

WESTERN JUNIPER (*JUNIPERUS OCCIDENTALIS*) DISTRIBUTION,  
BEAR CREEK BUTTES, DESCHUTES COUNTY, OREGON:  
SOME POSSIBLE ECOLOGICAL AND CULTURAL INFLUENCES

by

DENNIS MARSHALL FRATES

A RESEARCH PAPER

submitted to

THE DEPARTMENT OF GEOGRAPHY

in partial fulfillment of  
the requirements for the  
degree of

MASTER OF SCIENCE

August 1974

#### ACKNOWLEDGMENTS

I wish to thank my major professor, Robert Frenkel, for his many hours of patient help and professional contribution. I am also grateful to Jim Christian and Herschel Henderly for their assistance in conducting some of the more laborious field work.

Special thanks are also extended for the letters of guidance provided by the government agencies and private individuals mentioned in the paper.

TABLE OF CONTENTS

ABSTRACT. . . . .	1
INTRODUCTION. . . . .	1
PURPOSE AND SCOPE. . . . .	1
LITERATURE REVIEW. . . . .	4
CHOICE OF STUDY AREA . . . . .	5
DESCRIPTION OF STUDY AREA . . . . .	7
LOCATION . . . . .	7
GEOLOGY AND TOPOGRAPHY . . . . .	7
CLIMATE. . . . .	12
SOILS. . . . .	13
VEGETATION AND FLORA . . . . .	14
METHODS . . . . .	18
RESULTS AND DISCUSSION. . . . .	20
SOIL MOISTURE. . . . .	20
<u>Aspect</u> . . . . .	20
<u>Stoniness</u> . . . . .	26
<u>Rock Outcrops and Fractured Bedrock</u> . . . . .	27
<u>Texture</u> . . . . .	28
SOIL TEMPERATURE . . . . .	31
<u>Introduction</u> . . . . .	31
<u>Aspect and Slope</u> . . . . .	32
<u>Nature of Pumice Soils</u> . . . . .	36
<u>Other Cold Soil Phenomena</u> . . . . .	37
VEGETATION RELATION TO HABITAT CONDITIONS . . . . .	42
INTRODUCTION . . . . .	42
ARTEMISIA COVER. . . . .	44
ALLELOPATHY IN ARTEMISIA . . . . .	45
JUNIPER-SAGE MOISTURE COMPETITION. . . . .	46
VEGETATION-SOIL TEMPERATURE RELATIONSHIPS. . . . .	47
MASS WASTING-VEGETATION RELATIONSHIPS. . . . .	49
VEGETATION RESPONSE TO CULTURAL INFLUENCES. . . . .	50
JUNIPER INVASION . . . . .	50
DOMESTIC GRAZING . . . . .	50
OTHER "GRAZERS". . . . .	52
MAN-CAUSED DISTURBANCES. . . . .	52
FIRE . . . . .	53

SUMMARY AND CONCLUSIONS . . . . .	55
LITERATURE CITED . . . . .	57
APPENDIX 1 . . . . .	60
APPENDIX 2 . . . . .	64

## LIST OF ILLUSTRATIONS

### Figures

1	Location of study area. . . . .	2
2	Major subdivisions of the juniper woodland zone in relation to: aeolian sands, igneous residuum, old sediments, and the study area (Driscoll 1964) . . . . .	6
3	Upper south slope ridge A, showing fractured nature of rock outcroppings. . . . .	9
4	Upper north slope ridge B, showing lack of rock outcrops and juniper. Upper portion of photo reveals ecotone between rock outcroppings and juniper of ridge top and rock free north slope . . . . .	10
5	Topographic subdivisions in the study area. . . . .	11
6	Vegetation-landform relationship of shrub and juniper cover in study area . . . . .	16
7	Theoretical angle between surface and radiation values ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at $42^\circ$ N latitude and $0^\circ$ declination (Fons <i>et al.</i> , 1960) . . . . .	21
8	Theoretical angle between surface and radiation ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at $42^\circ$ N latitude and $22^\circ$ N declination (Fons <i>et al.</i> , 1960). . . . .	22
9	Theoretical angle between surface and radiation ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at $42^\circ$ N latitude and $22^\circ$ S declination (Fons <i>et al.</i> , 1960). . . . .	23
10	Upper north slope photo showing depth to and thickness of frozen layer . . . . .	33
11	Ridge B northeast facing slope frozen soil and slope relationships for March 16, 1974. . . . .	34
12	Prostrate and swaying shrubs indicate downslope soil movement. . . . .	38
13	Hummocky, step-like micro-topography of north slopes, showing soil accumulation on uphill side of grass clumps and wasting on the downhill side . . . . .	39
14	Cracked ground phenomena as observed on north and south slopes during March 1974. . . . .	40
15	Relation between % juniper cover and % shrub cover in the juniper zone, Oregon (Driscoll 1964). . . . .	43

### Tables

1	Dominant plant species and their canopy coverages in the study area. . . . .	15
2	Percentage moisture content and wilting point of study area soils. . . . .	25
3	Field capacity and wilting point measurements for selected soil layers within the study area. . . . .	30
4	Plant moisture stress measurements for juniper trees, upper north and upper south slopes of ridge B . . . . .	31a

WESTERN JUNIPER (*JUNIPERUS OCCIDENTALIS*) DISTRIBUTION,  
BEAR CREEK BUTTES, DESCHUTES COUNTY, OREGON:  
SOME POSSIBLE ECOLOGICAL AND CULTURAL INFLUENCES

ABSTRACT: Several environmental and cultural factors were studied to explain the distribution of western juniper (*Juniperus occidentalis* Hook.) in an area one mile northwest of Millican, Oregon. In the study area juniper grows densely on upper south slopes and only sparsely occurs on upper north slopes. Juniper moisture stress was found to be greater on upper south slope trees than on upper north slope trees. Frozen soils correlated well with the absence of juniper on upper north slopes. Domestic and wild animal grazing, man-made disturbances, and the lack of fire are also suggested as possible influences on the present day distribution of juniper in the study area.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this study is to suggest possible ecological and cultural influences on western juniper (*Juniperus occidentalis* Hook. subsp. *occidentalis* Hook.) distribution within Bear Creek Buttes, central Deschutes County (see Fig. 1).

It is not my intention to extrapolate findings from the study area to the entire western juniper zone of Oregon. To do this would be to intimate uniform habitat and genetic conditions throughout Oregon.

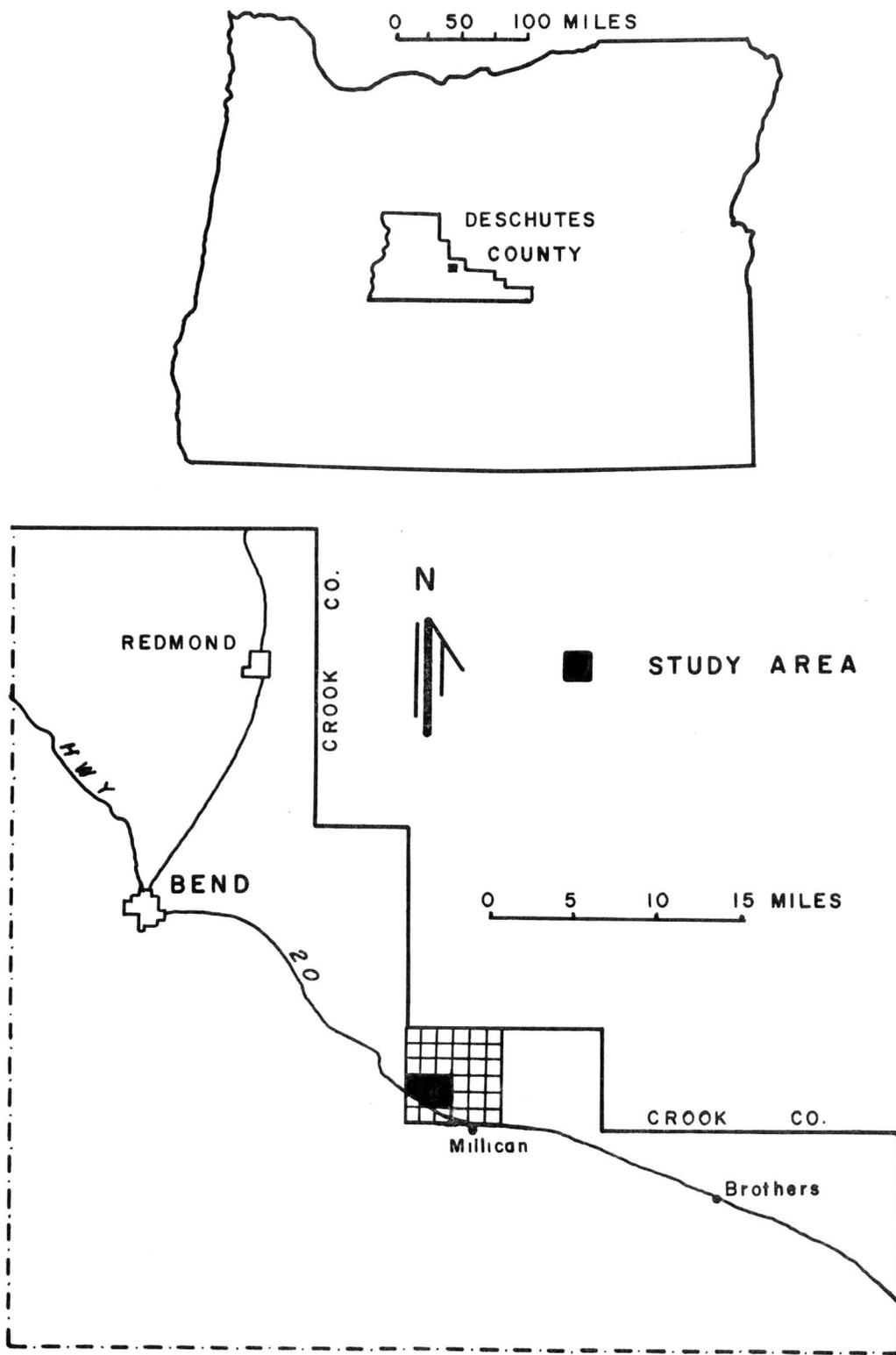


Fig. 1. Location of study area.

While habitat conditions may be geographically duplicated in the juniper zone, it is true from reconnaissance surveys that juniper growth occurs over a wide range of habitats. For example, juniper in Oregon can be found growing in moderately deep, rocky soils in valley bottoms, while on the adjacent ridges growth also occurs on shallow, stony soils (Driscoll 1964a). Therefore, there will be no attempt to apply the findings of this report uniformly throughout the juniper zone. On the other hand, processes and conditions that occur in the study area could be duplicated at other localities of western juniper growth. Future research in Oregon may confirm or deny the findings contained in this study.

Juniper distribution may be the result of all environmental factors at all times or of just one factor at various times. However, a complete study of juniper distribution should be framed as an holocoenotic approach. The holocoenotic concept as described by Billings (1952) emphasizes that changes in species over space and time cannot be interpreted in terms of only one factor. One factor may be more influential than others, but environmental forces seldom act independently of one another.

It is, therefore, necessary for this report to emphasize the holistic or holocoenotic approach, regardless of a lack of data for some environmental factors. It is a dilemma that ecology suggests evaluation of the whole, while the limitations of such a study are severely restrictive. Nevertheless, the merits of such an approach are acknowledged, and a partial attempt has been made to synthesize a vast quantity of information (in some cases without quantitative data) on factors influencing juniper distribution in the study area. It is hoped that this report will act as a springboard for more detailed autecological studies of

western juniper which can then be reincorporated into an improved synecological model to explain western juniper distribution.

#### LITERATURE REVIEW

Very little autecological work has been published on western juniper in central and eastern Oregon. This is probably due, in part, to juniper's lack of economic value. Until very recently, juniper was principally used for firewood and fenceposts.<sup>1</sup> Traditionally, the juniper has been disliked by ranchers more interested in a palatable forage for livestock, and by foresters who have ignored the tree because of its lack of merchantability. Hence, juniper in Oregon is one tree species that is essentially not managed for production, and consequently, there has been little incentive to know about the factors controlling its growth.

Driscoll (1964, 1964a) has completed a major vegetation classification of juniper associations in relation to soils in central Oregon. His emphasis was on description and was "somewhat constrained by a grazing management bias."<sup>2</sup> Although making excellent descriptions of soil-plant association relationships, he was only somewhat interested in the autecology of the species. Eckert (1957) studied Artemisia associations in Harney and Lake Counties, Oregon, and made only brief reference to "influences on western juniper establishment." Another major published study on western juniper growth was done in Idaho by Burkhardt and Tisdale

---

<sup>1</sup>Recently in Prineville, Oregon a private company has initiated construction of a small mill to process juniper into panel wood. Robert McMahon, Assistant Professor in Forest Economics, Oregon State University, personal communication, January 1974.

