts. Plant heights were then classified and averaged in the same height classes used to express the density of *Artemisia tridentata*.

Shrub crown cover is indexed by intercept measurements along the 50-foot transect lines. These measurements are made to the nearest 0.1 foot. Any separate intercept less than 0.05 foot is ignored. Seedlings are also ignored if their intercept is less than this minimum. Only foliage intercepts are measured. Gaps or sinuses in the foliage cover at the edge of a shrub are measured as continuous crown cover if they are narrower than the width of the average lobe of the shrub being measured. Gaps equal to or greater than the size of the average lobe are excluded from the intercept measurement. In cases of separate individuals of the same species, continuous ground cover is measured without regard to the individual plants. The crown intercept of each different shrub species is measured separately, and double cover may be encountered where crowns of different species overlap.

Constancy. In order to provide a complete species list for constancy data, the entire macroplot is carefully examined after the basal area and count data are taken and species which were not encountered on the observation plots are added to the list. These data are presented in Appendix 3.

Photography. One black and white and one color landscape photograph is taken from the reference corner of the macroplot looking diagonally across the plot. A black and white and a color photograph is also taken looking along transect 4 at the zero end with the camera tilted down to show greater vegetation detail.

Phenology and Soil Moisture. During the spring and summer of 1956 phenology and soil moisture depletion were studied on selected habitat types. Plant development data and duplicate soil moisture samples were collected at approximately two week intervals beginning the first week in April. The oven-dry soil moisture percentage was determined. The bulk density of each horizon sampled was determined by the method suggested by Daubenmire (20, p.39). This consists of removing the soil from a small hole in each horizon, determining its oven-dry weight, and correcting for stones and gravels. Sand is poured into the hole to determine the volume which the soil, stones, and gravels previously occupied. By dividing the oven-dry weight in grams by the volume of the soil in cubic centimeters, the bulk density, in grams/cc., is determined. The bulk density values obtained are presented in Appendix 1. Using the bulk density and per cent moisture at each sampling date, the inches of total moisture storage, as well as the inches of water remaining at each sampling date, can be calculated and compared to the stage of plant development.

Yield-Cover Correlation. Herbage cover and basal area estimations were compared on three habitat types, during the summer of 1956, to determine their relative values as indices of dominance. Dominance in this case was determined by total herbage yield. On each macroplot, ten 9.6-square-foot circular plots were located at random along the 4 transect lines. On each plot, herbage cover was estimated by one observer and basal area by another familiar with and practiced in each of the two techniques. The species on these plots were harvested at the ground line and bagged separately. These herbage samples were then air-dried and weighed. Analysis of covariance was carried out to determine the value of each estimation method as a measure of dominance.

Soils Investigation Methods

Soils data and samples for laboratory analysis are taken at each macroplot. This is essential for maximum progress in the study of ecology because it enables one to better understand the ecosystem and therefore the relationships between plant communities and their associated soils.

The Soil Survey Manual (87) is followed, in detail, for all physiographic and soil profile terminology. Each macroplot location is described as to relief, aspect, degree of slope, position on slope, and elevation.

A complete soil morphological description is prepared from a pit dug adjoining each macroplot and in a representative location. Pits were dug either to bedrock or to a cemented pan. All profile descriptions were checked in the field by Dr. Ellis G. Knox of the Oregon State College Soils Department. The following characteristics of each soil horizon were determined in the field: depth and thickness, nature of the boundary, dry and moist colors, field texture, structure, and consistence. Profile depth, depth to moderate hydrochloric acid effervescence, nature and depth of the restrictive layer, and type of parent material are also noted.

Soil samples were taken from each horizon and passed through a one-fourth inch screen and allowed to air dry. After drying, the samples were ground to pass a 2 mm screen. The stone and gravel component in each screen was determined. The samples were taken to the laboratory and the following characteristics determined:

The pH of the saturated paste was obtained by using the glass electrode. Soil salinity was indexed by two methods: (1) resistance of a saturated paste, and (2) the electrical conductivity of the saturation extract. The procedures followed for these determinations are presented in the Soil Salinity Handbook (85, pp.89-91). In addition, these determinations were made on a representative sample for the A_1 and A_3 horizons beneath *Artemisia* spp. and for the A_1 horizon beneath *Juniperus occidentalis* and *Grayia spinosa*. This was done to determine if there were any differences in the pH or salinity of bare soil as compared to that beneath shrubs and trees as has been shown by Roberts (68) for salt-tolerant species. The organic matter content of the soil horizons was determined by a modification of the Walkely-Black method as outlined by the Oregon State College Soil Testing Laboratory (60). The moisture equivalent percentage was determined by the method described by Briggs and MacLean (10). A portion of the mechanical analysis determinations were made by the Bouyoucos method (30) and a portion by the Bouyoucos method as modified by Youngberg (95). In this latter method the organic matter is destroyed by hydrogen peroxide and heating. The samples are shaken overnight in a reciprocating shaker with Calgon as the dispersing agent. Hydrometer readings are taken at 40 seconds to determine the per cent of sand and at 6 hours to determine the per cent total clay. The difference between the 40 second and 6 hour readings gives per cent silt. A 24 hour reading was made to determine the per cent of 1 micron and smaller clay particles. The advantage of increased dispersion by use of this method is shown in Table 5. Fifteen atmospheres moisture percentages were determined by the Soil Physics Laboratory of Oregon State College using a pressure membrane apparatus. The exchangeable cations potassium, calcium, magnesium, and sodium, as well as the total cation exchange capacity, were determined on selected samples by the Oregon State College Soil Testing Laboratory using the flame photometer and ammonium acetate methods respectively.

Two photographs, one black and white and one colored, were taken of each soil profile.

Reconnaissance

After completion of the intensive vegetation and

Table 5. Increased dispersion of clay colloid by use of the Bouyoucos hydrometer method as modified by Youngberg (95).

	Standard Bouyoucos Method			Modified Method		
	Mean of Duplicate Determinations					
Horizon	% Sand	% Silt	% Clay	% Sand	% Silt	% Clay
A_1	57.5	33.6	8.9	57.5	30.1	12.4
A_3	60.2	27.9	11.8	58.8	26.3	14.9
B_1	63.9	22.4	13.6	59.8	21.0	19.3
B_{21}	41.3	24.7	34.0	40.8	15.0	44.3
B_{22}	21.1	28.4	50.4	22.2	24.4	53.9

soil sampling, a reconnaissance of approximately 400 square miles around the Squaw Butte Experiment Station was undertaken to determine the repeatability of the habitat types studies, to determine other important habitat types of the service area, and to determine if these habitat types could be recognized on the basis of vegetation and soil information collected during intensive sampling. On this reconnaissance soils were examined occasionally to determine the repeatability of soil profile characteristics with vegetation types and to help classify the more depleted areas where little climax vegetation remains. The various recognizable associations were road-logged during this reconnaissance (Appendix 2).

RESULTS AND DISCUSSION

An analysis of the vegetation and soils on a total of 31 stands in the study area has resulted in the characterization of four associations[3] and an important phase of one of these associations. These are as follows:

Table 6. Associations and stands studied

Association	Number of stands
Artemisia tridentata/Agropyron spicatum	6
Artemisia tridentata/Agropyron spicatum, Stipa thurberiana phase	7
Artemisia tridentata/Festuca idahoensis	7
Artemisia arbuscula/Festuca idahoensis	6
Artemisia arbuscula/Agropyron spicatum	4
Artemisia tridentata/Agropyron spicatum-Artemisia tridentata/Festuca idahoensis intergrade	1

On the basis of a preliminary reconnaissance, these associations appeared to be the most important within the study area. However, the more extensive reconnaissance revealed that four of the five most important associations

3 The term association is used to denote a specific climax vegetation component of the ecosystem.

were actually studied (Appendix 2).

All of these stands were considered to be in good or better range condition. This criterion is open to question on one *Artemisia arbuscula/Agropyron spicatum* site due to the abundance of *Stipa thurberiana* and *Sitanion hystrix*. However, for the purpose of this study, this particular stand will be included in all calculations since there are no quantitative data to indicate whether this situation represents a deteriorated condition or the normal variability to be expected in species presence or dominance. The soil and vegetation intergrade was omitted from all calculations.

Dr. Ellis G. Knox of the Oregon State College Soils Department interpreted the 31 soil profiles described into nine uncorrelated soil series and was asked specifically to make this interpretation without regard to vegetation considerations. On the basis of morphology alone, this grouping shows some relationships between vegetation and the associated soil profiles (Table 7).

All of the stands studied are components of the southeastern Oregon equivalent of the *Artemisia tridentata/Agropyron spicatum* zone as defined by Daubenmire (18) and Poulton (66) and Tisdale (82). The associations studied are quite similar to those found in southern Idaho but are not floristically

Table 7. Tentative vegetation-soil relationships in the sagebrush-grass type of northern Harney and Lake Counties, Oregon.

Tentative Soil Series		Number of Examples Studied				
Series Number	Generalized Description	Artemisia tridentata/ Festuca idahoensis	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
1	Very strongly developed Brown soil from basalt residuum	1	2		1	4
2	Very strongly developed Brown soil from rhyolite residuum				2	
6	Brown soil from rhyolite colluvium				3	
3	Weakly developed Brown soil from basalt residuum			2		
7	Brown soil from basalt colluvium		2			
8	Brown soil from rhyolite and basalt fan materials		1	3		

Table 7, continued

Tentative Soil Series		Number of Examples Studied				
Series Number	Generalized Description	Artemisia tridentata/ Festuca idahoensis	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum, Stipa thur-beriana phase	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
5	Brown soil from rhyolite residuum	2	1	2		
4	Chestnut soil from basalt colluvium	2				
9	Brown soil from sandy rhyolite fan or colluvial material	2				

identical to the *Artemisia* zone vegetation in southeastern Washington and adjacent Oregon. Daubenmire (24) points out that the vegetation mosaic at the western end of the Snake River plains contains some associations apparently identical with those of Washington, whereas this area of southeastern Oregon is distinctive in nearly all respects.

Status of *Juniperus occidentalis*

In this thesis, for ease of presentation and readability, the associations studied will be discussed in accordance with the dominance of shrub and/or grass cover. This is a logical procedure since the cover of shrubs, grasses and forbs varies only slightly among the *Juniperus occidentalis* associations and their non-arborscent counterparts. These differences are noted both in the text and in Table 24, the key to habitat types. The reader should remember that *Juniperus occidentalis* can and does occur in all of the associations studied (Table 8).

Using Daubenmire's (21) concept of unions, the *Juniperus occidentalis* union occurs with various kinds of understory plants when conditions are suitable for the growth of this species. The well developed *Juniperus occidentalis* association immediately east of Bend,

Table 8. Density of *Juniperus occidentalis* in the associations studied.

Association	Stems per Acre Where Present Height Classes (feet)					
	Stands Sampled	Less Than 3	3 - 6	6 - 10	Greater Than 10	Total
Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase[1]	3	1.0	1.0	1.0	3.0	6.0
	1	-	2.0	2.0	24.0	28.0
Artemisia tridentata/ Festuca idahoensis	6	3.7	4.5	5.5	21.8	35.5
Artemisia arbuscula/ Festuca idahoensis	3	3.3	1.6	1.0	16.6	22.5
Artemisia arbuscula/ Agropyron spicatum[2]	3	3.3	2.7	2.3	11.7	20.0

1 *Juniperus occidentalis* occurred only on one of the seven *Stipa* phase stands studied.

2 In this association, *Juniperus occidentalis* seems to be limited to rock nets or stringers.

Oregon, would represent an area where the effective environment seems to approach the modal requirement for this species. Reconnaissance observations around the Squaw Butte Experiment Station indicate that *Juniperus occidentalis* becomes less important as one proceeds southward. In fact, in Nevada this species is completely replaced by *Juniperus utahensis*.

Juniperus occidentalis is unimportant in the *Artemisia tridentata/Agropyron spicatum* association as a whole, occurring to a limited extent on hilly relief where, in combination with these shrub and herb layers, it forms the *Juniperus occidentalis/Artemisia tridentata/Agropyron spicatum* association. *Juniperus occidentalis* is found on three of the four *Artemisia arbuscula/Agropyron spicatum* stands studied, primarily on rock stringers or nets. In the *Artemisia arbuscula/Festuca idahoensis* association, *Juniperus occidentalis* is an important component of the vegetation in hilly relief, but unimportant in plateau or undulating relief. *Juniperus occidentalis* is associated with six of the seven *Artemisia tridentata/Festuca idahoensis* stands studied. These six stands are on very hilly relief or escarpments and always on northerly exposures. On north slopes in undulating relief *Juniperus occidentalis* is not present. Only one stand represented this latter condition. Reconnaissance observations have shown these distributional patterns of *Juniperus occidentalis* to be consistent over a large area. Figure 6 shows a typical distribution pattern for this species. It can be seen that *Juniperus occidentalis* makes its maximum growth on rocky outcrops and steep slopes where there is little competition and where moisture conditions tend to be more favorable. In the valleys, *Juniperus occidentalis* is only occasionally present, mostly in intermittent drainages where moisture conditions are quite favorable, at least for a portion of the growing season.

Woodbury (94) has shown that pigmy conifers (*Pinus monophylla* and *Juniperus utahensis*) utilized the ridges, canyons, or rough slopes with coarse, rocky, or shallow soils. He postulated that the occurrence of these species is determined by a minimum requirement for moisture which, in any region, is not met by the climatic factors but rather by absorption, storage, and water supplying power of the soil. The results of this author tend to support the conclusion that species of *Juniperus occidentalis* may have a relatively high moisture requirement and that this requirement can be met by compensating factors which increase the effectiveness of precipitation. This hypothesis would tend to be supported by reconnaissance observations.

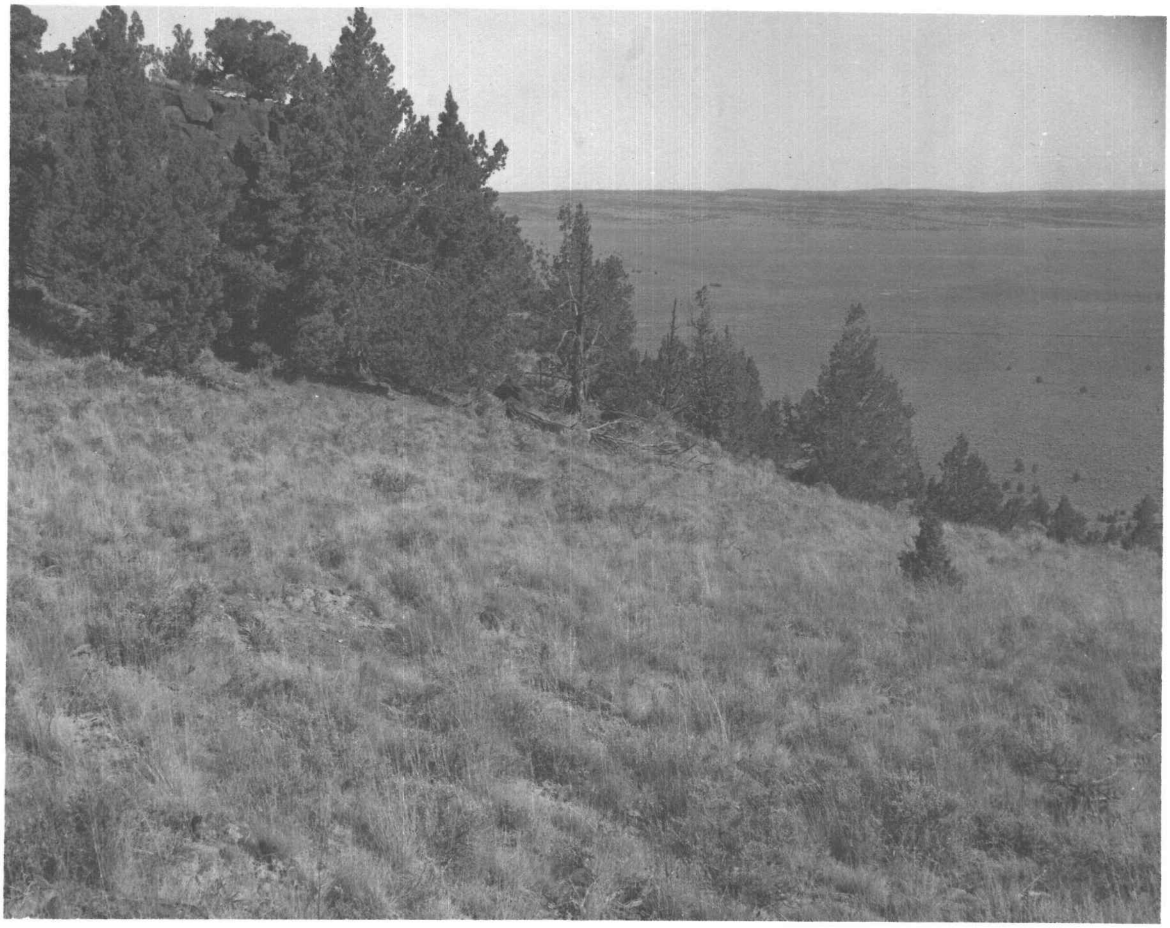


Figure 6. Photograph showing the distributional pattern of Juniperus occidentalis in the study area.

Because of its specialized distribution in the study area, *Juniperus occidentalis* is considered to be growing under environmental conditions which are close to the limit of its tolerance range; and, therefore, it occurs only on compensative habitats which tend to increase the effective moisture. In many respects, *Juniperus occidentalis* and *Festuca idahoensis* appear similar in some of their growth requirements, since both appear to be growing under environmental conditions near the limit of their tolerance range and both species commonly increase in dominance on some of the same specialized habitats. On the other hand, the environment of this region approaches the modal requirements of *Agropyron spicatum*. This species is found associated with *Juniperus occidentalis* only in hilly relief or on rocky outcrops.

Fire has, no doubt, played an important role in the present distribution and density of *Juniperus occidentalis*. Through ring counts, fires in the study area were dated at intervals of 100, 150, and 200 years ago. Some stands still reflect the influences of fire, while in others the reestablishment of *Juniperus occidentalis* has been rapid enough to all but mask these effects. Many stands showing evidence of previous fires do not now have enough fuel to carry a fire. These stands were in poor range condition and were not included in this study.

Several interesting phenomena are associated with the presence of *Juniperus occidentalis*. Samples taken beneath young *Juniperus occidentalis* trees reveal no significant increase in alkalinity over samples taken from bare soil in the openings between the shrubs and trees. The increased pH under older trees would seem to indicate that an accumulation of litter, *Festuca idahoensis*, and *Tortula ruralis* must be present in order to effect the typical increase of 1.0 pH unit under *Juniperus occidentalis*. It may be hypothesized that the *Juniperus occidentalis* roots extend deeper into the cracks of the substratum than do the *Artemisia tridentata* or grass roots to adsorb bases, or that this tree is more effective in the uptake of these materials than is sagebrush or grass. When the leaves of *Juniperus occidentalis* fall and decompose, these materials are released and the pH of the soil immediately beneath the tree is increased. The *Tortula ruralis* and grass roots may serve to recirculate these bases in the surface horizons. This increase in pH is interpreted as an effect rather than the cause of *Juniperus occidentalis* presence.

One species of perennial forb, *Hackelia cusickii*, has been found growing only beneath *Juniperus occidentalis* trees in competition with *Festuca idahoensis* and *Tortula* ruralis. This species did not occur on any macroplots, but was observed to be nearby.

When Juniperus occidentalis dies, the cover of Tortula ruralis and Festuca idahoensis deteriorates. If Artemisia tridentata is associated with this tree, Artemisia tridentata plants become established next to the dead tree. Even if Artemisia arbuscula is associated with this tree, Artemisia tridentata appears to become established around the dead tree (Figure 7). A preliminary study was made to determine why Artemisia tridentata becomes established around dead Juniperus occidentalis trees in an Artemisia arbuscula dominant stand. Artemisia arbuscula was the dominant shrub in the stand selected for study. There were numerous large Juniperus occidentalis trees on the stand as well as numerous dead trees approximately three to five feet in height. A trench was dug from the base of one mature, dead tree surrounded by Artemisia tridentata out into the Artemisia arbuscula dominated stand. The soil depth next to the tree was approximately 40 inches while beneath the Artemisia arbuscula it varied from 25 to 30 inches. It is hypothesized that Juniperus occidentalis propagules are disseminated more or less at random over a stand. Numerous seedlings are established but only those growing in the deeper soil areas can reach maturity.

Figure 7. Inclusion of Artemisia tridentata in an Artemisia arbuscula stand.

Those growing in shallow soil underlain by an impenetrable restrictive layer reach a certain size and then die.

In conclusion, except for stoniness and topographic position, no other consistent differences are apparent between *Juniperus occidentalis* and non-*Juniper occidentalis* sites within the study area. However, since associations with this arborescent overstory segregate according to these specialized habitat conditions, *Juniperus occidentalis* dominated stands will be considered as separate ecosystems.

Artemisia tridentata/Agropyron spicatum Association

This association represents the climatic climax of the high desert region of Oregon and is the most variable in both vegetation and soils. Based on intensive study and reconnaissance, this vegetation is found in poorer condition than any other association recognized. These two factors contribute to the difficulty of interpreting its vegetation-soil relationships. The interpretation can be improved by recognizing a *Stipa thurberiana* phase of this association. This division is logical on the basis of vegetation, but no characteristic soil differences have yet been demonstrated.

The possibility of a range condition difference being responsible for the *Stipa* phase cannot be ruled out until more research has been conducted. In this study, however, the possibility of condition differences is minimized for the following reasons: two stands, one *Artemisia tridentata/Agropyron spicatum* and the other a *Stipa thurberiana* phase, were spacially located only 100 yards apart (Figures 8 and 9). With the typical association and its *Stipa* phase occurring so close together, a condition difference is unlikely because it cannot be explained on the basis of livestock distribution. Another stand in which *Stipa thurberiana* was the dominant grass was located only 200 yards from a good condition *Artemisia tridentata/Festuca idahoensis* stand, thus reducing the possibility that the former was the result of heavy grazing.

Typical *Artemisia tridentata/Agropyron spicatum* Association

Vegetation. Table 9 shows the basal area and frequency of occurrence values together with their standard errors for the most important species and the ranges in these statistics for the plants of lesser importance for both the typical association and its *Stipa* phase. Appendix 3 indicates the constancy data for all associations studied. Appendix 4 and 5 give the density, crown cover and height values for all shrubby species.

Figure 8. Landscape view of one Artemisia tridentata/ Agropyron spicatum stand.

