FOREST TYPES OF THE NORTHERN ROCKY MOUNTAINS AND THEIR CLIMATIC CONTROLS [1]

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Introduction

The purpose in this report is to describe the natural forest types of the northern Rocky Mountains in Montana and northern Idaho, to point out their natural distribution and chief silvical characteristics, and to show in what degree they are controlled by differences in topography and climate. Such information may be useful in laying the foundation for later, more intensive silvical investigations and practices in a region rich in forest resources.

Information on the character and distribution of the forests has been obtained from the silvical maps and reports prepared in the various forest supervisors' offices; by conversation and correspondence with the forest supervisors and members of the District I Office (Missoula, Mont.) of the Forest Service, and by the writer's own work in this region covering a period of 14 years.

Some difficulty was experienced in assembling the forest type map (Fig. 1), because most of the existing maps for the individual forests show the present "cover" types [2] rather than the climatic or climax types (associations). Also, two or more persons may differ in type designations and interpretations. The author has, therefore, been forced to use a certain freedom in correlating and adjusting his material. In some instances where the subalpine forests were not clearly shown, the boundaries have been drawn according to topography and knowledge of the forest conditions in the region. In all cases the lines drawn around the types have followed natural divisions of permanent tree associations.

Lists of the most common species of grasses, herbs and shrubs found in each forest type, obtained from various published and unpublished sources, are presented because this information is of value in silviculture, grazing, and ecological studies.

The climatic controls of the forest types are based entirely upon air temperature and precipitation records. Such indices of forest type requirements as the relation of air temperature to precipitation, or of the latter to evapora-

[1] This paper includes the results of work done for the Northern Rocky Mountain Forest Experiment Station of the U. S. Forest Service.

The word "type" is virtually the equivalent of "association." Thus the western yellow pine type is the same as the *Pinus ponderosa* association.

[2] The "cover" type is the growth at present on the ground, and may be a stage in the successional series or may be the climax association.

tion, have been purposely avoided for two reasons. In the first place, evaporation records are as yet very limited; and secondly, few botanists agree on the true significance of these relationships.

The data on climate have been obtained from the printed reports of the United States Weather Bureau, and from some records gathered by the Forest Service of summer meteorological conditions on mountains. Whenever possible at least 5 weather stations have been chosen for each forest type and an effort has been made to have one at either altitudinal extreme. Records from the higher elevations have been very insufficient.

In the summations of temperature and precipitation which are given, the monthly data are stressed. These no doubt reflect a stronger limiting influence in many cases than do annual tabulations. Deficits in the spring rainfall restrict growth of conifers in the west. This is amply shown by records of climate and height growth of trees at the Priest River Experiment Station (Brewster, '28) and other places (Pearson, '28). The amount of summer rainfall, on the other hand, particularly that which falls during July and August, will indicate the relative drought resistance of the species.

Dates of the last killing frost in the spring and the first in the fall are taken from the averages for the stations within each type. It is well to bear in mind that none of the coniferous forest types in Montana or Idaho are free from killing frost at any time during the growing season. For this reason frost data are of little significance as limiting factors or as indicators of the length of the active growing season. They reflect, nevertheless, important climatic differences. The data on snowfall represent the averages for the type stations. These figures also, at best, reflect only the amount of winter precipitation and air temperature; unfortunately, the much more valuable figures on duration of snow cover and dates of disappearance of snow are yet largely lacking.

Broad Topographic and Climatic Controls of Forest Types

Montana and northern Idaho center around two great mountain systems, the Continental Divide and the Bitterroot Range. Between these two lie the Bitterroot and Flathead valleys, which drain northwest into Lake Pend Oreille. From the crest of the Bitterroot Range the forested spurs and sharp canyons descend westward and southwestward to the border of the treeless Columbia River Basalt Plateau. Central and eastern Montana slope gradually from the elevated region along the Continental Divide to the Great Plains.

The area under discussion therefore is divided into three distinct topographic divisions: (*a*) Washington and Idaho to the west of the Bitterroot Mountains; (*b*) Flathead and Bitterroot valleys between the Bitterroot Mountains and the main Continental Divide; and (*c*) Central Montana lying to the east of the Continental Divide. These major divisions are the foundations upon which the data and descriptions rest, and they will be adhered to throughout this report.

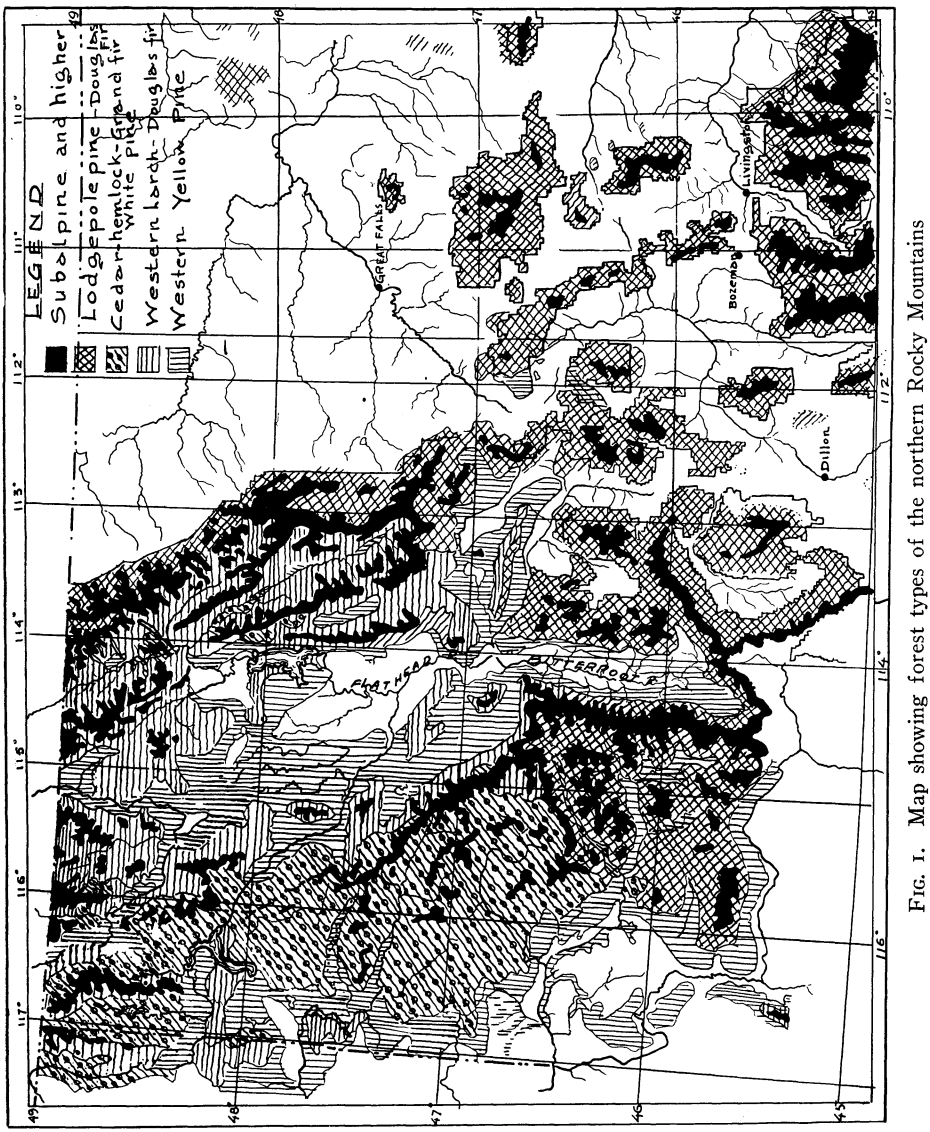

FIG. 1. Map showing forest types of the northern Rocky Mountains

In each of these three topographic units the forests range from prairie at the lower points to subalpine or alpine conditions near the mountain summits, through a series of altitudinal zones characterized by definite associations of trees, which are called forest types. These forest types are outlined in Table I, and are mapped in Fig. 1. Table II presents the area and volume contained in each type.

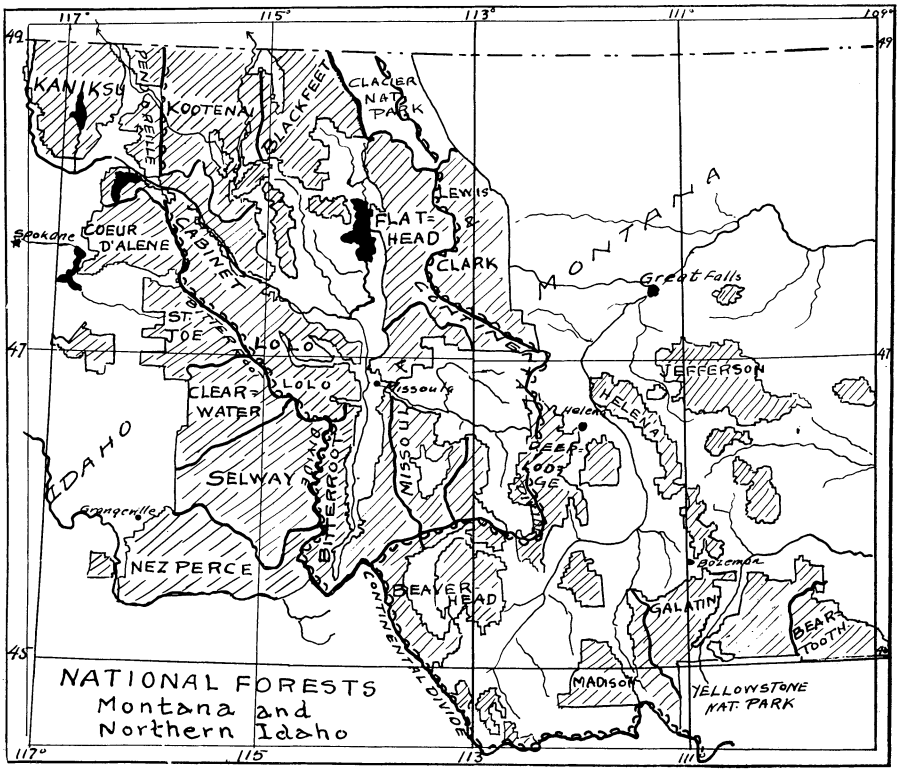

FIG. 2. Map showing National Forests in the northern Rocky Mountains

Table III shows that the western sections contain a much greater variety of trees than central and eastern Montana. In Idaho, in particular, there is a wealth of species. Conspicuous among these are mesophytic trees such as western red cedar, western hemlock, western white pine, and lowland white fir, which are not found east of the Continental Divide. Even the western larch, much less exacting in water requirements, does not appear in central or eastern Montana.

Climate, as affected by topography and geographical position, plays a leading part in affecting the variations in the forest cover. The essential elements of climate for the three major sections are set forth in Tables IV to X. The

TABLE I. *Altitudinal ranges of forest types in the Northern Rocky Mountains*

	Washington–Idaho		Flathead and Bitterroot Valleys		Central Montana	
	Forest types, climax or key species	Elevation, in feet, and associated species	Forest types, climax or key species	Elevation, in feet, and associated species	Forest types, climax or key species	Elevation, in feet, and associated species
Treeless prairies	*Prairies* of eastern Wash. *Prairies* of Palouse Plain	1,000–2,000 2,000–3,000	*Prairies*	2,500–3,500	*Prairies of* north central Mont.	2,500–4,000
Xerophytic forest	*Western yellow pine type* W. yellow pine	1,000–4,000 Lodgepole pine Western larch Douglas fir	*Western yellow pine* Western yellow pine Douglas fir	2,500–4,000 Lodgepole pine Western larch	*Western yellow pine*	*Juniperus scopulorum*
Mesophytic transition forest	*Cedar-hemlock-white fir* Western red cedar Western hemlock Lowland white fir Western white pine	2,000–5,500 Douglas fir Western larch Lodgepole pine W. yellow pine Engelmann spruce Alpine fir	*Douglas fir—western larch* Douglas fir Western larch	3,000–5,500 Lodgepole pine Engelmann spruce Some w. hemlock w. red cedar Lowland white fir W. white pine	*Douglas fir—lodgepole pine* Douglas fir Lodgepole pine, on drier sites	5,500–9.500 Engelmann spruce and alpine fir on more moist sites, scattered timber pine near tree-line
Mesophytic subalpine forest	*Spruce—fir—hemlock* Engelmann spruce Alpine fir Mountain hemlock, mainly on moist sites	5,500–7,500 Lodgepole pine Douglas fir White bark pine, mainly on dry sites	*Spruce—fir* Engelmann spruce Alpine fir, on moist sites	5,500–7,500 Lodgepole pine White bark pine Douglas fir, on drier sites	*Engelmann spruce* Alpine fir Lodgepole pine	Limber pine
Alpine forest			*Lyall larch* *Engelmann spruce* *Alpine fir*	7,500–11,000	*Engelmann spruce* *Alpine fir*	9,500–11,000

TABLE II. *Areas occupied by forest types, Montana and north Idaho* *

(Areas in thousand acres; stand in million board feet)

Section	Areas and estimated stand		Per cent by species								
			Open grass-land † (b)	W. y. pine	D. fir, lodge-pole pine	D. fir, w. larch	Cedar; hem-lock, w. w. p.	Eng. spruce	Sub-alpine	Bar-rens and alpine	Un-class-ified
Wash.-Idaho	Area	5,247.3	10.0	15.00	17.5	14.70	19.2	4.5	17.4	1.7	
	Stand	26,594		7.10	28.1	8.50	41.2	9.0			5.6
Western Montana	Area	8,540.3	3.4	11.70	33.2	23.90	4.1	4.4	15.9	3.2	
	Stand	19,724		14.20	40.0	23.10	4.1	13.3			5.6
Central Montana	Area	8,592.9	15.7	3.10	54.8	0.50		3.1	12.8	10.0	
	Stand	16,826		0.04	83.5	0.02		5.1			11.3
Total	Area	22,380.5									
	Stand	63,144.0									

* Data from figures compiled by the U. S. Forest Service, Missoula, Montana.
† Including non-reproducing burns.