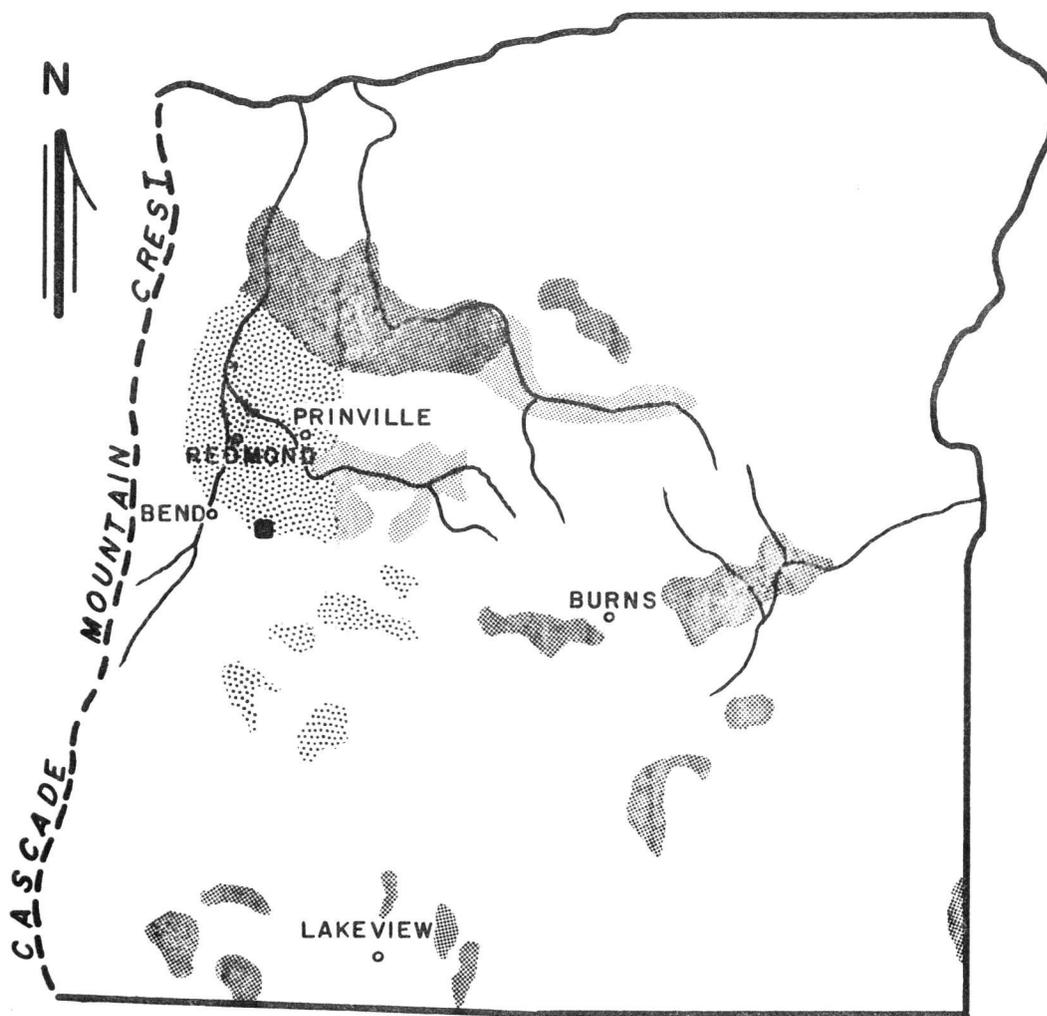
<sup>2</sup>Richard Driscoll, Principal Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, personal communication, February 1974.

(1968). They stressed juniper succession and suggested the topo-vegetation relationships of juniper communities.

Despite the meagerness of research on western juniper, numerous studies have documented the effects of fire, grazing, soils, topography, etc. on other juniper species (Juniperus monosperma, Juniperus scopulorum, Juniperus utahensis, Juniperus pachyphloea, Juniperus pinchotii) in the western United States (Leopold 1924, Cottle 1931, Emerson 1932, Cottam and Steward 1940, Parker 1945, Allred 1949, Arend 1950, Johnsen 1962, Ellis and Schuster 1968).

#### CHOICE OF STUDY AREA

The study area was chosen for two reasons. First, the area is at the southern margin of contiguous juniper growth in Oregon (Fig. 2), and therefore one or more environmental factors (i.e., temperature and precipitation) may be at their limit with respect to optimum conditions for western juniper. For example, junipers in the study area probably grow in narrower habitat conditions (i.e., less precipitation) than junipers west of the area, and thus determination of environmental factors affecting growth could be more easily assessed. Second, junipers grow almost exclusively on south slopes within the study area, and Artemisia and Chrysothamnus shrub land dominate north slopes. The ecotone between these two vegetation types is abrupt, indicating a possible concurrent change in one or more habitat factors. This permits an easier assessment of habitat changes since only a short distance of land is involved.



SCALE 0 50 100 150

LEGEND

	Soils from aeolian sands
	Soils from old sediments
	Soils from igneous materials
	Study area

Fig. 2. Major subdivisions of the juniper woodland zone in relation to: aeolian sands, igneous residuum, old sediments, and the study area (Driscoll 1964).

## DESCRIPTION OF STUDY AREA

### LOCATION

The study area is located approximately 23 miles east of Bend, north of U.S. Highway 20 and one mile west of Millican, Oregon. The area encompasses two ridges (Bear Creek Buttes) located in sections 19-21 and 28-30 of Township 19 South, Range 15 East, Willamette Meridian (Fig. 1).

### GEOLOGY AND TOPOGRAPHY

The study area lies within the High Lava Plains physiographic region which extends from the base of the Cascades, near Bend, eastward to Malheur Cave, and from the Blue Mountains on the north to the Basin-Range physiographic region on the south (Dicken 1950).

Figure 2 shows the major subdivisions of the juniper woodland zone, indicating the extent of juniper woodland distribution in relation to: 1) aeolian sands (pumice), 2) igneous residuum, and 3) old sediments. Note that the study area is located on the southern fringe of the aeolian sands subdivision.

Gravel and sand-size pumice particles (ash fall) were deposited on the ridges in the study area from the Mt. Mazama eruption<sup>3</sup> of approximately 7,000 years ago (Williams and Goles 1968). Due to aeolian and fluvial processes, the estimated six inches which was deposited on the study area has been redistributed so that in some colluvial locations pumice depths were observed to be much deeper.

---

<sup>3</sup> Joel Norgren, Research Associate, Soil Science, Oregon State University, personal communication, March 1974.

Two lava buttes occur in the study area and are of undetermined age but are presumed to be the result of geologically recent flows, since the High Lava Plains is the youngest and least eroded region in Oregon (Dicken 1950).

Elevation of the two ridges varies from 4200 to 4700 feet at the lowest and highest portions of the study area. As Appendix 1 shows, upper south slopes of both ridges are very steep (steepest portion is upper south slope ridge A, 45 percent grade), and rock outcroppings are clearly more evident there (for the upper south slopes of ridge A and B, 34 percent and 31 percent of the surface area consists of outcroppings respectively). The basaltic outcroppings are extremely fractured (Fig. 3). North slopes generally have moderate to gentle inclinations (steepest portion is upper north slope ridge B, 33 percent grade) with rock outcroppings never occurring on upper portions and only infrequently occurring on lower portions (lower north slope ridge B, 1 percent outcropping) (Fig. 4).

Figure 5 shows the topographic subdivisions in the study area. There are two ridges, A and B, with five topographic divisions on each. The upper portion of the fractional classification refers to the ridge and slope number. Slope number simply refers to the sequence of slopes starting from the lower south slope ridge A (number 1) to the lower north slope of ridge A (number 5). A similar sequence is used for ridge B. The lower part of the fractional classification indicates the steepness of the slope, G=gentle (0-17 percent), MS=moderately steep (17-25 percent), S=steep (25-45 percent), and RT=ridge top, and the direction the slope faces, SW=southwest, NE=northeast.



Fig. 3. Upper south slope ridge A, showing fractured nature of rock outcroppings.



Fig. 4. Upper north slope ridge B, showing lack of rock outcrops and juniper. Upper portion of photo reveals ecotone between rock outcroppings and juniper of ridge top and rock free north slope.

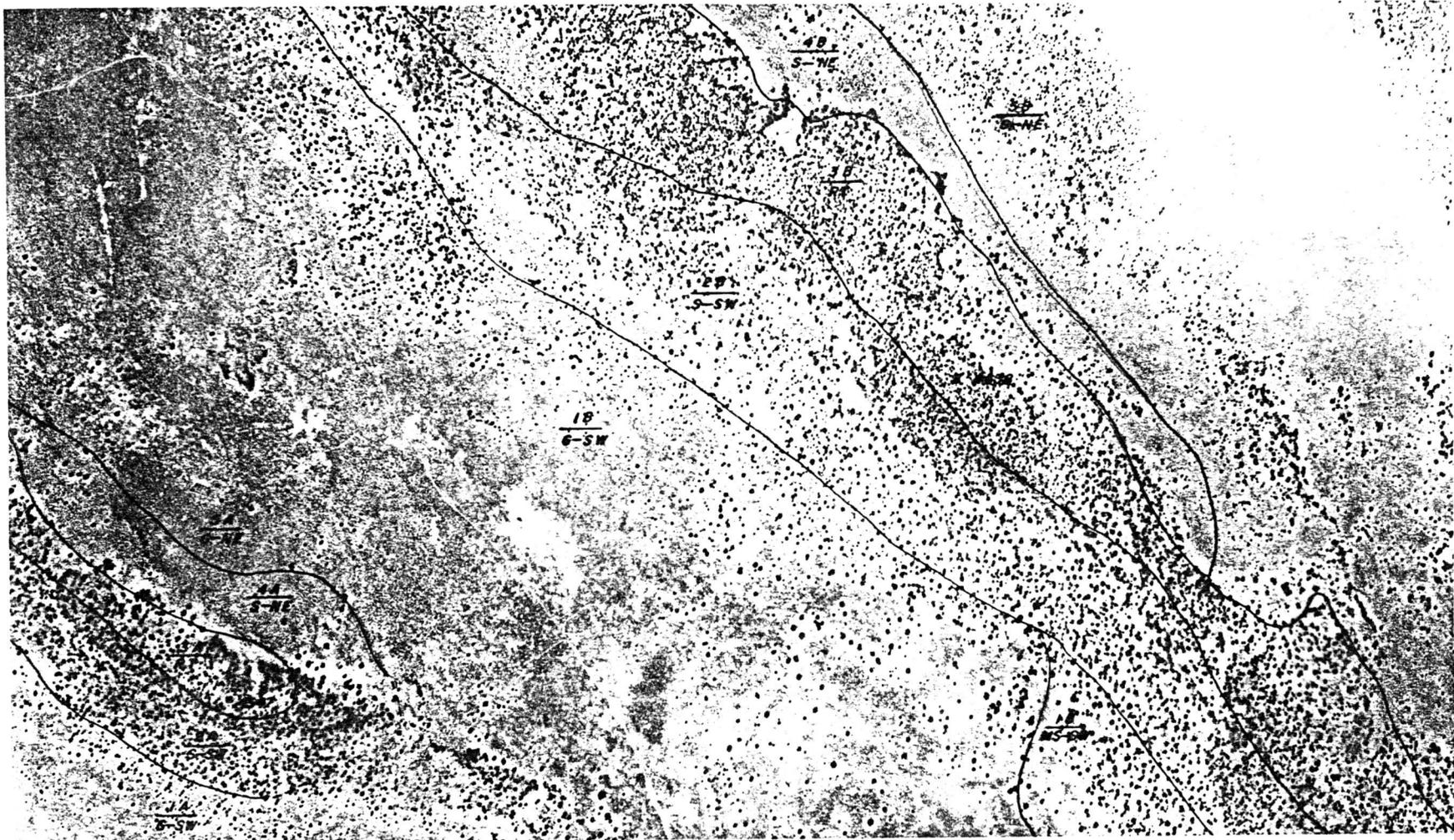


Fig. 5. Topographic subdivisions in the study area. See text for explanation of symbols. RF 1:11,250.

## CLIMATE

The climate of the study area is semi-arid, characterized by cold, relatively snow-free winters, warm, dry summers, and low annual precipitation. Generally, the majority of precipitation falls as rain during the winter months. However, variations in precipitation are common. For example, as Appendix 2 shows, in June of 1969 3.68 inches of precipitation fell at Brothers, ten miles east of the study area. In contrast, in June of 1962 .07 inch was recorded for the same area. Other months for differing years show similar opposing extremes. In December of 1964, 4.51 inches of precipitation occurred, while in the same month of the next year only .36 inch was recorded.

Year to year variations in precipitation also display a fairly wide range. For the ten year period covered in Appendix 2, (1962-1971), 8.60 inches of precipitation fell in 1962, and 14.99 were recorded for 1968. For the ten year period concerned, the average yearly rainfall was 11.20.

Annual mean temperatures (Appendix 2) show July -August as the warmest months and December-January as the coolest at Brothers. It should be noted that while diurnal winter temperatures vary sometimes only slightly, summer diurnal temperatures often exhibit a wide range, with frost sometimes occurring in the evenings and temperatures in the 80's to 90's during the day. Appendix 2 indicates that the more serious freezes (20<sup>o</sup>F and below) generally occur in early September and that these temperatures may persist from winter into late May and early June. The implications of these temperature extremes will be discussed in detail later.

## SOILS

The soils in the study area have been tentatively classified and delimited on a small scale map (1:175,000) based largely on reconnaissance surveys (SCS 1969). The Deschutes soil series dominates the study area and has been placed in the Xerollic Camborthid subgroup. There are three other (classification) units based on reconnaissance surveys that occur in the study area. A discussion of these units is omitted because detailed descriptions of them are lacking.

Further field investigations in the study area showed that all of these Aridisols contained medium to large quantities of pumice strewn throughout their horizons. The sandy pumice parent material often overlies a darker buried soil of finer texture.

Soil depth varies from 11 to 73+ inches in the study area. Soil texture ranges from coarse sand to sandy loam; however, most horizons were classified as sandy soils.

Soil color ranges from very dark gray when moist (10yr 3/1), to white when dry (10yr 8/1). Moist and dry soil colors from any one horizon often are 2-3 Munsell color values and 1-2 chroma notations apart. Vertical color changes from one horizon to another vary only slightly in most instances.

Soil reaction ranges from slightly acid (pH 6.4) in upper soil horizons, to strongly alkaline (pH 8.6) in lower horizons. Soil reaction recorded in this report was determined for March.

Of the nine soil pits dug, no profile was 100 percent stone free, although some lower south slope and upper north slope profiles had the least rock percentages of all, comprising approximately 5-20 percent of the total soil horizon.

For a more complete description of the soils in the study area, see Appendix 1.

#### VEGETATION AND FLORA

The only tree species occurring in the study area is Juniperus occidentalis subsp. occidentalis Hook. In the literature, this subspecies is often not distinguished from J. occidentalis ssp. australis Vasek. The two subspecies are physiognomically similar. J. occidentalis ssp. occidentalis is a submonoecious tree with brownish bark and scale-like leaves in two's or three's. J. occidentalis ssp. australis, while also commonly called western juniper, is a larger tree, mostly dioecious or occasionally monoecious, with reddish-brown bark and leaves mostly in three's. J. occidentalis ssp. occidentalis occurs in forest and sagebrush from Lassen County, California, northward through the northwest tip of Nevada and eastern Oregon, to southwest Idaho and southeast Washington. Subspecies australis occurs in forests and pinyon woodlands from Lassen County, California, south through the Sierra Nevada, to the San Bernardino Mountains (Vasek 1966).

Table 1 shows dominant vascular plant species and their canopy coverages in sample plots in the study area. The north slope of ridge A was sampled only once since little apparent variation in floristic composition occurred between upper and lower portions. Figure 6 schematically shows how shrubs and juniper are distributed in relation to landforms in the study area.