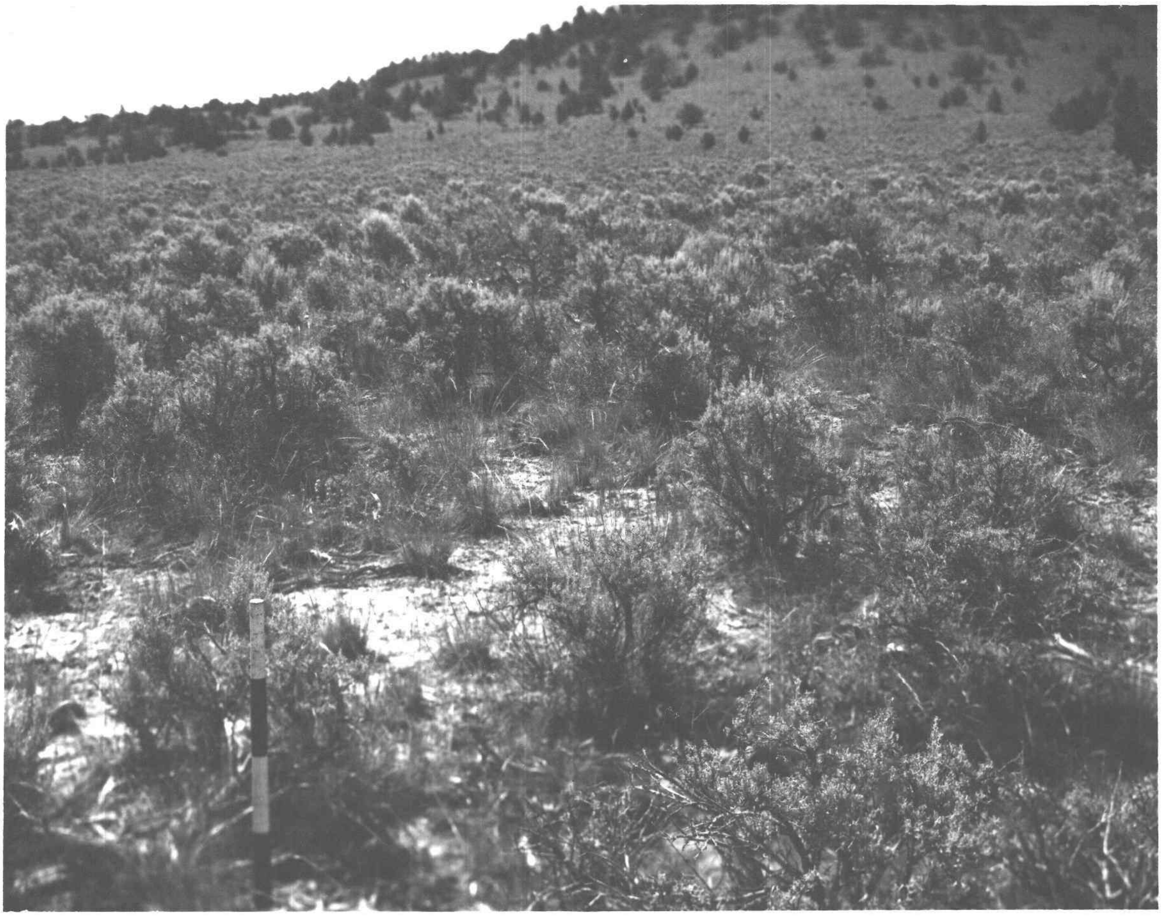


Figure 9. Landscape view of one *Artemisia tridentata*/ *Agropyron spicatum* *Stipa* phase stand.

Table 9. Basal area and frequency values for the Artemisia tridentata/Agropyron spicatum association and its Stipa thurberiana phase.

Mean and standard error[1] or range in basal area and frequency values where the species is present[2] but too rare to calculate a valid standard error.

	Artemisia tridentata/ Agropyron spicatum		Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	
	Basal Area (per cent)	Frequency (per cent)	Basal Area (per cent)	Frequency (per cent)
Perennial Grasses				
Agropyron spicatum	2.5 ± 0.4	66 ± 6	0.9 ± 0.2	45 ± 4
Poa secunda	2.2 ± 0.6	88 ± 5	1.6 ± 0.3	86 ± 4
Festuca idahoensis	0.4 ± 0.2	13 ± 7	1.0 ± 0.2	25 ± 5
Stipa thurberiana	0.3 ± 0.1	13 ± 5	1.6 ± 0.3	52 ± 7
Sitanion hystrix	0.3 - 0.6	18 - 38	T - 1.3	8 - 45
Koeleria cristata[3]	T - 0.5	3 - 25	T - 0.5	8 - 30
Oryzopsis webberi[4]	0.4	10	T	3
Poa cusickii	0.2	8	0.2	3
Oryzopsis hymenoides	-	-	T	3 - 8
Annual Grass				
Bromus tectorum	0.4	35		
Perennial Forbs				
Phlox diffusa	0.6 ± 0.2	17 ± 6	0.2 ± 0.1	12 ± 3
Erigeron filifolius	T - 0.9	3 - 40	0.4 - 0.5	28 - 43
Crepis acuminata	T - 0.5	8 - 45	T - 0.4	5 - 38
Antennaria dimorpha	T - 0.4	8 - 23	0.2 ± 0.1	12 ± 4
Eriogonum ovalifolium	T - 0.3	3 - 20	T - 0.2	3 - 18
Phlox longifolia	T - 0.3	3 - 28	T - 0.5	3 - 43

Table 9, continued

	Artemisia tridentata/ Agropyron spicatum		Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	
	Basal Area (per cent)	Frequency (per cent)	Basal Area (per cent)	Frequency (per cent)
Calochortus eurycarpus	T - 0.2	5 - 20	0.1	10
Delphinium andersoni	T - 0.2	3 - 15	0.1 - 0.2	13 - 18
Astragalus lentiginosus	0.2	10	-	-
Lomatium triternatum	T - 0.1	5 - 10	T	3
Arabis holboellii var. pendulocarpa	T - 0.1	3 - 13	0.2	15
Erigeron linearis	T - 0.1	3 - 10	-	-
Astragalus stenophyllus	T	3 - 8	T - 0.2	7 - 15
Lomatium macrocarpum	T	8	T - 0.1	3 - 5
Phoenicaulis cheiranthoides	T	8	-	-
Aster scopulorum	T	5	0.3	18
Allium parvum	T	3	T	3
Artemisia tridentata	T	3	-	-
Astragalus miser	T	3	T - 0.2	5 - 15
Balsamorhiza serrata	T	3	-	-
Chaenactis douglasii	T	3	T	3
Lupinus saxosus	T	3	T - 0.4	3 - 23
Microseris troximoides	T	3	0.2	15
Penstemon cinereus	T	3	T	5
Viola beckwithii	T	3	-	-
Allium acuminatum	-	-	0.3	30
Astragalus purshii	-	-	T - 0.3	3 - 15
Eriogonum proliferum	-	-	T	8
Zygadenus paniculatus	-	-	T	3
Aster canescens	-	-	T	3
Annual Forbs				
Collinsia parviflora	0.4 ± 0.1	32 ± 18	0.3 ± 0.1	31 ± 12
Microsteris gracilis	0.5 - 0.9	53 - 88	0.6 - 0.9	60 - 93

Table 9, continued

	Artemisia tridentata/ *Agropyron spicatum*		*Artemisia tridentata*/ *Agropyron spicatum* *Stipa thurberiana* phase	
	Basal Area (per cent)	Frequency (per cent)	Basal Area (per cent)	Frequency (per cent)
Lappula redowskii	0.2 - 0.6	15 - 63	0.2	20 - 23
Gayophytum ramosissimum	0.1 - 0.6	10 - 58	0.4 - 0.7	35 - 68
Descurainia pinnata	0.2 - 0.3	20 - 25	T - 0.2	5 - 23
Eriastrum filifolium	T - 0.3	5 - 25	T - 0.7	5 - 73
Lupinus brevicaulis	0.1	13	-	-
Cordylanthus ramosus	T	3	T	3
Mentzelia albicaulis	T	3	T	3 - 5
Phacelia linearis	T	3	T	8
Oenothera andina			T	5
Cryptogams and Soil Surface Conditions				
Tortula ruralis	7.0 ± 1.9	68 ± 12	5.3 ± 1.0	69 ± 6
Epigeous cryptogams	2.6 ± 0.7	89 ± 3	1.4 ± 0.2	79 ± 7
Stones	13.6 ± 4.3	-	8.5 ± 3.5	-
Gravel[5]	5.9 ± 2.0	-	3.7 ± 1.0	-
Litter[5]	18.1 ± 3.5	-	19.7 ± 2.3	-
Bare ground	47.4 ± 1.9	-	58.9 ± 3.7	-

1 $S_{\bar{x}} = \sqrt{\frac{s^2}{N}}$

2 Means based on six macroplots.

3 T is less than 0.1 per cent basal area.

4 Single values indicate species encountered in sampling on one macroplot only or on more than one macroplot with the same basal area and/or frequency value.

5 Mean based on five macroplots.

The typical Artemisia tridentata/Agropyron spicatum association is quite variable and additional study may indicate a need for subdivision. On the basis of existing information, however, further subdivision does not seem justified.

In this association, Artemisia tridentata has a crown cover of 10.3 ± 2.0 per cent, an average density of 11.0 ± 1.0 plants per 200 square feet and an average height of 22.9 ± 0.8 inches. Chrysothamnus nauseosus, Eriogonum sphaerocephalum, Leptodactylon pungens are insignificant members of the shrub layer, having densities of 0.3, 0.5, and 1.6 plants per 200 square feet, respectively. Chrysothamnus viscidiflorus occurs on only one macroplot. Eriogonum sphaerocephalum and Leptodactylon pungens are characteristically under 10 inches in height, while Chrysothamnus nauseosus averages 22 inches in height. These plants are all reasonably mature. Seedlings of the latter species were not encountered on any of the observation plots.

Agropyron spicatum is the dominant grass in this association with an average basal area of 2.5 ± 0.4 per cent. It occurs as a distinct bunchgrass. This species appears to be in high vigor for the most part, although the crowns of some of the older plants are beginning to die. This gives a loose appearance to these bunches.

Poa secunda has a basal area of 2.2 ± 0.6 per cent, but is only seasonally dominant since its maximum growth is made early in the spring when most of the factors of the environment are present in excess. In addition, this species is rather shallow rooted. Festuca idahoensis and Stipa thurberiana are relatively unimportant in the typical association.

The dominant forb in this and in all other associations studied is Phlox diffusa. Of the 25 species of perennial forbs encountered on the observation plots only one, Phlox diffusa, occurred on every macroplot sampled. This points out the kind of variation which may be expected in the presence and relative dominance among perennial forbs.

The total perennial forb cover is not characteristically different than in the other associations studied. However, species such as Aster scopulorum, A. canescens and Chaenactis douglasii occur only in the typical Artemisia tridentata/Agropyron spicatum association and in its Stipa phase. These species are not found beneath a Juniperus occidentalis overstory either in the typical association or its Stipa phase. Erigeron filifolius becomes important beneath the tree overstory.

The annual herb component of the Artemisia tridentata/Agropyron spicatum association including its

Stipa phase, is the richest encountered. Since this study involved sampling in an unfavorable as well as in a favorable year, it is felt that most annual species have been recorded. The presence and relative dominance of one of these annual species seems to have indicator value in characterizing this association in good or better condition. For example, Eriastrum filifolium occurs only in the Artemisia tridentata/Agropyron spicatum association and in its Stipa phase, but only when the Juniperus occidentalis overstory is not present. Annual species are valuable as indicators since most of these species make their demands on a site when many of the environmental factors are not limiting. Thus it seems that very small but important environmental differences may be the cause of changes in annual composition. Therefore, annuals may be important aids in interpreting the total vegetation of a site.

Tortula ruralis and epigeous cryptogams have a mean cover of 7.0 ± 1.9 per cent and 2.6 ± 0.7 per cent, and frequencies of 68 ± 12 per cent and 89 ± 3 per cent, respectively, in this association. In this, as in the other vegetation types studied, Tortula ruralis is found almost exclusively within the area of leaf fall of the shrub component. Epigeous cryptogams, on the other hand, are most frequently encountered in the shrub interspaces.

The total cryptogam cover in southeastern Oregon is quite small in comparison to the cryptogam cover in similar associations in northern Oregon and southeastern Washington where up to 100 per cent of the free soil surface may be covered by these species.

Soil surface characteristics. The average stone cover in this habitat type is 13.6 ± 4.3 per cent. However, the range of stone cover is from 1.8 to 26.7 per cent. The stony members of this habitat type are not suited to reseeding by ordinary cultural methods. The degree of stoniness does not seem to be a deterrent to livestock grazing as some stony areas were found to be in as poor range condition as the nonstony areas.

Most of the litter cover was found in the crowns of the older grass clumps, around the outside of the more vigorous grass bunches and beneath the shrubs. The area between shrubs and grasses is essentially bare except where epigeous cryptogam cover occurs.

The bare ground in this habitat type is lower than in any other studied, with a mean of 47.4 ± 1.9 per cent. This relatively low figure is due principally to the stoniness and to the greater than average coverage of *Tortula ruralis*.

Poulton (66) has concluded that in the Columbia

Basin region of Oregon bare ground is a very sensitive index of biotic pressure. It is doubtful if this conclusion applies to southeastern Oregon in this habitat type since the amount of bare ground is quite high even in stands of good or better condition.

Associated soils. Within the area of study, the *Artemisia tridentata/Agropyron spicatum* habitat type occurs on residual soils from basalt and rhyolite parent material and on alluvial fans developed from materials of basaltic and rhyolitic origin. In comparison, similar habitat types in British Columbia, southeastern Washington and northeastern Oregon have associated soils developed from glacial material and loess respectively. The soils which have developed in place in southeastern Oregon are characteristically the most stony. The soils which have developed on alluvial fans are underlain by an indurated restrictive layer cemented either by calcium carbonate or by siliceous materials.

These soils can be most advantageously discussed by series groupings. Table 10 presents selected morphological, chemical and physical characteristics of these soils.

Series 1, "very strongly developed Brown soil from basalt residuum," is found associated with two *Artemisia tridentata/Agropyron spicatum* stands (Figure 10). This

Table 10. Selected characteristics of the soils associated with the *Artemisia tridentata/Agropyron spicatum* habitat type.

Characteristics		Soil Series 1	5	7	8
No. of pits represented		2	1	2	1
Parent material		Basalt residuum (dissected)	Rhyolite residuum	Basalt alluvium	Basalt and rhyolite alluvium
Classification		Brown	Brown	Brown	Brown
Depth (inches)		19 - 23	21	24 - 38	21
Solum underlain by:		Bedrock	Bedrock	Calcium carbonate cemented pan	Silica cemented pan
Color Dry	A_1	10YR 5.5-6/2[1]	10YR 6/2	10YR 5/2	10YR 6/2
	B_2 or B_{22}	7.5YR 5/4-10YR 5/4	10YR 5/2	10YR 6/3	7.5YR 6/4
Color Moist	A_1	10YR 4/2	10YR 4/2	10YR 3/2	10YR 3/2
	B_2 or B_{22}	10YR 4/4 - 5/4	10YR 3/2	10YR 4/3 - 5/4	7.5YR 5/6
Textural Class	A_1	sl[2]	l	l	l
	B_2 or B_{22}	c	scl	cl	c
Structure	Primary A_1	2 f/m pl[2]	2 m pl	1/2 f/m pl	2 f pl

Table 10, continued

Characteristics		Soil Series 1	5	7	8
	Primary B_2 or B_{22}	1/3 m pr	1 f pr	1/3 m pr	2 m pr
	Breaking to: B_2 or B_{22}	2 f/m abk	1 m sbk	2/3 m/c sbk	3 f/m sbk
pH	A_1	7.0 - 7.3	6.5 - 6.6[3]	6.5 - 6.8	6.6
	B_2 or B_{22}	6.9 - 7.3	6.5 - 6.6	6.8 - 6.9	6.9 - 7.0
A_1 beneath *Artemisia tridentata*		6.4 - 6.9	6.7[3]	6.5 - 6.9	6.6 - 6.7
Salinity, mmhos/cm.	A_1	0.50 - 0.68	0.38 - 0.40	0.45 - 0.49	0.40 - 0.44
	B_2 or B_{22}	0.39 - 0.60	0.55 - 0.60	0.36 - 0.46	0.39 - 0.42
Organic matter, A_1		1.33 - 2.01	2.18 - 2.25	2.62 - 2.78	2.42
Moisture equivalent, %	A_1	19.3 - 21.9	20.4 - 20.5	20.2 - 25.7	25.8 - 26.2
	B_2 or B_{22}	49.0 - 57.1	10.1	25.9 - 38.9	47.6 - 48.4
15 Atms. moisture, %	A_1	7.27 - 9.69	8.01 - 8.04	11.01 - 12.01	12.11 - 12.23
	B_2 or B_{22}	32.62 - 36.98	9.45 - 10.13	15.88 - 24.97	32.22 - 32.25

1 Munsell color notations. Soil Survey Manual (87) pp. 195-201.

2 Soil texture and structure symbols. Soil Survey Manual (87) pp. 139-140.

3 When soil series is represented by one profile, ranges in values indicate duplicate determinations. All other ranges indicate variation between or among profiles within a series. Single values indicate either no variation within duplicate determinations or no variation between or among profiles within a series.

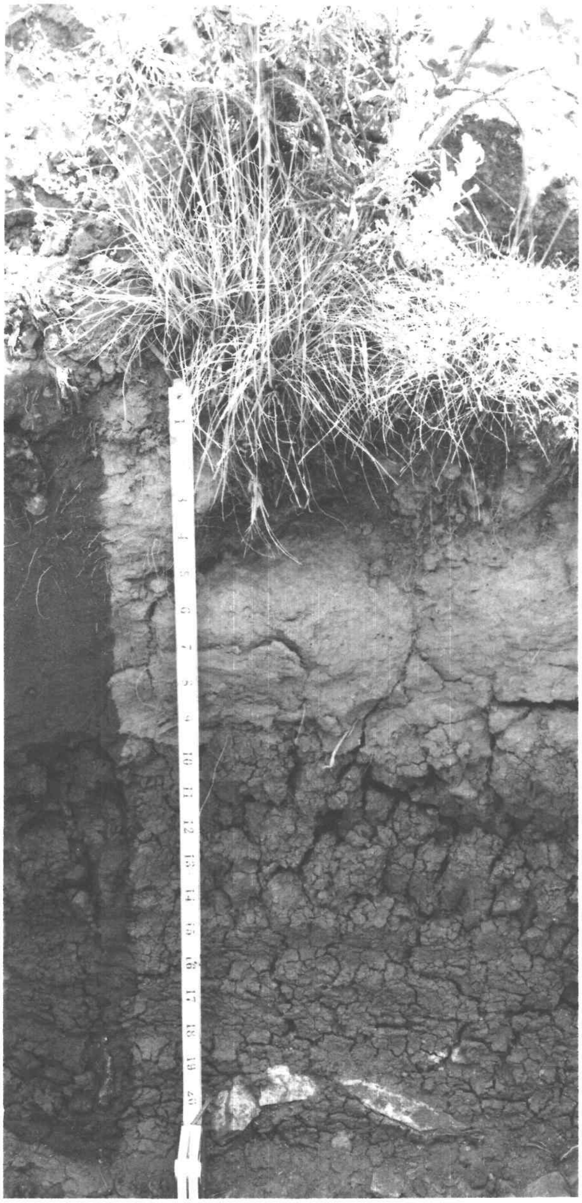


Figure 10. Soil profile representing soil series 1 and associated with an Artemisia tridentata/ Agropyron spicatum habitat type.

is by far the most stony soil found in this habitat type. Both profiles are shallow, 19 and 23 inches respectively. However, it is important to emphasize that they overlay dissected basalt. Roots up to 1/2 inch in diameter have been observed extending into these cracks. This increases the depth to which roots may extend for available moisture and nutrients. The effective root zone, therefore, is not limited to the depth of the profile as commonly expressed in terms of "depth to bed rock." The color of the surface soil is light grayish brown and tends toward yellowish brown in the B horizon. The texture of the surface horizon is a sandy loam. The per cent of clay increases strongly with depth and the well-developed B_{22} horizon is clay textured. The structure of the A horizon is platy changing to very strong, moderate prisms in the B. These prisms may be further broken down into fine, angular blocks. Both profiles are near neutral in reaction and non-saline throughout. Organic matter is quite low in these two soils, averaging between 1 and 2 per cent in the surface horizon. There is a consistent increase of organic matter in the B horizon just above the basalt substrate. This is also characteristic of other profiles (Table 17, p.124), and is thought to be caused by a concentration of roots in this layer, due to some restriction by the substrate. As would be expected, the moisture equivalent and 15 atmospheres moisture percentage increase with a finer textural class. As is the general case, however, the 15 atmospheres moisture percentage does not increase as rapidly as does the moisture equivalent. For this reason, these profiles have a rather high available moisture holding capacity in the heavier textured horizons.

The two soils comprising series 7 have a number of characteristics in common. Both have developed from alluvium of basaltic origin and both are underlain by a calcium carbonate cemented restrictive layer (Figure 11). The A horizons are darker than in the two soils previously discussed. The darker color is associated with a higher organic matter content of these horizons (Table 10). Surface color ranges from grayish brown to dark grayish brown. The texture of the profiles varies from a loam in the A horizon to sandy clay loams in the more well developed part of the B. The structure of the A horizon is platy while in the B the primary structural units are moderate prisms, breaking into subangular blocks. The pH of the horizons of these profiles ranges from 6.4 to 7.0. They are nonsaline throughout. A range in pH values from 7.9 to 8.3 indicate alkaline conditions in the calcium carbonate pan. The available soil moisture holding capacity of the soils of this series is much

Figure 11. Soil profile representing soil series 7 and associated with an _Artemisia_ _tridentata_/ _Agropyron_ _spicatum_ habitat type.

lower than that of series 1, due principally to the lighter texture of the profile.

The one soil profile comprising series 8 is in the Brown great soil group (Figure 12). It has developed from alluvial materials of rhyolitic and basaltic origin. This profile is free from large stones, yet contains some alluvial gravels. The profile is 21 inches deep with a silica cemented restrictive layer. The A horizon is light brownish gray in color. Brown to dark brown colors predominate in the lower part of the solum. The texture of the A horizon is a loam changing to clay loam in the well developed B. The surface horizon has a platy structure, while coarse prisms are the primary peds in the B horizon. The pH of the profile varies from 6.2 in the A horizon to neutral in the B_3 and to slightly alkaline, 7.8, in the cemented restrictive layer. There is no salt problem in this solum. Organic matter content averages between one and two per cent in the surface layer and increases slightly just above the restrictive layer due to root concentration. The increased clay content of the B_2 horizon is reflected in a higher available moisture holding capacity than was the case in series number 7.