TABLE III. *Evergreen trees of Montana and northern Idaho*

Arranged according to light requirement, the most tolerant of shade being placed last.

West of Continental Divide	*East of Continental Divide*
Juniperus occidentalis Sarg. Western juniper	*Juniperus scopulorum* Sarg. Rocky Mountain Juniper
Pinus albicaulis Engelm. Whitebark pine	*Pinus albicaulis*
Pinus flexilis James Limber pine	*Pinus flexilis*
Pinus ponderosa Laws. Western yellow pine	*Pinus ponderosa*
Larix lyalli Parl. Mountain larch	
Larix occidentalis Nutt. Western larch	
Pinus contorta var. *murrayana* Engelm. Lodgepole pine	*Pinus contorta*
Pseudotsuga taxifolia (Poir) Britt.-Douglas fir	*Pseudotsuga taxifolia*
Pinus monticola D. Don Western white pine	

TABLE III—(*Continued*)

West of Continental Divide	*East of Continental Divide*
Picea engelmannii Engelm. Engelmann spruce	*Picea engelmannii*
Abies grandis Lindl. Lowland white fir	
Abies lasiocarpa Nutt. Alpine fir	*Abies lasiocarpa*
Tsuga heterophylla Sarg. Western hemlock	
Tsuga mertensiana Sarg. Mountain hemlock	
Thuja plicata D. Don. Western red cedar	
Taxus brevifolia Nutt. Yew	

TABLE IV. *Sunshine, wind and relative humidity*

Averages of all records up to the time of latest periodic summary, from U. S. Weather Bureau Bulletin and later reports

Station, region and type of vegetation	Sunshine, per cent of possible			Wind, miles per hour			Relative humidity per cent 6:00 P.M.		
	Annual	May–Sept.[b]	Aug.	Annual	May–Sept.[b]	Aug.	Annual	May–Sept.[b]	Aug.
Spokane E. Washington W. yellow pine	52	70	76	5.7	5.8	5.0	50	31.2[a]	25
Lewiston N. Idaho Prairie	(No record)			4.3	4.4	4.3	48[c]	33.6[c]	31[c]
Kalispell N. w. Montana Prairie	48	62	68	4.8	5.3	5.1	57	42.0	37
Helena N. central Montana Prairie	58	65	73	7.5	7.7	7.3	50	38.4	32
Miles City S. e Montana Prairie	(No record)			6.1	6.2	5.3	61	48.2	43
Yellowstone Nat. Park, Wyo. S. central Montana	56	64	71	7.8	7.3	6.7	55	43.0	37

[a] Values for Spokane, 5 P.M., local time.

[b] Mean for the five month period, May to Sept., incl.

[c] Noon values, no available values for 6 P.M.

TABLE V. *Air temperature, in degrees F., for eastern Washington and Idaho*
From U. S. Weather Climatological Summaries for 1921–22

Type of vegetation	Stations	Elev. ft.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
			years													
East Washington Prairies	Hatton	1,100	17	27.4	34.1	43.5	50.8	57.3	64.4	72.2	70.0	61.2	50.6	39.2	30.2	50.0
Idaho-Palouse Plains....	Moscow, Rosalia Pullman	2,425–2,748	27–29	28.5	31.4	38.2	46.2	52.4	58.9	66.7	66.2	58.4	48.1	37.7	30.9	46.9
Wash.-Idaho w. yellow pine.....	6 stations	1,665–2,550	10–41	25.3	28.9	37.0	45.8	54.6	58.9	65.2	63.2	56.0	46.1	35.6	28.3	45.5
Clearwater River— w. yellow pine.....	Orofino	1,027	16	28.0	34.4	42.6	52.6	56.4	63.6	71.1	69.2	61.4	49.8	38.8	31.3	49.8
Cedar-hemlock-white fir.	6 stations	2,100–4,082	9–20	24.1	28.4	34.9	43.3	49.9	55.6	63.5	61.9	53.9	44.2	34.4	27.0	43.4
Cedar-hemlock-white fir (Lowest station).....	Sandpoint	2,100	10	25.6	29.0	36.6	45.6	51.6	58.4	64.6	63.0	54.6	45.0	35.4	28.6	44.9
Cedar-hemlock-white fir (Highest station).....	Burke	4,082	9	22.0	26.4	32.6	38.6	44.8	51.4	59.9	58.2	53.2	43.2	33.0	22.4	40.4
Subalpine type.....	Roosevelt	7,500	5	19.2	21.4	25.0	32.7	38.3	47.6	56.6	56.6	48.9	41.0	27.8	22.0	36.4

Temperature summations, in degrees F.

Type of vegetation	Mean ann.	Mean May-Sept.	Average max.— July	Average min.— Jan.	Abs. max.	Abs. min.	Days with mean			Frostless season		
							−32°	+43°	+70°	Last— spring	First— fall	Days
East Washington Prairies	50.0	65.0	92.0	19.7	112	−29	25	235	39	5/15	9/21	129
Idaho-Palouse Plains....	46.9	60.5	81.9	22.3	105	−26	60	205	0	5/13	10/4	144
Wash.-Idaho w. yellow pine.....	45.5	59.6	82.2	17.8	104	−30	58	201	0	5/16	9/24	131
Clearwater River— w. yellow pine.....	49.8	64.3	90.5	21.8	111	−30	25	241	24	4/20	10/17	173
Clearwater River— Grassland.....	63.9	79.4	89.9	26.8	110	−23	0	254	62	4/5	10/25	203
Cedar-hemlock-white fir.	43.4	56.9	80.4	17.2	106	−30	77	199	0	5/26	9/26	123
Cedar-hemlock-white fir (Lowest station).....	44.9	58.4	81.8	18.8	99	−21	71	201	0	5/22	9/19	120
Cedar-hemlock-white fir (Highest station).....	40.4	53.5	75.9	14.4	95	−21	90	165	0	—	—	—
Subalpine forest.....	36.4	49.6	—	—	100	−33	140	142	0	7/7	8/31	55

TABLE VI. *Precipitation in inches, for eastern Washington and Idaho*
From U. S. Weather Bureau Climatological Summaries for 1921–22

Type of vegetation	Stations	Elev. ft.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
			years													
East Washington prairies	Hatton	1,100	17	1.15	1.00	0.78	0.70	0.88	0.60	0.27	0.45	0.44	0.65	1.32	1.19	9.43
Idaho-Palouse plains	3 stations	2,425–2,748	27–29	2.48	1.96	1.93	1.53	2.00	1.18	0.65	0.66	1.18	1.54	3.04	2.44	20.54
Wash.-Idaho western yellow pine	6 stations	1,665–2,550	10–41	2.84	1.97	1.86	1.53	1.97	1.52	0.94	0.79	1.38	1.56	3.11	2.63	22.11
Clearwater River—western yellow pine	Orofino	1,027	16	3.21	3.05	2.99	2.03	2.65	1.99	0.82	0.66	1.66	2.05	3.75	3.17	28.03
Clearwater River	Culdesac	1,520		2.3	1.7	1.7	1.8	3.7	1.3	0.9	0.5	1.0	1.6	2.8	0.55	19.85
Clearwater River—Grassland	Lewiston	757	20	1.39	1.20	1.10	0.98	1.52	1.36	0.51	0.62	0.81	1.13	1.44	1.41	13.37
Cedar-hemlock-white fir	9 stations	2,100–4,082	9–20	4.25	3.28	3.68	2.50	3.06	2.14	1.38	1.09	2.19	2.75	4.45	4.26	35.07
Cedar-hemlock-white fir (Dryest station)	Sand Point	2,100	10	3.42	2.16	2.22	1.98	2.47	1.79	1.01	1.17	1.79	1.78	4.29	3.42	27.51
Cedar-hemlock-white fir (Wettest station)	Burke	4,082	9	6.17	5.30	4.78	2.50	3.09	2.84	1.68	1.03	2.62	3.27	5.48	5.48	44.24
Subalpine	Roosevelt	7,500	5	2.81	3.01	3.92	1.40	2.03	2.23	1.48	0.82	0.94	1.12	2.46	3.80	26.02

Precipitation summations, in inches

Type of vegetation	Mean, ann.	April–June	July–Sept.	May–Aug.	July–Aug.	Snowfall
East Washington prairies	9.43	2.18	1.16	2.20	0.73	17.4
Idaho-Palouse plains	20.54	4.71	2.49	4.49	1.31	31.6– 52.5
Wash.-Idaho western yellow pine	22.11	5.02	3.11	5.22	1.73	37.0–76.4
Clearwater River—western yellow pine	28.03	6.67	3.14	6.12	1.48	37.1– 56.0
Clearwater River	19.85	6.80	2.40	6.40	1.40	
Clearwater River—Grassland	13.37	3.86	1.84	3.91	1.03	16.3
Cedar-hemlock-white fir	35.07	7.70	4.66	7.69	2.47	66.0–207.0
Cedar-hemlock-white fir (Dryest station)	27.51	6.24	3.97	6.44	2.18	84.5
Cedar-hemlock-white fir (Wettest station)	44.24	8.43	5.33	8.64	2.71	207.0
Subalpine forest	26.02	5.66	3.24	6.56	2.30	

outstanding climatic characteristics found in the western and eastern sections are: in the west, relatively mild winters with heavy snowfall, and warm, dry summers; in the east, colder winters with light snowfall and somewhat more summer rains. Thus some parts of Idaho show an annual summer precipitation of only 5 inches, although the total for the year is 25 and over; while cen-

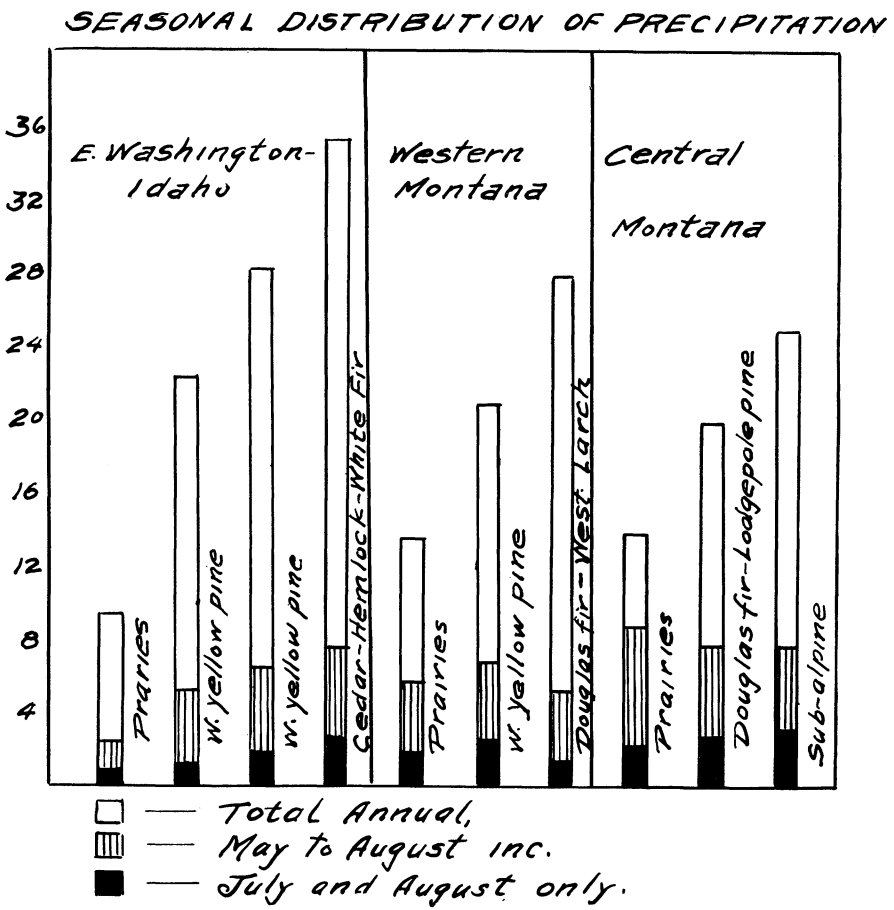

FIG. 3. Distribution of annual precipitation by months in eastern Washington–Idaho, western Montana, and central Montana

tral Montana receives an average of above 7 inches during the summer, the total annual there being about 15 inches for the prairies and 24 inches for the subalpine forests.