Species composition of the study area does not show any meaningful resemblance to Dealy's classification of central Oregon ecosystems (1971) or to Driscoll's classification of eastern Oregon plant associations (1964).

TABLE 1. Dominant plant species and their canopy coverages in the study area. The symbol + means less than 1 percent cover.

	RIDGE A			RIDGE B			
	L. SOUTH	U. SOUTH	NORTH	L. SOUTH	U. SOUTH	U. NORTH	L. NORTH
<i>Chrysothamnus viscidiflorus</i>	3		+	7		2	6
<i>Chrysothamnus nauseosus</i>	16	5	6	4	7		
<i>Artemisia tridentata</i>	6	3	22	9	8	20	18
<i>Festuca idahoensis</i>			16			13	17
<i>Agropyron spicatum</i>		18			7		
<i>Bromus tectorum</i>	16	29		9	23		+
<i>Stipa comata</i>					6		
<i>Collinsia parviflora</i>			3			2	1
<i>Phacelia bicolor</i>			+		+	2	
<i>Gayophytum racemosum</i>	2		+	1			2
<i>Amsinckia tessellata</i>	2			+			
<i>Layia glandulosa</i>				1			
<i>Microsteris gracilis</i>			+		+	+	+
<i>Descurainia richardsonii</i>	+						+
<i>Mentzelia albicaulis</i>	2		+	2			
Rock Outcropping		34			31		1
Bare Soil	58	9	60	65	31	53	50
Other Grasses	+	3	1	+	+	1	1
Other Herbs	+	2	+	+	+	+	+
<i>Juniperus occidentalis/acre</i>	19	32	+	19	37	6	23

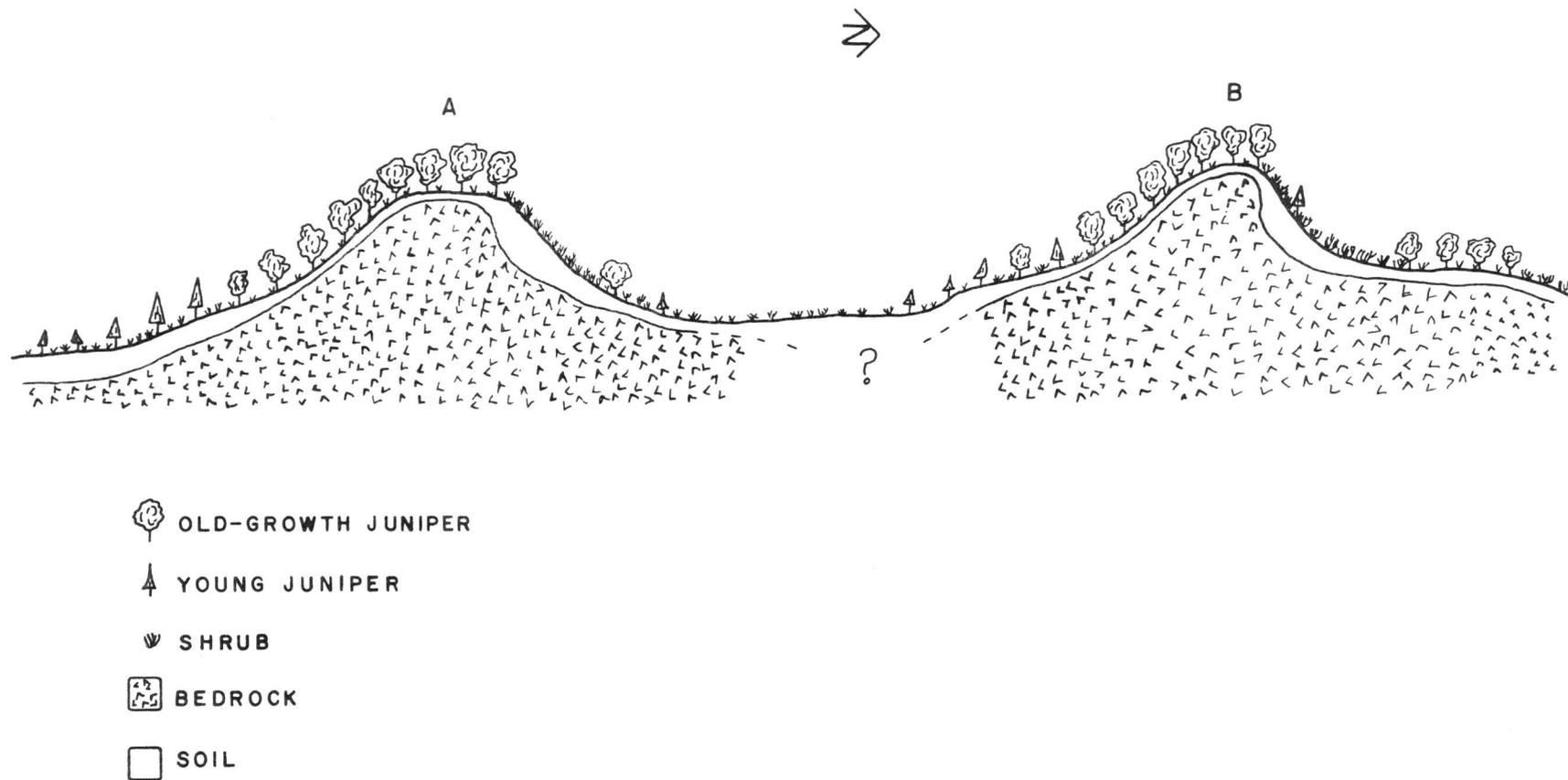


Fig. 6. Vegetation-landform relationship of shrub and juniper cover in study area.

17

Only one of Driscoll's associations may be represented in the study area. The upper and lower north slope of ridge B could fit into Driscoll's Juniperus/Artemisia/Festuca association; however, since different sampling methods were used, exact statements regarding the comparability of Driscoll's analysis with this study cannot be made. Nevertheless, there are some contrasts between the species composition of the study area and Driscoll's nine associations. Driscoll records Bromus tectorum as a very minor species while it is obviously a major component of south exposures in the study area. In addition, species of Chrysothamnus are plainly more prolific on both ridges of the study area. Both these species colonize disturbed habitats and their presence in the study area could reflect a greater degree of disturbance than prevailed in Driscoll's samples.

## METHODS

Most soil analysis was conducted at the Soil Testing Laboratory and the Department of Geography at Oregon State University. All soil descriptions were performed in accordance with the Soil Survey Manual (U.S. Bur. Plant Indus., etc., 1951).

Soil textural classes were determined by a mechanical sieve and a Boyoucou Hydrometer. Percentage pumice content was estimated from residue after soil sieving. Most pumice particles remained as sand or coarser texture in the larger sieves.

One-third (approximate field capacity) and 15 atmospheres (approximate wilting point) moisture tension for soils were determined by use of a pressure membrane (Pressure Plate Model PM, Instrument Development and Mfg. Corp., Pasadena, Calif.). Soil moisture, which came into equilibrium with a predetermined applied pressure, was assessed on a weight basis after 48 hours in the membrane. Percentage moisture content could thus be found for soils at field capacity and at wilting point.

Moisture stress for sampled plants of juniper and sage was determined by a pressure bomb apparatus made by the P.M.S. Instrument Company, Corvallis, Oregon, Model 1000. Plant segments were placed in a portable nitrogen field chamber and pressure applied. The pressure needed to exude sap was recorded; that is, the tension of the water held by the plant and thus the moisture stress of the tree or shrub could be determined. Two segments were taken from each tree or shrub, one from the lower south and the other from the lower north portion, and were collected between 11 pm and 3 am, August 8, 1974. All measurements were made

with a portable pressure chamber 2-5 minutes after detaching the segment. This was done to avoid discrepancies due to wilting. (A complete description of the instrument by Waring and Cleary, 1967, is available.)

The shrub and herbaceous layer was sampled by use of the Daubenmire cover estimation method (Daubenmire 1959). In most cases, 40-50 plots, 20 x 50 cm, were systematically placed adjacent to soil pits. Care was taken to sample an area that was characteristic of the entire stand. The number of trees per acre was determined from a large scale (1:7920) air photo of the study area. Age of juniper trees was determined by increment borings.

Slope angle was measured in percent with an Abney hand level. Elevation was taken from a 20 foot contour topographic map. (Millican, Oregon 1967, RT 1:24,000).

The two ridges of the study area are referred to in this paper as ridge A and B (Fig. 5 and 6), and are further identified as upper or lower, southwest or northeast slopes. This designation of aspect always refers to the direction in which the slope faces. For example, north slopes run east and west but face in a northerly direction.

Depth and thickness of the frozen layer were determined by random pits excavated every 50 feet in a transect from base to ridge top.

## RESULTS AND DISCUSSION

## SOIL MOISTURE

Aspect

Slope aspect is important as related to soil moisture content in the study area. Since the slopes in the area are oriented in a northeast and southwest direction and slope angles approach 30 percent and steeper, maximum soil surface temperatures, theoretically, occur during the later part of the day on southerly exposures. Figures 7, 8, and 9 indicate this and also show that northeast exposures receive significantly less direct radiation, especially during winter months. The maximum  $\theta \sin$  value (theoretical angle between surface and radiation) of southwest compared to northeast exposures is 29 percent higher at the equinoxes, 12 percent higher during the summer, and 57 percent greater during the winter.

This evidence suggests that southwest slope soils, especially under high sun conditions, undergo greater moisture depletion due to evapotranspiration than northeast facing slopes or the nearby flat lands. The rate at which evapotranspiration occurs depends, of course, upon plant, climatic and soil characteristics. Jamison (1955) has outlined the variables affecting the availability of soil moisture to plants. The variation of these factors (biotic, climatic and edaphic) also determines the degree to which evapotranspiration occurs. Jamison has listed the following as pertinent factors:

I. Plant (biotic)

- (a) plant conditions (including nutrients present, stage of growth, degree of turgor, etc.)

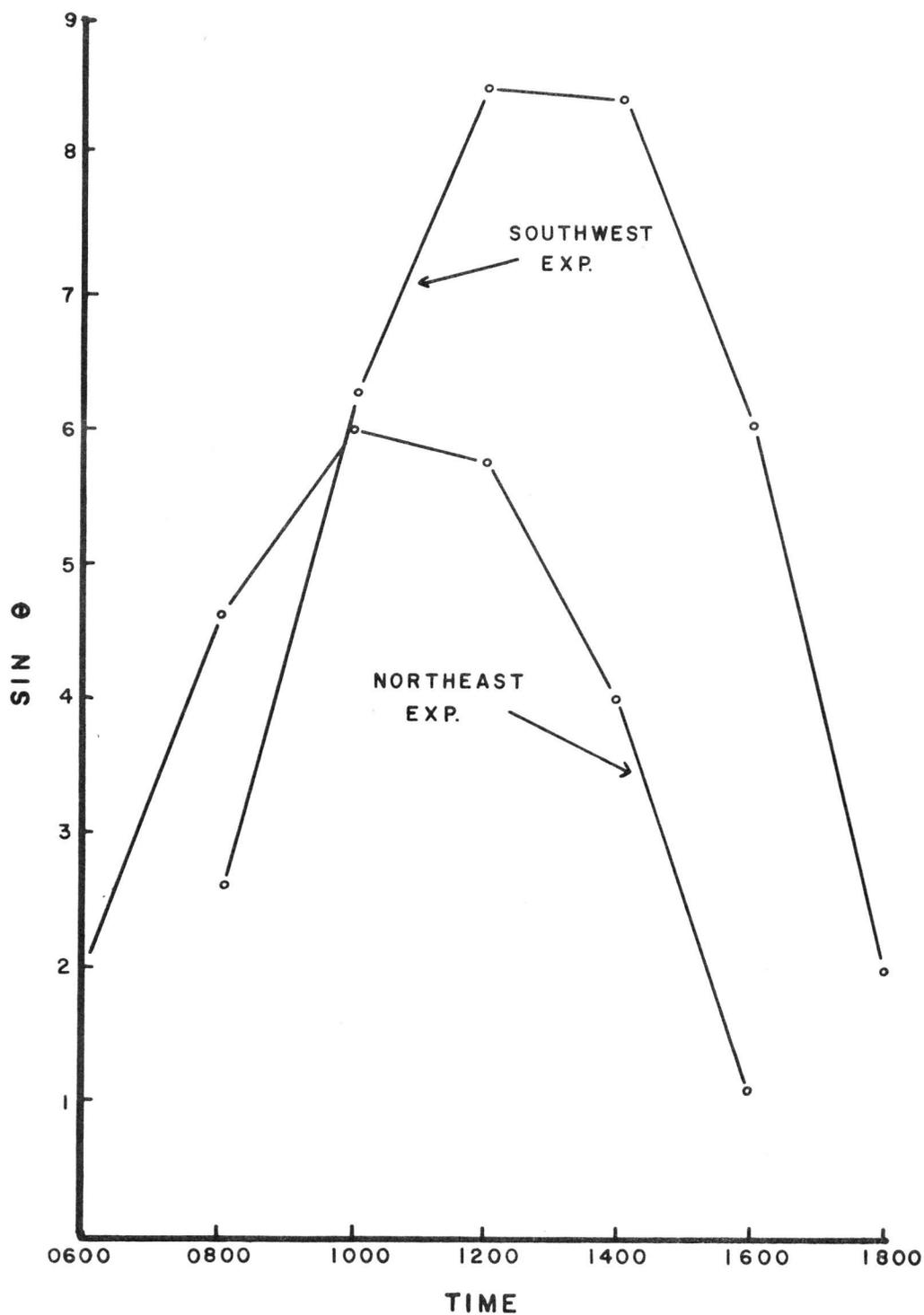


Fig. 7. Theoretical angle between surface and radiation values ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at  $42^\circ$  N latitude and  $0^\circ$  declination (Fons et al., 1960).