The one soil comprising series No. 5 is a Brown soil developed from rhyolite residuum (Figure 13). This is the lightest textured soil in the *Artemisia tridentata*/

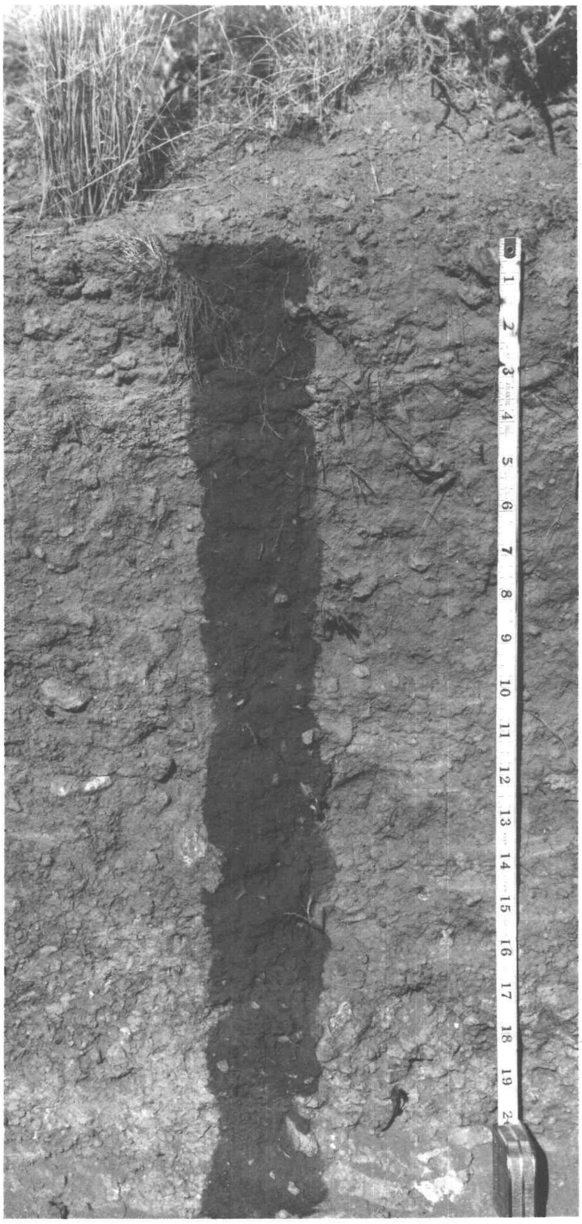


Figure 12. Soil profile representing soil series 8 and associated with an *Artemisia tridentata/ Agropyron spicatum* habitat type.

Figure 13. Soil profile representing soil series 5 and associated with an *Artemisia tridentata*/*Agropyron spicatum* habitat type.

Agropyron spicatum habitat type. The downward penetration of plant roots is limited by bed rock at a depth of from 21 to 35 inches. There is little color change in this profile. The A_1 is a light brownish gray, while the B_2 is a grayish brown. The texture of the surface horizon is a loam while a sandy clay loam is found in the B horizon. Primary peds range from platy in the A_1 to weakly developed fine prismatic in the B_2. The lack of clay in this profile is primarily responsible for the weak structural development. The entire solum is slightly acid and non-saline. Although this site is located on a south exposure where warm temperatures would tend to increase organic matter mineralization, the organic matter content of the A_1 is 2.2 per cent. This may be due to the exclusion of livestock for the past 18 years with the resulting buildup of decaying plant residues. The available soil moisture holding capacity of this profile is the lowest encountered in this study.

Stipa Phase of the *Artemisia tridentata*/*Agropyron spicatum* Association

The *Stipa* phase vegetation can be differentiated from the typical *Artemisia tridentata*/*Agropyron spicatum* vegetation on the following basis: the former has significantly more *Stipa thurberiana* and less *Agropyron spicatum* than does the latter type (Table 11).

Table 11. Comparison of the basal area and frequency values for the grass species which are significantly different in the *Artemisia tridentata/Agropyron spicatum* association and the *Stipa thurberiana* phase of this association.

	Artemisia tridentata/ Agropyron spicatum		*Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana* phase	
	Basal Area (per cent)	Frequency (per cent)	Basal Area (per cent)	Frequency (per cent)
Agropyron spicatum	2.5* ± 0.4	66 ± 6	0.9 ± 0.2	45 ± 4
Stipa thurberiana	0.3 ± 0.1	13 ± 5	1.6** ± 0.3	52 ± 7
Festuca idahoensis	0.4 ± 0.2	13 ± 7	1.0[1] ± 0.2	25 ± 5

* Significantly larger at the 5% level of probability.

** Significantly larger at the 1% level of probability.

1 Approaches significance at the 10% level of probability.

Leptodactylon pungens has a constancy of 5/7 and a density of 6.3 plants per 200 square feet in the Stipa phase as compared to 1/6 and 1.6 in the typical Artemisia tridentata/Agropyron spicatum association (Appendix 3 and 5).

On the basis of accumulated evidence relating to the density and constancy of Leptodactylon pungens and the dominance of Stipa thurberiana and Agropyron spicatum, this author concludes that the Stipa phase is an entity, recognizable on vegetation characteristics, but which lacks the status of a separate association. On the basis of reconnaissance these differences seem to be consistent over a rather wide area. The same situation has also been reported in Idaho by Tisdale (83).

During phenology observations and reconnaissance of the Stipa phase it was noted that Stipa thurberiana was preferred by livestock. In the typical association the most preferred grass was Agropyron spicatum. Hyder (41) has data which support this observation and which show that on some areas of the Squaw Butte Experiment Station Stipa thurberiana is the principal decreaser[4]. In range condition guides, this species has been thought to increase

4 A decreaser species is a plant, preferred by livestock, which tends to be reduced in dominance as grazing pressure increases (27).

under the influence of grazing. The information gathered in this study and which has been confirmed by Tisdale and Hyder indicates that we need to change our concepts about the climax and seral nature of *Stipa thurberiana* in some associations.

Vegetation. *Artemisia tridentata* has an average crown cover of 12.0 ± 1.3 per cent, with an average density of 12. ± 1.2 plants per 200 square feet, and an average maximum height of 25.8 ± 0.6 inches (Appendix 4). *Eriogonum sphaerocephalum*, *Chrysothamnus viscidiflorus*, *Chrysothamnus nauseosus*, *Grayia spinosa*, and *Tetradymia glabrata* are minor components of this vegetation as indicated by their low constancy and density values. (Appendix 3 and 5). *Eriogonum sphaerocephalum* and *Chrysothamnus viscidiflorus* are low growing shrubs, generally under 12 inches in height, while *Chrysothamnus nauseosus*, *Tetradymia canescens*, and *Grayia spinosa* are taller. The former two average 18 to 24 inches and the latter 42 inches in height. Seedlings of these shrubs were not encountered on the observation plots.

The term "*Stipa* phase" is not used to indicate dominance of this species. Of the seven stands studied, *Stipa* was dominant on five while *Agropyron spicatum* was the dominant grass on the remaining two. The criterion used in naming this phase was a basal area of Stipa thurberiana equal to or exceeding one-half of the basal area of Agropyron spicatum. On the basis of seven macroplots, Stipa thurberiana had an average basal area of 1.6 ± 0.3 per cent as compared with 0.9 ± 0.2 per cent for Agropyron spicatum (Table 11). Festuca idahoensis has a basal cover of 1.0 ± 0.2 in the Stipa phase as compared to 0.4 ± 0.2 in the typical association. Poa secunda has a basal cover of 1.6 ± 0.3 per cent, but is only seasonally dominant because of its early maturity.

All grass species in the Stipa phase have the bunch type growth form. Stipa thurberiana typically dies from the center of the crown outward, giving a circular appearance to the remaining part of the crown.

There is no diagnostic feature of the presence or dominance of perennial forbs which would serve to differentiate the Stipa phase from the typical Artemisia tridentata/Agropyron spicatum vegetation. Phlox diffusa is the dominant perennial forb, having a basal cover of 0.2 ± 0.1 per cent, a frequency of occurrence of 12 ± 3 per cent, and a constancy of 6/7. A total of 24 perennial forb species were recorded on 7 macroplots representing this phase. Not one of these species had a constancy of 7/7. On the basis of reconnaissance, however, three species, Aster scopulorum, A. canescens, and

Chaenactis douglasii were found to be characteristic of the phase when the *Juniperus occidentalis* overstory is not present. *Erigeron filifolius* becomes one of the dominant perennial forbs beneath the tree overstory.

As in the typical *Artemisia tridentata/Agropyron spicatum* association, the annual forb component of the *Stipa* phase is one of the richest found. *Collinsia parviflora* is the dominant annual species. *Eriastrum filifolium* is found only in the *Stipa* phase and in the typical climatic climax where a tree overstory is not present. This characteristic annual, together with the three perennial forbs listed above, and the lack of consistent soil differences, would tend to indicate a close relationship between the phase and the typical association, both with and without an arborescent overstory.

Soil surface characteristics. The average cover of *Tortula ruralis*, epigeous cryptogams, and stones is characteristically less in the *Stipa* phase than in the typical *Artemisia tridentata/Agropyron spicatum* habitat type, while litter cover is only slightly higher. As a result, the per cent of bare ground in the *Stipa* phase is the highest among the habitat types studied. With the exception of two intensively studied stands, the *Stipa* phase occurs principally on alluvial fans near the valley bottoms. Reconnaissance observations also confirm this finding. Because of this feature and the lack of stones, the *Stipa* phase would be the most suitable for cultivation and reseeding.

Associated soils. The *Stipa* phase habitat type occurs on three soil series: series 3, series 5, and series 8 (Table 7). Table 12 presents selected morphological, chemical and physical characteristics of these soils. All of these soils belong to the Brown great soil group. In general, the *Stipa* phase occurs on lighter textured soils than the typical *Artemisia tridentata/ Agropyron spicatum* association when both are found on the same kind of relief and on soils formed from the same parent material (Table 13).

Series 3, "weakly developed Brown soil from basalt residuum with some evidence of alluvial deposits" is characteristic of two *Stipa* phase stands. Both profiles are shallow to the restrictive layer, 17 and 25 inches respectively. On one stand, a crack in the bed rock was noted in one corner of the soil pit (Figure 14). This crack was about 2½ feet in width with a B_{23} and B_3 horizon developed in the opening which extended to a depth of 49 inches where bed rock was again encountered.

Table 12. Selected characteristics of the soils associated with the *Stipa* phase of the *Artemisia tridentata/Agropyron spicatum* habitat type.

Characteristics	Soil Series 3	Soil Series 5	Soil Series 8
No. of pits represented	2	2	3
Parent material	Basalt residuum (some evidence of alluvial deposits)	Rhyolite residuum	Basalt and Rhyolite alluvium
Classification	Brown	Brown	Brown
Depth (inches)	17 - 25	18 - 23	25 - 32
Solum underlain by:	Bedrock	Bedrock	Calcium carbonate cemented pan
Color, Dry, A_1	10YR 6/2[1]	10YR 5.5 - 6/2	10YR 5/2 - 6/2
Color, Dry, B_2 or B_{22}	10YR 5.5/2 - 5/3	10YR 5/3	10YR 4 - 5/3
Color, Moist, A_1	10YR 3/3 - 4/2	10YR 3 - 4.5/2	10YR 3 - 4/2
Color, Moist, B_2 or B_{22}	10YR 4/2 - 4/3	10YR 3/3 - 4/4	10YR 3 - 3.5/3
Textural Class, A_1	l[2]	sl - l	sl - l
Textural Class, B_2 or B_{22}	l	scl - cl	sl - scl - cl
Structure, Primary A_1	2/3 f pl[2]	1/2 f/m pl	2 f pl
Structure, Primary B_2 or B_{22}	2 m/c pr	2/3 f/m/c pr	1/2/3 m/c pr
Structure, Breaking to: B_2 or B_{22}	2 m sbk	2 f/m sbk	2/3 m/c sbk

Table 12, continued

Characteristics	Soil Series 3	5	8
pH A_1	5.8 - 6.5[3]	6.3 - 6.7	6.1 - 6.7
pH B_2 or B_{22}	6.7 - 6.8	6.6 - 6.7	6.5 - 8.1
A_1 beneath *Artemisia tridentata*	6.4 - 6.6	6.6 - 6.7	6.7 - 7.4
A_1 beneath *Grayia spinosa*		7.3 - 7.6	
A_1 beneath *Juniperus occidentalis* (old tree)		7.3 - 7.4	
Salinity, mmhos/cm.			
A_1	0.43 - 0.69	0.40 - 1.25	0.54 - 0.73
B_2 or B_{22}	0.25 - 0.54	0.41 - 0.68	0.55 - 1.37
Organic matter, A_1	1.82 - 2.00	1.30 - 4.53	1.25 - 1.57
Moisture equivalent, %			
A_1	23.4 - 24.9	14.9 - 22.5	17.9 - 25.7
B_2 or B_{22}	27.8 - 28.4	23.9 - 32.3	17.7 - 30.4
15 Atm. moisture, %			
A_1	10.65 - 11.59	6.87 - 9.71	8.06 - 10.94
B_2 or B_{22}	14.66 - 15.54	10.80 - 20.51	9.24 - 16.82

1 Munsell color notations. Soil Survey Manual (87) pp.195-201.
2 Soil texture and structure symbols. Soil Survey Manual (87) pp. 139-140.
3 A range in values indicates variation within a soil series.

Table 13. Results of a mechanical analysis of two soils representing two stands of the *Artemisia tridentata*/*Agropyron spicatum* association. Both soils belong to the Brown great soil group and have developed from mixed rhyolite and basalt materials on the same alluvial fan.

	Artemisia tridentata/ *Agropyron spicatum*			*Artemisia tridentata*/ *Agropyron spicatum*, *Stipa thurberiana* phase		
Horizon	% Sand	% Silt	% Clay	% Sand	% Silt	% Clay
A_1	40.5	38.7	20.8	43.7	35.5	20.8
A_3	39.5	36.1	24.4	43.4	32.3	24.3
B_1	40.6	29.1	30.3	45.5	29.7	24.9
B_{21}	35.5	27.4	37.9	42.2	26.6	31.2
B_{22}	24.4	26.5	49.1	49.1	20.6	30.3
B_3	41.6	18.6	39.8			

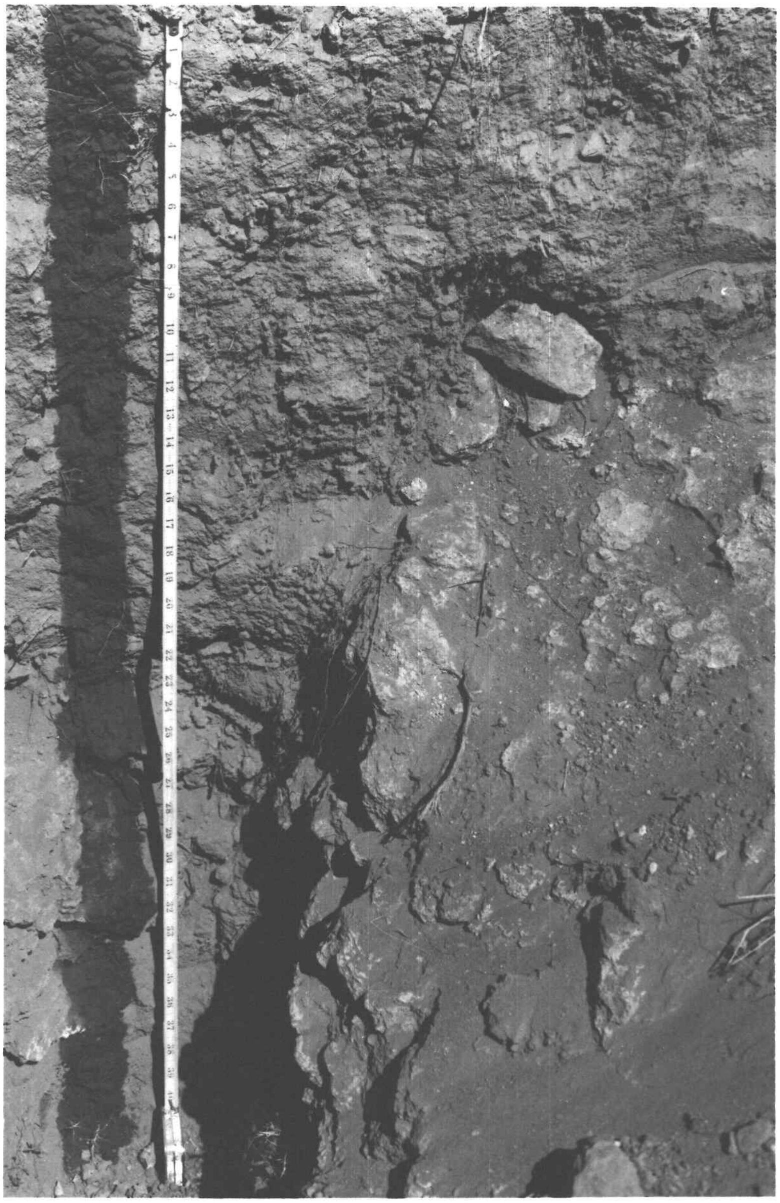


Figure 14. Soil profile representing soil series 3 and associated with the *Stipa* phase of the *Artemisia tridentata*/*Agropyron spicatum* habitat type.

Attempts were made to locate similar openings elsewhere around the macroplot, but none was found. This condition was considered atypical. The typical profile is terminated by bed rock at 22 inches. The color of the surface horizon of these two soils is light brownish gray, changing to grayish brown to brown in the B horizon. Both profiles have a loam texture. The structure of the surface horizon is platy. The primary peds in the B_2 horizon are moderate, coarse prisms. The shallower of the two profiles has a surface pH of 5.8, while the pH of the A_1 horizon of the deeper profile is 6.5. The B horizon of both profiles has a pH of from 6.7 to 6.8. The entire solums of both soils are nonsaline. Organic matter content ranges from 1 to 2 per cent in the surface horizon. On the basis of mechanical analysis there is little indication of the textural bulge in B horizon. This is further indicated by the moisture equivalent and 15 atmospheres moisture percentage which are approximately the same in all horizons of each profile.

Three *Stipa* phase stands were found on series 8, "Brown soils from rhyolitic and basaltic fan material." These three soils were developed on three different alluvial fans and show quite a wide variation in characteristics as well as some similarities. The depths to restrictive layers are approximately 25, 26, and 32 inches respectively. The restrictive layer in all cases is an indurated calcium carbonate pan (Figure 15). The color of the surface soil is light brownish gray changing to brown in the B_2 horizons of all three profiles. The textural classes of the surface horizon are sandy loams and loams. The texture of the B horizons is quite different, ranging from sandy loam to sandy clay loam to clay loam in the three different soils. All surface soils have a platy structure. In the B horizon of the light textured soils, the primary peds are strong, coarse prisms. In the clay loam B horizon, the primary structural unit is smaller and weaker, being weak, medium prisms. The secondary ped in all B horizons is moderate to strong, subangular blocky. The pH values range from 6.1 to 6.7 in the surface and from 7.0 to 8.1 in the subsoil. The pH of the calcium carbonate pans is quite similar, 8.1 to 8.5. *Artemisia tridentata* plants in the *Stipa* phase appear to accumulate some alkaline materials from the pans, since surface soils from beneath these plants have a pH of 7.3 to 7.4 as compared to 6.1 and 6.7 in the openings between the shrubs. All three profiles are non-saline. Organic matter values are lower than in the soils previously described and range from approximately 1.0 to 1.5 per cent. The two shallower soils show an increase in organic matter content in the lower part

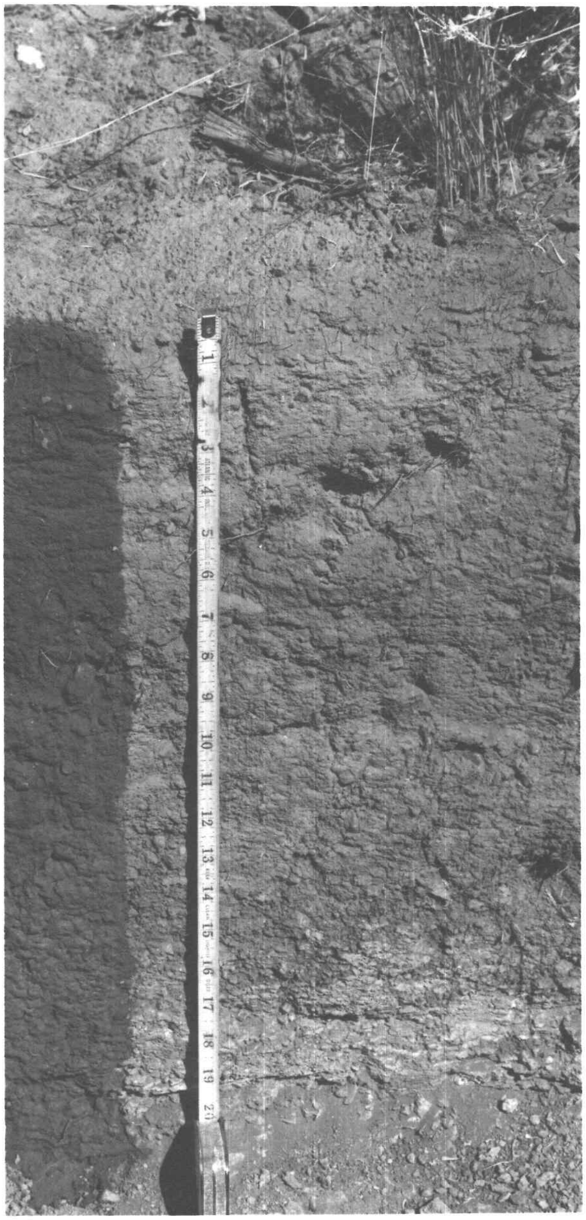


Figure 15. Soil profile representing soil series 8 and associated with the Stipa phase of the Artemisia tridentata/Agropyron spicatum habitat type.

of the B horizon. The available soil moisture holding capacity of the two lighter textured soils is less than in the heavier textured soil, although this is partly compensated for by the greater depth of the former two.