Climate, as affected by topography and geographical position, plays a leading role in determining the variations in forest cover. There are two outstanding meteorological differences between the western and eastern sections

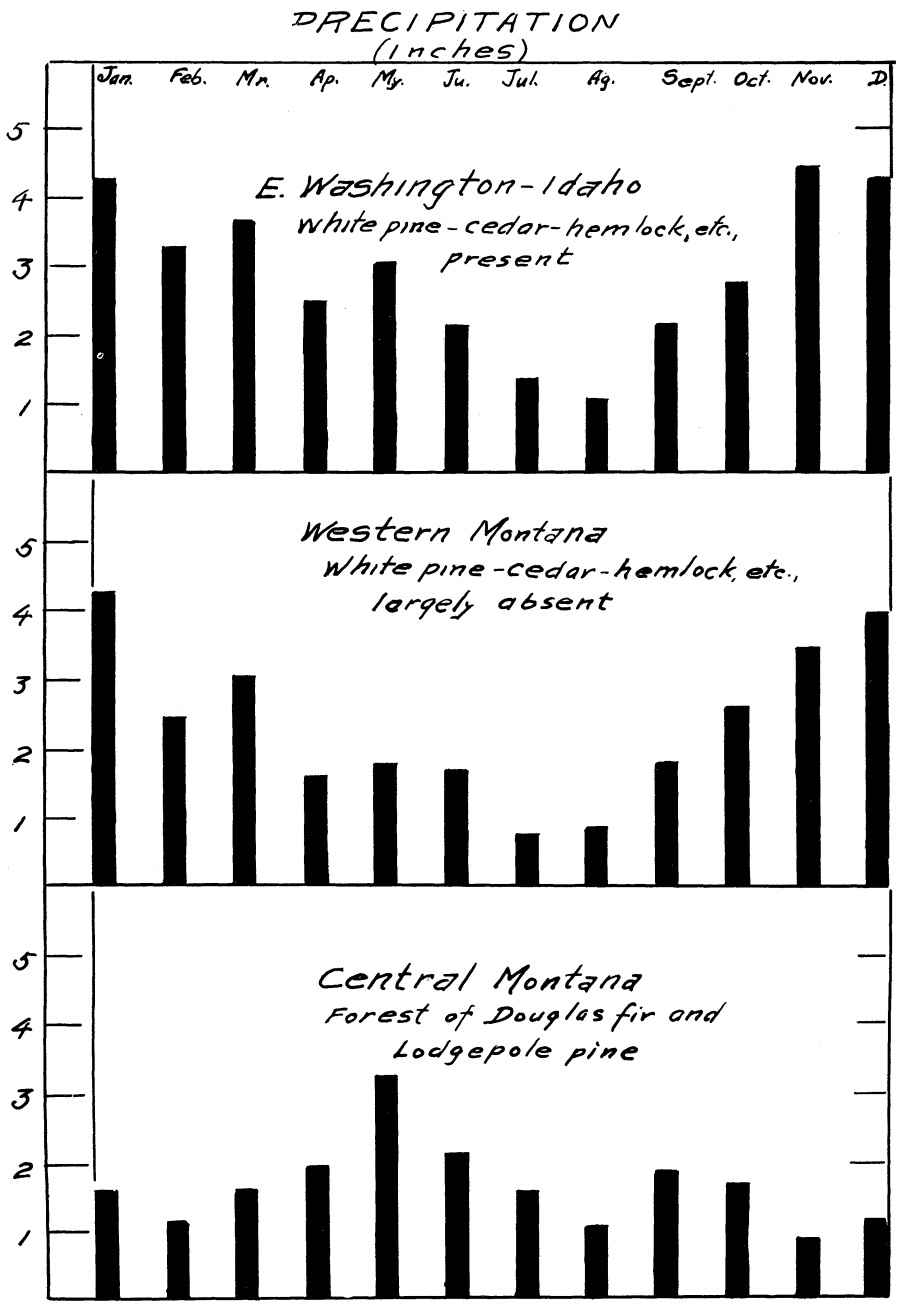

FIG. 4. Seasonal distribution of precipitation for the principal types of vegetation in eastern Washington–Idaho, western Montana, and central Montana

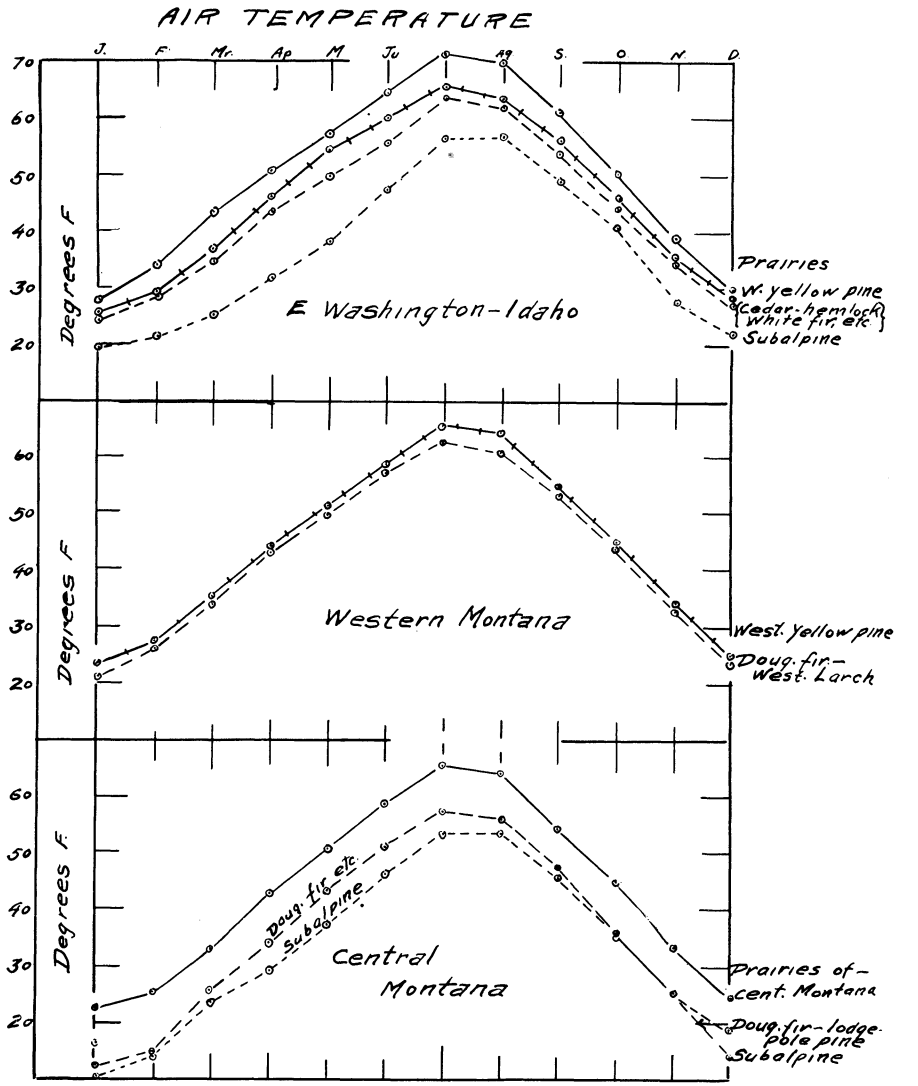

FIG. 5. Curves showing the mean air temperature by months throughout the year for the principal types of vegetation in eastern Washington–Idaho, western Montana, and central Montana.

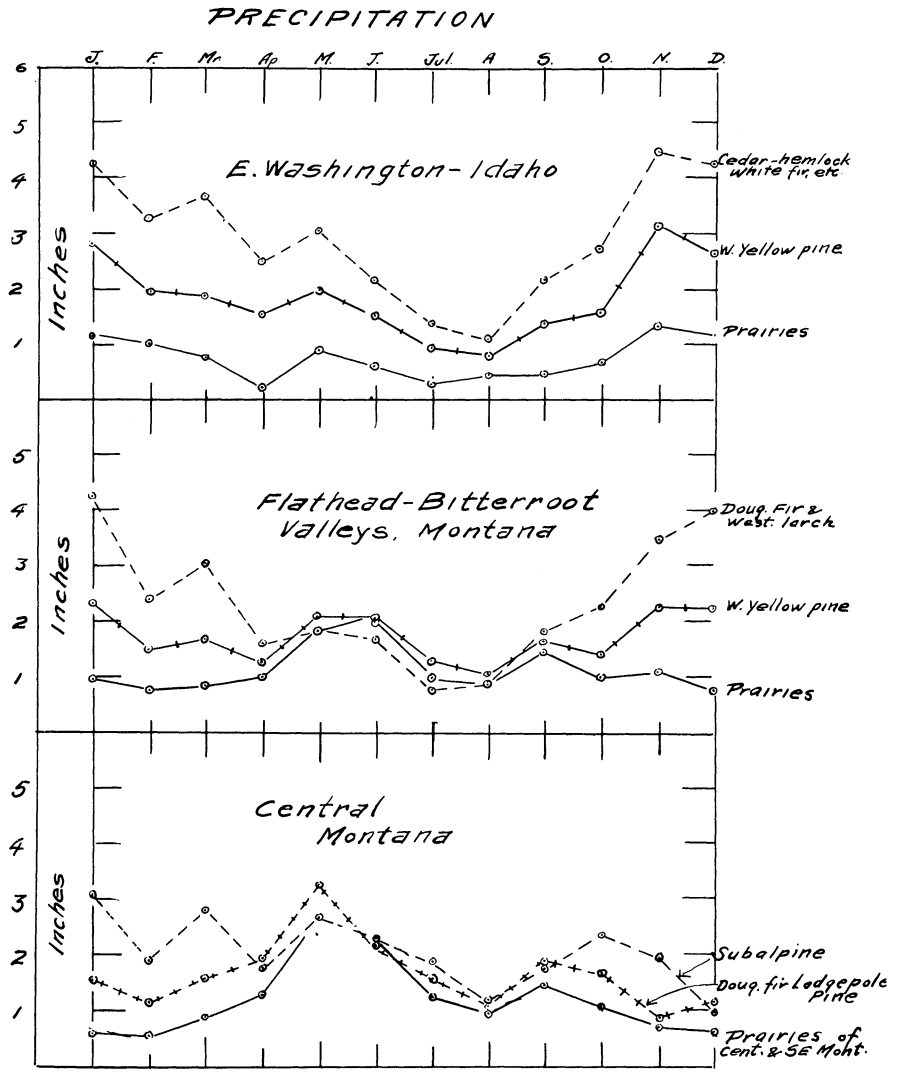

FIG. 6. Curves showing precipitation by months throughout the year for eastern Washington–Idaho, western Montana, and central Montana

of the Northern Rocky Mountain region. In winter, Idaho has milder temperatures but more snow than eastern Montana; in summer, it has considerably less rain. The climate of the intermountain valleys is intermediate be-