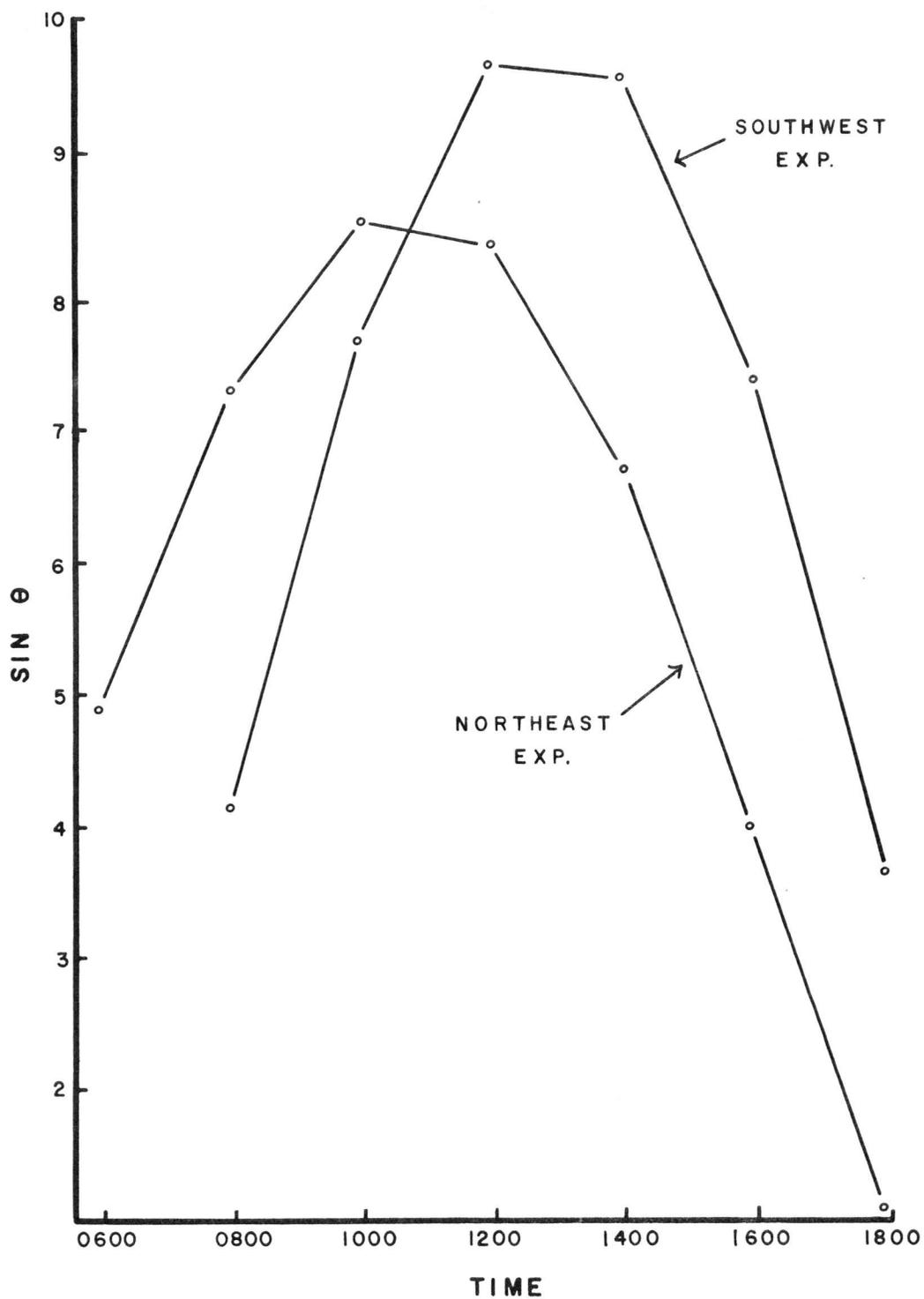


Fig. 8. Theoretical angle between surface and radiation values ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at  $42^{\circ}$  N latitude and  $22^{\circ}$  N declination (Fons *et al.*, 1960).

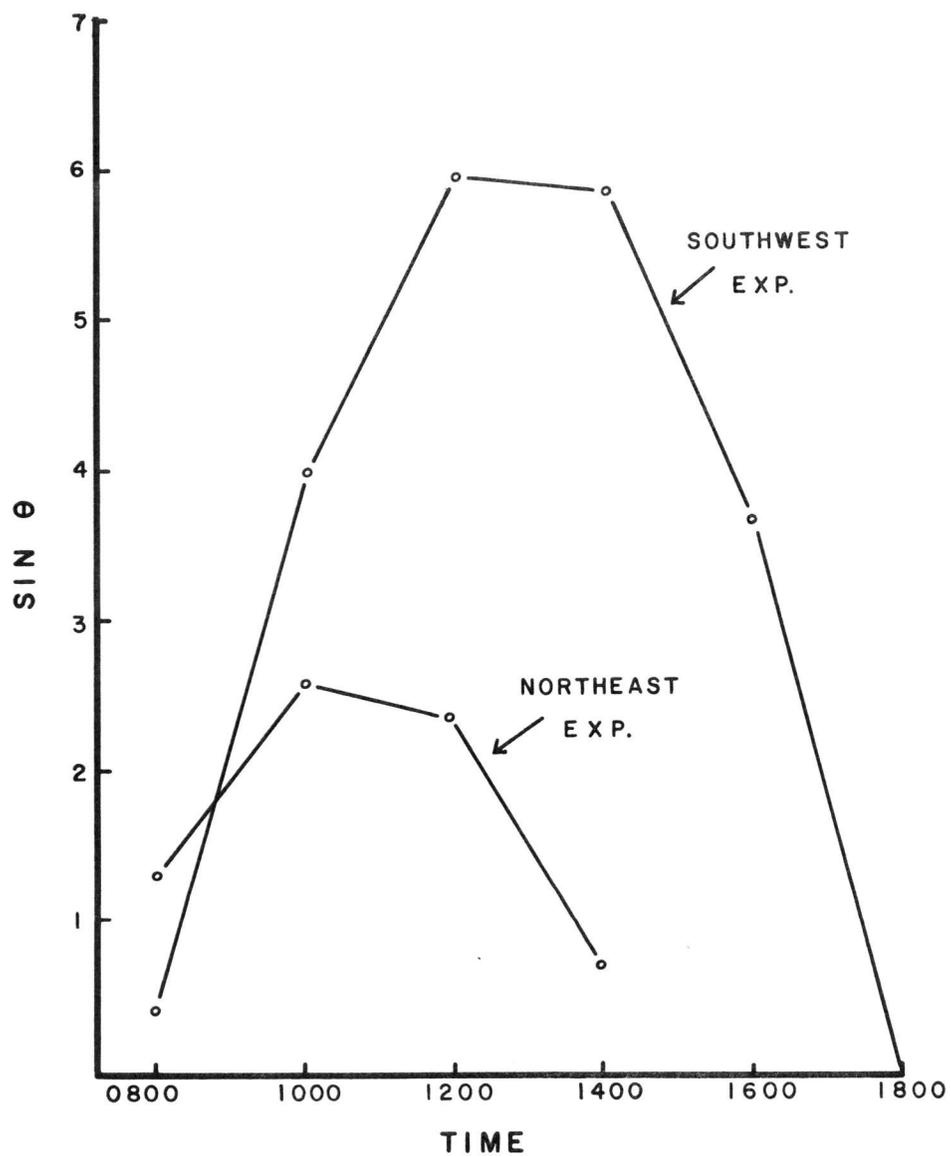


Fig. 9. Theoretical angle between surface and radiation ( $\theta \sin$ ) for northeast and southwest exposures; for 30% slope at  $42^{\circ}$  N latitude and  $22^{\circ}$  S declination (Fons *et al.*, 1960).

- (b) rooting habit (including depth of rooting, degree of ramification, and absorptive activity)
- (c) plant resistance to drought

## II. Climatic

- (a) air temperature, air humidity and precipitation (including the effect of fogs and wind)

## III. Soil (edaphic)

- (a) moisture tension relations
- (b) soil solution osmotic pressure effects
- (c) kinds of ions present in the soil solution
- (d) soil moisture conductivity
- (e) soil depth
- (f) soil stratification, including the effect of hardpans and textural layering
- (g) soil temperature and temperature gradients

The data presented in Table 2 shows that March subsurface soil samples taken from pits 1 through 4 (south slopes) and 6 and 7 (lower north slopes) generally had higher weight percentages of moisture than did subsurface samples from pits 5, 8, and 9 (upper north slopes), and that soil moisture greatly decreased with depth on upper north slopes. This apparent incongruity between north and south slope soil moisture content cannot be accounted for by the fact that upper north slope soils are coarse and thus gravitationally drain more rapidly than the slightly finer soils of south slopes. As will be seen later, upper north slope soils, despite their coarser texture, in certain cases have higher available moisture capacities than some south slope soils.

A number of factors account for the contradiction. First, since soil moisture determinations were made for March when plants were physiologically inactive, moisture depletions on south slopes due to high solar intensities that would force evapotranspiration were, for the most part, insignificant. Second, as will be demonstrated later, upper north slope soils remain frozen during the majority of the winter and a portion of early April. This condition impedes infiltration and thus could partially

TABLE 2. Percentage moisture content and wilting point of study area soils. Pits 1-4, south slopes, pits 5-9, north slopes. Samples taken March and June 1974.

PIT	SAMPLE	% MOISTURE*		WILTING POINT	PIT	SAMPLE	% MOISTURE*		WILTING POINT
		MARCH 16	JUNE 20				MARCH 16	JUNE 20	
1	0 - 13"	14	8	8.70	5	0 - 24"	14	11	6.37
"	13 - 28"	9	5	8.39	"	24 - 42"	2	5	9.95
"	28 - 42"	10	5	--	"	42 - 45"	2	3	9.19
					"	45 - 60+"	4	5	--
2	0 - 9 "	16	12	--					
"	9 - 23"	15	10	--	6	0 - 11"	17	11	7.62
"	23 - 42"	14	7	--	"	11 - 21"	8	10	7.30
"	42 - 59"	2	5	--	"	21 - 32"	7	7	--
3	0 - 10"	15	4	9.30	7	0 - 13"	20	8	6.39
"	10 - 18"	17	9	10.16	"	13 - 26"	13	10	7.30
"	18 - 28"	14	9	7.08	"	26 - 35"	8	8	--
4	0 - 3 "	30	7	13.84	8	0 - 24"	16	11	6.77
"	3 - 8 "	20	6	10.12	"	24 - 39"	3	3	7.98
"	8 - 11"	19	7	13.93	"	39 - 52+"	4	2	--
					9	0 - 29"	12	12	--
					"	29 - 61"	3	4	--
					"	61 - 73+"	7	3	--

\*Percentage wet weight versus oven dried weight of 150-200 grams of soil.

account for the low percentage of moisture content with increasing depth. Third, the frozen surface layer induces subsurface moisture to be drawn up by capillary force, thence freezing on contact with and adding to the slow accretion of frozen surface soil (Geiger 1965).

June soil moisture determinations indicate a similar trend of lower moisture content with depth on upper north slopes (Table 2). Evidently, upper north slope soil freezing not only induces moisture differences in lower horizons during March, but also results in a carrying of this condition into summer. Lower layers of lower north slope and south slope soils generally contained more moisture (on a weight basis) than did lower layers of upper north slope soils, showing a distinct similarity to March conditions (Table 2).

Table 2 also shows percent moisture content at wilting point for selected pits. Note that lower north slope and south slope soils remained above the wilting point for a greater portion of the year than did upper north slope soils.

#### Stoniness

Some quantity of rock fragments was imbedded within the horizons of all soil pits in the study area. Generally, the greater the percentage of rock fragments in a solum, the less the water storage capacity. It has been noted that rocks in sandy soils beyond 20 percent by volume can have an unfavorable effect on plant growth (Lutz and Chandler 1946). Not only is field capacity decreased in stony soils, but root growth may be restricted also.

Upper south slope soils were estimated to contain the largest percentages of rock fragments. North and lower south facing slopes generally

contained only small quantities of rock fragments, at least in uppermost horizons.

#### Rock Outcrops and Fractured Bedrock

Rock outcroppings are more prevalent on upper south slopes than on any other slope position. The effect of rock outcroppings on soil moisture in the study area is unknown. Lutz and Chandler (1946) report that in some instances rocks in and on soils tend to decrease losses of water by evaporation.

Fractured bedrock was encountered at the bottom of all nine excavated soil pits. Commonly, on upper south slopes a few roots were observed growing in the fissures of these basal rocks. Root penetration of rock fissures occurred more often on upper south slopes where soil depth was shallow and roots often proliferated all horizons. The roots of plants observed in pits 5, 8 and 9 (north slopes) appeared to terminate most of their growth approximately 18 inches below the surface, and roots were never observed growing in the fractured bedrock below. The effect of fractured bedrock on plant growth and its relation to provincially deeper soils and thus greater moisture supply was not measured directly.

Johnsen (1962) points out that basal rock fissures may increase moisture availability for Juniperus monosperma in northern Arizona by trapping moisture in cracks and crevases, effectively extending favorable moisture conditions into late spring and early summer. He notes that soils of adjacent grasslands were at or near the permanent wilting point much sooner than soils found in rock outcroppings. Burkhardt and Tisdale (1968) suggest that bedrock fractures in southwest Idaho act as

concentration zones for both western juniper roots and soil moisture. Eckert (1957) indicates that western juniper in central Oregon grows best on rocky outcrops because moisture conditions are "quite favorable" there, at least for a portion of the growing season. It should be mentioned, however, that both Eckert, and Burkhardt and Tisdale lack soil moisture measurements to prove their hypotheses.

### Texture

As indicated at the beginning of this section, the apparent contradiction in the March determinations of soil moisture content with aspect (p. 24) cannot be explained in terms of differing soil textures. This is true because of the special physical make-up of pumice soils. Conventional mineral soils generally exhibit a decrease in available moisture with an increase in particle size beyond silt loam. While an increase in the size of an individual pumice particle may show a decrease in available moisture, this decrease may be negligible because it is somewhat compensated for by the vascular nature of pumice soils. Consequently, this soil may equally compare in available moisture capacity with a finer textured mineral soil.

The vascular configuration of a pumice grain increases the air and capillary pore space potential beyond that of a conventional mineral soil grain of equal diameter. For example, Packard (1957, p. 282) reports that New Zealand sandy pumice soils possess moisture storage properties "more like those of silt loams than those of sand." Youngberg and Dyrness (1964), conducting experiments on a central Oregon Mazama pumice soil, found that moisture tensions of coarse, gravelly, pumice sand and gravelly, pumice sand appear to be similar to those for normal sandy soils, and that those

for loamy, coarse, pumice sand and coarse, pumice, sandy loam are more like those for non-pumice loams or silt loams.