Soil series 5, "Brown soils from rhyolite residuum" is represented by two soil profiles. Both are shallow, 18 and 19 inches respectively, to bedrock (Figure 16). Surface horizons are light brownish gray. The B horizons are grayish brown to brown. Texturally, the A_1 horizons are sandy loams with the amount of clay increasing in the B horizon to change the textural class to sandy clay loam and clay. The A horizons have a platy type of structure, while in the B horizon the primary ped is moderate to strong, medium prisms breaking to moderate to fine, medium subangular blocky. Soil pH ranges from 6.3 to 6.7 at the surface and from 6.6 to 7.0 in the B horizon. Both profiles are non-saline throughout, including the surface horizon under _Grayia spinosa_. Ranges in pH from 7.3 to 7.6 beneath this plant as compared with 6.3 to 6.4 away from this shrub indicate that this species appears to accumulate alkaline materials from the soil. The organic matter content in the A_1 horizon of these two soils shows a considerable amount of variation, with 1.3 and 4.5 per cent respectively. The value of 4.5 could have resulted from a sampling error as it is much larger

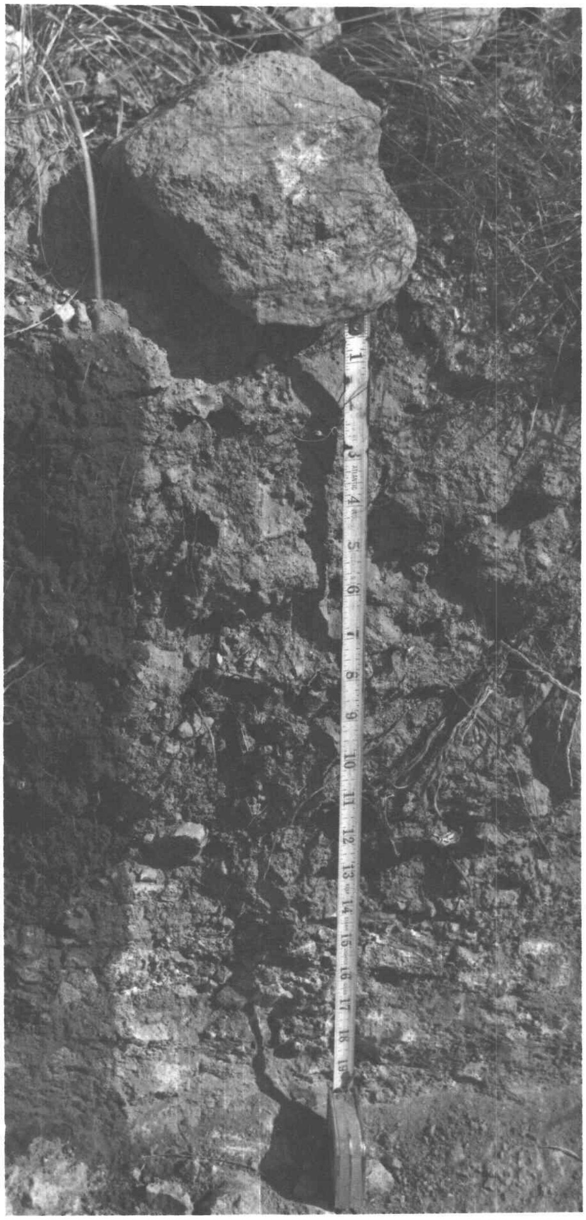


Figure 16. Soil profile representing soil series 5 and associated with the Stipa phase of the Artemisia tridentata/Agropyron spicatum habitat type.

than would normally be expected except beneath a shrub or tree. In spite of the rather large textural difference in the two profiles, the available soil moisture holding capacity of each is not much different.

In an attempt to explain some of the environmental differences between the typical Artemisia tridentata/ Agropyron spicatum habitat type and its Stipa phase, exchangeable bases and cation exchange capacities were determined for one soil representing each of these environmental units. These two stands are located 100 yards from each other on the same type of parent material and relief. Both soils are members of series 8, however, the Agropyron spicatum dominated stand has a heavier textured profile. Table 14 shows the results of these analyses. These data would tend to indicate that Agropyron spicatum requires a more fertile soil than does Stipa thurberiana. This hypothesis could be tested by greenhouse trials and/or by reciprocal transplants made in the field.

Available soil moisture seems to have a great deal of importance in affecting plant distribution when two different soil series are compared. The results of a soil moisture depletion study are shown in Figure 17. The Artemisia tridentata/Agropyron spicatum habitat type is represented by series 1 and its Stipa phase by series

Table 14. Results of cation exchange capacity and exchangeable base determinations of two soils representing series 8.

Cation Exchange Capacity
Habitat Type

Artemisia tridentata/ Agropyron spicatum			Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase		
Horizon	Depth (Inches)	ml/100 gms.	Horizon	Depth (Inches)	ml/100 gms.
A_1	0 - 3	21.65	A_1	0 - 3	19.03
A_3	3 - 6	24.13	A_3	3 - 7	20.63
B_1	6 - 9	26.12	B_1	7 - 12	20.90
B_{21}	9 - 15	30.60	B_2	12 - 17	30.60
B_{22}	15 - 18	49.14	B_3	17 - 21	40.85
B_3	18 - 21	51.15			

Exchangeable Bases (p.p.m.)

	K	Ca	Mg	Na		K	Ca	Mg	Na
Horizon Composite	675	2590	1880	285	Horizon Composite	595	2100	1350	120

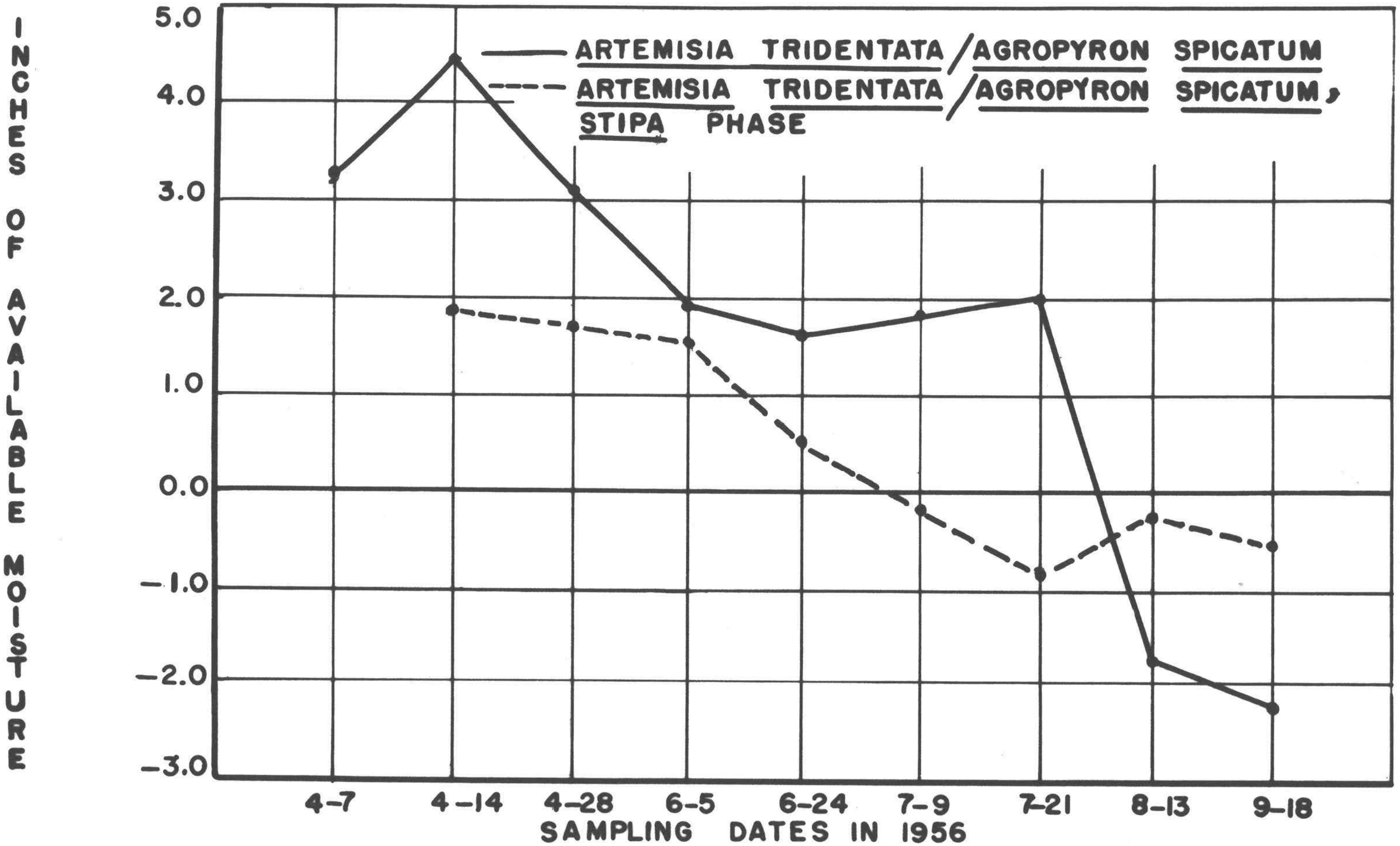


FIGURE 17. MOISTURE DEPLETION, BY VOLUME, IN TWO *ARTEMISIA TRIDENTATA/AGROPYRON SPICATUM* STANDS

8. The graph shows that the *Artemisia tridentata*/*Agropyron spicatum* habitat type has soil moisture available much longer into the growing season than does the *Stipa* phase.

Artemisia tridentata/*Festuca idahoensis* Association

In southeastern Oregon this vegetation represents a topographic climax. It was encountered on northerly exposures varying from 11 to 30 per cent slope. This topographic position together with the dominance of *Festuca idahoensis* makes this vegetation easy to recognize (Figure 18). Reconnaissance observations have revealed stands of this association to be in a better range condition than any other association recognized.

Throughout the study area a slight change in relief to a northerly exposure results in dominance of *Festuca idahoensis*. This striking phenomenon is not common in southeastern Washington. The physiological basis for this segregation of plant communities has not been fully explained. These stands encountered in southeastern Oregon represent outlying fragments of the *Festuca idahoensis* union inserted beneath an *Artemisia* overstory. In these fringe areas near the extremes of tolerance for the species, *Festuca idahoensis* will attain dominance only in specialized habitats. On these north exposures,

Figure 18. Landscape view of an Artemisia tridentata/ Festuca idahoensis stand with an arborescent overstory.

aspect appears to compensate for moisture and temperature by creating a microclimate where effective moisture is greater and temperature cooler than in the surrounding area. In southeastern Washington, on the contrary, the total effective environment approaches the modal requirements for this species. Therefore, Festuca idahoensis occurs generally throughout the area irrespective of topography.

This association in southeastern Oregon is not as rich a vegetation type as are similar associations in Idaho. Table 15 presents the average basal area and frequency values together with their standard errors for the grasses and more important forbs and cryptogams. The ranges in basal area and frequency are shown for subordinate species. The average values for the shrub crown cover, density, and height are given in Appendix 4 and 5.

Vegetation. Juniperus occidentalis is characteristic but not diagnostic of this association (Figures 18 and 19, Appendix 3). This species occurs on the more rocky types of soil and other locations which tend to increase the amount of effective moisture.

The dense cover of Festuca idahoensis and Tortula ruralis beneath the older Juniperus occidentalis trees in eastern Oregon would tend to indicate more favorable moisture conditions directly beneath these trees. It was

Table 15. Basal area and frequency values for the Artemisia tridentata/Festuca idahoensis association.

Mean and standard error or range in basal area and frequency values where the species is present[1] but too rare to calculate a valid standard error.

	Basal Area (per cent)	Frequency (per cent)
Perennial Grasses		
Festuca idahoensis	5.1 ± 0.6	94 ± 3
Poa secunda	1.5 ± 0.3	98 ± 1
Agropyron spicatum	1.0 ± 0.2	49 ± 9
Koeleria cristata	0.4 - 1.1	25 - 80
Stipa thurberiana	0.1 - 0.3	8 - 20
Sitanion hystrix[2]	0.3	15
Perennial Forbs		
Phlox diffusa	1.3 ± 0.3	53 ± 9
Antennaria corymbosa	0.6 ± 0.2	16 ± 5
Erigeron filifolius[3]	T - 0.8	5 - 56
Lupinus saxosus	T - 0.5	3 - 45
Calochortus eurycarpus	T - 0.4	3 - 40
Erigeron corymbosa	0.4	25
Crepis acuminata	T - 0.3	3 - 30
Lomatium triternatum	T - 0.3	5 - 28
Eriogonum proliferum	0.2 - 0.3	13 - 15
Phlox longifolia	T - 0.2	3 - 20
Microseris troximoides	T - 0.2	3 - 18
Astragalus stenophyllus	T - 0.2	5 - 13
Penstemon cinereus	T - 0.1	3 - 10
Eriogonum heracleoides	0.1	5
Allium parvum	T	8
Antennaria dimorpha	T	3 - 8
Eriogonum ovalifolium	T	8
Lomatium macrocarpum	T	5
Silene drummondii	T	5
Eriogonum umbellatum	T	3
Lithophragma bulbiferum	T	3
Lithospermum ruderale	T	3
Annual Forbs		
Collinsia parviflora	T - 0.2	3 - 20
Lappula redowskii	T	5
Cordylanthus ramosus	T	3

Table 15, continued

	Basal Area (per cent)	Frequency (per cent)
Cryptogams and Soil Surface Conditions		
Tortula ruralis	5.3 ± 1.3	85 ± 5
Epigeous cryptogams	2.3 ± 0.3	83 ± 7
Stones	7.7 ± 1.9	
Gravels[4]	3.4 ± 1.5	
Litter[4]	18.8 ± 2.3	
Bare ground	56.8 ± 4.0	

1 Means based on 7 macroplots.

2 Single values indicate species encountered in sampling on one macroplot or on more than one macroplot with the same basal area and/or frequency.

3 T is less than 0.2 per cent basal area.

4 Means based on 6 macroplots.

Figure 19. Landscape view of an Artemisia tridentata/ Festuca idahoensis stand without an arborescent overstory.

also noted that *Festuca idahoensis* rarely sets seed beneath these trees.

On the basis of stands intensively studied or noted on reconnaissance, *Artemisia tridentata* attains its least expression of dominance in the *Artemisia tridentata*/*Festuca idahoensis* association. The average crown cover of the species is 7.1 ± 0.9 per cent with an average density of 15.2 ± 2.5 plants per 200 square feet, and an average maximum height of 20.7 ± 0.7 inches (Appendix 4). The small, rather widely spaced sagebrush plants give this association a more open, grassy appearance (Figure 19) than in the *Artemisia tridentata*/*Agropyron spicatum* association.

Chrysothamnus viscidiflorus is an important component of this association. This species has a constancy of 5/7 and an average density of 3.6 plants per 200 square feet. As interpreted, this species is a member of the climax community and increases in dominance with range deterioration. This conclusion is also supported by reconnaissance observations. *Chrysothamnus viscidiflorus* is also well represented in the *Artemisia arbuscula*/*Festuca idahoensis* association, thus suggesting a relationship among *Chrysothamnus viscidiflorus*, *Festuca idahoensis*, greater effective moisture, and cooler temperatures. McKell (53) has noted that *Chrysothamnus* viscidiflorus predominated on north facing slopes and in moist draws in regions of central Oregon. Poulton (66) also reports that in the Columbia Basin region of Oregon Chrysothamnus viscidiflorus is associated with north facing slopes where Festuca idahoensis is dominant.

Leptodactylon pungens, Artemisia arbuscula, and Tetradymia canescens are unimportant members of stands in good or better condition. Symphoricarpos rotundifolius and Ribes cereum are important in the Artemisia tridentata/Festuca idahoensis association. The occurrence of these species is quite rare on the study plots. Reconnaissance observations have indicated that these two species are too widely spaced to be encountered in sampling but do have a high fidelity for this association.

Festuca idahoensis is by far the dominant herbaceous species. It has a mean basal cover of 5.1 ± 0.6 per cent and a frequency of 94 ± 3 per cent. Poa secunda and Agropyron spicatum make up the largest portion of the remaining herbaceous vegetation. Festuca idahoensis occurs in rather distinct bunches. This species is characterized by rather short leaves averaging about 7 inches in height. In dry years seed stalks are few or totally lacking. In favorable years seed stalks may be 18 inches in height.

Agropyron spicatum generally occurs as a rather loose bunchgrass. On some stands of this association, a distinctly rhizomatic growth form is evident. This growth form is typical of the more mesic habitats. Poa secunda develops early in the spring and is only seasonally dominant. Poa cusickii seems to be more important in this association than in any of the others studied. In a poor seed year this species can be distinguished from Festuca idahoensis only by careful observation.

Phlox diffusa is the dominant perennial forb in this association (Table 15). One perennial forb, Antennaria corymbosa, is diagnostic of the Artemisia tridentata/ Festuca idahoensis association and was not found in any other association studied (Appendix 3). This species, like Phlox diffusa, has a prostrate growth form which is quite effective in covering the soil.

In addition to Antennaria corymbosa, several other species of perennial forbs, while not diagnostic of this association, are characteristic as a group. Erigeron filifolius, Eriogonum heracleoides, Eriogonum umbellatum, and Lithospermum ruderale have a high fidelity to this environment and are helpful in recognition.

The annual herb component of the Artemisia tridentata/Festuca idahoensis association is represented by only three species, Collinsia parviflora, Cordylanthus ramosus, and Lappula redowski. No member of the annual population appears to have indicator value for recognizing this association. The sparsity of annuals may be due to greater perennial grass competition in this association than in others (Table 19, p.142). However, since 6 of the 7 stands were studied in a very dry year, 1955, subsequent sampling may reveal additional annual species or important differences in the dominance of those listed which will be helpful in recognition.

Soil surface characteristics. The average cover of stones was 7.7 ± 1.9 per cent. Stone cover was 14.4, 11.7, and 11.3 per cent respectively in three habitat types (Table 15). The amount of stone cover is not the only factor limiting cultivation and seeding. The slope of the land is so great as to prohibit the use of machinery. Consequently these stands must be maintained and/or improved through grazing management and/or sagebrush control by aerial spraying.

Moisture relations would appear to favor a more complete cryptogam cover than now exists. The lack of this type of cover may be due to livestock and game use, water movement, and/or soil creep which may result in some terracing along the slopes. The high percentage of bare ground is not evident as one looks at an *Artemisia tridentata/Festuca idahoensis* stand from a short distance.

As one looks into the vegetation from above, however, this character is quite evident. Most of the litter present is not scattered over the soil surface as in other associations but is somewhat concentrated behind immovable objects especially on the steeper slopes. In this habitat type, the amount of bare ground, litter, and cryptogams may be important indicators of biotic pressure.

Associated soils. The *Artemisia tridentata*/*Festuca idahoensis* association is found growing on four soil series (Table 7). Table 16 presents selected morphological, physical and chemical characteristics of these soils. Series No. 1, "very strongly developed Brown soil from basalt residuum" is found associated with one habitat type (Figure 20). This solum is 43 inches deep--the deepest encountered in this association. The color of the A horizon is light brownish gray to grayish brown, changing to brown in the well-developed part of the B horizon and to yellowish brown in the B_{23} horizon. The surface is a loam texture but contains a maximum of silt. The well-developed B_{21} is a clay loam. A platy type of structure prevails in the A horizon. In the B_{21} horizon the structural unit is a strong, coarse, prism, which breaks into strong, coarse, angular blocks. The pH varies from 6.1 in the surface layer to 7.8 at the bottom of the profile. The entire profile is non-saline.

Table 16. Selected characteristics of the soils associated with the *Artemisia tridentata*/*Festuca idahoensis* habitat type.

Characteristics	Soil Series 1	4	5	9
No. of pits represented	1	2	2	2
Parent material	Basalt residuum	Basalt colluvium	Rhyolite residuum	Rhyolite alluvium or colluvium
Classification	Brown	Chestnut	Brown	Brown
Depth (inches)	43	19 - 38	24 - 37	41 - 42
Solum underlain by:	Bedrock	Bedrock (dissected)	Bedrock (dissected and non-dissected)	Calcium carbonate cemented pan
Color, Dry, A_1	10YR 5-6/2[1]	10YR 5/2 - 5/3	10YR 6/2	10YR 5-6/2
Color, Dry, B_2 or B_{22}	10YR 5/3	10YR 4/3	10YR 4/3 - 5/3	10YR 5-6/3
Color, Moist, A_1	10YR 4/2	10YR 3-4/2	10YR 4/2	10YR 3/2
Color, Moist, B_{22}	10YR 4/4	10YR 3-4/2	10YR 3/2 - 4/3	10YR 4/3
Textural Class				
A_1	l[2]	l	l	sl - l
B_{22}	l	cl	l	sl
Structure				
Primary A_1	2 m pl[2][3]	2 f pl	2 f/m pl	1/2 m pr
Primary B_{22}	2 f pr	3 f/m pr	1 mpr - 1 fsbk	2 c/m pr
Breaking to: B_{22}	2 f sbk	3 f/m sbk	2 m sbk	1 - 2/m sbk

Table 16, continued

Characteristics	Soil Series 1	4	5	9
pH A_1	6.1 - 6.2[3]	6.6 - 6.8	6.0 - 6.3	6.0 - 6.1
pH B_{22}	7.5 - 7.6	6.5 - 6.6	6.5 - 7.0	6.6 - 8.0
A_1 beneath *Artemisia tridentata*	6.7 - 6.9	6.4 - 6.6	6.4	6.0 - 6.3
A_1 beneath *Juniperus occidentalis*				
Young trees		6.6 - 7.1	-	-
Old trees		-	7.5 - 7.7	7.8 - 7.9
Salinity, mmhos/cm.				
A_1	0.36 - 0.40	0.34 - 0.50	0.31 - 0.40	0.28 - 0.44
B_{22}	0.40	0.41 - 0.47	0.28 - 0.33	0.44 - 0.69
Organic matter, A_1	2.76 - 2.84	2.29 - 3.57	2.15 - 2.43	2.32 - 2.39
Moisture equivalent, %				
A_1	30.8 - 31.2	25.5 - 29.6	26.8 - 30.2	23.9 - 25.3
B_{22}	34.6 - 37.5	28.3 - 43.9	33.2 - 40.6	19.1 - 22.9
15 Atm. moisture, %				
A_1	12.14 - 12.28	11.44 - 12.48	10.26 - 10.46	9.77 - 10.16
B_{22}	17.34 - 17.88	16.88 - 22.74	15.12 - 20.21	9.09 - 9.21

1 Munsell color notations. Soil Survey Manual (87) pp. 195-201.

2 Soil texture and structure symbols. Soil Survey Manual (87) pp. 139-140.

3 When soil series is represented by one profile, ranges in values indicate duplicate determinations. All other ranges indicate variation between or among profiles within a series. Single values indicate either no variation within duplicate determinations or no variation between or among profiles within a series.