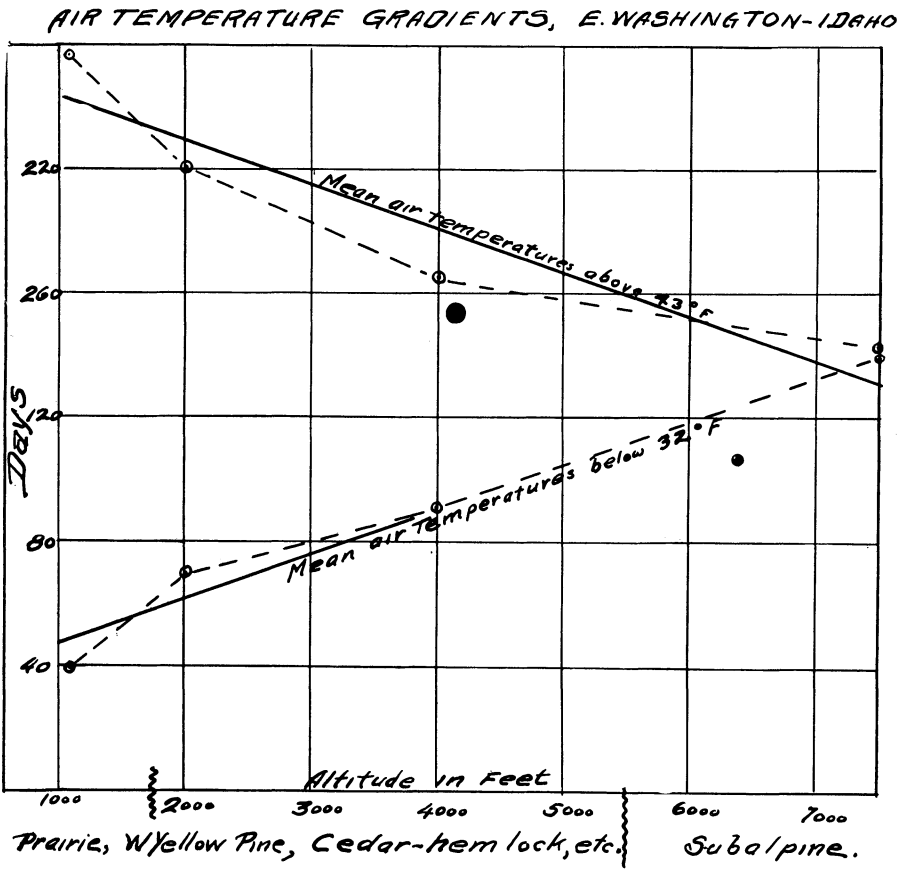

FIG. 7. Air temperature gradients for eastern Washington–Idaho, showing the relation of altitude to the number of days with a mean temperature above 43° F., and a mean temperature below 32° F.

tween that of the regions on either side. These characteristics are brought out graphically in Figs. 3, 4, 5, and 6. The relation of altitude to the length of the growing season, based on temperature above 43° F., is shown in Fig. 7.

Section Lying West of the Bitterroot Range

PRAIRIES OF EASTERN WASHINGTON

The prairie lands overlying the Columbia Basalt Plateau, between the Cascade Mountains in Washington and the Bitterroot Mountains in Idaho,

are for the most part flat. They are broken here and there by old water courses which have exposed basaltic cliffs, and round boulders or "nigger heads." Occasional depressions of better, moister soil are occupied by alfalfa ranches and may contain a few planted poplars. These bright green patches stand out in vivid contrast to the otherwise parched landscape.

The arid nature of this region is reflected by the dominant xerophytic vegetation of *Artemisia tridentata, A. tripartita, Chrysotamnus nauseosus, C. vescidiflorus, Eriogonum microthecum, Sarcobatus vermiculatus, Rhus toxicodendron, Erigeron concinnus, Lupinus pusillus, Zygadenus paniculatus,* and *Rumex venosus* (Weaver, '17, Gail, '24).

These prairies are chiefly of interest in this study because of their hot summer days and the drying winds which come from them, causing extreme drought and dangerous fire weather in the forested mountains to the east. These winds also carry particles of soil from the semi-arid region causing it to be deposited over the Palouse Plains and to some extent over the forests in the Clearwater drainage basin (Larsen, '23).

The Palouse Region

Between the semi-arid Columbia Basin and the western yellow pine forests is a billowy, treeless region. This is the rich wheat-producing area in eastern Washington and adjacent Idaho, known as the "Palouse country." The nature of the soil, the distribution of vegetation, and the climatic conditions have been well described by Weaver ('27).

Climatic conditions, as represented by records from Moscow, Rosalia, and Pullman, show a mean annual air temperature of 46.9° F., and a yearly precipitation of 20.54 inches, of which 2.49 inches occur during July, August and September.

The air temperature, as well as the amount of precipitation which falls here, appears to be suitable for a forest of western yellow pine. Probably the principal reason why this area is not covered with timber is the extremely adverse condition prevailing in summer, due to extreme drought and high winds. It is not unlikely that recurring prairie fires and shifting soil have also helped to tip the scales to the disadvantage of the trees. Measurements made by Gail ('24) show a really remarkable difference in drying power of the air between exposed and protected aspects. He found a wind movement 19 times greater on the southwest than on the northeast aspect, and a loss of water from evergreen twigs 2.89 times greater on the exposed than on the protected slopes. Consequently it is not surprising that pine is actually found on the north side of Steptoe Butte and along the Palouse River, and that the eastern or northern aspects of the smaller hummocks may readily be reforested.

The Western Yellow Pine Forests

The lower border of the forest in the section west of the Bitterroot range consists of the western yellow pine type. The tree line follows the Clearwater

canyon from Grangeville to Orofino and Lapway; then closely parallels the Northern Pacific branch line to Moscow; then goes north along the eastern

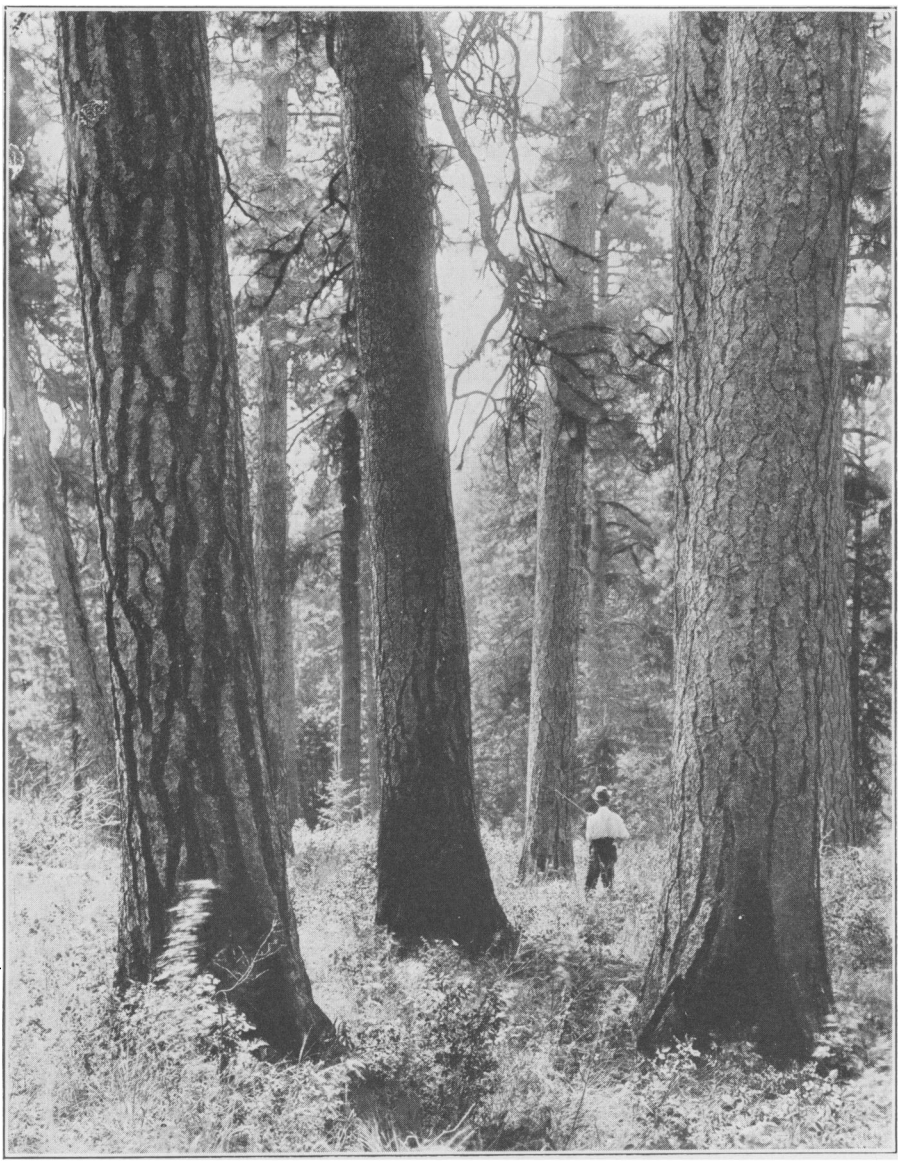

FIG. 8. Western yellow pine, *Pinus ponderosa* Laws in eastern Washington

edge of the Palouse Plain, cutting northwest about 20 miles south from Spokane, Washington. This type of forest is found generally between an elevation of 2,000 and 4,000 feet, but goes down to 1,000 feet in the Clear-

water canyon. In the Salmon River drainage on the Nezperce National Forest it reaches an elevation of 6,000 to 7,000 feet. The upper line is very irregular, receding along streams and protected slopes and advancing upward on warm and dry aspects.

Western yellow pine is everywhere the climax species of this type and it usually maintains itself in pure stands, once the ideal forest cover of needles and light grass has been established. It is mainly after fires that Douglas fir and lodgepole pine seed in. On the better sites, at lower elevations, as well as along the upper edge of the type other species are frequently associated with the yellow pine.

The characteristic yellow pine forest shows a rather open, park-like stand, with light vegetation (Fig. 7). This permits of wind movement along the surface, and more sunlight and evaporation than occurs in the other forest belts. These conditions, combined with the scant humus and litter, result in a soil poor in loam and of low water-holding capacity. There is invariably much rock material near the surface which causes it to heat greatly in summer, and brings about wider soil temperature fluctuations than in the other forest types (Larsen, '23).

The more outstanding species of shrubs and other vegetation commonly associated with western yellow pine are listed below: (Much more shrubbery is encountered on the mountain slopes than on the more level and even surfaces near the lower type border).

Arctostaphylos Uva-ursi (L.) Spreng. ..... Kinnickinnick
Agropyron spicatum Pursh. ..... Wheat grass
Apocynum androsaemifolium L. ..... Dog bane
Balsamorrhiza sagittata Pursh. ..... Balsam root
Berberis aquefolium Gray. ..... Oregon grape
Bromus marginatus Nees ..... Brome grass
Calamagrostis suksdorfii Vasey ..... Reed grass
Clarkia pulchella Pursh. .....
Campanula rotundifolia L. ..... Bluebell
Ceanothus sanguineus Pursh. ..... Mountain balm
Drymocallis glandulosa Linl. ..... Cinquefoil, five-finger
Erythronium grandiflorum Pursh. ..... Dogtooth violet
Heuchera avalifolia Nutt. ..... Alum root
Hieraceum albiflorum Hook. ..... Hawkweed
Holodiscus dumosus Nutt. ..... Oceanspray
Lupinus ornatus Doug. ..... Lupine
Nacrea lanata A. Nels ..... Everlasting
Philadelphus Lewisii Pursh ..... Mock orange
Physocarpos malveceus Kuntze ..... Nine bark
Pteridium aquilinum ..... Brake fern
Prunus demissa (Dietr.) ..... Chokecherry
Pentstemon sp. ..... Pentstemon
Salix scouleriana (Barr.) ..... Willow
Senicio-var. species ..... Groundsel
Spiraea lucida Doug. ..... Spiraea

Sedum Douglasii Hood. .....Stone crop
Rosa nutkana .....Wild rose
Zygadenus venenosus .....Death camas

The weather data for this type were obtained from nine stations: Spokane, Coeur d'Alene, Potlatch, Port Hill, Bonners Ferry, Newport, Orofino, Culdesac, and Kooskia. Orofino, which lies in the Clearwater Canyon at an elevation of only 1,027 feet, has the highest mean annual air temperature, 49.8° F. Newport, on the plateau south of the Selkirks at an elevation of 2,300 feet, has a mean temperature of only 43.6° F. From these figures it appears that 43 and 50 degrees represent roughly the limiting mean annual temperatures of the yellow pine type in the region west of the Bitterroots. It must be stressed, however, that these figures are mere approximations, since it is quite probable that at other localities where there are no weather stations the yellow pine exceeds this range. As regards precipitation, the lower limit of this type would seem to fall between the 17.47 inches of annual rainfall of Spokane, and the 16.34 inches of rainfall at Reardon which lies just outside this type. As for the upper limit, the 28.03 inches of precipitation at Orofino was the highest encountered.