Laboratory moisture tension measurements of pumice soils with varying pumice contents in the study area agree with the previous findings. Appendix 1 shows that the 42-45 inch level of pit 5 contains approximately 90 percent sand-sized pumice particles. Table 3 indicates that this soil has an available moisture capacity (1/3 atm minus 15 atm) of 12.42 percent, which equals and in most cases surpasses available moisture capacities of finer textured soils and pumice deficient sandy soils in the study area.

Initially, before field tests were made, I hypothesized the following:

- (1) North slope soils with their high pumice content, regardless of their coarse texture, may have greater available moisture capacities than finer textured soils of upper south slopes.
- (2) Upper south slope rock outcrops may allow water to be trapped interstitially in rock fissures with little subsequent evaporation.
- (3) In terms of evaporation, upper south slope soils may actually retain greater amounts of soil water than lower south or north slopes because crevice water is protected from evaporating.
- (4) North slope soils, with their greater capillary water holding potential, may inhibit rainwater from infiltrating to lower depths where it could be utilized by plants. Because the moisture is held nearer the surface, this could increase water losses due to evaporation.
- (5) South slope soils with less pumice content have lower capillary water holding potential and may readily pass water to lower horizons, storing some moisture in subsurface rock fissures. These conditions coupled with the frozen soil phenomenon of upper north slopes during winter may account for the desiccation of lower layers and cause north slope trees to be under greater stress.

TABLE 3. Field capacity and wilting point measurements for selected soil layers within the study area. Pits 1-4, south slopes, pits 5-8 north slopes. Samples collected January 26, 1974.

SAMPLE		% MOISTURE AT 1/3 atm	% MOISTURE AT 15 atm	AVAIL. MOIS. (1/3 atm minus 15 atm)
Pit 1	0 - 13"	14.56	8.70	5.86
	13 - 28"	13.82	8.39	5.43
	28 - 42"	12.40	--	--
Pit 3	0 - 10"	16.31	9.30	7.01
	10 - 18"	15.30	10.16	5.14
	18 - 28"	12.26	9.08	3.18
Pit 5	0 - 24"	15.92	6.37	9.55
	24 - 42"	13.09	9.95	3.14
	42 - 45"	21.61	9.19	12.42
	45 - 60+"	16.91	--	--
Pit 6	0 - 11"	13.97	7.62	6.35
	11 - 21"	16.82	7.30	9.52
	21 - 32"	18.25	--	--
Pit 7	0 - 13"	17.61	6.38	11.23
	13 - 26"	19.06	7.30	11.76
	26 - 35"	19.57	--	--
Pit 8	0 - 24"	17.59	6.77	10.82
	24 - 39"	20.00	7.98	12.02
	39 - 52+"	18.08	--	--
Chehalis Silty Clay Loam*		31.34	15.03	16.31

\*Collected and used as a control sample by the Soils Testing Laboratory at Oregon State University.

However, subsequent moisture tension measurements (Table 4) showed that south slope trees are under greater moisture stress than north slope trees. Using a hierarchical design of a single factor analysis of variance, it can be concluded at a .99 confidence coefficient level that a difference exists between south slope as compared to north slope trees. Furthermore, at a .95 confidence level, the mean value of trees on the north slope will fall between 237.34 and 262.02 of the present mean of 249.68. At the same confidence level, trees on the south slope will fall between 281.45 and 296.67 of the present mean of 289.06 (Table 4). Thus, it can be concluded that the moisture stress measurements are significant, and that south slope trees are under greater moisture stress.

Nevertheless, my original hypothesis regarding north and south slope moisture concentrations may be valid. In other words, rock fissures and mineral soils on south slopes may permit provincially greater amounts of moisture to accumulate there than on north slopes, but south slope trees could deplete (through transpiration) this reservoir at a faster rate since solar insolation is greater on this slope (see Figs. 7, 8 and 9). This could account for the greater stress measured on south slopes.

## SOIL TEMPERATURE

### Introduction

The pumice region in Oregon has a large range of diurnal and yearly temperatures. Summer days are warm to hot with rapid cooling to possible freezing temperatures occurring at night. Winter temperatures are for the most part without wide diurnal fluctuations characteristic of summer temperatures. The ambient air, as well as surface soil temperatures, may remain below 32<sup>o</sup>F for a large portion of the winter (Appendix 2).

TABLE 4. Plant moisture stress measurements for juniper trees, upper north and upper south slopes of ridge B. Measurements taken August 8 and 9, 1974, 11:00 p.m. to 3:00 a.m.

NORTH SLOPE		SOUTH SLOPE	
North Side of Tree	South Side of Tree	North Side of Tree	South Side of Tree
255	245	340	325
300	310	240	230
295	305	300	285
305	315	305	305
230	230	310	315
220	210	270	265
185	195	270	260
195	200	305	300
<hr/> 1985	<hr/> 2010	<hr/> 2340	<hr/> 2285
$\bar{X} = 249.68$		$\bar{X} = 289.06$	
237.341 $\bar{X}$ 262.02 at .95 confidence level		281.45 $\bar{X}$ 296.67 at .95 confidence level	

In general, the pumice region of Oregon expresses very cold summer and winter soil temperatures. Some explanations have been advanced: 1) high altitude, 2) predominance of clear nights, 3) relatively dry airmass, and 4) unique properties of pumice soils (Cochran 1969, p. 2). The low density of vegetation cover should be considered as an additional factor.

#### Aspect and Slope

Soil freezes frequently during winter months on northerly slopes in the study area (Fig. 10). Frozen soil was observed January 26, March 16 and April 15, 1974.<sup>4</sup> During the March and April observations, the thickness of the frozen strata was found to be directly proportional to an increase in slope angle and also depended on slope aspect (Fig. 11). The depth of unfrozen soil to the frozen layer was found to be inversely proportional to an increase in slope angle.

As shown in Figure 11, an increase in steepness of 25 percent on the northeast facing slope of ridge B correlates with an increase in thickness of the frozen layer from 0.5 inch to over 6 inches. At the same time, the depth of the frozen layer decreased from approximately 4 inches to a little over 1 inch. These relationships could only be demonstrated for north slopes during the specific dates mentioned for March and April. With the exception of the January 26 measurement, frozen soil was not encountered on south facing slopes. This fact is not surprising considering the amount of solar radiation received on the southwest as opposed to northeast facing slopes (Figs. 7, 8 and 9). It is not known if frozen ground conditions existed before January, as observations were not initiated until mid-January.

---

<sup>4</sup>The frozen soil layer was frozen solid throughout but did not freeze in visible ice lenses.



Fig. 10. Upper north slope photo showing depth to and thickness of frozen layer. Knife indicates lower extent of frozen soil. Photo taken in March.

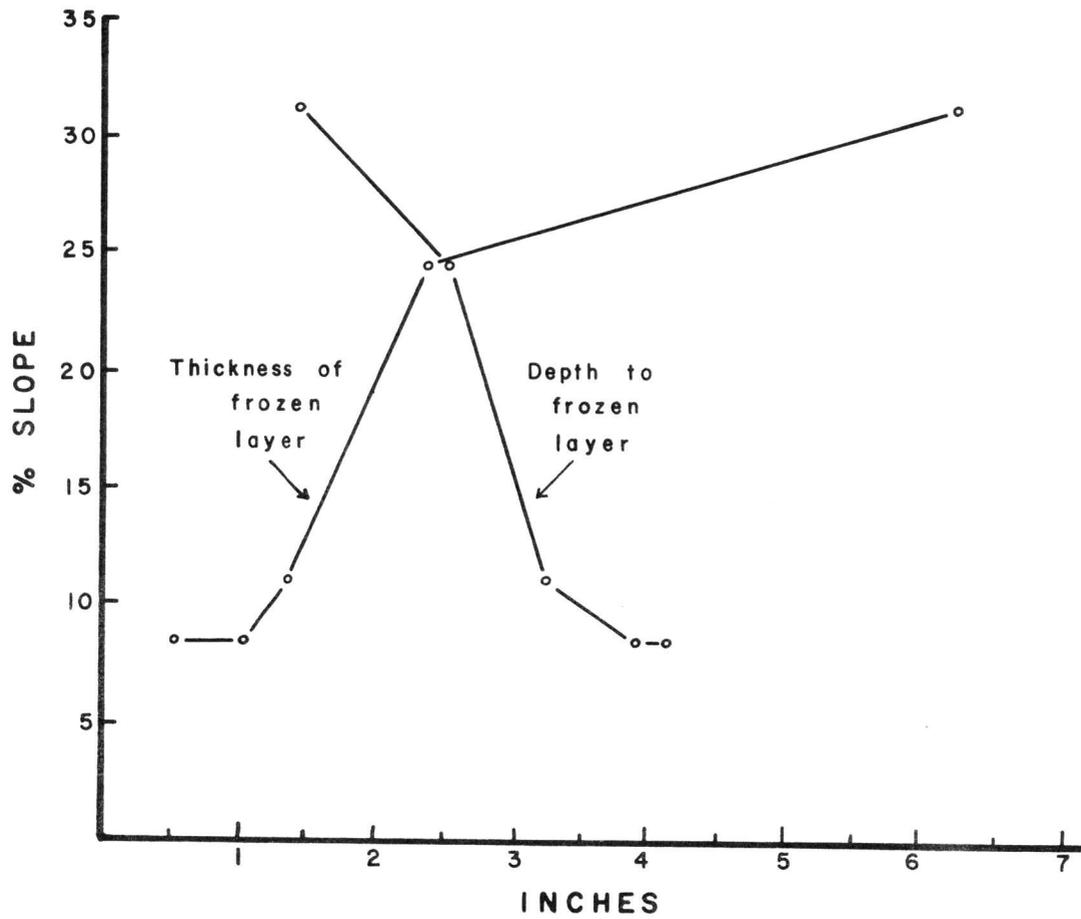


Fig. 11. Ridge B northeast facing slope frozen soil and slope relationships for March 16, 1974.

April 15 observations revealed a rapid decrease in thickness, and an increase in depth of the frozen layer. Soils were frozen only on the very steepest portions of north slopes. Several random measurements showed that the thickness of the frozen ground never exceeded 3.5 inches, and that on the average 9 inches of unfrozen, loose and saturated soil blanketed the frozen strata.<sup>5</sup>

Goodell (1939), in a study of slope aspect and soil temperatures in southern Illinois, reports that soil freezing occurred to a greater depth on northerly exposures as compared to south facing slopes in the northern hemisphere. He attributes this difference to the factor of aspect alone. It is not suggested here that aspect alone is the primary factor in causing soil to freeze in the study area. As will be pointed out later, other factors may be strongly influencing soil temperature. Nevertheless, slope aspect is undoubtedly one of the key elements in explaining the frozen soil phenomenon.

An intriguing micro-climate was created within the soil on upper north slopes and was evident during all measurements taken. Without exception, the thickness and depth of the frozen layer varied widely depending upon the proximity to shrubs, rock outcrops and trees. For example, scattered examination of soil underneath the southwest portion of approximately 20 north slope shrubs always revealed the thickest layer of frozen ground. On April 15 when the frozen layer was receding and could only be found intermittently, these southwest shrub portions often harbored the only frozen layer within a radius of five feet. Frozen soil

---

<sup>5</sup> Presumably, the loose, saturated overburden indicates the recentness of thaw.

likelihood of freezing during winter months. Summer conditions may differ greatly. For example, limited observations on the evening and morning of August 8 and 9 showed that coolest temperatures occurred in valley bottoms with ridge positions being 10 to 15<sup>o</sup> warmer. Cochran et al. stress that even during summer months when the Lapine pumice soils were completely thawed, the rapid loss of heat from these soils could induce nighttime freezing just at the soil surface.

#### Other Cold Soil Phenomena

The extreme cold condition of north slope soils in winter (i.e., frozen condition) may accelerate other processes that produce dynamic changes in the soil profile. For example, several observations were made which suggest some form of mass wasting is occurring on the north slopes of the study area:

- 1). Many shrubs on steep slopes lie prostrate to the slope or at least slope downhill, suggesting a downslope soil movement (Fig. 12).
- 2). The hummocky, step-like micro-topography that exists on both shrub and grass covered slopes suggests that vegetation has acted as a barrier to downslope soil movement. Examination of the base of the vegetation shows more soil accumulation on uphill than downhill sides (Fig. 13).
- 3). Cracked ground observed on both north and south slopes indicates a freeze-thaw cycle, and this may cause displacement of at least surface layers (Fig. 14). A wet-dry cycle is probably not important in displacement of soil since cracked ground could not be found during the summer when this process would be expected to occur.
- 4). During spring thaw, north slope soils, while thawed at the surface, remain frozen a few inches below the ground (Fig. 10). This condi-



Fig. 12. Prostrate and swaying shrubs indicate downslope soil movement. Note upturned nature of shrubs suggesting they were not merely downed after dying.



Fig. 13. Hummocky, step-like micro-topography of north slopes, showing soil accumulation on uphill side of grass clumps and wasting on the downhill side.