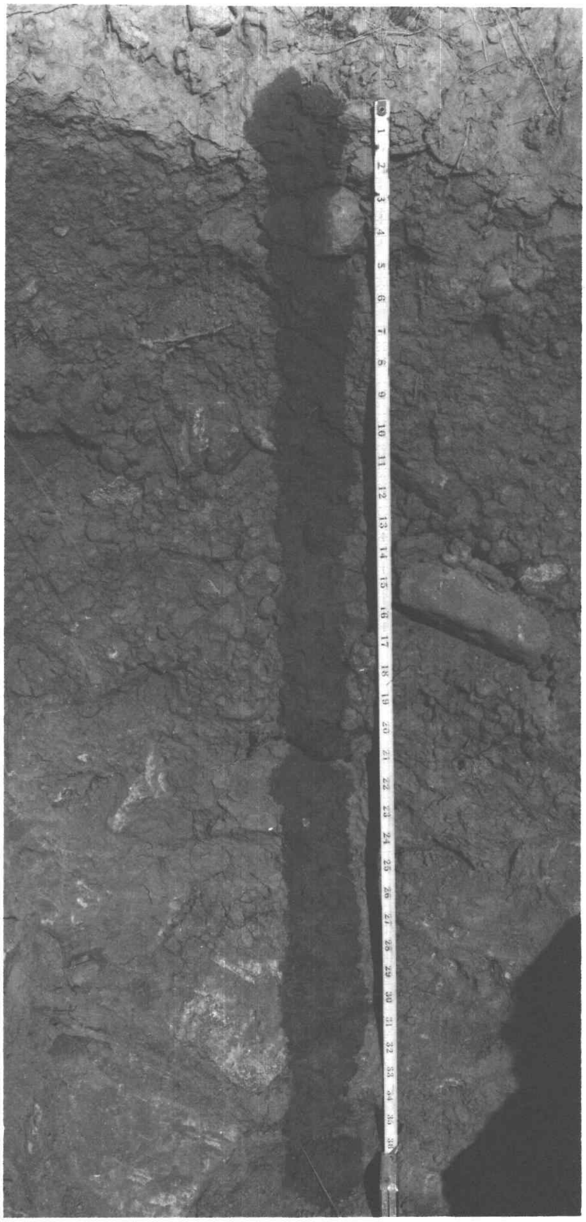


Figure 20. Soil profile representing soil series 1 and associated with an Artemisia tridentata/ Festuca idahoensis habitat type.

Organic matter averages 2.8 per cent in the A_1 horizon, decreases in the B_1 and B_{22}, then increases immediately above the restrictive layer (Table 17). Moisture equivalent and 15 atmospheres moisture percentages for the B horizon are quite high as would be expected with a high per cent of clay. Series 1 is also found associated with two *Artemisia tridentata/Agropyron spicatum*, one *Artemisia arbuscula/Festuca idahoensis*, and four *Artemisia arbuscula/Agropyron spicatum* associations. It is quite confusing to find the same interpretive soil units supporting such diverse vegetational units. This suggests that the individual soil pits comprising series 1, although similar in gross morphological characters, differs in minor but important compensating characters which allow distinctly different vegetational units to exist. This casts some doubt on our present series level interpretation. Closer soils examination may reveal observable morphological differences enabling refinement of the series interpretation, or the differences may be limited to the chemical and physical characteristics of these soils.

An attempt was made to explain partially some of the factors concerned with this discrepancy in the vegetation associated with series 1, as defined. The available soil moisture-holding capacity is one soil characteristic

Table 17. Example of organic matter increase immediately above a restrictive layer.

Habitat Type	Horizon	Depth	Per Cent Organic Matter (Mean of Duplicate Determinations)
Artemisia tridentata/ Festuca idahoensis	A_1	0 - 4	2.80
	A_3	4 - 8	2.32
	B_1	8 - 17	1.57
	B_{21}	17 - 26	0.81
	B_{22}	26 - 36	0.68
	B_{23}	36 - 43	1.33
	Dr	43 +	

which is useful in indicating why certain types of vegetation occur on a given soil profile. This soil physical characteristic is determined by the difference between the moisture equivalent and the 15 atmospheres moisture percentages. A graph, similar to that in Figure 22, was constructed for the soil pits included in series 1. The results indicate that certain profiles represent entirely different moisture regimes. The *Artemisia tridentata/Festuca idahoensis* habitat types occurred on soils which are characterized by a greater available soil moisture-holding capacity than do the other habitat types represented in this series as now interpreted. In series 1 this increased capacity is due primarily to the depth of the solum. Using this approach the soils of the *Artemisia tridentata/Festuca idahoensis* habitat type in series 1 need to be more finely interpreted in order to be consistent with the vegetation. Our series level interpretation needs to be reevaluated before soil correlation is complete.

The results also indicate that the soils of two *Artemisia tridentata/Agropyron spicatum*, two *Artemisia arbuscula/Agropyron spicatum*, and one *Artemisia arbuscula/Festuca idahoensis* habitat types cannot be differentiated on the basis of soil moisture-holding capacity. This would suggest that this characteristic is not of primary importance in determining the distribution of these three plant associations. However, this does explain, in part, how these differ from the *Artemisia tridentata/Festuca idahoensis* association on the basis of moisture storage capacity of the associated soils.

Two *Artemisia tridentata/Festuca idahoensis* habitat types are associated with series No. 5, "Brown soil from rhyolite residuum" (Figure 21).

The two soils representing series No. 5 are 24 and 37 inches deep, respectively. The pit which is 24 inches in depth is underlain by a rubbly type of rhyolite which allows roots to extend deeper than the 24-inch "depth" would suggest. The deeper profile is underlain by a rather continuous sheet of rhyolite which prevents further root penetration. The surface horizon color varies from a light brownish gray to grayish brown, with an organic matter content between 2.0 and 2.5 per cent. The texture of the A_1 and B_{22} horizons is a loam, but the lower part of the solum is higher in clay. This is reflected in a higher moisture equivalent and 15 atmospheres moisture percentage in the B_{22}. Surface horizons in both soils have a platy structure which changes to moderate sized prisms in the B horizons. These primary peds break into moderate, subangular blocks. The solum pH varies from 6.0 to 6.3 in the surface and from 6.4 to

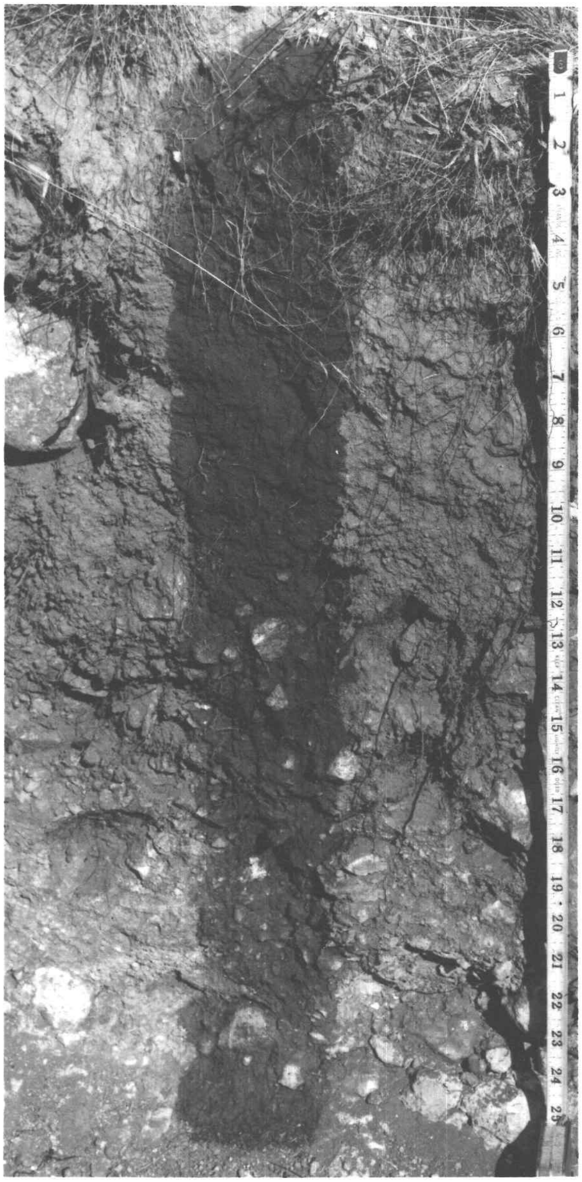


Figure 21. Soil profile representing soil series 5 and associated with an *Artemisia tridentata*/ *Festuca idahoensis* habitat type.

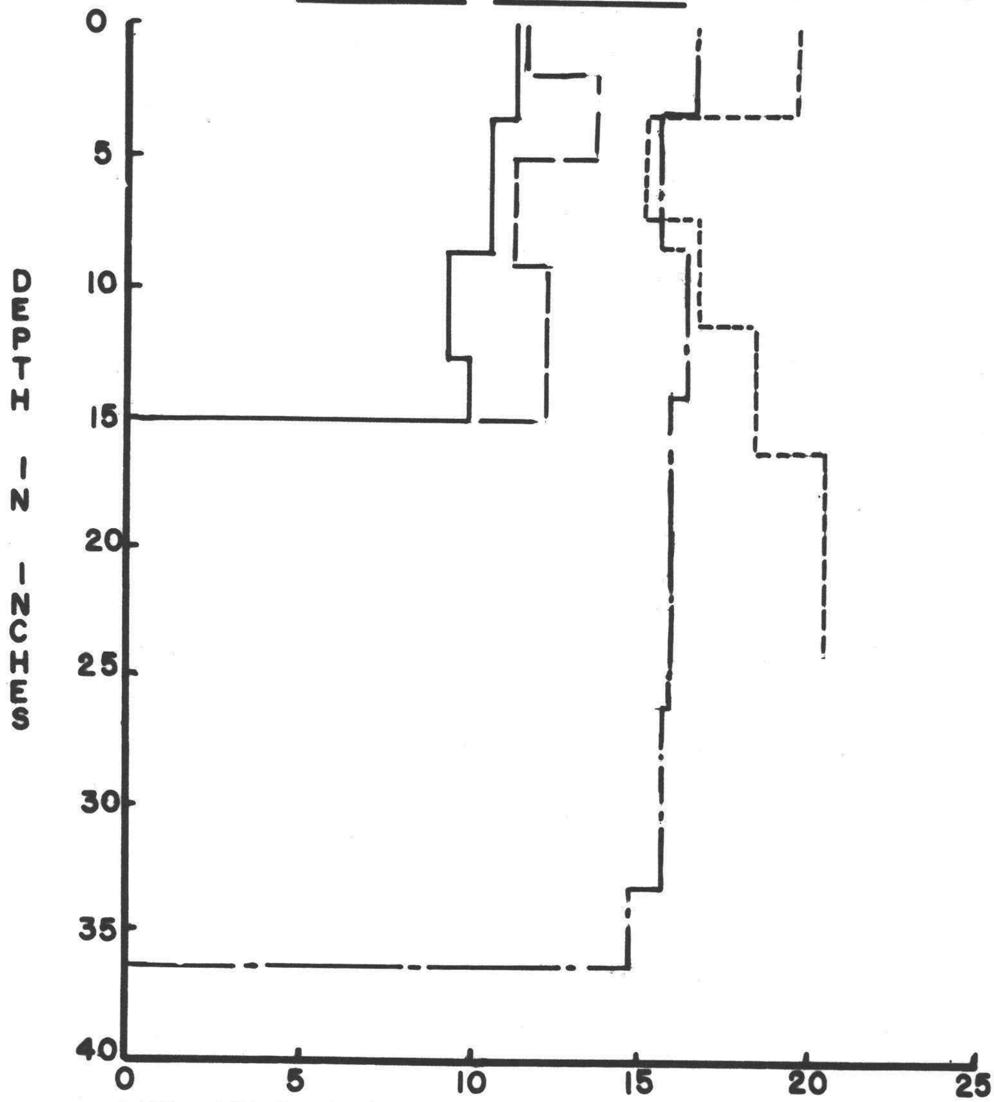
7.5 in the B horizon. The profile is non-saline throughout.

In addition to the *Artemisia tridentata*/*Festuca idahoensis* habitat types which occur on series 5, one *Artemisia tridentata*/*Agropyron spicatum* habitat type and two of its *Stipa* phases also occur on this same series as presently interpreted (Table 7). Using the approach as outlined above, available soil moisture-holding capacity of each horizon is plotted against depth (Figure 22). It is evident that the *Artemisia tridentata*/*Festuca idahoensis* habitat type occurs on soils which are characterized by greater available soil moisture-holding capacity. In series 5, this capacity is due to a greater solum depth as well as to a greater moisture-holding capacity of each horizon. This suggests that it may be possible to interpret this series more finely in order to be consistent with the vegetation.

Two *Artemisia tridentata*/*Festuca idahoensis* habitat types were encountered on series 4, "Chestnut soil from basalt colluvium" (Figure 23).

For many years the system of soil classification has consisted of the zonal, intrazonal, and azonal orders. Under this system, any great soil group found in an atypical climatic or soil zone is termed an intrazonal soil. In this study, and in keeping with the polyclimax

FIGURE 22. AVAILABLE SOIL MOISTURE HOLDING CAPACITY BY HORIZON IN TWO *ARTEMISIA TRIDENTATA* HABITAT TYPES



ALL OF THE ABOVE PROFILES ARE MEMBERS OF SERIES 5, BROWN SOIL FROM RHYOLITE RESIDUUM

KEY TO SYMBOLS

——— *ARTEMISIA TRIDENTATA/AGROPYRON SPICATUM*

— — *ARTEMISIA TRIDENTATA/AGROPYRON SPICATUM, STIPA* PHASE

—-—*ARTEMISIA TRIDENTATA/FESTUCA IDAHOENSIS*

------ *ARTEMISIA TRIDENTATA/FESTUCA IDAHOENSIS*

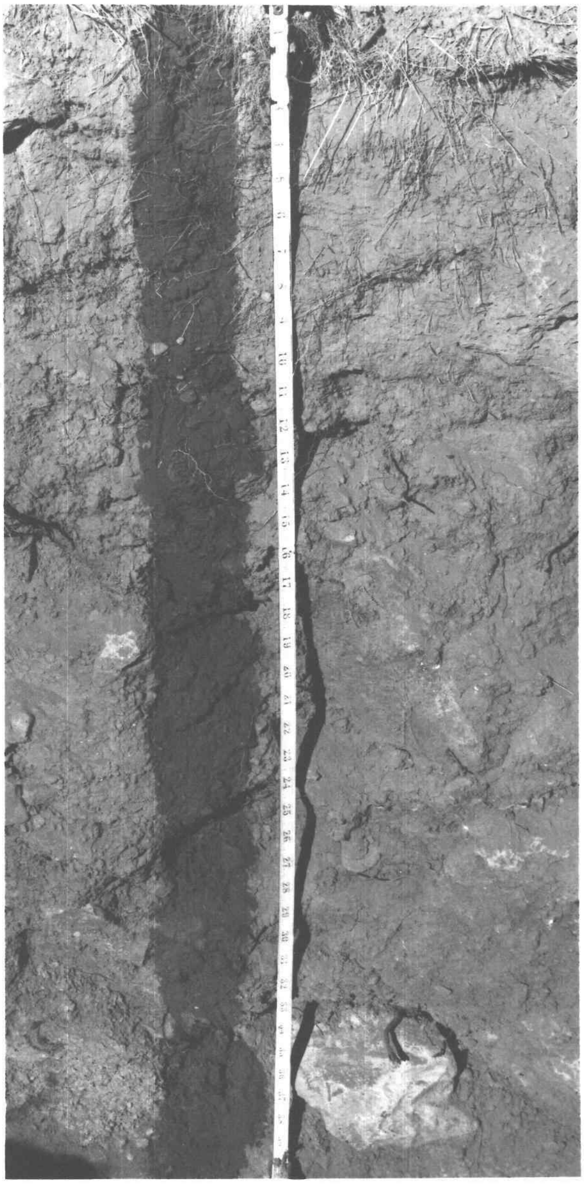


Figure 23. Soil profile representing soil series 4 and associated with an *Artemisia tridentata*/ *Festuca idahoensis* habitat type.

interpretation of vegetation, each plant association is considered climax whether due to a regional climate or to compensating factors. Likewise the soils characteristic of topographic and edaphic climaxes, if different from the normal soils of the zone, will not be termed intrazonal soils but zonal soils.

The two soils of series 4 occur on northerly exposures of from 26 to 30 per cent slope. The color of these solums is consistently darker than previously found in any of the other series. The surface horizons vary in color from grayish brown to brown, with the well developed B being dark brown. Surface organic matter contents are found to range from 2.3 to 3.6 per cent.

The depths of the two profiles are 19 and 38 inches respectively. Both restrictive layers are dissected basalt. Large roots have been observed penetrating these cracks, especially in the shallower profile. This observable difference in depth is partially compensated for by the increased clay content in the B horizon of the shallower solum. The shallower profile has approximately 7 per cent more clay in this horizon than does the deeper profile. This is reflected in an approximately 7 per cent more available moisture-holding capacity in the shallower profile. Compensating factors such as this, if recognized and properly interpreted, can be of great value in explaining some of the observable vegetation-soil relationships. The texture of the A horizon in both soils is a loam. The texture of the B_{22} in both profiles is a clay loam. The A horizons in both soils have a platy structure. The primary peds of the B_{22} horizon are strong prisms in both cases. The size of these peds is different, ranging from fine to moderate. The secondary peds are strong, fine to moderate subangular blocks. The profiles are nonsaline with pH values of 6.6 to 6.8 in the surface and 6.5 to 6.6 in the B_{22} horizon. The deeper profile had a B_3 horizon composed of a loamy material which has a pH of 7.3 to 7.4. A B_3 horizon was not observed in the shallow profile, although it may have been present at some depth beneath the jointed, rocky substratum.

Two _Artemisia tridentata/Festuca idahoensis_ stands are associated with series 9, "Brown soil from sandy rhyolitic or colluvial materials" (Figure 24). These soils are found on north exposures ranging from 26 to 30 per cent in slope. The effective rooting depths were 39 and 41 inches, respectively. In both cases the restrictive layer is a calcium carbonate pan. Surface soil colors are light brownish gray and grayish brown with 2.2 to 2.4 per cent organic matter. The color darkens in the B horizon to pale brown and brown to yellowish brown at

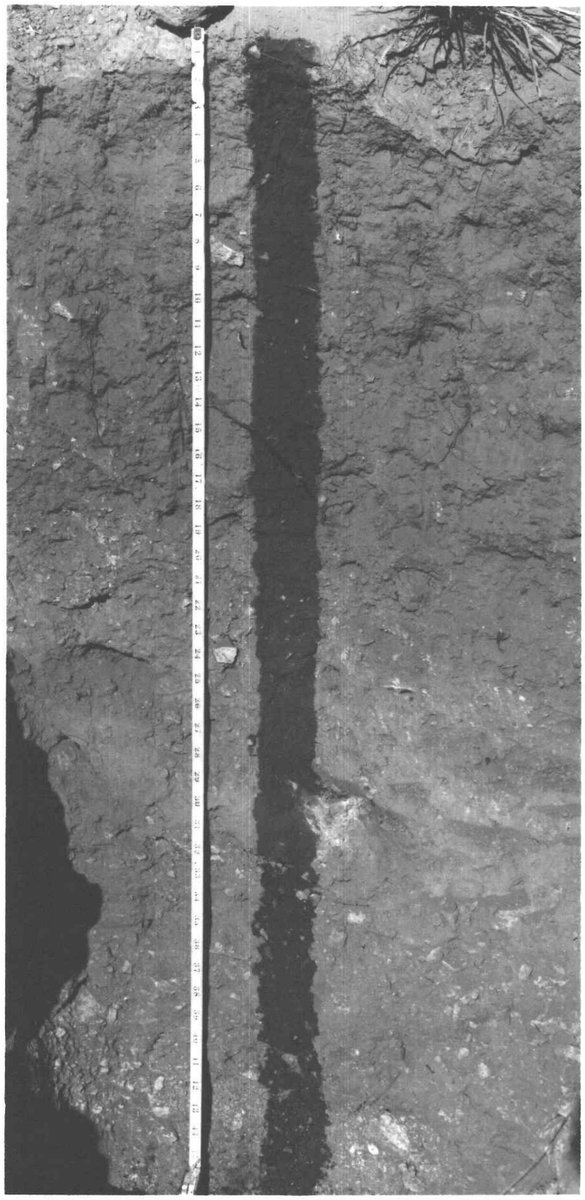


Figure 24. Soil profile representing soil series 9 and associated with an *Artemisia tridentata*/ *Festuca idahoensis* habitat type.

the bottom of the solum. These two soils are quite light in texture, with sandy loam to loam in the A_1 horizons and loam in the B_2. The structural units of the A horizon are plates while the primary peds of the B are moderate to coarse medium prisms, breaking to moderate, medium, subangular blocks. In one profile the pan is weakly cemented and has a structureless massive type of development. At the time of excavation this horizon was quite moist and friable, indicating conditions favorable for root penetration. This factor, no doubt, compensates in part for the higher available soil moisture-holding capacity in the other profiles where root penetration is restricted by an indurated calcium carbonate pan. The pH of the surface horizons varies from 6.0 to 6.1, from 7.3 to 8.0 in the lower part of the B, and from 8.0 to 8.4 in the calcium carbonate pan. The profiles are nonsaline throughout. Surface pH under young Juniperus occidentalis trees was 6.4, but 7.8 to 7.9 under old trees. Such a relationship was not evident under Artemisia tridentata.

The pattern of vegetation and soil in the Artemisia tridentata/Festuca idahoensis association has been attributed, at least in part, to the microclimatic influences of the northerly aspects. Murdock and Rickard's findings (58) in the Palouse region indicate that complex interrelationships of moisture and temperature conditions may be responsible for the distributional pattern of *Festuca idahoensis*. McMinn (54) has shown a similar trend with respect to moisture in the Rocky Mountains. Both of these studies indicate that *Festuca idahoensis* is a more mesic species than *Agropyron spicatum*.

An attempt was made to establish such a relationship in southeastern Oregon. The procedure used has been outlined in the methods section. Depletion of the available volume of soil moisture was studied. Results showed that the available soil moisture in the upper profile was depleted earlier in the *Artemisia tridentata*/*Festuca idahoensis* habitat type than in the others studied.

In such a sampling procedure, one cannot be sure all of the root zone has been sampled for moisture. One of the *Artemisia tridentata*/*Festuca idahoensis* stands was underlain by a dissected type of basalt, and another by a rubbly type of rhyolite. Plant roots were penetrating into areas which could not be adequately sampled for moisture. In view of this sampling difficulty, no conclusive results could be drawn from this experiment. The rapid depletion of moisture above the substrata is attributed to the density of vegetation in this association.

Artemisia arbuscula/Festuca idahoensis Association

This association represents the second largest vegetation type found in the immediate area of the Squaw Butte Experiment Station. Accepting the *Artemisia tridentata/ Agropyron spicatum* association as the climatic climax of the region, the *Artemisia arbuscula/Festuca idahoensis* association represents a topoedaphic climax in which the soils are shallow, stony, and have a moderate to strongly developed B horizon high in clay. Stands representing this association occur on northerly slopes and undulating uplands (Figure 25), predominantly on rhyolitic parent material. Only one stand of the six studied occurred on soil from basaltic parent material. This relationship between vegetation types and parent material was also recognized on reconnaissance.