It is not considered that maximum air temperatures *per se,* or the extremes of air temperature are sufficient to impose limiting conditions to the downward extension of the western yellow pine in this region, for Orofino, with excellent yellow pine forests, exhibits extremes comparable to those observed over the open prairies. The limitation is found rather in deficient precipitation.

As to the upper altitudinal limit, the line between the yellow pine and the white pine type is drawn rather clearly at 43 or 44 degrees F. as a mean annual air temperature, and at a growing season of 200 days during which the mean averages above 43 degrees. It should be observed also that at the Dalles, Oregon, elevation 112 feet, under conditions of higher relative humidity and less of the dry winds than obtain in eastern Washington, the western yellow pine thrives with a mean air temperature of 52.9 degrees F., and only 15.4 inches of precipitation annually. Evidently increased atmospheric humidity compensates for decreased precipitation in this case.

From the standpoint of silviculture it may be said that the bulk of this forest type is characterized by pure or nearly pure stands in groups of different age classes. These range from large and old trees, sometimes 400 years in age, to patches of reproduction.

Western White Pine Type

The commercial value and great abundance of the western white pine has led to the adoption of the name " western white pine type," though in reality this pine is not a climax species, since the more tolerant hemlock, western red cedar, and even white fir ultimately replace it.

The western white pine type extends from southern Canada to the Locksa Divide between the Selway and Locksa rivers. To the east it extends to some of the better soils in the Purcell, Cabinet, and northern Bitterroot mountains. On the west it is terminated by the upper edge of the yellow pine type. It occurs also in scattered patches of little commercial importance outside of these boundaries.

It thrives best on deep, well-drained, moist soil, and is therefore found on protected slopes in broken topography where the extremes of climate are considerably reduced, not only by precipitation and cloudiness, but also by protection from sun and wind. Though much of the forest area is now occupied principally by even-aged white pine forests, canyon bottoms still contain enormous trees of live or dead—mostly dead—virgin cedar and hemlock in uneven-aged forest.

The western white pine type is richer in plant associates than any other forest type in the region. The most characteristic species are given below:

Acer glabrum Torr. ..... Rocky mountain maple
Actaea arguta ..... Bane berry
Adenocaulon bicolor Hook. ..... Silver green
Adiantum pedatum L. ..... Maidenhair fern
Alnus tenuifolia Nutt. ..... Alder
Aralia nudicaulis L. ..... Sarsaparilla
Aspidium sp. ..... Wood fern
Asarum caudatum Lindl. ..... Wild ginger
Atragene occidentalis Hornem. ..... Clematis
Betula fontinalis Sarg. ..... Birch
Circaea pacifica Asch, and Magn. ..... Circaea
Claytonia perfoliata Donn ..... Spring beauty
Clematis occidentalis Hornem. Hort. ..... Virgin bower
Clintonia unifolia (Schult.) Kunth ..... Clintonia
Coptis occidentalis (Nutt.) T. & G. ..... Gold thread
Cornus canadensis L. ..... Trailing dogwood
Cornus stolonifera Michx. ..... Dogwood
Dryopteris Felix-mas (L.) Schott. ..... Shield fern
Epilobium adenocaulon ..... Willow herb
Fatsia horrida Bent. & Hook. ..... Devil's club
Galium triflorum Michx. and *asperrimum* Gray ..... Northern bedstraw
Geranium carolinianum L. ..... Geranium
Geum macrophyllum ..... Large leaved aven
Linnaea borealis L. ..... Twin flower
Lonicera involucrata Banks ..... Honeysuckle
Lonicera ciliata Poir ..... Honeysuckle
Lycopodium annotinum and *clavatum* ..... Clubmoss
Mertensia ciliata (Torr.) Don. ..... Lungwort
Mentha canadensis L. ..... Wild mint
Mitella trifida Graham and *stauropetala* ..... Bishop's cap
Montia spatulata acerifolia and *siberica* ..... Miner's lettuce
Osmorihza sp. ..... Sweet cicily
Polygonum spergularaeforme Meis ..... Knot weed
Polysdictum lonchitis L. ..... Holly fern

Pyrola secunda and *bracteata* ..... Wintergreen
Ribes viscossimum Pursh. ..... Gooseberry
Rubus melanolasius Focke ..... Red raspberry
Rubus parviflorus Nutt. ..... Thimble berry
Rubus sp. ..... Blackcap raspberry
Sambucus melanocarpa A. Gray ..... Elderberry
Sambucus glauca Nutt. ..... Elderberry
Smilacina sessilifolia Nutt. ..... Solomon seal
Spiraea densiflora Nutt. ..... Spiraea
Spiraea lucida Dougl. ..... Spiraea
Stellaria longpipes laeta Nutt. ..... Chickweed
Streptopus amplexifolius ..... Twisted stalk
Tiarella unifoliata Hook. ..... Coolwort
Thalictrum occidentale A. Gray ..... Meadow rue
Trautvetteria grandis Nutt. .....
Trillium petiolatum Pursh. ..... Trillium
Valeriana sitchensis ..... Valerian
Vaccinium membranaceum (Doug.) Hook. ..... Huckleberry
Vaccinium occidentale A. Gray ..... Huckleberry
Vagnerica lilacea (Greene) Rydb. ..... False solomon seal
Viola glabella Nutt. ..... Violet
Viola blanda Wild ..... Violet (yellow)
Zylosteon sp. ..... Bush honeysuckle

Dense virgin stands contain no grass and scant underbrush because very little light reaches the ground. There do appear a few characteristic plants, often in distinct colonies, including *Triarella unifoliata, Asarum caudatum, Aralia nudicaulis, Cornus canadensis, Linnaea borealis, Coptis occidentalis,* several species of *Lycopodium* and many mosses. Along the streams is a great profusion of herbaceous plants among which are *Adenocaulon bicolor, Osmorihza nuda, Actaea arguta, Galium asperrimum, Ribes* and *Fatsia horrida.* Some of the typical shrubs are *Amelanchier alnifolia, Alnus alternifolia, Ceanothus velutinus, Acer glabrum* and *Cornus stolonifera.*

After fires, however, a great many herbaceous species take possession of the ground, including the majority of the plants listed above (Larsen, '29). These cover whole hillsides with luxuriant growth of *Chamaenerion angustifolium, Ribes viscossimum, streptopus, etc.* After five or six years these give way to shrubs of *Ceanothus velutinus, C. sanguineus, Acer glabrum, Amelanchier alnifolia, Symphoricarpos recemosus, Alnus, Lonicera involucrata* and *L. utahensis,* etc.[3]

The weather stations representative of the western white pine forest are Sandpoint, Lakeview, Priest River Experiment Station, Prichard, Avery, Murray, Wallace, Musselshell, Elk City, and Burke. Of these, Sandpoint is the lowest and warmest, with a mean annual temperature of 44.9° F., and Burke the highest and coldest showing a mean annual temperature of 40.4°. The range in temperature requirement for this type lies therefore between

[3] Fires and forest succession in the Bitterroot Mountains is more fully treated in author's report, Larsen, '29.

about 40° and 45° F. The growing season is from 165 to 200 days. The mean annual rainfall varies between 27 and 45 inches, with not less than 2 inches during July and August. It may truly be said that the southward and downward extension of this type is limited by insufficient moisture, and the upward or northward extension by low temperature. A minimum of 27 inches per year is required in the former case, and a mean annual temperature of 40° F. in the latter.

One outstanding climatic characteristic of this type is the abundance of snowfall. The contrast is very distinct between this type and the western yellow pine, where snow is shallow and intermittent. The deep snow cover is naturally a great protection to seed and seedlings, as well as a source of moisture in spring and early summer.

On the moister soils, especially along water courses and on north aspects, western red cedar, western hemlock, and Engelmann spruce are abundant. On the drier south and west aspects, and on the exposed, rocky slopes Douglas fir, western larch, and lowland white fir are much in evidence, while western yellow pine is frequently found. Lodgepole pine is found on the poorer sites, while alpine fir is common at the upper edge of the type. The white pine is rarely found in pure stands, but not infrequently young stands have such a large proportion of this species as to appear practically pure at first sight.

Due to the influence of fires western white pine stands are characteristically even aged. However, it frequently happens that these fires do not completely destroy the original forest, and in such case a two or more aged forest may result. The more tolerant cedar, hemlock, spruce, and white fir often enter the stand considerably after the dominant species.

White pine forests (Fig. 8) are among the most beautiful in existence. The mature trees are tall, straight, full bole and cylindrical, yielding a high amount of select lumber and a much heavier cut per acre than any other forest in this region: certain sections having averaged 50,000 board feet per acre at 150 years, over and above the usual reserve for seed trees and fire insurance. Many western white pine trees attain a height of 200 feet and diameters up to 50 inches. Western red cedar also is a tree of no mean stature for it frequently measures 200 feet in height and sometimes 12 feet in diameter.

Subalpine Forests

The subalpine forests in the Bitterroot Mountains (Fig. 10) begin at an elevation of 5,500 feet, where the white pine type ceases. They continue upward to mountain tops at six and seven thousand feet elevation. In general this high country is not precipitous, although there are conspicuous exceptions. The soil, especially on the broad ridge tops, is rather deep and fertile, fostering excellent stands of mountain hemlock which is here the climax species. The Engelmann spruce and alpine fir inhabit north slopes and moist situations, while the lodgepole pine, Douglas fir and white bark pine prefer exposed and drier sites.

FIG. 9. Forest of western white pine *Pinus monticola* D. Don (*A*), western red cedar *Thuja plicata* D. Don (*B*), and western hemlock *Tsuga heterophylla* Sarg. (*C*), on bottomland in northern Idaho.

FIG. 10. Subalpine species, consisting of white bark pine *Pinus albicaulis* Eng. (*A*) and alpine fir *Abies lasiocarpa* (*B*). Summits of Bitterroot Mountains, Idaho

Under mature climax hemlock forests the vegetation is composed principally of *Vaccinium microphyllum,* sedges, and broom grasses. Under spruce and alpine fir are found *Menzisia glabella, Vaccinium membranaceum, Sorbus scopulina,* and *Alnus tenuifolia.* Around each spring and seep is much laurel, alder, elder, and a wealth of succulent species, but these have no bearing on forest distribution. The complete correlation of vegetation to forest types has not yet been ascertained.

Recurring fires originating from lightning have greatly reduced the areas properly belonging to the climax species and have favored reproduction and spread of lodgepole pine and to some extent Douglas fir, for the latter species withstand drought and exposure in the seedling stage much better than hemlock, spruce and fir; but they are not as valuable or effective as protectors of the ground and conservers of moisture.

Stands of lodgepole pine and Douglas fir are abundant on the south and west aspects. Lodgepole pine is inavirably most abundant toward the upper part of the slope while Douglas fir is more plentiful as a general slope species. This forest may be even aged over large areas, having originated after a fire of considerable size, or even aged in small irregular groups. In the latter case it is the result of ground fires in young stands. Sometimes veterans of much older age than the surrounding trees grow in draws and protected situations. The mature Douglas fir trees may vary in height from 100 to 150 feet according to the quality of the site, while lodgepole pine seldom exceeds 80 or 90 feet in height. The trees in this zone are rather tapering and limby.

On the whole there is little underbrush present on the upper part of such southerly slopes, but much grass, much of which is bear grass. One very typical plant association under the upper slope lodgepole pine is *Xerophyllum tenax* and *Vaccinium microphyllum.* Sufficient natural reproduction does not take place and there are very few seedlings of any kind, or none, under the trees.

White bark pine is a tree occurring mostly in openings on south and west aspects. It is there a short tree seldom over 60 feet in height, more often 30 or 40 feet with a low, wide-spreading crown and tapering trunk. Lyall larch is found on isolated higher peaks above 7,500 feet. This species is not plentiful, but the stands found are even-aged and pure. It merely marks the beginning of what would be a true alpine type had the mountains been of greater elevation.