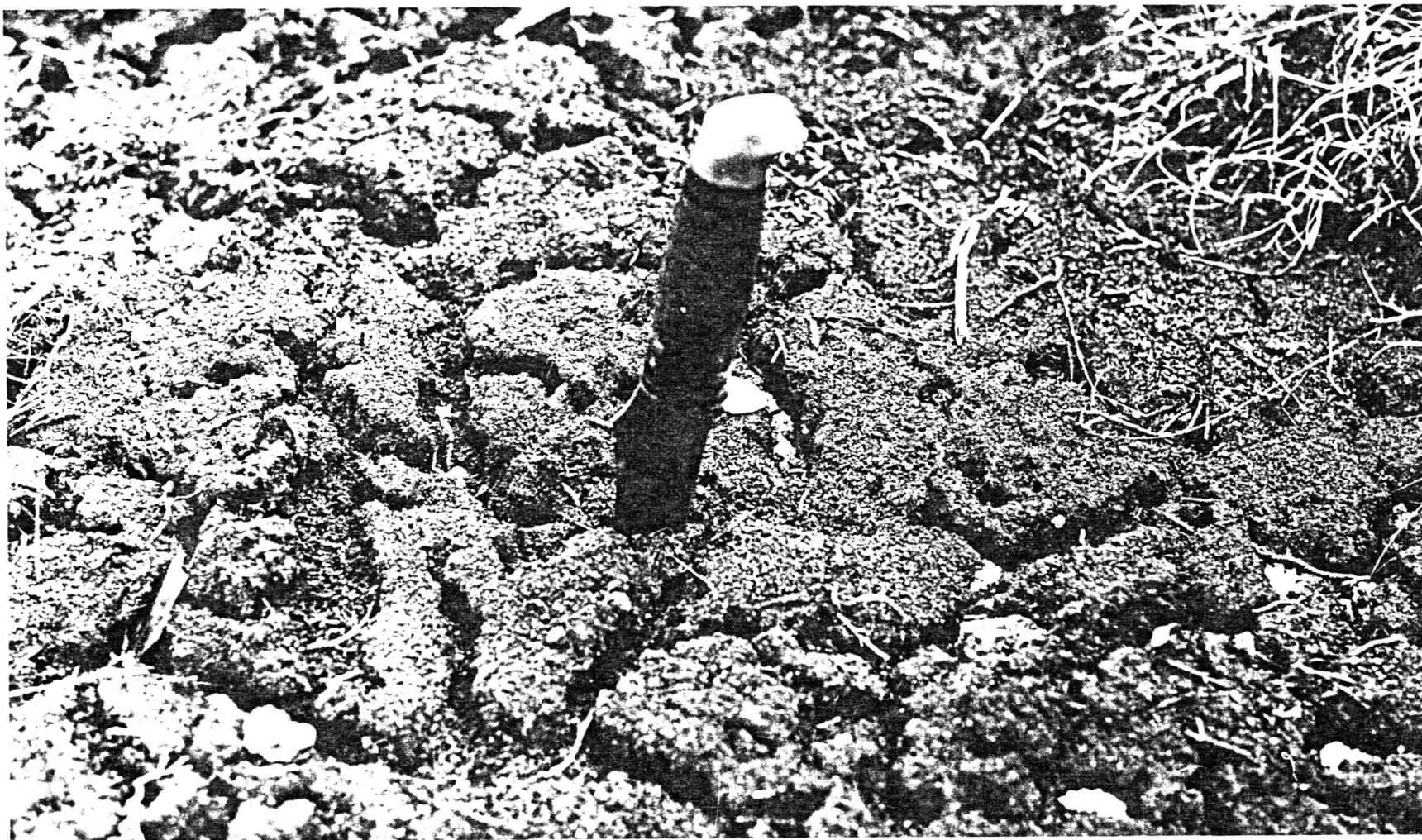


Fig. 14. Cracked ground phenomena as observed on north and south slopes during March 1974.

tion of an impenetrable frozen subsoil layer overlain by a saturated, mobile surface layer of soil causes a downslope surface soil movement.

Since the first and fourth conditions mentioned above are more prevalent on north slopes, it is believed that these soils undergo greater rates of mass movement in this respect. Furthermore, south slope surface soils are anchored by rock outcroppings which may restrain downslope movement. North slope soils, however, are only partially anchored by the dense shrub cover occurring there, but this entire vegetation cover may move downslope in a series of tongues while many of the rock buttresses of south slopes remain stationary and inhibit such a movement.

Because upper north slope soils are among the coldest in the study area, they remain frozen for a longer portion of the winter than those on any other topographic position in the study area. Freeze-thaw fluctuations which are essential to the incidence of mass wasting would appear to be minimal on north slopes during winter when soils are completely frozen. On the other hand, south slope soils during winter months receive greater heat inputs and may fluctuate more around  $0^{\circ}\text{C}$ , thus leading to greater mass wasting on these slopes at this time. During summer months, this situation may be reversed. That is, since south slope soils receive larger quantities of solar radiation and also display a greater mass of heat-retaining rock outcroppings, these soils may only infrequently freeze. Conversely, north slope soils, because of their northerly topographic position, low surface rock content, and high pumice content, may experience occasional to frequent summer nighttime frosts and thus experience greater rates of mass wasting.

## VEGETATION RELATION TO HABITAT CONDITIONS

## INTRODUCTION

Billings (1952) in a classic publication points out that vegetation is an indicator of the whole environmental complex and is not the outcome of any one single element. Factors influencing vegetation distribution should be studied in total, for in viewing single variables, interrelationships between variables may be overlooked. One may attempt to characterize vegetation distribution on the basis of a few single, although complex, agents such as fire, climate, or parent material, but an explanation based on these agents acting independently suggests an entirely new set of explanations when the agents are perceived as depending upon one another.

It is hardly feasible to consider every variable affecting the distribution of western juniper. Soil moisture and temperature, among the physical possibilities, have been considered thus far. The interrelationships between these two elements in relation to soils and topography probably contain the key to understanding western juniper distribution in the study area.

In order to best comprehend what abiotic conditions favor juniper growth, an understanding of the factors governing the distribution of the accompanying shrub and grass cover must be gained. This is requisite because findings in the study area (Table 1) and for other locations in the western juniper zone (Fig. 15, Driscoll) indicate that communities with high percentage shrub cover display low juniper cover; and, on the other hand, communities with low shrub cover exhibit a more

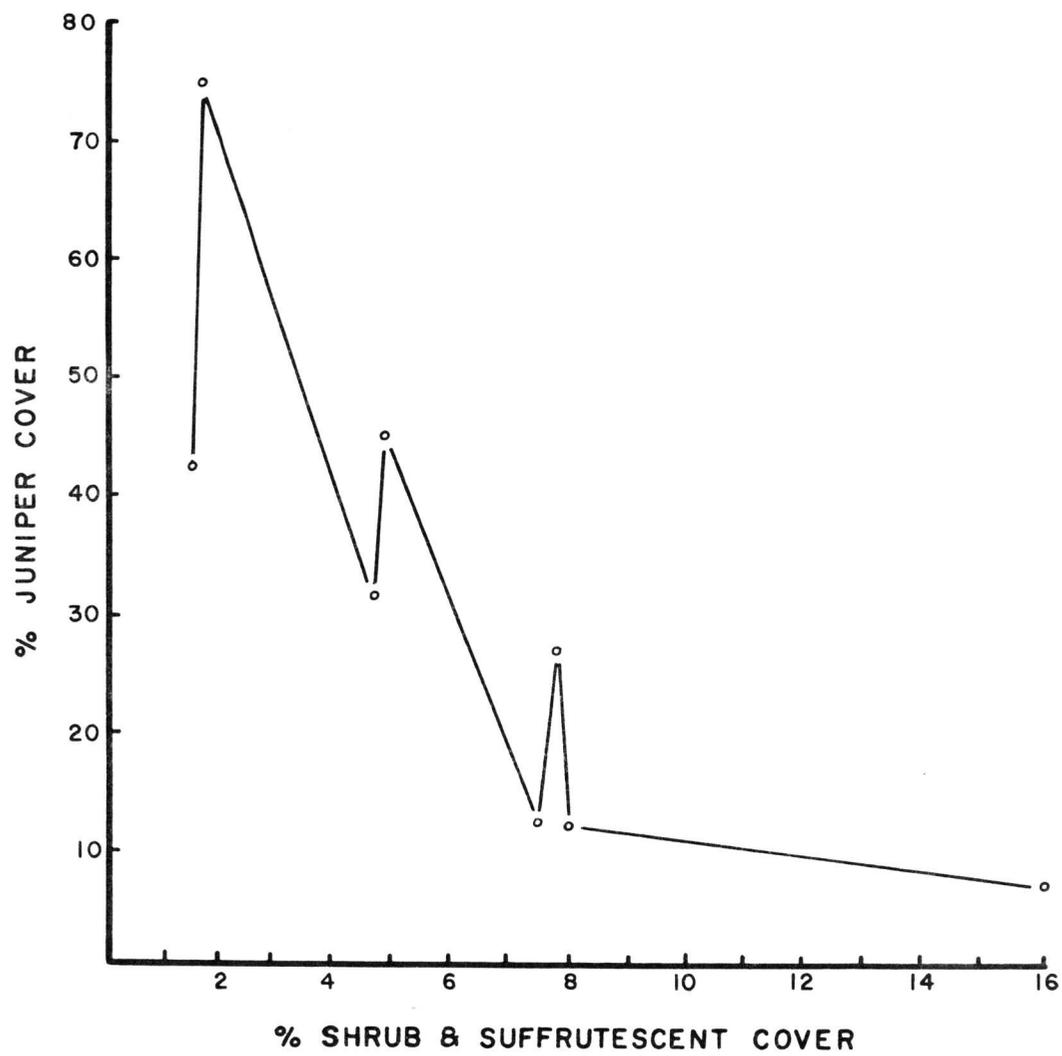


Fig. 15. Relation between % juniper cover and % shrub cover in the juniper zone, Oregon (Driscoll 1964).

dense stand of juniper. A strong competition may exist between Chrysothamnus, Artemisia, and juniper, or these species may have been selected out by more favorable habitats, or both. On the other hand, fire, grazing, or chance may be influencing factors. A preliminary comparison of grass cover with both shrub and juniper canopy reveals little positive or negative correlation. This is not to suggest that grasses grow independently of other vegetation, for some relationship probably exists between all plants in the study area.

#### ARTEMISIA COVER

The factors governing the distribution of Artemisia tridentata vary depending upon the area of investigation. However, there is some general agreement between researchers. Brooks (1969) in south central Washington found that A. tridentata dominated in deep, fine textured soils. Tabler (1964) in Wyoming and Shown et al. (1969) in Mexico, Colorado, Utah, Idaho, Oregon and Nevada have demonstrated that A. tridentata develops a deep tap root which allows utilization of subsurface moisture and nutrients. Goodwin (1956) in Washington has shown that on deep, well-aerated soils, A. tridentata develops a tap root with few lateral roots, but that on shallow soils containing a hardpan, a root system of many widely branching laterals without a tap root may be found. Johnson and Payne (1968) concluded that soil texture was not related to the reinvasion rate of A. tridentata in southwestern Montana. Both Brooks (1969) and Johnson and Payne (1968) indicate that north facing exposures favor the establishment and growth of A. tridentata. Griffiths (1902) in his reconnaissance survey of the Great Basin in 1901

noted that A. tridentata grows in the "best soil." He observed that the shrub dominates in soil that is excellent for crops such as hay and alfalfa.

Some of the above observations apparently hold for the study area; that is, A. tridentata clearly dominates the shrub cover on northerly exposures. A few random samples revealed a dominant, well-developed tap root does occur with shrubs on deep soils associated with north exposures, while an extensive taproot is lacking from shrubs occurring on shallow soils of south exposures. There is no apparent relationship between fine textured soils and an increase in A. tridentata cover. I could find no reference in the literature to temperature as related to Artemisia cover. That north slope habitats favor growth of A. tridentata is evidenced by the extremely large height attained by these shrubs and by their prolific distribution on these slopes.

There is no apparent negative relationship between cold soils and the growth of A. tridentata. In fact, these colder habitats seem to favor big sage. There may be some relationship between the heated soils of south slopes and the inability of Artemisia to withstand these temperatures. Measurements were not taken to determine maximum south exposure soil temperatures. It should be noted, however, that Goodwin (1956) in Washington found that soil temperatures exceeding 25°C inhibited germination of this shrub.

#### ALLELOPATHY IN ARTEMISIA

There is evidence that the dense stand of Artemisia tridentata that occurs on north slopes and the less dense stand on south slopes may create differential allelopathic conditions for other plants

occurring there (McCahon et al., 1973). McCahon demonstrated that A. tridentata produces physiologically active or phytotoxic chemicals that may cause conditions of allelopathy.

Schlatterer and Tisdale (1969) conducted green house studies on the effect of litter from A. tridentata on the germination and growth of Stipa thurberiana, Sitanion hystrix and Agropyron spicatum. They found that early growth of these grasses was retarded, but that four weeks after germination, growth was stimulated in response to the greater availability of nitrogen in the Artemisia litter.

This delay in growth suggests that grasses may be prevented from attaining a prolific development under A. tridentata. The question here, however, concerns the possible retarding effects on the germination or growth of Juniperus occidentalis by the Artemisia litter. In other words, is it possible that Artemisia litter is allelopathic for juniper? Can it be considered that big sage retards juniper germination and growth, thus allowing other vegetation (especially big sage) to "outcompete" it?

It should be remembered that both Driscoll's (1964) and this study demonstrate that sage and juniper stands are mutually exclusive of one another; that is, sage and juniper do not share cover dominance. An allelopathic environment created by the sage may be the causative factor, but this possibility must be demonstrated by laboratory studies and chemical analysis followed by field experiments.

#### JUNIPER-SAGE MOISTURE COMPETITION

Juniper establishment on upper north slopes may be related to moisture competition, especially during early growth. Juniper seedlings not only must compete with dense shrub cover that can develop extensive sub-

surface root systems, but must also compete with grass roots which may also occupy near surface soil layers.

It is very difficult to interpret March and June soil moisture determinations (Table 2). It was shown, for example, that the lower soil layers on upper north slopes remained below the wilting point for both March and June measurements, and that the entire soil profiles of the lower north slopes and south slopes generally contained greater moisture on a weight basis, and also were above the wilting point at times of moisture measurements. This may indicate that upper north slope trees and/or shrubs enter the growing season with less available moisture than similar vegetation on lower north and all south slopes. However, it was also suggested (p. 31) that upper south slope trees may deplete soil moisture at a faster rate and thus create higher stress conditions for these trees.

#### VEGETATION-SOIL TEMPERATURE RELATIONSHIPS

It has been suggested that upper north slope soils are the thickest frozen soils of the study area, and that precisely at these positions juniper ceases to be found or only infrequently occurs and shrub cover significantly increases. For example, measurements taken on the upper north slope of ridge B on January 26 show that at one location where a slope of 33 percent was recorded, only very small and infrequently-occurring juniper trees were encountered. Just 100 meters west of this position where slope angle was 25 percent, a denser medium-sized juniper stand occurred while Artemisia cover decreased slightly. A concurrent

lessening in the thickness of the frozen layer was also observed between these two areas. The steeper portion of the slope had a frozen layer 6-7 inches thick, while the gentle segment had a 1-1.75 inch thick frozen layer. Other preliminary observations showed that steep north slopes (33 percent or more) were only sparsely covered with juniper, while gentler north slopes (less than 33 percent) had a greater coverage of juniper. In other words, there seems to be a correlation between the steepness of north facing slopes, the thickness of the frozen layer, and consequently, the density of juniper cover.