This association is easily recognized by the dominance of *Artemisia arbuscula* and *Festuca idahoensis*. Table 18 presents the basal area and frequency values together with their standard errors for the more important herbaceous species. Ranges in these statistics are given for subordinate species. Appendix 4 and 5 give the density, crown cover, and heights of the shrubby components of this association.

Vegetation. *Juniperus occidentalis* occurs on five

Figure 25. Landscape view of an _Artemisia arbuscula/ Festuca idahoensis_ stand on undulating uplands.

Table 18. Basal area and frequency values for the Artemisia arbuscula/Festuca idahoensis association.

Mean and standard error or range in basal area and frequency values where the species is present[1] but too rare to calculate a valid standard error.

	Basal Area (per cent)	Frequency (per cent)
Perennial Grasses		
Festuca idahoensis	3.5 ± 0.5	82 ± 7
Poa secunda	1.9 ± 0.2	97 ± 1
Agropyron spicatum	0.8 ± 0.2	32 ± 7
Koeleria cristata[2]	T - 1.1	5 - 56
Sitanion hystrix	T - 0.4	3 - 15
Stipa thurberiana	T - 0.1	8 - 13
Annual Grass		
Bromus tectorum	T	5
Perennial Forbs		
Phlox diffusa	0.9 ± 0.3	41 ± 13
Microseris troximoides	0.2 - 0.5	15 - 48
Phlox hoodii	0.2 - 0.5	15 - 35
Antennaria dimorpha	T - 0.5	5 - 33
Astragalus stenophyllus	0.1 - 0.5	10 - 33
Lupinus saxosus	0.1 - 0.5	13 - 30
Trifolium gymnocarpon	T - 0.4	8 - 40
Phlox longifolia	T - 0.3	3 - 28
Crepis acuminata	T - 0.3	3 - 23
Erigeron linearis	T - 0.3	3 - 23
Trifolium macrocephalum[3]	0.2	18
Haplopappus stenophyllus	0.2	13
Penstemon cinereus	0.2	13
Lomatium macrocarpum	0.1	13
Lomatium triternatum	T - 0.1	5 - 13
Fritillaria pudica	0.1	10
Arenaria franklinii	T	5
Calochortus eurycarpus	T	3 - 5
Astragalus purshii	T	3
Delphinium andersoni	T	3
Eriogonum heracleoides	T	3
Phoenicaulis cheiranthoides	T	3
Silene drummondii	T	3

Table 18, continued

	Basal Area (per cent)	Frequency (per cent)
Annual Forbs		
Collinsia parviflora	0.5 ± 0.2	35 ± 15
Cordylanthus ramosus	0.3 ± 0.2	19 ± 12
Gayophytum ramosissimum	T	5
Lappula redowskii	T	5
Cryptogams and Soil Surface Conditions		
Tortula ruralis	4.7 ± 1.3	72 ± 10
Epigeous cryptogams	2.9 ± 0.9	97 ± 2
Stones	6.3 ± 1.9	
Gravels[4]	3.9 ± 1.3	
Litter[4]	16.4 ± 2.6	
Bare ground	51.4 + 10.8	

1 Means based on six macroplots.

2 T is less than 0.1 per cent basal area.

3 Single values indicate species encountered in sampling on one macroplot or on more than one macroplot with the same basal area and/or frequency.

4 Means based on five macroplots.

of the six stands studied but is important on only three--those in hilly country. Reconnaissance has shown the _Artemisia arbuscula/Festuca idahoensis_ association to be widely distributed both with the tree layer in hilly country and without the tree layer in the plateau type of topography.

Artemisia arbuscula has a crown cover of 13.5 ± 2.8 per cent and a density of 55.2 ± 7.6 plants per 200 square feet. The height and density of this shrub was expressed in height classes of 0 - 6, 7 - 12, and greater than 12 inches. The average _Artemisia arbuscula_ height in each of these classes is 3.5 ± 0.6 inches, 8.6 ± 0.2 inches, and 13.5 ± 2.3 inches. The density of plants in each height class is expressed as a per cent of total density and is as follows: 14.5, 73.9, and 11.4 per cent respectively.

As a result of this study and a similar one in Idaho (83), some confusion has arisen over the identity of some forms of _Artemisia arbuscula_. In the study area of southeastern Oregon, two distinct types of this species have been encountered. The first is a small headed type which flowers from the middle of August well into September. The second form has a much larger head and blooms from the middle of July until the middle of August. There is a distinct difference in the odor of the foliage of these two types. The smaller headed type has a typical sagebrush odor, while the large headed, earlier flowering type has a more sour smell. In Ward's treatise of the *Artemisia* in North America (89) it appears that he names the large headed, early flowering type as *Artemisia arbuscula* sub-species *arbuscula*. He also recognized a form with small heads that is found in southern Idaho, southeastern Oregon, northeastern California, and northwestern Nevada. This small headed type is much more common in the study area of southeastern Oregon than is the typical large headed type as described by Ward. He states that there is some indication that the small head size is associated with edaphic and moisture conditions. Of the ten *Artemisia arbuscula* stands studied, nine were dominated by the typical small headed form. In some instances several plants of the large headed form were noted in the same stand. One stand, however, was completely dominated by the large headed type. For the purposes of this thesis, both types will be considered as *Artemisia arbuscula*. This author will await further experimental taxonomic work before attempting to separate ecosystems on the basis of the dominance of the different forms of *Artemisia arbuscula*. Due to the difference in the phenology of these two forms, it appears that some revision in nomenclature is desirable.

Chrysothamnus viscidiflorus is an important component of this association, having a constancy of 5/6 (Appendix 3). As interpreted, this species is present in climax and increases with range abuse. On reconnaissance, an abundance of this species was noted on deteriorated sites representing this association. *Eriogonum sphaerocephalum* is a variable component of this vegetation, having densities of from 0 to 20 plants per 200 square feet. It appears to become more important on the deeper soil. *Artemisia tridentata*, *Leptodactylon pungens*, and *Purshia tridentata* are unimportant in this association (Appendix 4 and 5). *Chrysothamnus nauseosus* was not encountered on any stands.

Festuca idahoensis is the dominant herbaceous plant in this association. It has a basal cover of 3.5 ± 0.5 per cent and a frequency of 82 ± 7 per cent. *Poa secunda* has a basal cover of 1.9 ± 0.2 per cent. *Agropyron spicatum* was the only other grass species of importance encountered on the observation plots, but it has a basal cover of only 0.8 ± 0.2 per cent. The total grass cover in this association is second only to the *Artemisia tridentata/Festuca idahoensis* vegetation (Table 19). The three grasses mentioned all have a typical bunch growth form.

In addition to the dominance of *Festuca idahoensis*,

Table 19. Total basal area of the perennial grass species in the associations studied.

Species List	Habitat Type				
	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
	Basal Area, per cent				
Festuca idahoensis	0.4	1.0	5.1	3.5	0.4
Agropyron spicatum	2.5	0.9	1.0	0.8	2.0
Poa secunda	2.2	1.6	1.5	1.9	2.1
Koeleria cristata	0.1	0.3	0.5	0.5	0.4
Stipa thurberiana	0.3	1.6	0.1	-	0.2
Sitanion hystrix	0.1	0.5	-	-	0.3
Poa cusickii	-	-	-	-	-
Oryzopsis webberi	0.1	-	-	-	-
Oryzopsis hymenoides	-	-	-	-	-
Total	5.7	5.9	8.2	6.7	5.4

this association is characterized by three species of perennial forbs which, while not occurring in all stands, may be helpful in recognition. These three species are *Trifolium macrocephalum*, *Trifolium gymnocarpon*, and *Phlox hoodii*. These species do not occur with high constancy on the macroplots studied, but do have a high fidelity in this ecosystem. *Phlox diffusa* is the dominant perennial forb in this association. It is the only species of perennial forb having a constancy of 6/6.

The annual herb component is very poor. *Collinsia parviflora* attained its highest relative dominance in this association with a basal area cover of 0.5 ± 0.2 per cent. This is important considering that 5 of the 6 stands representing this association were sampled during a very dry year. *Cordylanthus ramosus*, with a basal area cover of 0.3 ± 0.2 per cent, seems to have some indicator value in recognizing the *Artemisia arbuscula*/*Festuca idahoensis* vegetation in good condition. It has not been found in such large amounts in any other association studied. On the basis of reconnaissance, this species appears also to increase rapidly with range deterioration.

Tortula ruralis has its lowest mean cover and epigeous cryptogams their highest mean cover in the *Artemisia arbuscula*/*Festuca idahoensis* association.

Soil surface characteristics. This association is characteristically non-stony, although the surface is quite gravelly. The non-stony nature, and small cover of litter and *Tortula ruralis*, are responsible for the typically large per cent of bare ground.

Associated soils. The *Artemisia arbuscula/Festuca idahoensis* association is associated with three soil series (Table 7). Table 20 presents selected morphological, chemical and physical characteristics of these soils. One stand is found on series 1, "very strongly developed brown soil from basalt residuum." This is the only stand of this association found on parent material other than rhyolite (Figure 26).

This basalt-derived profile is 26 inches deep to a silica cemented restrictive pan. The surface horizon is light brownish gray in color with 2.7 per cent organic matter. The B_{22} is light yellowish brown in color. Organic matter increases slightly just above the restrictive layer indicating some root concentration. The A_1 horizon is a loam texture with a strong, coarse, platy structure. The B_{21} horizon has a clay texture and a strong, medium prismatic structure which breaks into very strong angular blocks. The entire profile is non-saline. The pH of the surface is 6.4 and increases to 6.6 to 6.9 in the lower part of the solum. The

Table 20. Selected characteristics of the soils associated with the *Artemisia arbuscula/Festuca idahoensis* habitat type.

Characteristics			Soil Series 1	Soil Series 2	Soil Series 6
No. of pits represented			1	2	3
Parent material			Basalt residuum	Rhyolite residuum	Rhyolite colluvium
Classification			Brown	Brown	Brown
Depth (inches)			26	18 - 30	19 - 23
Solum underlain by:			Silica cemented pan	Silica cemented pan	Bedrock, silica and calcium carbonate cemented pan
Color	Dry	A_1	10YR 6/2[1]	10YR 5 - 6/2	10YR 6/2
		B_2 or B_{22}	10YR 6/4	10YR 5/3 - 5/4	10YR 5/3 - 5/4 - 6/3
	Moist	A_1	10YR 3/2	10YR 3/2	10YR 3/2
		B_2 or B_{22}	10YR 5/4	10YR 5/3 - 4/4	10YR 4/3 - 4/4
Textural Class	A_1		l[2]	sl - l	l
	B_2 or B_{22}		cl	scl - cl	l - cl
Structure	Primary A_1		3 c pl[2]	2 m pl	1/2 f/m pl
	Primary B_2 or B_{22}		3 mpr	1/3 f pr	2/3 m pr
	Breaking to: B_2 or B_{22}		3 f abk	2/3 f/m sbk	2/3 m sbk - 2 f sbk

Table 20, continued

Characteristics	Soil Series 1	2	6
pH A_1	6.4[3]	6.1 - 6.4	5.8 - 6.3
pH B_2 or B_{22}	6.6 - 6.7[3]	6.4 - 7.3	6.3 - 7.2
A_1 beneath *Artemisia arbuscula*	6.2	6.4 - 6.5	5.9 - 6.5
A_1 beneath *Juniperus occidentalis* (old tree)	-	7.6 - 7.7	8.1
Salinity, mmhos/cm. A_1	0.51 - 0.54	0.35 - 0.39	0.37 - 0.80
B_2 or B_{22}	0.25 - 0.28	0.33 - 0.43	0.27 - 0.40
Organic matter, A_1	2.64 - 2.76	1.31 - 2.28	2.67 - 3.18
Moisture equivalent, % A_1	29.1 - 29.5	19.1 - 24.2	24.6 - 36.0
B_2 or B_{22}	49.7 - 50.6	29.6 - 39.8	30.3 - 44.7
15 Atm. moisture, % A_1	11.89 - 11.98	8.10 - 10.86	12.11 - 12.95
B_2 or B_{22}	30.68 - 30.86	16.33 - 24.33	15.64 - 25.66

1 Munsell color notations. Soil Survey Manual (87) pp. 195-201.

2 Soil texture and structure symbols. Soil Survey Manual (87) pp. 139-140.

3 When soil series is represented by one profile, ranges in values indicate duplicate determinations. All other ranges indicate variation between or among profiles within a series. Single values indicate either no variation within duplicate determinations or no variation between or among profiles within a series.

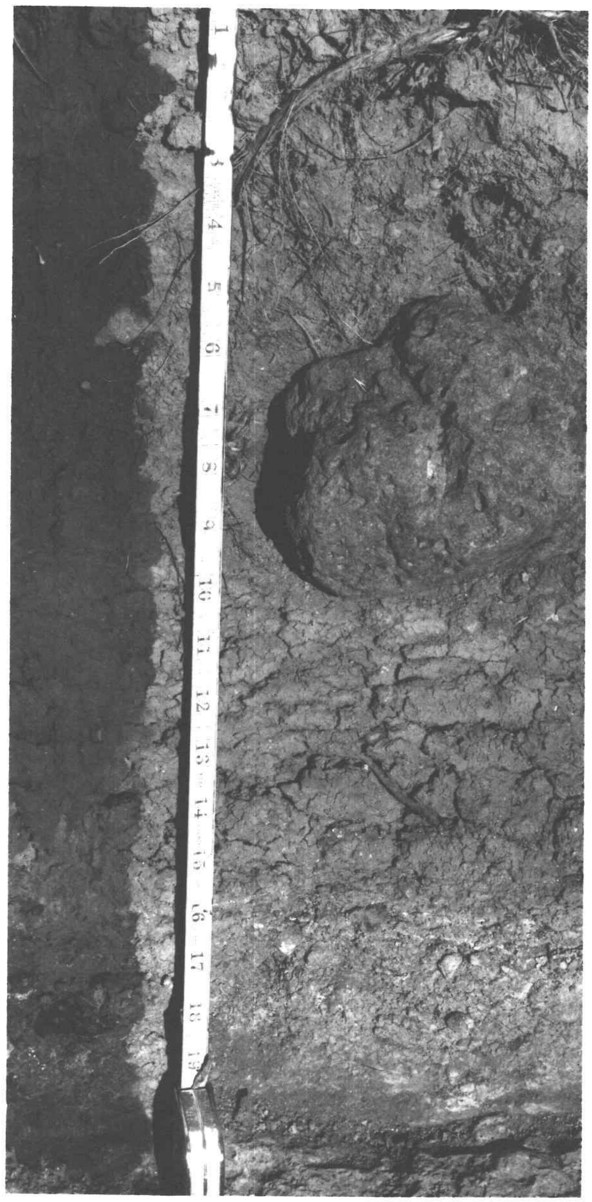


Figure 26. Soil profile representing soil series 1 and associated with an _Artemisia arbuscula/ Festuca idahoensis_ habitat type.

restrictive layer has a pH of 6.6 to 6.8 indicating a lack of calcium carbonate accumulation. The high clay content of the B horizon is reflected in very high moisture equivalent values. The 15 atmosphere moisture percentage value is not as large in relation to the clay content and results in a rather large available soil moisture-holding capacity. The clay content in the B horizon of this soil is second only to the strongly developed soil, also of series 1, representing an *Artemisia tridentata/Agropyron spicatum* habitat type. Both of these soils have developed from basalt residuum, indicating that weathering of montmorillonite clay may be more rapid from basaltic than from rhyolitic parent material. The available soil moisture-holding capacity is not an effective way of separating this habitat type from the *Artemisia tridentata/Agropyron spicatum* and *Artemisia arbuscula/Agropyron spicatum* habitat types occurring on the same soil series, as presently interpreted.

Two *Artemisia arbuscula/Festuca idahoensis* habitat types are also associated with series 2, "very strongly developed Brown soils from rhyolite residuum" (Figure 27). The two examples studied are 18 and 30 inches deep, respectively, to a silica cemented restrictive layer. The restrictive layer underlying the shallower profile is

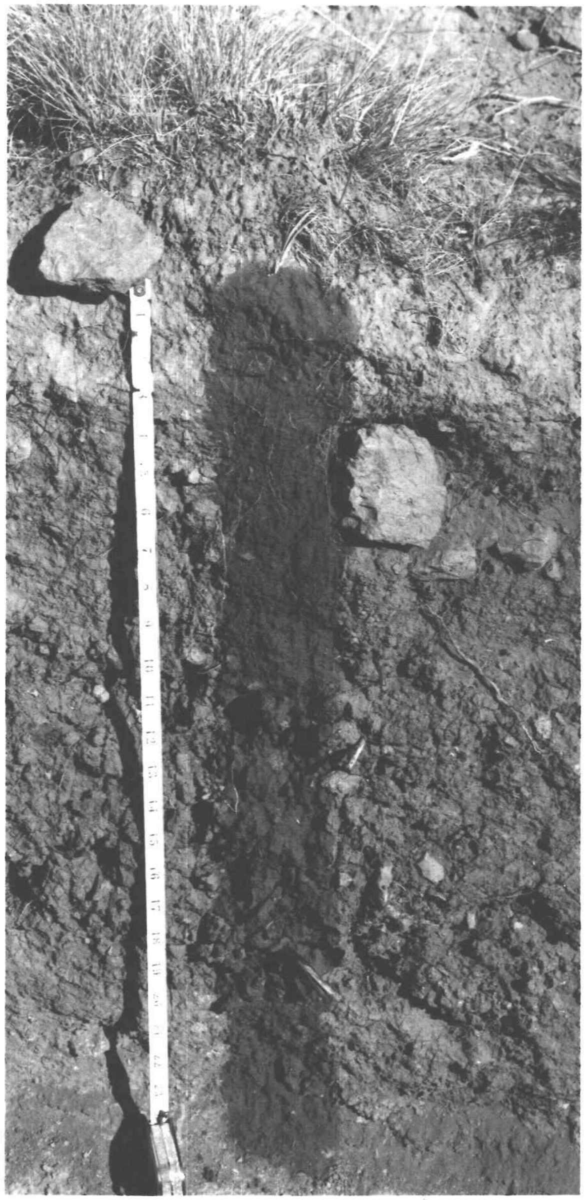


Figure 27. Soil profile representing soil series 2 and associated with an *Artemisia arbuscula*/*Festuca idahoensis* habitat type.

rather weakly cemented in contrast to the strongly cemented pan underlying the deeper profile. Large roots of *Juniperus occidentalis* penetrate the weakly cemented pan of the shallow profile. The surface horizon color is grayish brown, with organic matter contents varying from 1.3 to 2.1 per cent. Laboratory results have shown that the shallower of the two profiles has approximately $1\frac{1}{2}$ to 2 times as much organic matter in each horizon as does the deeper profiles. Soil color darkens with depth, becoming brown to yellowish brown in the lower part of the solum.

In all of the soil studied, soil color darkened (decreased in value and/or chroma) with depth, although organic matter generally decreased with depth. This darkening of color with depth cannot, therefore, be explained on the basis of organic matter. The clay flows which cover the structural peds in the B horizons may contribute to this color change by altering the reflection of light. The standard procedure for determing soil color is to use the fresh surface of a ped. If these structural peds are finely crushed, their color becomes lighter.

The surface horizons of this series are sandy loams to loams in texture with a moderate, medium platy structure. The increased clay content in the B horizon changes the texture to sandy clay loam and clay loam, with the primary peds being fine prisms breaking to fine to medium subangular blocks. The profiles are nonsaline throughout with pH values ranging from 6.1 to 6.4 in the surface to 6.4 to 7.3 in the B_{22} horizon.

The surface pH under an old *Juniperus occidentalis* tree is 7.6 to 7.7 as compared to 6.5 under an *Artemisia arbuscula* shrub and 6.1 to 6.2 in a bare area between shrubs and trees.

Although the moisture equivalent values of each horizon are much higher in the deeper profile, the 15 atmospheres moisture percentages are also high, with the result that the available soil moisture-holding capacities of the two profiles are not markedly different.

Three *Artemisia arbuscula/Festuca idahoensis* stands are found associated with series 6, "Brown soil from rhyolite colluvium" (Figure 28). These soils were 19, 21, and 23 inches deep, respectively, to bedrock, or to a silica or calcium carbonate cemented restrictive pan. The color of the A_1 horizon of these soils is light brownish gray, becoming pale brown to yellowish brown in the more well developed part of the B horizon. Surface organic matter content varies from 2.7 to 3.2, which is higher than the surface horizons of the other soil series supporting the *Artemisia arbuscula/Festuca*

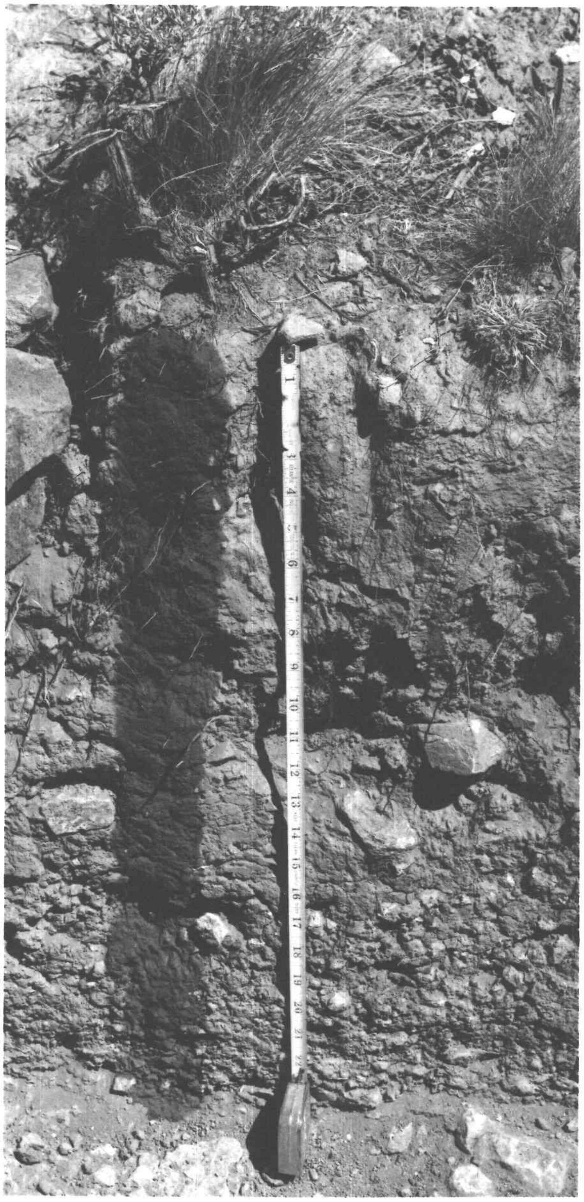


Figure 28. Soil profile representing soil series 6 and associated with an *Artemisia arbuscula*/ *Festuca idahoensis* habitat type.

idahoensis association. The A_1 horizon of all profiles is loamy in nature, while sandy clay loam and clay loam predominate in the heaviest part of the B. The primary peds in the A horizons are plates; moderate to strong, medium prisms predominate in the B_2 and B_{22} horizons. The secondary peds in these horizons are strong to moderate, fine to medium subangular blocks. Profile pH values range from 5.8 to 6.4 on the surface and from 6.3 to 7.3 in the lower part of the solum. Moisture equivalent and 15 atmospheres moisture percentage values are quite varied in these three soils. The soil profile with the highest clay content has the greatest available soil moisture-holding capacity. The surface pH under an old *Juniperus occidentalis* tree is 8.1 as compared to 6.4 under *Artemisia arbuscula* and 6.3 to 6.4 in an opening between shrubs and trees.