C. H. Shattuck ('15), in ascending Graves Peak on the Clearwater Forest in 1917, listed the following species:

Trees

Abies lasiocarpa (up to 8,000)
Larix lyalli (7,500 to 7,800)
Picea Engelmanni (up to 8,000)
Pinus albicaulis (timber line)

Shrubs

Alnus sp.	
Cladothamnus campanulatus	Fowler, Flora of the Northwest
Gaultheria humifusa	Coulter and Nelson,
Gaultheria humifusa	Coulter and Nelson, Rocky Mt. Flora
Juniperus nana	Fowler
Kalmia glandulosa	Piper
Ledum glandulosum	Coulter and Nelson
Phyllodoce impetriformis	Coulter and Nelson
Sambucus melanocarpus	Coulter and Nelson
Spiraea arbuscula	Fowler
Vaccinium occidentale	Coulter and Nelson
Vaccinium microphyllum	Fowler

Pteridophytes

Cryptogamma fragilis	Fowler or Gray Manual of Botany
Cryptogamma acrosticoides	Fowler or Gray
Cystoperis occidentale	Fowler or Gray
Isoetes sp. (in the lake)	

Herbaceous Plants

Antennaria parviflora	Coulter and Nelson
Antennaria media	Coulter and Nelson
Arnica pedunculata	Coulter and Nelson
Aster palustris	Fowler
Boykinia major	Fowler
Campanula rotundifolia	Coulter and Nelson
Campanula uniflora	Coulter and Nelson
Cicuta purpureata	Fowler
Clematis douglasii	Coulter and Nelson
Crepis elegans	Coulter and Nelson
Epilobium spicatum	Coulter and Nelson
Eryogonum jamesii	Coulter and Nelson
Erythronium grandiflorum	Coulter and Nelson
Gentiana calycosa	Coulter and Nelson
Hypericum formosum	Coulter and Nelson
Media citriodora	Fowler
Mimulus lewisii	Coulter and Nelson
Narthecium americanum	
Pedicularis lunata	Coulter and Nelson
Phlox diffusa	Coulter and Nelson
Potentilla uniflora	Coulter and Nelson
Poligonium viscosum	Fowler
Rumex occidentalis	Coulter and Nelson
Valeriana sitchensis	Coulter and Nelson
Veronica scutilata	Coulter and Nelson
Zerophyllum tenax	Coulter and Nelson

Unfortunately, year-long weather records at these high elevations are limited. Roosevelt, Idaho, at 7,200 feet, south of the Salmon River in the Thunder Mountain region, was the nearest station. This is, of course, a good distance south of the western white pine type, but much higher. Here a mean annual temperature of 36.4° F. is recorded and a total precipitation of 26.59 inches. The site may be too cold and the precipitation in summer deficient for the cedar-hemlock and white fir type. No permanent snow records are available, but casual observations show that snowfall here is much greater than anywhere else in the section west of the Bitterroot Mountains. On Cook Mountain, 6,575 feet elevation, the snow usually covers the buildings completely and does not disappear entirely before July 1.

Observations of weather conditions on lookout points in this region during July, August and September, 1919, show that the air is cooler by day and warmer by night at stations lower down, such as Oxford and Musselshell. The differences are about 10° F.

The relative humidity fluctuates less on the mountain than in the valley in summer, and wind movement on the mountain is from 3 to 4 times as great and fairly constant both night and day, while at low stations the air is fairly calm at night.

One very noticeable feature of the temperature variations at different elevations is in the differences which appear in the spring and fall. In the spring a greater gradient is observed for different altitudes than in the fall. This is most likely because the snow cover lingers late in the mountains in the spring, while during the fall the snow cover comes more nearly simultaneously at all elevations.

Flathead and Bitterroot Valleys

In the intermontane basins of Flathead and Bitterroot Valleys another fairly regular altitudinal succession of forest types occurs, ranging from prairies on the bottom lands and rolling plains at about 3,000 feet elevation, through western yellow pine on the foothills, Douglas fir and western larch on lower and intermediate slopes, to subalpine and alpine forests on higher slopes and summits. Since the western larch does not go south into the Bitterroot Valley generally, the intermediate type above the western yellow pine south of Missoula consists chiefly of Douglas fir—lodgepole pine. This is in most respects similar to that found in central Montana and central Idaho.

Prairies of the Flathead and Bitterroot Valleys

The intermontane valley floors are in most cases rather flat, originating from old lake bottoms. They are sometimes gently rolling, the result of wind-blown deposits.

The line between the open grassland and the western yellow pine forests is in most places regular and distinct. On the west side of the valleys the thin lower border of yellow pine follows closely the lowest part of the slopes,

TABLE VII. *Flathead and Bitterroot Valleys—Air temperature, in degrees F.*
From U. S. Weather Bureau Climatological Summaries for 1921–22

Type of vegetation	Stations	Elev. ft.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
			years													
Prairie	4 stations	2,911–4,509	16–29	23.6	26.2	34.3	44.1	51.9	59.7	66.6	64.2	53.9	44.7	34.2	24.9	44.0
Western yellow pine	4 stations	2,424–3,100	8–26	23.7	27.4	35.3	44.0	51.2	58.7	65.5	64.2	54.8	44.3	34.1	25.3	44.0
Douglas fir-w. larch	Haugan	3,150	10	21.1	26.4	34.0	43.1	49.7	57.4	62.7	60.8	53.0	43.8	32.9	23.5	42.4

Temperature summations in degrees F.

Type of vegetation	Mean ann.	Mean May–Sept.	Average max.—July	Average min.—Jan.	Abs. max.	Abs. min.	Days with mean			Frostless season		
							−32°	+43°	+70°	Last—spring	First—fall	Days
Prairie	44.0	63.3	81.7	14.6	108	−42	76	187	0	6/22	9/20	78
Western yellow pine	44.0	62.9	84.4	14.7	108	−40	82	170	0	6/4	9/9	97
Douglas fir—w. larch	42.4	60.7	83.2	9.8	107	−49	75	170	0	6/13	9/1	80

TABLE VIII. *Flathead and Bitterroot Valleys—Precipitation, in inches*
From U. S. Weather Bureau Climatological Summaries for 1921–22

Type of vegetation	Stations	Elev.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
			years													
Prairie	4 stations	2,911–4,509	16–29	0.96	0.75	0.82	0.99	1.84	2.06	0.98	0.84	1.44	0.99	1.08	0.74	13.50
Western yellow pine forest	4 stations	2,424–3,100	8–26	2.32	1.50	1.69	1.26	2.08	1.95	1.27	1.04	1.65	1.39	2.25	2.22	20.60
Douglas fir—w. larch	Haugan	3,150	10	4.26	2.40	3.01	1.58	1.78	1.68	0.76	0.87	1.80	2.26	3.47	3.96	27.83

Precipitation summations, in inches

Type of vegetation	Mean annual	April–June	July–Sept.	May–Aug.	July–Aug.	Snowfall
Prairie	13.50	4.89	3.26	5.72	1.82	29.1–45.5
Western yellow pine forest	20.60	5.29	3.96	6.34	2.31	52.3–67.8
Douglas fir—w. larch forest	27.83	5.04	3.43	5.99	1.63	41.2–44.3

but on the east side the outlying foothills are bare of forest up to a distance of 500 and sometimes 1,000 feet above the valley floor. At the mouth of lateral canyons on the east side the demarcation is abrupt and sharply drawn, with forest on north aspects and prairie on those facing west.

The weather stations which were chosen to represent this type are St. Ignatius, by far the most typical, Kalispell and Hamilton, somewhat on the borderline between the prairie and the western yellow pine. Deerlodge is also a prairie station but much higher and colder than Kalispell. These stations show a variation in mean air temperature from 42.8 to 46.0° F., Deerlodge being the coldest and Hamilton the warmest. Neither of these records nor the extremes listed in Table VII are sufficient to account for the absence of tree growth, since the temperature conditions are less extreme than those observed to the west of the Bitterroot Mountains. The general absence of forest must be ascribed to deficient annual rainfall which averages only 13.50 inches, and in some years drops as low as 10 inches. Here and there the cause is evidently lack of drainage, alkalinity, and recurring fires; but these merely exercise a local effect.

Western Yellow Pine Forests

The forests of western yellow pine and the associated vegetation in the Flathead and Bitterroot valleys are, in most respects, similar to the Idaho-Washington yellow pine forests. It is in effect a part of the same forest type, joined to it by narrow strips which follow the south and west slopes, often steep rocky cliffs, along the Flathead and Kootenai rivers. Its best development is reached in the southern portions of the Bitterroot Valley from Hamilton to Como.

The upper limit of the type is near 4,000 feet in the northern portions of the Flathead National Forest, and near 6,000 feet in southern parts of the Bitterroot. However, this type does not reach its lowest possible elevation here but continues downward along the rivers which drain into northern Idaho and Washington. The tree line is, nevertheless, rather generally associated with the base of the mountains, giving way to prairies as stated above.

The weather stations selected to represent this type are Libby, Thompson Falls, Superior, and Columbia Falls. Of these, Thompson Falls is the lowest and warmest with a mean annual air temperature of 45.0° F., which Columbia Falls, the coldest, has a mean of 42.8° F. The latter is apparently close to the minimum for the yellow pine here, as shown both by comparison with other records in Idaho and the sudden transition at Columbia Falls from a western yellow pine to the larch-Douglas fir type.

Nowhere in these valleys do the air temperatures reach such high points as in the Idaho yellow pine type. The maxima are lower here, and the absolute minimum is — 40° instead of — 30°. It should be noted that the average length of the growing season in this type has here only 179 days, and that it is over 200 days in the western part. The conclusion is reached therefore

that the yellow pine is not growing under optimum temperature conditions in the Flathead or in the northern parts of the Bitterroot Valley.

The precipitation is about 20 inches, one station, Superior, within the type registering only 17.50. This compares well with the minima recorded in eastern Washington, Spokane, near the lower edge of the type, showing 17.47. The station Fortine near the very edge of this type has a precipitation of 18.10, and Kalispell, outside the type, 15.21 inches. But the summer months, April to September inclusive, register about 9 inches rainfall in the intermontane valleys and about 8 inches to the west. Most likely less severe drying conditions and more rainfall compensate somewhat for decreased air temperature. The conclusion is reached in this case also that the lower or downward extension of the western yellow pine type is limited by insufficient moisture rather than by too high temperature.

Douglas Fir-Western Larch Forests

Within the Kootenai and Flathead watersheds in northwestern Montana the position between the upper margin of the western yellow pine type and the subalpine forests is occupied by Douglas fir-western larch forests (Fig. 9). These occur at elevations from 3,000 to 5,500 feet on benchland, foothills, and slopes and ridges generally. To be sure, there is also a great abundance of Engelmann spruce and lodgepole pine, the former mostly on north slopes, benches and along streams, the latter everywhere without reference to aspect. The larch and lodgepole pine occupy extensive areas as temporary forests because they have been favored in their distribution and quantity by past fires. The larch resists fire well on account of its thick bark; the lodgepole pine seeds in on burns very readily, and is favored by its early seed production, and the preservation of the seed within the tightly shut cones. Both species show prompt germination and establishment on the ashes.

Western larch, Douglas fir and lodgepole pine make up at least 90 per cent of the species within the type. Englemann spruce appears mainly along creeks and bordering swamps or low places. Certain pockets with more favored soil and moisture are occupied by the cedar-hemlock and white fir mixture representative of northern Idaho. The latter type has a scattering of western white pine; but the form, growth, and health of these mesophytic trees are far inferior to those growing in Idaho.

Even-aged stands are the rule everywhere within the type, the age classes being well represented and having originated after more or less general fires. Since larch is very fire-resistant, veterans of this species exist everywhere, these having survived several very bad fires. Douglas fir, since it is more tolerant of shade than the larch, reproduces prolifically underneath the larch. The natural tendency is therefore for Douglas fir to supplant larch, and, were it not for recurring fires which destroy the Douglas fir and cause profuse larch restocking by exposure of fresh ashes as a seed bed, this type would naturally revert to Douglas fir and Engelmann spruce.

FIG. 11. Forest of western Larch *Larix occidentalis* Nutt. in Flathead Valley, Montana. Understory of Douglas fir *Pseudotsuga taxifolia* (La M.) Britt, Englemann spruce *Picea engelmanni* Engelm. and some alpine fir *Abies lasiocarpa* (Hooker) Nutt.

The vegetation within and underneath the Douglas fir-Western larch timber is not so varied in species nor so tall or luxuriant as that observed in the cedar-hemlock-white fir forests of Idaho. In this it reflects the drier conditions of Montana as compared with Idaho. Shrubs of *Amelanchier, Ceanothus, Shepherdia, Sorbus, Symphoricarpos, Lonicera, Kalmia,* etc. are common in minor openings or on double burns. Other typical species are listed below. For the character and distribution of the vegetation see Harshberger ('11, p. 550), and Whitford ('05, pp. 99, 194, and 276).