Western juniper germinates in the spring (USDA 1965, p. 224). Germination is clearly not hampered by the frozen layer since thaw occurs well before spring germination begins. Frozen soil may, however, be injurious to the roots of juniper after seedling establishment. Frequent night frosts occur in the juniper zone during spring and fall months. For example, in Appendix 2 the weather station at Brothers shows that from middle to late May, temperature minima often dip below 20°F and that September temperature minima can dip to 16°F. Spring frost may be detrimental to juniper germination occurring during this time.

Further autecological research is needed to determine the length of time a particular low temperature is needed to reduce juniper growth or cause seedling mortality, and then to relate this to the actual duration and intensity of summer nighttime frosts.

The presence of rock outcroppings may beneficially affect the growth of juniper in terms of a more favorable temperature regime. Field observations showed that increases in juniper growth on north slopes coincided with greater surface expressions of rock. Areas with larger rock outcrops always supported numerous juniper trees, with approximately

80-90 percent of all lower north slope rock outcroppings supporting stands of juniper.

#### MASS WASTING-VEGETATION RELATIONSHIPS

The effects of freeze-thaw, wet-dry cycles and soil creep on the vegetation of the study area are, for the most part, unknown. Examination of north slopes showed that several shrubs were bent in a downhill direction, presumably in response to soil movement in that direction.

No downed juniper tree saplings were observed, nor did any of the few established north slope trees display a downhill curve of the stem. It can be assumed that downslope movement does not affect juniper morphology after its establishment, but downslope movement coupled with the freeze-thaw process of surface soils may be detrimental in very early stages of juniper growth.

## VEGETATION RESPONSE TO CULTURAL INFLUENCES

## JUNIPER INVASION

Edward Dealy reports that western juniper invasion northwest of Dayville, Oregon has resulted in massive increases of western juniper from hilltops to valley bottoms.<sup>6</sup> He does not suggest an explanation for this invasion but merely notes it has proceeded rapidly since 1920.

There has been an apparent increase in the spread of juniper in the study area in recent years. This invasion was probably initiated on ridge tops where the oldest trees are located today. Air photo reconnaissance, field checks, and a few age determinations by increment borings indicate that very young trees (5-40 years) exist at the base of both ridges, and that young trees occur only sparingly on upper slopes and ridge tops. The fact that juniper cover has increased but that juniper has generally not invaded north slopes suggests that either natural or cultural factors or both have been restrictive on these steep north slopes. Some possible natural limitations have already been considered. Next, juniper exclusions resulting from overgrazing, man-made disturbances, and fire will be discussed.

## DOMESTIC GRAZING

It has been generally accepted and adequately documented elsewhere by numerous researchers that overgrazing can induce rapid increases in

---

<sup>6</sup>Edward J. Dealy, Plant Ecologist, Range and Wildlife Habitat Laboratory, USDA Forest Service, La Grande, Oregon, personal communication, February 1974.

woody vegetation other than juniper (Allred 1950, Laycock 1967, Leopold 1924, Cottam and Steward 1940). The consensus of these workers is that overgrazing frees the land of grass competitors and invites invasion of woody species.

Equally well-documented are accounts dealing with the invasion of various species of juniper as a result of overgrazing. Johnsen (1962) points out that overgrazing in northern Arizona causes a reduction in competing grass, allowing Juniperus monosperma to invade grasslands. He also notes that grazing animals increase the spread of J. monosperma seeds by endozoogamic dispersal.

Lloyd Luelling, a leasee of the land in the study area since 1930, relates that the whole area had been overgrazed and abused for years.<sup>7</sup> He reports that in 1930, wild horses grazed on it the year round. In the winter and spring of that year, bands of sheep grazed there with a supplement of hay. When spring came, new, tender grass arose, and the sheep fed on it. Mr. Luelling notes that shrub and juniper cover began increasing during this time.

Laycock (1967) at the U.S. Sheep Experimental Station in Idaho reports rapid increases in sagebrush production after sheep had caused damage to a range that was previously in good condition.

Apparently, as Mr. Luelling suggests, one year of heavy grazing in the study area may have been enough to invite immediate invasions from juniper and especially shrubs.

---

<sup>7</sup>Lloyd Luelling, rancher, Bend, Oregon, personal communication, January 1974.

#### OTHER "GRAZERS"

Jay Gashwiler, a wildlife biologist conducting research on animals in the Horse Ridge Research Natural Area, located only a few miles from the study area, notes that other mammals are important in juniper dispersal.<sup>8</sup> He points out that coyotes may play an important role in this respect since 100 percent of their droppings may be composed of juniper berries.

Birds have also been known to disseminate juniper seeds. Phillips (1910) notes that in extreme cases birds were responsible for 90-95 percent of Juniperus monosperma and Juniperus pachyphloea reproduction in New Mexico. Neither of these factors was examined in reference to the study area, and therefore, juniper distribution related to these variables is unknown.

#### MAN-CAUSED DISTURBANCES

In addition to the heavy grazing pressures in 1930, Mr. Luelling points out that homesteaders, of which his parents were a part, often caused irreversible damage to the land in an attempt to improve it. Between 1910 and 1914 when the majority of the area was settled, homesteaders were required to accomplish a certain amount of improvement to the land in order to gain titles to their claims. With good intentions, they proceeded to plow the ground, which in turn destroyed the native grasses and effectively quelled reestablishment of the removed grasses. He also claims shrubs and juniper promptly invaded the newly plowed area.

---

<sup>8</sup>Jay Gashwiler, Wildlife Biologist, Fish and Wildlife Service, Bend, Oregon, personal communication, January 1974.

Other homesteading practices induced losses of grass and invasion of shrub and juniper in the study area. Mr. Luelling gives this account: "In 1930 I talked to a man that still lived here on his homestead. He told me that in 1910, when he first came, he took a mower and cut the native grasses for hay. In 1930 his land was covered with sage."<sup>9</sup> Presently, there are no places in the study area worthy of cutting for hay.

Thus, certain homesteading practices, along with possible abuses of natural forage by wild horses and sheep, caused juniper and sage to encroach upon land previously occupied by grasses. Even with this condition, juniper only sporadically populates upper north slopes.

#### FIRE

Juniper's thin bark renders it very susceptible to damage by fire. Although some researchers claim naturally occurring fires can be lethal to mature juniper (Arend 1950), most admit kills (resulting from grass fires) are confined to trees three feet high or less (Jameson 1959, Parker 1945). Evidently, grass fires are not hot enough nor do they last long enough to harm older, more resistant trees. Literature dealing with shrub fires and western juniper kills is lacking, while most reports discuss grass fires and suppression of other species of juniper. Nonetheless, shrub fire or shrub-grass fire, under proper meteorological conditions may kill older juniper.

It has been generally accepted that the absence of natural or man-made fire has resulted in massive increases in other species of juniper cover in various parts of the United States (Johnsen 1962, Arend 1950,

---

<sup>9</sup>Lloyd Luelling, personal communication, January 1974.

Ellis and Schuster 1968, Leopold 1924, and Parker 1945). While sporadic lightning-caused fires have killed individual juniper trees, wide-spread fires have not occurred in the study area since at least 1900.<sup>10</sup> Today fires that begin in the juniper zone are quickly quelled by the Bureau of Land Management and the U.S. Forest Service.

Fire preceding 1900 is unknown as to its extent and frequency, but one may assume that if ground fuel was sufficient, fires may have burned unchecked. Field notes of the township and range survey in 1879 indicate the study area at that date was populated with juniper and an understory of "greesewood"<sup>11</sup> and sage (U.S. Surveyor General 1879). No mention is made of grasses; however, these particular field notes are exceptionally scanty in their description of the vegetation and are probably of little value when one is looking for a detailed description.

Since little is known about fires preceding 1900, little can be said concerning their effect on the vegetation in the study area. If wide-spread fires decreased in occurrence since the turn of the century, then it would seem probable that juniper and possibly sage were permitted to grow in areas that previously lacked any juniper establishment. On the other hand, if fires were of little importance before 1900, then the increase in juniper could be attributed to factors other than the absence of killing fires.

---

<sup>10</sup>Lloyd Luelling, personal communication, January 1974.

<sup>11</sup>It is assumed the surveyor was referring to Chrysothamnus.

## SUMMARY AND CONCLUSIONS

Since year round monitoring of temperature and moisture related factors was not accomplished, little can be said in the way of definitive conclusions. This report was not intended to imply which factor or factors, cultural or natural, have had the greatest influence on present day juniper distribution in the study area. It is felt, however, that all of the factors discussed have been instrumental in modifying vegetation distribution in the study area. Furthermore, the effects of wind movements, relative humidity, soil nutrients, climatic changes with time, and varying light intensities, which were not discussed in this report, may also be influential.

In summary, the following points should be emphasized:

### Temperature

1. Slope aspect plays an important role in solar insolation received at the soil surface and thus may directly affect evapotranspiration and soil freezing.
2. The greater accumulation of pumice on upper northerly slopes together with slope aspect and degree slope partially accounts for the severe soil freezing at these locations during the winter. Juniper are sparse in locations that experience severe freezing.
3. Rock outcroppings apparently reduce soil freezing on both north and south slopes. There seems to be a positive correlation between rock outcroppings of north and south slopes and juniper growth.

4. Mass wasting is an important process on north slopes and apparently occurs to a lesser degree on south slopes. The effect of mass wasting on the existing vegetation is for the most part unknown.

#### Soil Moisture

1. Moisture availability tests showed upper north slopes, with their greater pumice content, to have slightly higher moisture holding capacities. This may cause moisture to be held nearer the surface and thus be subjected to greater evaporation. This, coupled with the frozen soil that occurs on upper north slopes, may account for the desiccation that occurs with soil depth.
2. Moisture stress measurements show that south slope trees are under more moisture stress than north slope trees. South slope trees may deplete soil moisture at a faster rate than north slope trees.

#### Cultural Factors

1. Grazing by domestic and wild animals may have been influential in the spread of shrubs and juniper in the study area.
2. Man-caused disturbances and the lack of fire may have enhanced shrub and juniper encroachment.

## LITERATURE CITED

- Allred, B.W. 1949. Distribution and control of several woody plants in Texas and Oklahoma. *Journal of Range Management*, 2:17-29.
- Arend, John L. 1950. Influence of fire and soil on distribution of eastern redcedar in the Ozarks. *Journal of Forestry*, 48:129-130.
- Billings, W.D. 1952. The environmental complex in relation to plant growth and distribution. *Quarterly Review of Biology*, 27:251-265.
- Brooks, William H. 1969. Some quantitative aspects of the present shrub community in Ginkgo State Park, Washington. *Northwest Science*, 43(4):185-190.
- Burkhardt, Wayne J. and E.W. Tisdale. 1968. Nature and successional status of western juniper vegetation in Idaho. *Journal of Range Management*, 22:264-270.
- Cochran, P.H. 1969. Lodgepole pine clearcut size affects minimum temperatures near the soil surface. U.S.D.A. Forest Service Research Paper, PNW-86, 4pp.
- Cochran, P.H., L. Boersma and C.T. Youngberg. 1967. Thermal properties of a pumice soil. *Soil Science Society of America Proceedings*, 31: 454-459.
- Cottam, W.P. and George Steward. 1940. Plant succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862. *Journal of Forestry*, 38:613-626.
- Cottle, H.J. 1931. Studies in the vegetation of southwest Texas. *Ecology*, 12:105-155.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Science*, 33:43-64.
- Dealy, Edward J. 1971. Habitat characteristics of the Silver Lake Mule Deer Range. U.S.D.A. Forest Service Research Paper, PNW-125, 99pp.
- Dicken, Samuel N. 1950. *Oregon Geography*. Edward Brothers, Inc., Ann Arbor, Michigan, 104pp.
- Driscoll, Richard S. 1964. Vegetation soil units in the central Oregon juniper zone. U.S.D.A. PNW Forest & Range Experiment Station Research Paper, PNW-19, 57pp.
- Driscoll, Richard S. 1964a. A relict area in the central Oregon juniper zone. *Journal of Ecology*, 45(2):345-353.

- Eckert, Richard E. 1957. Soil Vegetation Relationships in Some Artemisia Types in Northern Harney and Lake Counties, Oregon. Unpublished Ph.D. dissertation, Oregon State University, 208pp.
- Ellis, Dalton and Joseph L. Schuster. 1968. Juniper age and distribution on an isolated butte in Garz County, Texas. *The Southwestern Naturalist*, 13(3):343-348.
- Emerson, Fred W. 1932. The tension zone between the grama grass and pinyon juniper associations in northeastern New Mexico. *Ecology*, 13:347-358.
- Fons, W.L., H.D. Bruce, and Alan McMasters. 1960. Tables for estimating direct beam solar irradiation on slopes at 30° to 46° latitude. Pacific Southwest Forest and Range Experiment Station, Berkeley, California, 298pp.
- Geiger, Rudolf. 1965. *The Climate Near the Ground*. Harvard University Press, Cambridge, Mass., 611pp.
- Goodell, B.C. 1939. Soil freezing as affected by vegetation and slope aspect. *Journal of Forestry*, 37:626-629.
- Goodwin, DuWayne L. 1956. Autecological studies of Artemisia tridentata Nutt. *Dissertation Abstracts*, 17:487.
- Griffiths, David. 1902. Forage conditions of the northern border of the Great Basin. U.S. Bureau of Plant Industry Bulletin No. 15, 60pp.
- Jameson, D.A. 1959. Fire use in juniper control is considered in four categories--research progress report. Research Committee, Western Weed Control Conference, Salt Lake City, Utah, March, 1p.
- Jamison, Vernon C. 1956. Pertinent factors governing the availability of soil moisture to plants. *Soil Science*, 81:459-471.
- Johnsen, Thomas N., Jr. 1962. One-seed juniper invasion of northern Arizona grasslands. *Ecological Monographs*, 32:187-207.
- Johnson, James R. and Gene F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. *Journal of Range Management*, 21:209-213.
- Laycock, William A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. *Journal of Range Management*, 20:206-213.
- Leopold, Aldo. 1924. Grass, brush, timber, and fire in southern Arizona. *Journal of Forestry*, 22:1-6.
- Lutz, H.J. and R.F. Chandler. 1946. *Forest Soils*. Wiley & Sons, Inc., New York, 514pp.