Artemisia arbuscula/Agropyron spicatum Association

In the study area of southeastern Oregon, this association is poorly represented. On reconnaissance this vegetation was observed only as small association fragments. This association occurs most commonly on level or very gently sloping plateau relief (Figure 29). This generally level relief, together with the small, discontinuous areas which this association occupies, may

Figure 29. Landscape view of an *Artemisia arbuscula/ Agropyron spicatum* stand.

account for its rather poor range condition.

Because of its disjunct nature, this association may be interpreted as a plant community which can successfully compete with other types of vegetation only under highly specialized environmental conditions--habitats which are rarely found in the study area. This interpretation is substantiated by the fact that all stands of this association, whether intensively or extensively studied, were restricted to one soil series, that from basalt residuum parent material (Table 7).

Vegetation. This association has been observed with and without an overstory of *Juniperus occidentalis*. This species is most commonly found on rock stringers and/or on rock outcrops (Figure 29) and has a constancy of 1/4 in this association.

Artemisia arbuscula is the dominant shrub in this association, having a crown cover of 15.8 ± 2.0 per cent and a density of 56.4 ± 0.6 plants per 200 square feet (Appendix 4). Density and height values are expressed in three height classes, 0 - 6, 7 - 12, and over 12 inches; 30.2, 65.9, and 4.8 per cent of the total density is found in each of these classes, respectively. The average heights in each of these classes are 4.0 ± 0.3 inches, 8.7 ± 0.2 inches, and 14.0 ± 0.6 inches, respectively. A comparison of the shrub layer of this association with the Artemisia arbuscula/Festuca idahoensis association shows the latter to be composed of slightly smaller shrubs in all height classes, more shrubs in the two larger height classes, and less shrubs in the 0 - 6 inch height class. The smaller number of shrubs in the 0 - 6 inch class may be due to the increased competition offered by the greater grass cover in the Artemisia arbuscula/Festuca idahoensis association. Chrysothamnus viscidiflorus and Artemisia tridentata are unimportant in this association, having densities of 0.7 and 0.3 plants per 200 square feet, respectively (Appendix 5). Eriogonum sphaerocephalum is important on one stand where the density was 11.5 plants per 200 square feet. Artemisia tridentata has a mean height of 14 inches, while Chrysothamnus viscidiflorus and Eriogonum sphaerocephalum are characteristically under 12 inches in height.

Agropyron spicatum is the dominant herbaceous species and has a basal cover of 2.0 ± 0.3 per cent with a frequency of 66 ± 7 per cent. Poa secunda and Festuca idahoensis are the subdominant grasses with basal covers of 2.1 ± 0.2 per cent and 0.4 ± 0.1 per cent, respectively (Table 21). Stipa thurberiana, Sitanion hystrix, and Koeleria cristata were important only on certain

Table 21. Basal area and frequency values for the Artemisia arbuscula/Agropyron spicatum association.

Mean and standard error or ranges in basal area and frequency values where the species is present[1] but too rare to calculate a valid standard error.

	Basal Area (per cent)	Frequency (per cent)
Perennial Grasses		
Agropyron spicatum	2.0 ± 0.3	66 ± 7
Poa secunda	2.1 ± 0.1	99 ± 1
Festuca idahoensis	0.4 ± 0.1	28 ± 4
Sitanion hystrix[2]	T - 1.1	5 - 43
Stipa thurberiana	T - 0.8	3 - 23
Koeleria cristata	0.3 - 0.7	13 - 50
Perennial Forbs		
Phlox diffusa	1.5 ± 0.7	49 ± 18
Erigeron linearis	T - 0.5	3 - 25
Lupinus saxosus	T - 0.4	5 - 43
Astragalus stenophyllus	0.2 - 0.4	18 - 20
Phlox hoodii[3]	0.4	20
Phlox longifolia	0.3 - 0.4	20 - 30
Arenaria franklinii	0.1 - 0.3	10 - 23
Microseris troximoides	T - 0.3	5 - 28
Antennaria dimorpha	T - 0.2	3 - 20
Crepis acuminata	T - 0.2	3 - 15
Eriogonum ovalifolium	T - 0.2	3 - 13
Penstemon cinereus	T - 0.2	5 - 8
Haplopappus stenophyllus	0.1	10
Lomatium macrocarpum	T - 0.1	3 - 10
Silene drummondii	0.1	5
Calochortus eurycarpus	T	8
Lomatium triternatum	T	5 - 8
Phoenicaulis cheiranthoides	T	5
Fritillaria pudica	T	3
Eriogonum proliferum	T	3
Annual Forbs		
Collinsia parviflora	0.3 ± 0.2	30 ± 19
Lappula redowskii	0.2	18
Gayophytum ramosissimum	0.2	20
Cordylanthus ramosus	0.1	10
Oenothera andina	T	3

Table 21, continued

	Basal Area (per cent)	Frequency (per cent)
Cryptogams and Soil Surface Conditions		
Tortula ruralis	4.9 ± 1.0	90 ± 5
Epigeous cryptogams	2.5 ± 0.7	89 ± 4
Gravels[4]	0.4	
Stones	24.4 ± 6.3	
Litter[4]	21.5	
Bare ground	47.7 ± 11.4	

1 Means based on four macroplots.

2 T is less than 0.1 per cent basal area.

3 Single values indicate species encountered in sampling on one macroplot or on more than one macroplot with the same basal area and/or frequency.

4 Means based on two macroplots.

stands and unimportant in the association as a whole. The total grass cover is smaller in this association than in any other studied (Table 19, p.142).

Phlox diffusa attained its greatest ground cover in the Artemisia arbuscula/Agropyron spicatum association with a cover of 1.5 ± 0.7 per cent, a frequency of 49 ± 18 per cent, and a constancy of 6/6. This species and Erigeron linearis are the only perennial forbs encountered in sampling each macroplot. No species of perennial forb appears to be useful in recognition of this association.

Collinsia parviflora is the most abundant annual forb in this association and the only species having a constancy of 4/4. As in the other Artemisia arbuscula association, the annual population here is quite sparse, and none of these species seem to be characteristic of this vegetation. In this association, Tortula ruralis and epigeous cryptogams have covers of 4.9 ± 1.0 and 2.5 ± 0.7 per cent, respectively (Table 21).

Soil surface conditions. This association is by far the stoniest, with a cover of 24.4 ± 6.3 per cent. This stone cover, together with the relatively large quantity of litter, results in a comparatively small amount of bare ground.

Associated soils. This association seems to be restricted to soil series 1, "very strongly developed Brown soil from basalt residuum" (Figure 30). Table 22 presents selected morphological, chemical and physical characteristics of these soils. The four pits studied were 21, 24, 24, and 26 inches deep, respectively, two to bedrock and two to a calcium carbonate cemented restrictive layer. The color of the A_1 horizon varies from light brownish gray to dark grayish brown with organic matter contents of from 2.0 to 3.7 per cent. The highest organic matter content corresponds to the darkest surface soil color. The subsoil color ranges from pale brown, to brown, to light yellowish brown. A loam texture is found in all surface horizons. The texture in the heavy part of the B horizon varies from loam, to clay loam, to clay. The A horizon of all profiles has a platy structure. The primary peds in the well developed part of the B are moderate to strong, medium to coarse prisms breaking to moderate to strong, medium subangular blocks. The primary ped of the clay textured B_2 horizon breaks into strong, moderate angular blocks.

Two soil profiles in this group are definitely nonsaline. There is some question as to the salinity status of the other two. Table 10, page 351 of the Soil Survey Manual (87) was used to determine the degree of salinity.

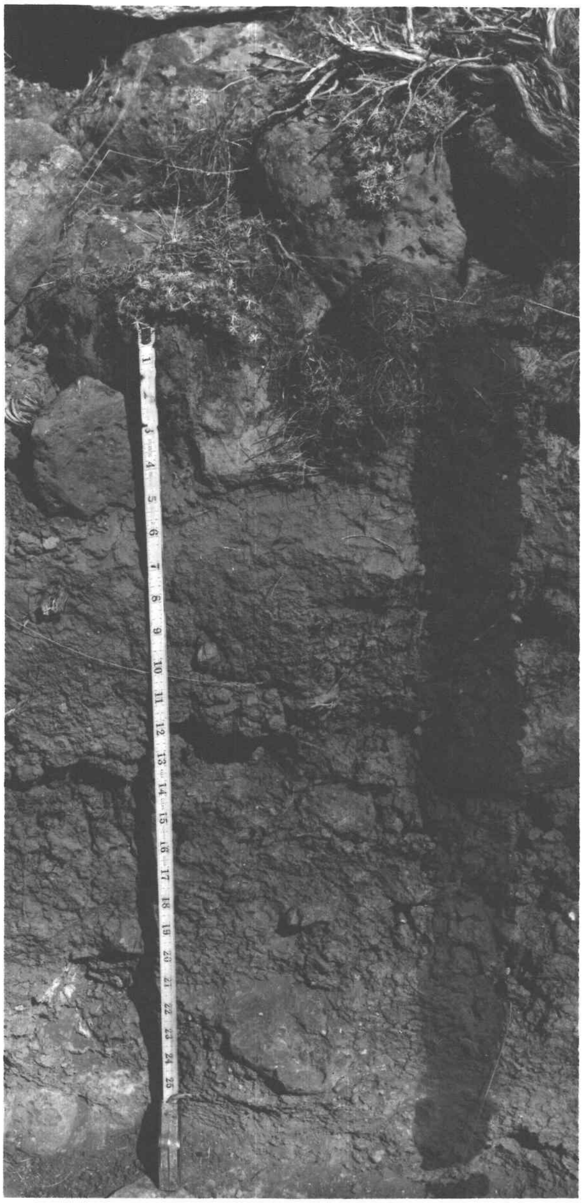


Figure 30. Soil profile representing soil series 1 and associated with an Artemisia arbuscula/ Agropyron spicatum habitat type.

Table 22. Selected characteristics of the soils associated with the *Artemisia arbuscula/Agropyron spicatum* habitat type.

Characteristics			Soil Series 1
No. of pits represented			4
Parent material			Basalt residuum and alluvium
Classification			Brown
Depth (inches)			21 - 26
Solum underlain by:			Bedrock and calcium carbonate cemented pan
Color	Dry	A_1	10YR 4 - 6/2[1/]
		B_2 or B_{22}	10YR 4 - 5/3
	Moist	A_1	10YR 3 - 4/2
		B_2 or B_{22}	10YR 3/4 - 4/3
Textural class	A_1		l[2/]
	B_2 or B_{22}		l - cl - c
Structure	Primary A_1		2 f/m pl[2/]
	B_2 or B_{22}		2/3 c/m pr
	Breaking to: B_2 or B_{22}		3 m sbk - 2/3 f/m abk
pH	A_1		6.3 - 6.9[3/]
	B_2 or B_{22}		6.3 - 7.3
A_1 beneath *Artemisia arbuscula*			6.2 - 6.6
Salinity, mmhos/cm.	A_1		0.40 - 0.65
	B_2 or B_{22}		0.50 - 0.62
	B_3		0.82 - 1.23
Salinity, resistance, B_3			1.94 - 2.36

Table 22, continued

Characteristics	Soil Series 1
Organic matter, A_1	1.95 - 3.68
Moisture equivalent, %	
A_1	24.0 - 28.4
B_2 or B_{22}	25.2 - 55.8
15 Atm. moisture, %	
A_1	9.67 - 11.88
B_2 or B_{22}	14.31 - 30.55

[1] Munsell color notations. Soil Survey Manual (87) pp.195-201.

[2] Soil texture and structure symbols. Soil Survey Manuel (87) pp. 139-140.

[3] When soil series is represented by one profile, ranges in values indicate duplicate determinations. All other ranges indicate variation between or among profiles within a series. Single values indicate either no variation within duplicate determinations or no variation between or among profiles within a series.

The electrical resistance values obtained from field samples indicate that the B_3 horizons of two soil profiles are slightly saline. Electrical conductivity measurements, however, indicate that these horizons are free from excess salts (Table 22). Since the latter method of salinity determination is the most acceptable for measuring this soil chemical characteristic, the two horizons are considered non-saline. The pH values ranged from 6.3 to 6.9 on the surface to 6.6 to 7.9 in the well developed B. Restrictive layer pH values range from 7.8 to 8.4. There is no increase in alkalinity beneath the *Artemisia arbuscula* plants. Moisture equivalent and 15 atmospheres moisture percentage values vary widely as would be expected with the difference in the amount of clay present in the 4 profiles. However, the available soil moisture-holding capacity among these four profiles is not markedly different.

An explanation is needed concerning the soil pit summary (Table 22). In introducing the section on soils of the *Artemisia arbuscula/Agropyron spicatum* association, it was stated that all these soils developed from basalt residuum. In the soil summary, however, it will be noted that the parent material for one stand is listed as basalt alluvium. This interpretation is based on the fact that the lower portion of this profile had some alluvial characteristics. Additional exploratory soil holes adjacent to this macroplot, as well as pits examined on reconnaissance, have shown no other evidence of alluvial deposits in the soils of this association. The question, whether this profile developed from alluvial material or whether there was some alluvial influence while this soil was being weathered from bedrock, is unanswered.

Comparison of Basal Area and Herbage Cover as Indices of Dominance

Due to differences of opinion regarding the value of herbage cover estimation as an index of dominance, this method was compared to the basal area estimation method through an analysis of covariance.

Preliminary to analysis of covariance calculations, both basal area and herbage cover estimates of *Festuca idahoensis*, *Agropyron spicatum*, *Koeleria cristata*, and annual forbs were plotted against yield data for these species. Curves relating herbage cover of all these species to yield and curves relating basal area of *Festuca idahoensis*, *Agropyron spicatum*, and *Koeleria cristata* to yield indicated some relationship. The curve relating basal area of annual forbs to yield showed no relationship; therefore, calculations were not made for this group of species.

Stewart and Keller (77) have pointed out that the correlation coefficient (r) gives a measure of the extent of the relationship between two variables. The closeness of this relationship is expressed by $100 \times r^2$. This gives the per cent of the variation in yield which is accounted for by the variation in the estimation techniques.

The correlation coefficients (r and $100 \times r^2$) between basal area and yield and between herbage cover and yield are as follows:

Table 23. Results of the analysis of covariance

Species	Basal Area		Herbage Cover	
	r	$100 \times r^2$	r	$100 \times r^2$
Festuca idahoensis	0.66	43.5	0.71	50.3
Agropyron spicatum	0.32	10.1	0.81	65.5
Koeleria cristata	0.79	62.6	0.84	70.4
Annual Forbs	No correlation		0.93	87.3

These results substantiate the statement made earlier that herbage cover estimation gives a better index of dominance as measured by yield than does basal area estimation. The results also indicate that it is difficult to index *Agropyron spicatum* dominance by the basal area method. Thus interpretations based on the dominance of this species, as indexed by the basal area method, may need reevaluation by herbage cover before the characterization of some associations is complete. Calculations were not made for Poa secunda since by August much of the herbage had dried and shattered, thus making yield sampling and herbage cover estimation impossible. Other species of perennial grasses and forbs did not occur on the sampling plots with sufficient frequency to enable an adequate measure of cover or yield.

Analysis of these data by the "F" test indicates that for each of the four groups of plants tested a single regression equation may be calculated for estimating yield from either basal area or herbage cover estimations. Also, since 100 x r^2 values for herbage cover are higher than for basal area, the former method of estimation would result in a more valid measure of yield from a regression equation than would the latter method of estimation.

From the yield data gathered, the average August herbage production from selected habitat types was obtained under the rather favorable growing conditions of 1956 (Appendix 6).

NEED FOR ADDITIONAL RESEARCH

Perhaps one of the most pressing research needs is for information relating to the recognition and characterization of the phases of habitat types. It is essential to know whether these phases are sufficient distinct from the typical habitat types to be managed separately or should they, for all practical purposes, be lumped with the typical habitat type for management purposes. It is biologically more sound to "split" first and "lump" later than to "lump" different entities together and be unable to separate them at a later date. The problem of recognizing a *Stipa* phase of the *Artemisia tridentata/ Agropyron spicatum* association would be alleviated through autecological studies of *Stipa thurberiana*, *Agropyron spicatum*, and *Festuca idahoensis* emphasizing possible differences in moisture and fertility requirements. Reciprocal field transplants should be used to evaluate the effect of the total environment on these three species. Additional study of soil morphological, chemical, and physical characteristics may hold the key to the understanding of these phases. In order to recognize these phases one must know more about such things as the ecotypic variations of *Artemisia arbuscula* and differences in the phenology of this and other species. The grass termed "Festuca idahoensis" in southeastern Oregon can be keyed to this species in the Manual of Grasses of the United States (38). However, workers familiar with the typical Festuca idahoensis of the Columbia Basin have observed some consistent differences which leave some doubt as to the taxonomic identity of this southern Oregon form. Experimental taxonomic work is needed to determine the ecotypes of this species.

After these associations and phases have been characterized so that they can be easily recognized, there is the problem of regional nomenclature. For example, the Artemisia tridentata/Agropyron spicatum association in southeastern Washington is a much different vegetation type than the Artemisia tridentata/Agropyron spicatum association in southeastern Oregon, yet such a name does not separate these ecosystems. There is also a need for the definition of criteria to be used in differentiating the Juniperus occidentalis associations from their non-arborescent counterparts. Because of these, and no doubt other regional differences in vegetation units with similar dominant shrubs and grasses, some standard of nomenclature must be developed if this kind of synecological information is to be easily understood.

Species adaptation and yield information on different habitat types is needed by the land manager as a basis for recommendations relating to seeding practices, natural revegetation, and carrying capacity determinations.

If synecological information is to be used by "action" agencies in the field, some indication of expected variability must be given. Additional vegetation and soil studies within a habitat type, as now interpreted, should be directed to show differences in vegetation corresponding to differences in soil characteristics and to determine how much soil difference is necessary before there is a corresponding change in the vegetation. This kind of research would show more clearly the range in soil variability over which the same plant community could exist.

Finally, there is a need for additional soil correlation work. This will result in a better understanding of some of the basic vegetation-soil relationships and will permit an ecosystem to be described in terms of its vegetative cover as well as by a soil series, type, and phase.

SUMMARY AND CONCLUSIONS

1. This thesis presents the results of a two and one-half year study of the vegetation-soil relationships in northern Harney and Lake Counties, Oregon. This portion of Regional Project W-25 of the Research and Marketing Act represents Oregon's contribution and has dealt primarily with developing an improved understanding of the ecology of the sagebrush-grass type.

2. The vegetation and soils were studied together on 31 stands. These stands were selected by means of a reconnaissance of the Squaw Butte Experiment Station and surrounding area. The vegetation was analyzed by species constancy, frequency, basal area, density and line intercept methods.

3. A complete soil morphological description was made from a soil pit immediately adjacent to each study site. These soil descriptions were checked in the field by Dr. Ellis G. Knox of the Oregon State College Soils Department and interpreted into nine uncorrelated soil series. A soil sample from each horizon of the profile was taken to the laboratory and the following physical and chemical characteristics

determined: pH, resistance of a saturated paste, electrical conductivity of a saturation extract, mechanical analysis, moisture equivalent, 15 atmospheres moisture percentage, and organic matter. Total exchange capacity and the exchangeable cations calcium, sodium, potassium, and magnesium were determined for horizon composites of selected profiles.

4. Analyses of the vegetation and soils on the stands studied have resulted in characterization of the following four associations and an important phase of one of these associations:

    Artemisia tridentata/Agropyron spicatum,
    Artemisia tridentata/Agropyron spicatum, *Stipa thurberiana* phase,
    Artemisia tridentata/Festuca idahoensis,
    Artemisia arbuscula/Festuca idahoensis, and
    Artemisia arbuscula/Agropyron spicatum.

    A reconnaissance revealed that four out of the five most important plant associations of the area were studied.

5. A *Juniperus occidentalis* overstory has been encountered in some stands of all associations studied. These are interpreted as *Juniperus occidentalis*

climaxes to indicate an arborescent ecosystem.

6. The vegetation mosaic of the study area belongs to the *Artemisia tridentata/Agropyron spicatum* zone. The climatic climax vegetation is represented by the *Artemisia tridentata/Agropyron spicatum* association. This association is the most variable in both vegetation and soils, and, on the basis of reconnaissance is found in poorer condition than any other association recognized. The soils of the *Artemisia tridentata/Agropyron spicatum* association belong to the Brown great soil group and represent four soil series. These soils have developed from alluvial fan and from residual basaltic and rhyolitic parent material. The soils which have developed on alluvial fans are underlain by an indurated restrictive layer cemented either by calcium carbonate or by silicious materials.

7. In southeastern Oregon the *Artemisia tridentata/Festuca idahoensis* and the *Juniperus occidentalis/Artemisia tridentata/Festuca idahoensis* associations represent topographic climaxes. They are encountered on northerly exposures varying from 11 to 30 per cent. Reconnaissance observations have shown these associations to be in a better range condition than

any other recognized. One species of perennial forb, *Antennaria corymbosa*, is diagnostic of these associations. The soils associated with five of these stands belong to the Brown great soil group. The soils associated with two *Juniperus occidentalis/Artemisia tridentata/Festuca idahoensis* stands belong to the Chestnut great soil group.

8. The *Artemisia arbuscula/Festuca idahoensis* and the *Juniperus occidentalis/Artemisia arbuscula/Festuca idahoensis* associations are the second largest vegetation type found in the immediate area of the Squaw Butte Experiment Station. These associations represent topo-edaphic climaxes in which the soils are shallow, stony, and have a moderate to strongly developed B horizon high in clay. Five of the six stands studied in this association were found on soils developed from rhyolitic parent material. One stand was found on a soil developed from basalt parent material. The soils of this habitat type belong to the Brown great soil group and represent three soil series.