Amelanchier alnifolia Nutt. ..... June berry
Arctostaphylos Uva-ursi (L.) Spreng. ..... Kinnickinnick
Antennaria rosea (D. C. Eat.) Greene ..... Everlasting
Antennaria racemosa Hook. ..... Everlasting
Berberis repens Lindl. ..... Oregon grape
Calypso borealis Salisb. .....
Castilleja miniata Dougl. ..... Indian paint brush
Ceanothus velutinus Dougl. ..... Mountain balm
Chimalphila umbellata (L.) Nutt. ..... Princess pine
Drymochallis glandulosa Lindl. .....
Fragaria sp. ..... Wild strawberry
Linnaea borealis L. ..... Twin flower
Lonicera Utahensis Wats. ..... Honeysuckle
Pachystima myrsinites Raf. ..... Goat brush
Symphoricarpos racemosus Michx. ..... Snowberry
Shepherdia argentia Nutt. ..... Silver bush
Sorbus angustifolia Rydg. ..... Mountain ash

Climatic conditions within the Douglas fir-Western larch forest type are taken from Fortine, Haugan, Belton and Upper Yaak. For these stations the mean annual air temperature varies between 40.6° and 42.4° F. Belton and Fortine are the colder and Haugan the warmer. The growing season as taken from the curves gives 170 days. These temperature records give conditions nearer the optimum than the average for the type. It is impossible from these records to determine the average or optimum as well as the minimum temperature tolerated by this type.

Precipitation records indicate an average of 27.83 inches for the year. This, however, is far above the minimum, Fortine on the lower borderline showing 18.10 inches. The exact requirement will naturally vary according to the local soil and its moisture-holding qualities.

The conclusions are that the lack of moisture limits the downward extension of this type, and that the air temperatures which prevail here are suitable for the cedar-hemlock-white fir type but that precipitation is generally insufficient for it.

Subalpine Forests

Above 5,500 feet elevation in the northern Flathead Valley, and above 6,500 in the Bitterroot Valley, the forests are distinctly subalpine, composed of alpine fir, Engelmann spruce (Fig. 12), and white bark pine.

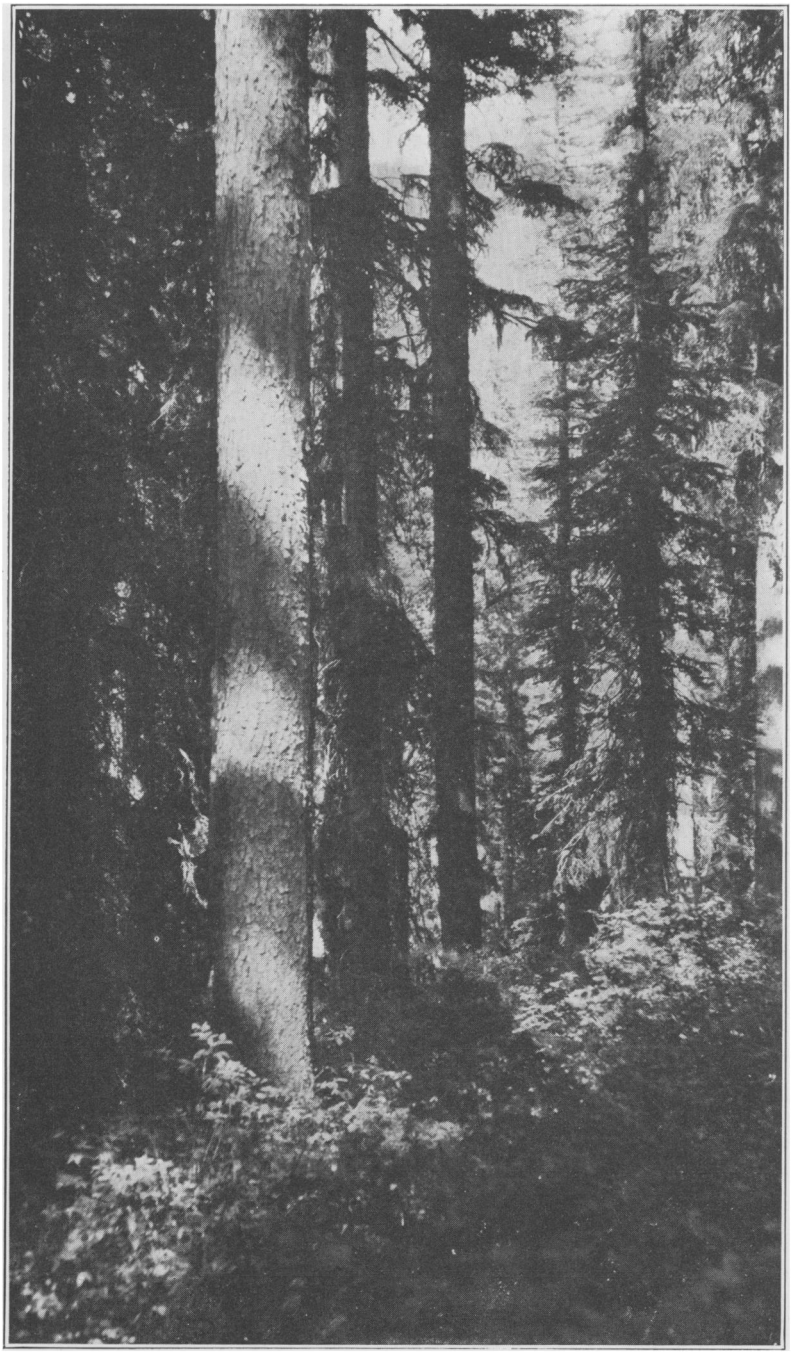

FIG. 12. Engelmann spruce *Picea engelmanni* Engelm., Blackfeet National Forest, northwestern Montana

For this type the same general characteristics previously described for the subalpine forests west of the Bitterroot Divide hold true. Points of difference are: a much greater amount of Engelmann spruce in the northern Flathead watershed, sometimes forming extensive pure or nearly pure forests; the absence of mountain hemlock; and the greater abundance of lodgepole pine and Douglas fir, especially on south and west slopes. This type is chiefly of importance for watershed protection. It is moreover too inaccessible for present day exploitation.

The following species of true subalpine plants are found above 6,000 feet in the Selkirk Mountains (Harshberger, '11):

Botrychium simplex E. Hitchcock
Phegopteris alpestris Hoppe
Lycopodium Selago L.
Lycopodium sitchense Rupr.
Festuca brachyphylla Schultes
Trisetum subspicatum L.
Carex atratiformis Britton
Carex pseudo scirpoidea Rydg.
Carex rupestris
Juncus Mertensianus Borg.
Juncus Parryi Engelm.
Luzula spicata DC.
Tofieldia borealis Wahlenb.
Oxyria digyna L.
Silene acaulis L.
Silene Lyallii Wats.
Alsine laeta Rich.
Arenaria capillaris Poir. v. nordifolia
Anemone Drummondii Wats.
Anemone patens L. v. Nutt. G.
Ranunculus nivalis L.
Ranunculus alpeophilus A. Nelson
Ranunculus pygmaeus Wahl.
Viola cania L. v. adunca G.
Drayas octopetala L.
Rubus arcticus L. v. grandiflorus
Sibbaldia procumbens L.
Oxytropis (Aragallus) alpicola Rydg.
Epilobium anagallidifolium Lam.
Bryanthus glanduliflorus G.
Gaultheria humifusa Graham
Androsace subumbellata A. Nelson
Castelleja pallida Kunth.
Veronica alpina L.
Myosotes alpestris Schmidt
Aplopappus Lyalli Gray
Aplopappus (Pyrrocoma) Brondegei A. Gray
Erigeron simplex Greene (= E. *uniflorus* Hook.)
Senecio triangularis Hook.
Taraxacum rupestre Greene
Taraxacum scopulorum Gray

For the subalpine forests no true climatic records are available. Snowfall measurements in 1926 on Mt. Silcox (6,870 feet) north of Thompson falls, show the following:

Date	Jan. 15	Feb. 24	Mar. 31	May 2	June 21
Depth, inches	76.5	105.0	156.0	142.0	42.4
Weight, lbs. of cu. ft. of snow	19.5	36.2	27.2	43.7	21.7

The observers in climbing the mountain took measurements at different depths as follows:

Elevations	3,723	4,924	5,795	6,870
Type	Yellow pine	Yellow pine	Larch—D. f.	Subalpine
Feb. 24	15.3″	29.0″	52.0″	105.0″
Mar. 31	21.0″	—	79.0″	156.0″

Central Montana

Throughout most of central Montana the transition from prairies to forest is to the Douglas Fir-Lodgepole Pine Zonation, thus skipping almost entirely the zone of western yellow pine so common in the two western sections. A poorly developed forest of yellow pine occurs on the Helena National Forest. We occasionally find the juniper-limber pine border association on steep slopes overlying coarse sandstone formations. From Douglas fir-lodgepole pine the forest changes at higher elevations to subalpine in character, with a greater proportion of alpine fir and Engelmann spruce. Eventually, toward the upper limits of tree growth true alpine conditions prevail with limber pine, alpine fir and Engelmann spruce.

Prairies

The Great Plains section in this territory changes from level plains at the lower points, to rolling undulating plains and to steeper foothills. It exhibits wide variations in floristic composition according to differences in soil and situation. Ecologists and botanists will recognize Sage-Brush Formation; Grama-Grass Formation; Wheat-Grass Formation, Cercocarpus Formation; Wet Meadow Formation, etc. The student is referred to the excellent works of Harshberger, Shantz, Rydberg and Kirkwood. The vegetative composition is generally xerophytic, with *Stipa, Comata, Agropyron spicatum, Astralagus mollissima, Tradescantia virginica,* etc. as leading species.

Stations representing the climate of these treeless stretches are located on the lowest and most level parts of the plains within the agricultural sections. They are; Helena, Dillon, Renova, Deerlodge, Phillipsburg, and Virginia City, varying in elevation from 4,000 to 6,000 feet. For these the mean annual temperature is 43.4° F., with extremes of 103° and —40°; 187 days duration above 43 degrees, and precipitation under 15 inches per year. These values, compared with those prevailing in the Western yellow pine zones to the west, are dangerously low. Furthermore, there are on record 3 years, 1917, 1918 and 1919, when the average annual precipitation, taking the 3 years together, was below 12 inches. From 1902 to 1905, inclusive, the annual precipitation records for Helena, Havre and Miles City averaged 10.47 inches per year per station. Under such critical moisture conditions not only the natural restocking of the forest, but its maintenance and persistence in the face of fire and drought is seriously jeopardized. Temperature for the central and eastern Montana section is given in Table IX, and precipitation in Table X, and the relation of air temperature to altitude is shown in Fig. 13.

TABLE IX. *Air temperature, in degrees F., for central and eastern Montana*
From U. S. Weather Bureau Climatogical Summaries for 1921–22

Type of vegetation	Stations	Elev.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Prairies of central Montana	6 stations	4,110–5,880	14–42	22.8	25.5	33.0	42.7	50.4	58.8	65.7	64.2	54.6	44.9	33.4	24.6	43.4
Douglas fir—Lodgepole pine	Red Lodge	5,548		20.9	20.7	27.9	38.6	45.9	55.7	61.4	60.2	51.2	41.0	31.5	23.3	39.9
Douglas fir—Lodgepole pine	Hegben Dan	6,700		12.2	14.8	25.6	34.4	43.3	51.1	57.7	56.3	47.6	36.9	25.1	13.8	34.8
Subalpine forest	Lake Yellowstone	7,733		11.9	14.0	23.7	29.4	37.2	46.2	53.4	53.5	45.5	35.7	25.6	18.8	31.4

Temperature summations—degrees F.