- McCahon, Charlotte, et al. 1973. Physiological effects of compounds extracted from sagebrush. *Bulletin of the Torrey Botanical Club*, 100:23-28.
- Packard, R.Q. 1957. Some physical properties of Taupo pumice soils of New Zealand. *Soil Science*, 83:273-289.
- Parker, K.W. 1945. Juniper comes to the grassland. *American Cattle Producer*, 27:12-14.
- Phillips, F.J. 1910. The dissemination of junipers by birds. *Forestry Quarterly*, 8:60-73.
- Schlatterer, Edward F. and E.W. Tisdale. 1969. Effects of litter of Artemisia, Chrysothamnus, and Tortula on germination and growth of three perennial grasses. *Ecology*, 50:869-873.
- Schramm, J.R. 1958. The mechanisms of frost heaving of tree seedlings. *American Philosophical Society Proceedings*, 104:333-350.
- Shown, L.M., R.F. Miller and F.A. Branson. 1969. Sagebrush conversion to grassland as affected by precipitation, soil, and cultural practices. *Journal of Range Management*, 22:303-311.
- Soil Conservation Service, U.S.D.A. 1969. Deschutes Drainage Basin General Soil Map Report with Irrigable Areas. Oregon State University publication, 116pp.
- Tabler, Ronald D. 1964. The root system of Artemisia tridentata at 9,500 feet in Wyoming. *Ecology*, 45:633-636.
- U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering. 1951. *Soil Survey Manual*. U.S. Department of Agriculture Handbook 18, 503pp.
- U.S. Department of Agriculture. 1965. *Silvics of Forest Trees of the United States*. Agricultural Handbook 271, 762pp.
- U.S. Weather Bureau, Climatological Data, Summary. Oregon, 1962-1971.
- U.S. Surveyor General. 1879. Field notes for survey of Township 19 South, Range 15 East, Willamette Meridian, Oregon. (On file at state B.L.M. Office, Portland, Oregon.)
- Vasek, Frank C. 1966. The distribution and taxonomy of three western junipers. *Brittonia*, 18:350-372.
- Williams, Howel and Gordon Gales. 1968. Volume of the Mazama ash-fall and the origin of Crater Lake Caldera. *Andesite Conference Guide-book Bulletin*, Oregon State Division of Mines and Mineral Industries, 62:37-41.
- Youngberg, C.T. and C.T. Dyrness. 1964. Some physical and chemical properties of pumice soils in Oregon. *Soil Science*, 97:391-399.

APPENDIX 1  
SOIL DESCRIPTIONS

Pit 1: south slope, ridge A (under juniper, 15 percent slope).

- 0 - 13" -- brown (7.5y 5/2 dry), dark brown (10yr 3/3 moist) sand; weak granular structure, loose when dry, very friable when moist, non-sticky, nonplastic when wet; few large and small roots; pH 6.8.
- 13 - 28" -- light brownish gray (10yr 6/2 dry), dark brown (7.5y 3/2 moist) sand; weak granular structure, loose when dry, very friable when moist, nonsticky, nonplastic when wet; boundary gradual, wavy; few small roots; 25 percent+ gravelly, cobbly; pH 7.2.
- 28 - 42" -- light brownish gray (10yr 6/2 dry), very dark gray (10yr 3/1 moist) sand; structureless, loose when dry, very friable when moist, nonsticky, nonplastic when wet; boundary gradual, wavy; many small roots; 50 percent+ gravelly, cobbly; pH 7.2.

Pit 2: south slope, ridge A (open, 17 percent slope).

- 0 - 9" -- light brownish gray (10yr 6/2 dry), very dark grayish brown (10yr 3/2 moist) sand; moderately weak structure, loose when dry, very friable when moist, nonsticky, nonplastic when wet; many small and medium roots; pH 6.4.
- 9 - 23" -- pale brown (10yr 6/3 dry), dark brown (10yr 3/3 moist) sand; weak granular structure, loose when dry, very friable to loose when moist, nonsticky, nonplastic when wet; boundary diffuse; few small roots; pH 7.0.
- 23 - 42" -- pale yellow (5y 7/3 dry), yellowish brown (10yr 5/6 moist) coarse sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary diffuse; very few small roots; pH 7.4.
- 42 - 59" -- white (5y 8/1 dry), light gray (2.5y 7/2 moist) coarse sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary clear, wavy; very few, very small roots; pH 8.4.

Pit 3: south slope, ridge A (open, 45 percent slope).

- 0 - 10" -- grayish brown (10yr 5/2 dry), very dark grayish brown (10yr 3/2 moist) loamy sand; moderate granular structure soft when dry, friable when moist, slightly sticky and slightly plastic when wet; many small roots; 30 percent+ cobbly; pH 6.4.
- 10 - 18" -- grayish brown (10yr 5/2 dry), very dark grayish brown (10yr 3/2 moist) sand; weak granular structure, soft when dry, very friable when moist, non-sticky, nonplastic when wet; boundary diffuse, many small to large roots; pH 6.8.
- 18 - 28" -- light brownish gray (10yr 6/2 dry), very dark grayish brown (10yr 3/2 moist) sand; weak granular structure, loose when dry, very friable when moist, non-sticky, nonplastic when wet; boundary diffuse; few small roots; pH 6.8.

Pit 4: south slope, close to top of ridge A (under juniper, 26 percent slope).

- 0 - 3" -- dark grayish brown (10yr 4/2 dry), black (10yr 2.5/1 moist) loamy sand; medium granular structure, soft when dry, very friable when moist, slightly plastic and slightly sticky when wet; few small roots; large partially decomposed organic matter content; pH 7.0.
- 3 - 8" -- grayish brown (10yr 5/2 dry), very dark gray (10yr 3/1 moist) loamy sand; medium granular structure, soft when dry, friable when moist, slightly plastic and slightly sticky when wet; boundary clear, smooth; few small roots; pH 7.2.
- 8 - 11" -- brown (10yr 5/3 dry), very dark grayish brown (10yr 3/2 moist) gravelly loamy sand; medium granular structure, slightly hard when dry, firm when moist, slightly plastic, slightly sticky when wet; boundary clear, irregular; very few small to large roots; pH 7.0.

Pit 5: north slope, ridge A (open, 25 percent slope).

- 0 - 24" -- light brownish gray (10yr 6/2 dry), dark brown (10yr 3/3 moist) sand; structureless, loose dry, loose moist, nonsticky, nonplastic when wet; few small roots; pH 7.0.

- 24 - 42" -- white (10yr 8/2 dry), yellowish brown (10yr 5/4 moist) sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary clear, wavy; many small to medium roots (approximately 80 percent); pH 8.2.
- 42 - 45" -- white (10yr 8/1 dry), light brownish gray (10yr 6/2 moist) sand; structureless, loose when dry, loost when moist, nonsticky, nonplastic when wet; approximately 90 percent pumice content; boundary abrupt, wavy; very few small roots; pH 8.2.
- 45 - 60"+ -- light gray (10yr 7/1 dry), very dark grayish brown (10yr 3/2 moist) loamy sand; structureless, loose when dry, very friable when moist, nonsticky, nonplastic when wet; boundary abrupt, wavy; very few small roots; possible buried soil profile; pH 8.6.

Pit 6: north slope, ridge A (under juniper, 12 percent slope).

- 0 - 11" -- pale brown (10yr 6/3 dry), brown (10yr 5/3 moist) loamy sand; very weak granular structure, loose when dry, very friable when moist, nonsticky and nonplastic when wet; many small roots; pH 7.2.
- 11 - 21" -- pale brown (10yr 6/3 dry), dark brown (10yr 3/3 moist) sandy loam; structureless, loose when dry, very friable when moist, nonsticky, nonplastic when wet; boundary gradual, wavy; few medium to small roots; pH 7.4.
- 21 - 32" -- pale brown (10yr 6/3 dry), dark brown (10yr 3/3 moist) loamy sand; structureless, loose when dry, very friable when moist, nonsticky, nonplastic when wet; boundary diffuse; very few small roots; 50 percent+ gravelly, cobbly; pH 8.0.

Pit 7: north slope, ridge B (under juniper, 11 percent slope).

- 0 - 13" -- brown (10yr 5/3 dry), very dark grayish brown (10yr 3/2 moist) loamy sand; weak granular structure, soft when dry, very friable when moist, nonsticky, nonplastic when wet; few small to medium roots; Ph 6.4.
- 13 - 26" -- light gray (10yr 7/2 dry) brown to dark brown (10yr 4/3 moist) loamy sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary gradual, wavy; few small to medium roots; pH 6.6.

26 - 35" -- pale brown (10yr 6/3 dry), dark brown (10yr 3/3 moist) sandy loam; strong granular structure, hard when dry, friable when moist, sticky, plastic when wet; boundary abrupt, irregular; few small roots; 25 percent+ cobbly; possible buried soil; pH 7.4.

Pit 8: south slope, ridge B (under juniper, 25 percent slope).

0 - 24" -- grayish brown (10yr 5/2 dry), very dark grayish brown (10yr 3/2 moist) loamy sand; weak granular structure, loose when dry, very friable when moist, nonsticky, nonplastic when wet; few small to medium roots; pH 6.6.

24 - 39" -- pale brown (10yr 6/3 dry), dark brown (10yr 3/3 moist) loamy sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary clear, wavy; few small to medium roots; pH 7.0.

39 - 52"+ -- very pale brown (10yr 7/3 dry), dark grayish brown (2.5y 4/2 moist) loamy sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary diffuse; many small roots (approximately 80 percent); 25 percent+ gravelly, cobbly; pH 8.0.

Pit 9: south slope, ridge B (open, 33 percent slope).

0 - 29" -- brown (10yr 5/2 dry), dark brown (10yr 3/3 moist) sand; weak granular structure, loose when dry, loose when moist, nonsticky, nonplastic when wet; very few small to medium roots; pH 7.0.

29 - 61" -- light brownish gray (10yr 6/2 dry), dark brown (10yr 3/3 moist) sand; structureless, loose when dry, loose when moist, nonsticky, nonplastic when wet; boundary gradual, wavy; many small roots (approximately 70-80 percent); pH 8.4.

61 - 73"+ -- brown (10yr 5/3 dry), very dark grayish brown (10yr 3/2 moist) sandy loam; weakly cemented structure, friable when moist, slightly sticky, slightly plastic when wet; boundary clear, irregular; few small roots; 40 percent+ gravelly, cobbly; pH 8.6.

APPENDIX 2  
WEATHER DATA 1962-1971

---

BROTHERS, OREGON\*

Average Temperatures (mean monthly)

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971	29.9	31.0	30.5	38.5	47.9	51.8	63.8	65.7	49.1	41.1	34.6	24.0
1970	30.0	34.6	33.3	32.9	47.1	57.9	62.8	62.0	48.5	42.0	34.2	23.9
1969	24.7	26.0	34.1	40.2	51.1	56.3	60.7	59.8	54.5	40.0	36.5	31.5
1968	26.9	36.2	39.1	38.9	46.8	55.9	65.4	57.2	54.5	44.9	36.3	26.1
1967	30.4	34.9	33.2	33.2	47.8	55.6	64.2	66.0	58.1	45.2	37.1	25.4
1966	26.4	29.1	36.2	41.1	51.0	51.6	59.3	60.1	56.0	45.1	36.7	29.9
1965	28.6	34.9	33.9	41.7	45.2	54.2	61.5	59.3	48.2	49.4	36.0	26.6
1964	25.9	30.9	31.8	38.0	44.5	52.8	61.4	58.2	52.1	48.0	33.0	27.3
1963	24.0	38.3	32.6	35.5	49.5	52.3	56.3	60.7	59.3	46.5	36.6	29.8
1962	23.5	29.4	31.6	43.3	42.2	52.4	58.1	56.8	53.7	44.3	36.4	32.3

\*U.S. Weather Bureau, 1962-1971

---

BROTHERS, OREGON\*

Temperature Extremes and Freeze Data

	Date of Last Spring Minimum Temperature of:					Date of First Fall Minimum Temperature of:				
	16° or Below	20° or Below	24° or Below	28° or Below	32° or Below	32° or Below	28° or Below	24° or Below	20° or Below	16° or Below
1971	4-17	5-20	6-29	6-29	6-29	7- 3	7- 3	7- 3	9- 7	9-18
1970	5-11	5-28	6-30	6-30	6-30	7-22	7-29	9- 9	9- 9	9-13
1969	5- 2	5- 3	5- 4	6-26	6-30	7- 3	8- 5	8- 5	9- 5	10- 5
1968	5- 6	5-14	6-12	6-29	6-30	7-20	7-20	9-22	9-22	10- 7
1967	4-29	5-26	6- 2	6-10	6-14	7-19	8- 7	9-12	10-14	10-22
1966	4-27	5-22	6-24	6-25	6-30	7- 3	7-25	7-25	10- 9	10- 9
1965	5-17	6-27	6-27	6-27	6-27	7- 9	7- 9	8-30	9-17	9-18
1964	5-23	5-26	5-26	6-27	6-28	7- 5	7- 9	7- 9	9- 3	9-18
1963	4-22	4-28	5-25	6-29	6-29	7- 8	8- 1	10- 7	10-19	10-19
1962	6- 5	6- 5	6- 7	6- 7	6-27	7- 2	7- 2	7- 2	7- 2	10- 5

\*U.S. Weather Bureau, 1962-1971

---

BROTHERS, OREGON\*

Total Precipitation (mean monthly)

	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1971	1.70	.43	1.08	.58	.67	.88	.69	.09	.49	1.00	2.28	1.05	10.94
1970	2.78	.91	.85	.33	.99	1.36	T	.16	.17	.73	3.09	.92	12.29
1969	2.58	.59	.15	.66	.67	3.68	.20	.00	T	.77	.70	1.28	11.28
1968	1.41	1.40	.09	.35	1.73	.54	.00	2.09	.07	.64	4.00	2.67	14.99
1967	2.64	T	.93	1.34	.51	.91	.00	.00	.35	1.20	.32	.37	8.57
1966	.82	.23	.46	.15	.66	1.44	.80	.01	.87	.59	2.56	2.36	10.95
1965	2.64	.07	T	.95	.47	1.70	1.12	3.13	.10	.11	1.65	.64	12.58
1964	1.42	T	.27	.33	.30	1.56	1.31	.00	.00	.46	1.03	4.51	11.19
1963	.84	1.09	.40	1.61	.93	1.07	.37	.36	.88	.56	1.13	.36	9.60
1962	1.05	.75	.51	.11	1.80	.07	.18	.06	.36	1.87	.96	.88	8.60

\*U.S. Weather Bureau, 1962-1971

---