9. In the study area, the *Artemisia arbuscula/Agropyron spicatum* association represents a topo-edaphic climax in which the soils are shallow, very stony,

and have a moderate to strongly developed B horizon high in clay. The soil surface is characteristically very stony. All stands studied were restricted to one soil series from basalt parent material and belong to the Brown great soil group.

10. As the result of this study, a key to the important habitat types of the study area has been developed (Table 24). It is hopes that a person familiar with the species of the area can use this guide to recognize the habitat types described therein. Soil information has been omitted from the key. When dealing with near climax vegetation, the plant communities themselves are adequate indicators of the ecosystem. Soils information can aid the researcher in establishing such guides through an understanding of vegetation-soil relationships.

11. Plant development and soil moisture depletion, by volume, were studied during the second year. This provided an explanation of some vegetation-soil relationships. Some of the problems involved in studying moisture depletion are discussed.

12. Herbage cover and basal area estimations were compared through analysis of covariance to determine

Table 24. A key to five important habitat types in the *Artemisia tridentata/Agropyron spicatum* zone, northern Harney and Lake Counties, Oregon.

A. Shrub cover dominated by *Artemisia tridentata*

B. Herbaceous cover dominated by *Agropyron spicatum* or *Stipa thurberiana*

C. Basal area of *Agropyron spicatum* at least twice that of *Stipa thurberiana*

D. Without a *Juniperus occidentalis* overstory most common situation

Artemisia tridentata/
Agropyron spicatum

High constancy species:
Eriastrum filifolium

High fidelity species:
Chaenactis douglasii
Aster canescens
Aster scopulorum

Tortula ruralis cover--8.3 per cent

Mostly on undulating relief

DD. With a *Juniperus occidentalis* overstory uncommon situation

Juniperus occidentalis/
Artemisia tridentata/
Agropyron spicatum

Erigeron filifolius one of dominant perennial forbs.
Tortula ruralis cover--0.4 per cent
On hilly relief

CC. Basal area of *Stipa thurberiana* equal to or exceeding one-half the basal area of *Agropyron spicatum*

E. Without a *Juniperus occidentalis* overstory most common situation

Table 24, continued

Artemisia tridentata/
Agropyron spicatum/
Stipa thurberiana phase

Basal area of *Festuca idahoensis* higher than in typical habitat type.

High constancy species:
- *Leptodactylon pungens*
- *Eriastrum filifolium*

High fidelity species:
- *Chaenactis douglasii*
- *Aster canescens*
- *Aster scopulorum*

Tortula ruralis cover--6.0 per cent

Generally on undulating relief

EE. With a *Juniperus occidentalis* overstory uncommon situation

Juniperus occidentalis/
Artemisia tridentata/
Agropyron spicatum/
Stipa thurberiana phase

Erigeron filifolius one of dominant perennial forbs.

Tortula ruralis cover--0.9 per cent

On hilly relief

BB. Herbaceous cover dominated by *Festuca idahoensis*

F. With a *Juniperus occidentalis* overstory most common situation

Juniperus occidentalis/
Artemisia tridentata/
Festuca idahoensis

Diagnostic species:
- *Antennaria corymbosa*

Erigeron filifolius one of dominant forbs

Table 24, continued

High constancy species:
Chrysothamnus viscidiflorus

High fidelity species:
Ribes cereum
Symphoricarpos rotundifolius
Lithospermum ruderale
Eriogonum heracleoides
Eriogonum umbellatum

Always on northerly exposures on very hilly relief.
Stony soils

FF. Without a *Juniperus occidentalis* overstory--uncommon condition

Artemisia tridentata/
Festuca idahoensis

Diagnostic species:
Antennaria corymbosa

Always on northerly exposures but not on very hilly relief

AA. Shrub cover dominated by *Artemisia arbuscula*

G. Herbaceous cover dominated by *Festuca idahoensis*

H. With a *Juniperus occidentalis* overstory--common situation

Juniperus occidentalis/
Artemisia arbuscula
Festuca idahoensis

Annual forbs with high relative dominance:
Collinsia parviflora
Cordylanthus ramosus

High constancy species:
Chrysothamnus viscidiflorus

High fidelity species:
Trifolium gymnocarpon
Trifolium macrocephalum
Phlox hoodii

Table 24, continued

Found on soils developed from rhyolitic parent material.

HH. Without a Juniperus occidentalis overstory--common situation

Artemisia arbuscula/ Festuca idahoensis

Annual forbs with high relative dominance:
- Collinsia parviflora
- Cordylanthus ramosus

High constancy species:
- Chrysothamnus viscidiflorus

High fidelity species:
- Trifolium gymnocarpon
- Trifolium macrocephalum
- Phlox hoodii

Occurs primarily on soils developed from rhyolite parent material

GG. Herbaceous cover dominated by Agropyron spicatum

Artemisia arbuscula/ Agropyron spicatum

Found with a Juniperus occidentalis overstory; however, this species occurs primarily on rock stringers or rocky outcrops.
Soil surface characteristic:
very stony

their relative values as indices of dominance. Dominance was determined by herbage yield. Results indicated that for *Festuca idahoensis*, *Agropyron spicatum*, *Koeleria cristata*, and annual forbs, herbage cover gives a better measure of dominance than does basal area.

13. The need for additional research is discussed.

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A P P E N D I C E S

Appendix 1. Bulk density of selected soils.

Habitat Type	Horizon	Bulk Density (gms/cc)	Horizon	Bulk Density (gms/cc)
Artemisia tridentata/ Agropyron spicatum	A_1	1.12		
	0-2	1.23		
	A_3	1.27		
	3-6	1.26		
	B_1	1.26		
	6-10	1.04		
	B_{21}	1.18		
	10-19	1.35		
	B_{22}	1.45		
	19-24	1.49		
Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	A_1	1.05		
	0-3	0.95		
	A_3	1.10		
	3-7	1.00		
	B_1	0.97		
	7-12	1.21		
	B_2	1.28		
	12-17	1.03		
	B_3	1.46		
	17-21	1.24		
Artemisia tridentata/ Festuca idahoensis	A_1	0.96	A_1	1.05
	0-3	0.98	0-3	0.95
	A_3	1.04	A_3	1.10
	3-7	1.03	3-7	1.00
	B_1	1.04	B_1	0.97
	7-11	1.04	7-12	1.21
	B_{21}	0.85	B_{21}	1.20
	11-16	1.00	12-17	1.03
	B_{21}	0.86	B_{22}	1.46
	16-24	0.94	17-21	1.24
Artemisia arbuscula/ Festuca idahoensis	A_1	1.03	A_1	1.15
	0-3	1.10	0-4	1.13
	A_3	1.00	A_3	1.18
	3-7	1.10	4-8	1.13
	B_1	1.10	B_1	1.31
	7-12	1.05	8-13	1.50
	B_2	1.45	B_{21}	1.65
	12-18	1.32	13-21	1.52
			B_{22}	1.08
			21-30	1.17

Appendix 1, continued

Habitat Type	Horizon	Bulk Density (gms/cc)	Horizon	Bulk Density (gms/cc)
Artemisia arbuscula/ Agropyron spicatum	A_1	1.08	A_1	1.06
	0-2	1.03	0-2	0.98
	A_3	1.06	A_3	1.07
	2-5	1.03	2-5	1.13
	B_1	1.14	B_1	0.97
	5-10	1.17	5-8	1.14
	B_2	1.16	B_2	1.33
	10-19	1.15	8-16	1.23
			B_3	0.94
			16-21	1.13

Appendix 2. Importance of the major plant associations in the immediate service area of the Squaw Butte Experiment Station.

Association	Miles Logged	General Topographic and Geologic Features
Artemisia tridentata/ Agropyron spicatum*	79.75	Gentle north slopes, gentle to steep east, south, and west slopes, and on undulating bottom land on alluvial fan or residual parent material.
Artemisia arbuscula/ Festuca idahoensis*	47.50	North slopes and undulating uplands, predominantly on rhyolitic parent material.
Artemisia tridentata/ Festuca idahoensis*	47.25[1/]	Fairly steep to steep north slopes on residual or colluvial parent material.
Artemisia tridentata/ Agropyron spicatum* Stipa thurberiana phase	32.25	Similar to Artemisia tridentata/ Agropyron spicatum topography.
Artemisia tridentata/ Festuca idahoensis Purshia tridentata phase	18.00	Similar to Artemisia tridentata/ Festuca idahoensis topography.
Artemisia arbuscula/ Agropyron spicatum*	15.50	Plateau tops, south and west slopes generally, from residual basaltic parent material.
Artemisia tridentata/ Stipa comata/ Carex sp.	14.00	Generally at base of slopes with level topography and a sandy surface horizon. Not on the bottom lands.
Artemisia tridentata/ Elymus cinereus	5.00	Level relief in the bottom lands.
Artemisia tridentata/ Agropyron spicatum Purshia tridentata phase	2.50	Gentle to steep south slopes on rather stony soils.
Artemisia tridentata/ Grayia spinosa	2.00	Very steep southerly talus slopes.

Appendix 2, continued

Association	Miles Logged	General Topographic and Geologic Features
Artemisia tridentata-Sarcobatus vermiculatus/Stipa thurberiana	0.50	Gentle to steep west slopes.
<u>Complex of Habitat Types</u>		
Artemisia tridentata/Festuca idahoensis-Artemisia arbuscula/Festuca idahoensis	12.50	Undulating uplands - gentle north slopes.
Artemisia arbuscula/Festuca idahoensis-Artemisia arbuscula/Agropyron spicatum	2.00	Stony soils on gentle north slopes with many drainage channels.

1 Since roadways are not commonly constructed along north facing slopes where the Artemisia tridentata/Festuca idahoensis association is found, this association was logged where it could be easily seen from the road.

* Associations intensively studied.

Appendix 3. Constancy values for all species occurring in the associations studied. Constancy based on a plot of fifty by one hundred feet.

Species List	Association: Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
	Number of macroplots				
	6	7	7	6	4
Trees					
Juniperus occidentalis		1	6	5	1
Shrubs					
Artemisia tridentata	6	7	7	2	2
Eriogonum sphaerocephalum	4	3	3	2	1
Chrysothamnus nauseosus	2	1	2		1
Leptodactylon pungens	1	5	3	2	2
Chrysothamnus viscidiflorus	1	1	5	5	2
Tetradymia canescens		2	3		
Grayia spinosa		1			
Ribes cereum			2		
Symphoricarpos rotundifolius			2		
Purshia tridentata				1	
Artemisia arbuscula	1		1	6	4

Appendix 3, continued

Species List	Association				
	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
<u>Perennial Grasses</u>					
Agropyron spicatum	6	7	7	6	4
Poa secunda	6	7	7	6	4
Sitanion hystrix	6	7	1	5	2
Festuca idahoensis	5	6	7	6	4
Stipa thurberiana	5	7	3	3	3
Koeleria cristata	3	6	6	5	1
Poa cusickii	2	2	2		
Oryzopsis webberi	1	2			
Oryzopsis hymenoides		4			
<u>Annual Grass</u>					
Bromus tectorum	1	1		1	
<u>Perennial Forbs</u>					
Phlox diffusa	6	7	7	6	4
Eriogonum ovalifolium	6	6	5	1	1
Erigeron linearis	6	3	7	6	4
Crepis acuminata	6	7	7	6	2
Lomatium triternatum	5	4	7	5	2
Allium parvum	5	4	4	4	1

Appendix 3, continued

Species List	Association Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
Antennaria dimorpha	5	7	7	6	4
Phlox longifolia	5	4	4	5	1
Microseris troximoides	4	3	7	5	4
Delphinium andersoni	4	4	1	1	1
Astragalus stenophyllus	4	1	7	3	1
Fritillaria pudica	4	3	7	6	4
Ranunculus glaberimus	4	1	4	4	3
Erigeron poliospermus	3	1		1	
Calochortus eurycarpus	3	2	6	6	4
Lupinus saxosus	3	3	4	5	2
Erigeron filifolius	3	4	7	3	1
Eriogonum proliferum	3	4	5	5	2
Arabis holboelii var. pendulocarpa	3	2	1	1	1
Astragalus lentiginosus	3	6	2	1	2
Castilleja angustifolia	2	1	1	2	
Arenaria franklinii	2	1	1	2	3
Lomatium macrocarpum	2	6	2	2	3
Penstemon cinereus	1	2	5	2	3
Phoenicaulis cheiranthoides	1			3	1
Achillea millefolium	1		1		1
Astragalus miser	1	2	3	2	2
Lewisia rediviva	2			1	
Aster scopulorum	2	4			
Chaenactis douglasii	2	2			

Appendix 3, continued

Species List	Association: Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
Balsamorhiza serrata	2				
Viola beckwithii	1				
Astragalus probably ourvicarpus		1			
Penstemon speciosus		2	1		
Senecio integerrimus		1		1	
Astragalus purshii		5		3	
Townsend florifer		1			
Allium acuminatum		1			
Zygadenus paniculatus		1			
Aster canescens		1			
Silene drummondii		2	6	3	4
Lithospermum ruderale		1	5	2	
Eriogonum heracleoides		1	6	3	
Lupinus argenteus			3		1
Castilleja hispida			1	1	
Lithophragma bulbiferum			4	1	
Haplopappus stenophyllus			1	1	
Antennaria corymbosa			7		
Lupinus sericeus			1		
Balsamorhiza sagittata			1		
Erigeron corymbosa			1		
Castilleja linariaefolia			1		
Trifolium macrocephalum				1	
Trifolium gymnocarpon				2	
Phlox hoodii				2	1

Appendix 3, continued

Species List	Association: Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
Annual Forbs					
Lupinus brevicaulis	1				
Blepharipappus scaber	1	2			
Eriastrum filifolium	2	5			
Minulus nanus	1	3	1		
Phacelia linearis	1	4			1
Oenothera andina		3		1	4
Descurainia pinnata	4	3		1	1
Mentzelia albicaulis	1	4	1		1
Microsteris graciles	2	4	1		4
Cordylanthus ramosus	2	1	3	4	3
Gayophytum ramosissimum	3	6	2	2	1
Lappula redowskii	4	7	3	2	3
Collinsia parviflora	5	7	4	6	4

Appendix 4. Mean cover, density, and height values for the dominant shrub species in the associations studied.

Item	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
Total Artemisia tridentata density per 200 square feet	11.0 ± 1.0	12.1 ± 1.2	15.2 ± 2.5	0.5	0.3
Per cent composition by height classes					
0 - 6	0.9	2.5	40.1		
7 - 12	20.9	15.7	24.3		
12 +	79.1	81.0	34.9		
Per cent Artemisia tridentata crown cover (line intercept)	10.3 ± 2.0	12.0 ± 1.3	7.1 ± 0.9	T	0.2
Mean maximum Artemisia tridentata height in inches	22.9 ± 0.8	25.8 ± 0.6	20.7 ± 0.7		

Appendix 4, continued

Item	Artemisia tridentata/ Agropyron spicatum	Artemisia tridentata/ Agropyron spicatum, Stipa thurberiana phase	Artemisia tridentata/ Festuca idahoensis	Artemisia arbuscula/ Festuca idahoensis	Artemisia arbuscula/ Agropyron spicatum
Total Artemisia arbuscula density per 200 square feet			0.1	55.2 ± 7.6	56.4 ± 0.6
Per cent composition by height classes					
0 - 6				14.5	30.2
7 - 12				73.9	65.9
12 +				11.4	4.8
Per cent Artemisia arbuscula crown cover (line intercept)			0.1	13.5 ± 2.8	15.8 ± 2.5
Artemisia arbuscula height in inches by height classes					
0 - 6				3.5 ± 0.6	4.0 ± 0.3
7 - 12				8.6 ± 0.2	8.7 ± 0.2
12 +				13.5 ± 2.3	14.0 ± 0.6

Appendix 5. Mean cover and density values for subordinant shrubs species in the associations studied.

Species List	*Artemisia tridentata*/ *Agropyron spicatum*		*Artemisia tridentata*/ *Agropyron spicatum*, *Stipa thurberiana* phase		*Artemisia tridentata*/ *Festuca idahoensis*		*Artemisia arbuscula*/ *Festuca idahoensis*		*Artemisia arbuscula*/ *Agropyron spicatum*	
	C*	D*	C	D	C	D	C	D	C	D
Eriogonum sphaerocephalum	T	0.5	-	0.1	0.1	0.1	0.4	3.4	0.4	1.9
Chrysothamnus viscidiflorus	-	-	0.1	0.2	0.6	3.6	0.9	3.6	-	0.7
Leptodactylon pungens	0.5	1.6	0.2	6.3	0.1	1.0	-	-	-	-
Chrysothamnus nauseosus	0.4	0.3	0.1	0.3	0.1	-	-	-	-	-
Tetradymia canescens	-	-	-	0.1	0.2	0.3	-	-	-	-
Ribes cereum	-	-	-	-	-	T	-	-	-	-
Symphoricarpos rotundifolius	-	-	-	-	T	-	-	-		
Grayia spinosa	-	-	T	T	-	-	-	-	-	-
Purshia tridentata	-	-	-	-	-	-	-	T	-	-

* Per cent crown cover (line intercept).

** Density (plants per 200 square feet).

T = Less than 0.1 plant per 200 square feet or less than 0.1 per cent crown cover.

Appendix 6. August herbage yields on selected habitat types.

Habitat Type	Species	Yield in Pounds/Acre Macroplot 1	Macroplot 2
Artemisia tridentata/ Festuca idahoensis	Festuca idahoensis	196	267
	Agropyron spicatum	68	102
	Poa secunda	32	21
	Stipa thurberiana	31	-
	Koeleria cristata	30	24
	Lupinus saxosus	66	88
	Crepis acuminata	18	1
	Other Perennials*	21	50
	Annuals**	8	20
	Total	470	573
Artemisia arbuscula/ Festuca idahoensis	Festuca idahoensis	252	186
	Agropyron spicatum	34	53
	Koeleria cristata	12	42
	Poa secunda	12	23
	Stipa thurberiana	-	4
	Sitanion hystrix	2	1
	Poa cusickii	1	-
	Lupinus saxosus	-	20
	Other Perennials1/	12	21
	Annuals**	24	43
	Total	378	393

Appendix 6, continued

Habitat Type	Species	Yield in Pounds/Acre	
		Macroplot 1	Macroplot 2
Artemisia arbuscula/ Agropyron spicatum	Agropyron spicatum	72	73
	Sitanion hystrix	74	3
	Stipa thurberiana	56	-
	Poa secunda	49	33
	Festuca idahoensis	35	49
	Poa cusickii		5
	Koeleria cristata		3
	Crepis acuminata	35	16
	Other Perennials 2/	9	41
	Annuals 3/	25	14
	Total	355	235

* Mostly Erigeron filifolius
** Mostly Cordylanthus ramosus
1 Mostly Calachortus euryocarpus and Penstemon cinereus
2 Mostly Erigeron linearis
3 Mostly Collinsia parviflora

Appendix 7. Species List

Achillea millefolium L.
Agropyron spicatum (Pursh) Scribn. and Smith
Allium acuminatum Hook.
Allium parvum Kell.
Antennaria dimorpha (Nutt) T. & G.
Antennaria corymbosa E. Nels.
Arabis holboellii Hornem. var. pendulocarpa (Nels) Rollins.
Arenaria franklinii Dougl.
Artemisia arbuscula Nutt.
Artemisia tridentata Nutt.
Aster canescens Pursh.
Aster scopulorum Dougl.
Astragalus probably curvicarpus (Sheld.) Macbr.
Astragalus purshii Dougl.
Astragalus stenophyllus T. & G.
Astragalus miser Dougl.
Astragalus lentiginosus Dougl.

Balsamorhiza sagittata (Pursh) Nutt.
Balsamorhiza serrata Nels. & Macbr.
Blepharipappus scaber Hook.
Bromus tectorum L.

Calochortus eurycarpus S. Wats.
Castilleja angustifolia (Nutt.) G. Don.
Castilleja hispida Benth.
Castilleja linariaefolia Benth.
Chaenactis douglasii (Hook) H. & A.
Chrysothamnus nauseosus (Pall.) Britt. var albicaules (Nutt) Rybd.
Chrysothamnus viscidiflorus (Hook) Nutt. var. humulis (Greene) Jeps.
Collinsia parviflora Dougl.
Cordylanthus ramosus Nutt.
Crepis acuminata Nutt.
Delphinium andersoni Gray.
Descurainia pinnata (Walt.) Britt.

Eriastrum filifolium (Nutt) Wool. & Standl.
Erigeron corymbosus Nutt.
Erigeron filifolius Nutt.
Erigeron linearis (Hook) Piper
Erigeron poliospermus Gray.

Eriogonum heracleoides Nutt.
Eriogonum ovalifolium Nutt.
Eriogonum proliferum T. & G.
Eriogonum sphaerocephalum Dougl.
Eriogonum umbellatum Torr.
Festuca idahoensis Elmer
Fritillaria pudica (Pursh) Spreng.

Appendix 7, continued

Gayophytum ramosissiumum Torr. & Gray.
Grayia spinosa (Hook.) Moq.

Haplopappus stenophyllus Gray
Juniperus occidentalis Hook.
Koeleria cristata (L.) Pers.
Lappula redowskii (Hornem.) Greene
Lewisia rediviva Pursh.
Leptodactylon pungens (Torr.) Rydb.
Lithophragma bulbiferum Rydb.
Lithospermum ruderale Lehm.
Lomatium macrocarpum (H. & A.) C. & R.
Lomatium triternatum (Pursh.) C. & R.
Lupinus argenteus Pursh.
Lupinus brevicaulis Wats.
Lupinus sericeus Pursh.
Lupinus saxosus How.

Lygodesmia spinosa Nutt.

Mentzelia albicaulis Dougl. ex Hook.
Microseris troximoides Gray.
Microsteris gracilis (Dougl. ex Hook) Greene
Mimulus nanus H. & A.

Oenothera andina Nutt.
Oryzopsis hymenoides (R. & S.) Ricker
Oryzopsis webberi (Thurb.) Benth

Penstemon cinereus Piper
Penstemon speciosus Dougl.
Phacelia linearis (Pursh.) Holz.
Phlox diffusa Benth.
Phlox hoodii Richn.
Phlox longifolia Nutt.
Phoenicaulis cheiranthoides Nutt.
Poa secunda Presl.
Poa cusickii Vasey
Purshia tridentata (Pursh.) D.C.
Ranunculus glaberimus Hook.

Ribes cereum Dougl.

Senecio integerrimus Nutt.
Silene drummondii Hook.
Sitanion hystrix (Nutt) J. G. Smith
Stipa thurberiana Piper
Symphoricarpos rotundifolius Gray

Appendix 7, continued

Tetradymia canescens D. C.
Townsendia florifer (Hook.) Gray
Trifolium gymnocarpon Nutt.
Trifolium macrocephalum (Pursh.) Poir.

Viola beckwithii T. & G.
Zygadenus paniculatus (Nutt.) Wats.