Type of vegetation	Annual	May Sept.	Average max.—July	Average min.—Jan.	Abs. max.	Abs. min.	Days with mean			Frostless season		
							−32°	+43°	+70°	Last—spring	First—fall	Days
Prairies of central Montana	43.4	58.7	81.4	13.0	103	−45	82	187	0	5/25	9/18	116
Douglas fir—Lodgepole pine	39.9	54.9	75.4	9.1	110	−40	108	138	0	6/8	9/4	83
Douglas fir—Lodgepole pine	34.8	51.2	76.5	0.6	98	−60	130	135	0	7/3	8/15	43
Subalpine forest	31.4	47.2	70.5		94	−51	181	110	0	7/8	8/26	49

TABLE X. *Precipitation in inches, for central and eastern Montana*
From U. S. Weather Bureau Climatological Summaries for 1921–22

Type of vegetation	Stations	Elev.	Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
			years													
Prairies of central Montana	6 stations	4,110–5,880	14–42	0.62	0.54	0.83	1.30	2.63	2.33	1.21	0.93	1.46	1.03	0.70	0.61	14.19
Douglas fir—Lodgepole pine	Redlodge and Hebgen Dam	5,548–6,700		1.58	1.13	1.60	1.93	3.27	2.13	1.53	1.02	1.87	1.67	0.86	1.11	19.72
Subalpine forest	Lake Yellowstone	7,733		3.08	1.90	2.83	1.76	2.64	2.26	1.88	1.15	1.75	2.35	1.93	0.92	24.53

Precipitation summations, in inches

Type of vegetation	Mean annual	April–June	July–Sept.	May–Aug.	July–Aug.	Snowfall
Prairies of central Montana	14.19	6.26	3.60	7.10	2.14	24.2– 68.9
Douglas fir—Lodgepole pine	19.72	7.33	4.42	7.95	2.55	106.0–150.3
Subalpine forest	24.53	6.66	4.78	7.83	3.03	178

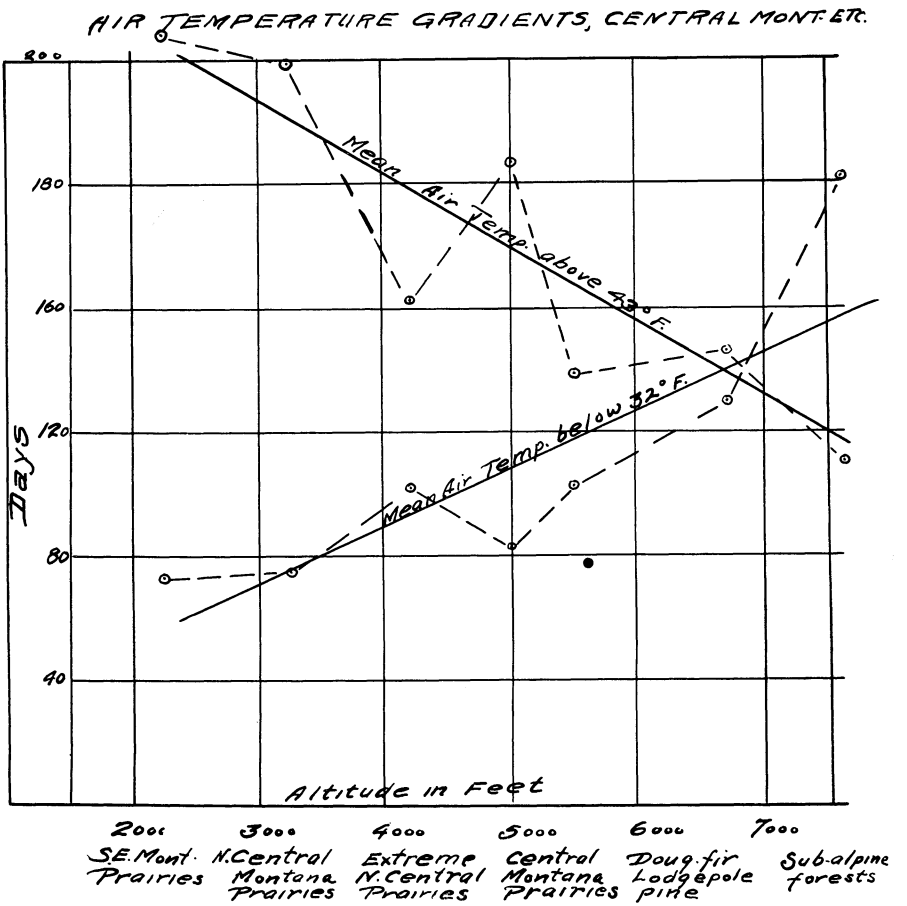

FIG. 13. Air temperature gradients for central Montana, showing the relation of altitude to the number of days with a mean temperature above 43° F., and a mean temperature below 32° F.

DOUGLAS FIR-LODGEPOLE PINE FORESTS

The outstanding and predominating forest type throughout central Montana is a mixture of Douglas fir and lodgepole pine. Leiberg ('—) has well described a typical arrangement and occurrence of the species on the Gallatin and Absaroka National Forests as follows: from 5,000 to 6,000 feet elevation limber pine and a small proportion of western yellow pine may be seen, while scattered groups of Douglas fir form thin fringes of forest which become fairly well stocked on northern slopes. From 6,000 to 8,000 feet lodgepole pine is abundant, either in closely stocked pure stands or mixed with Douglas fir and Engelmann spruce. The former is more abundant on dry, rocky slopes, while the latter occurs most commonly along canyon bottoms and places with considerable seepage. Above 7,800 feet the lodgepole thins out and is

replaced by limber pine, alpine fir and Engelmann spruce, which together constitute the subalpine forest. Timberline is found at 9,300 feet on north and east aspects and at 9,800 feet on south and west exposures; in some places on the eastern part of Beartooth Plateau it occurs at 10,000 and 11,000. Near timberline the Engelmann spruce is found in greater abundance and vigor than any other species, with limber pine second. Both are mere shrubs at the uppermost limits.

These forests are invariably even-aged in character. The Douglas fir is seen in greatest abundance on south and west aspects, while pure stands of lodgepole pine are more common on north and east slopes. It is here also that Engelmann spruce occurs especially along the creeks. Alpine fir is also rather prevalent in lodgepole pine stands on east and north aspects. It is a climax species over most parts now occupied by the Douglas fir–lodgepole pine type, being much more tolerant of shade than either of those species.

The great abundance and wide distribution of lodgepole pine is due to extensive fires, it being well known that the fire opens the cones of this species thereby making the seed available for prompt germination in the ashes. The dense young stands of lodgepole pine which have sprung up on burned ground form well-nigh impenetrable thickets.

Typical and common plant associates occurring with the Douglas fir-lodgepole pine forest are: *Delphinium cucullatum* (tall larkspur); *Geranium viscosissimum* (geranium); *Sieversia ciliata* (sieversia); *Festuca ovina* (roll leaf festuca); *Agropyron tenerum* (wheat grass); *Bromus pasteri* (drooping brome grass); *Mertensia ciliata* (bluebell); *Thalictrum occidentale* (meadow rue); *Dasiophora fructicosa* (shrubby cinquefoil); *Vaccinium scoparium* (small blueberry); *Cercocarpas ledifolius* (mt. mahogany).

A cross section of the climatic conditions of this forest type is obtained by records for Red Lodge just below the forest border at 5,548 feet, and for Hebgen Dam at 6,700, well within the upper half of the type. At Red Lodge the mean annual air temperature is 39.9° F., average maximum for July of 75.4° F., absolute maximum 110°, absolute minimum —40°; and the growing season is 138 days. This would be far too cold for western yellow pine. Red Lodge receives an annual precipitation of 19.72 inches, which is probably near the minimum for Douglas fir, and Hebgen Dam shows 24.16 inches. It is the writer's conclusion that this region receives insufficient rainfall for such mesophytic species as hemlock, white fir, western white pine, larch and cedar, which are found west of the Continental Divide. Western larch would come nearest to finding suitable moisture conditions here, but the air temperature appears far too low and the growing season too short. Larch in western Montana grows under a mean annual air temperature of 42.4° and a growing season of 170 days. The records here show a mean from 34.5 to 40.0° and a growing season 20 to 30 days shorter.

Subalpine Forests

In the subalpine forest type Engelmann spruce, alpine fir, and white-bark pine increase in proportion to increase in elevation until lodgepole and Douglas fir disappear entirely from the stand. The only available weather station for this zone is Lake Yellowstone at 7,733 feet. This shows a mean annual air temperature of 31.4° F., a growing season about 150 days, and precipitation of 24.53 inches per year. This appears much too cold for trees such as western larch, and both too dry and too cold for western hemlock, white fir, western red cedar and western white pine.

The alpine flora of the Yellowstone Park as listed by Tweedy (1886) is as follows:

Antennaria alpina Gaertn.
Aplopappus (Pyrrocoma) Lyallii A. Gray
Arenaria verna L. var. *hirta* Wats.
Arenia stricta Michx.
Artemisia scopulorum A. Gray
Astragalus alpinus L.
Bryanthus (Phyllodoce) empetriformis Smith
Castilleja pallida Kunth. var. *septentrionalis* Gray (= *C. acuminata* Pursh)
Carex atrata L.
Carex alpina Swartz
Carex concinna R. Br.
Carex seirpoidea Michx.
Carex rigida Good.
Douglasia montana A. Gray
Draba alpina L.
Draba aurea Vahl.
Draba crassifolia Graham
Dryas octopetala L.
Epilobium latifolium L.
Eritrichium aretioides DC.
Erigeron uniflorus L.
Erigeron ursinus Eaton
Erigeron radicatus Hook.
Festuca ovina L. var. *brevifolia* Wats.
Habenaria obtusata Richards
Hulsea nana A. Gray
Ivesia (Horkelia) Gordonii Hook.
Juncus Drummondii E. Meyer
Juncus Parryi Engelm.
Lloydia serotina Sweet.
Luzula spicata Desv.
Mertensia alpina Torr.
Oxyria digyna Camptd.
Pedicularis Parryi A. Gray
Pedicularis scopulorum A. Gray
Pedicularis groenlandica Retz.

Summary and Conclusion

A study of the distribution and requirements of permanent forest types in Montana and northern Idaho has led to the following conclusions:

1. The occurrence of climax or permanent forest types is mainly in altitudinal belts or zonations which are determined chiefly by air temperature and precipitation. Minor variations or differences in the forest composition within any one of these belts or zones are due to local variations in soil, aspect, gradient, etc.

2. Each of these climax belts or permanent forest types exhibits a definite requirement in temperature and precipitation which differs materially from any other type. The types at lower altitudes require relatively large amounts of heat and little moisture, and those of high elevations little heat and relatively large quantities of moisture.

3. In every case the downward extension of the type is limited by deficient moisture, while the upper limit is determined by a temperature too low for the species which occur within the given type. The grasslands exhibit a wide range of temperature requirement from 39° to 50° F. These grasslands occur wherever the annual precipitation is insufficient for tree growth. For most sections 17 inches a year or less result in grassland, regardless of air temperature.

4. Each permanent forest type exhibits a fairly definite association of vegetation in the form of annuals, shrubs, and other perennials; and these, as well as density and composition of the forest itself, react upon the site and tend to form for each forest type a fairly typical soil and surface condition. These conditions vary considerably for the different types of forest. They influence both the natural and artificial establishment of trees, and therefore the silvicultural management.

5. Since the annual precipitation is much less east of the Continental Divide than in the western sections, such mesophytic species as cedar, hemlock, lowland white fir and white pine are not present there. On the other hand, on account of the very dry summers in the western, compared to the eastern section, Douglas fir, lodgepole pine, and western yellow pine, require a greater annual precipitation in Idaho than in central Montana.

6. The following are the requirements for the various types: The western yellow pine grows with a mean annual air temperature ranging from 44° to 50° F., precipitation from 17 to 22 inches per year. The cedar-hemlock-white fir type in Idaho grows under a mean annual temperature from 40° to 45°, and an annual precipitation ranging from 27 to 44 inches. The larch-Douglas fir type in Montana requires a mean air temperature also from 40° to 45° F., but requires less moisture than the cedar-hemlock-white fir type. For the larch-Douglas fir the precipitation ranges from about 20 to 30 inches annually. The Douglas fir and lodgepole pine type thrives with a mean annual air temperature ranging from 35° to 40° F., and an annual precipitation from 20 to about 25 inches. Subalpine forests require mean air temperatures from 30° to 35° F. and precipitation varying from 24 to 30 inches in central Montana, and up to 36 inches in Idaho.

In subalpine forests the length of the growing season is usually less than 150 days, *i.e.,* the period during which the mean air temperature averages above 43° F. In western yellow pine forests on the other hand it is from 180 to 241 days.

7. It follows also that forest types of high elevations show much greater snowfall, greater depth of snow and longer duration of snow cover than the lower types. Snowfall in the subalpine type in Idaho is up to 207 inches a year, while that in western yellow pine is usually less than 50 inches. Furthermore, snow cover in subalpine regions is continuous throughout the winter, while in the western yellow pine forest the ground is often bare during warm periods in winter.

The preparation of this paper was begun on the suggestion of Raphael Zon of the U. S. Forest Service. It could not have progressed without the kind cooperation of the members of the U. S. Weather Bureau and the supervisors of the different National Forests. Valuable suggestions and criticisms have been given by J. Kittredge, Jr., G. A. Pearson, C. G. Bates, J. F. Preston, J. W. Toumey, and Robert Marshall.

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