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An ecological study of sagebrush Artemisia tridentata Nutt. in western Montana

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AN ECOLOGICAL STUDY OF SAGEBRUSH, *Artemisia tridentata* Nutt., IN WESTERN MONTANA

by

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INTRODUCTION

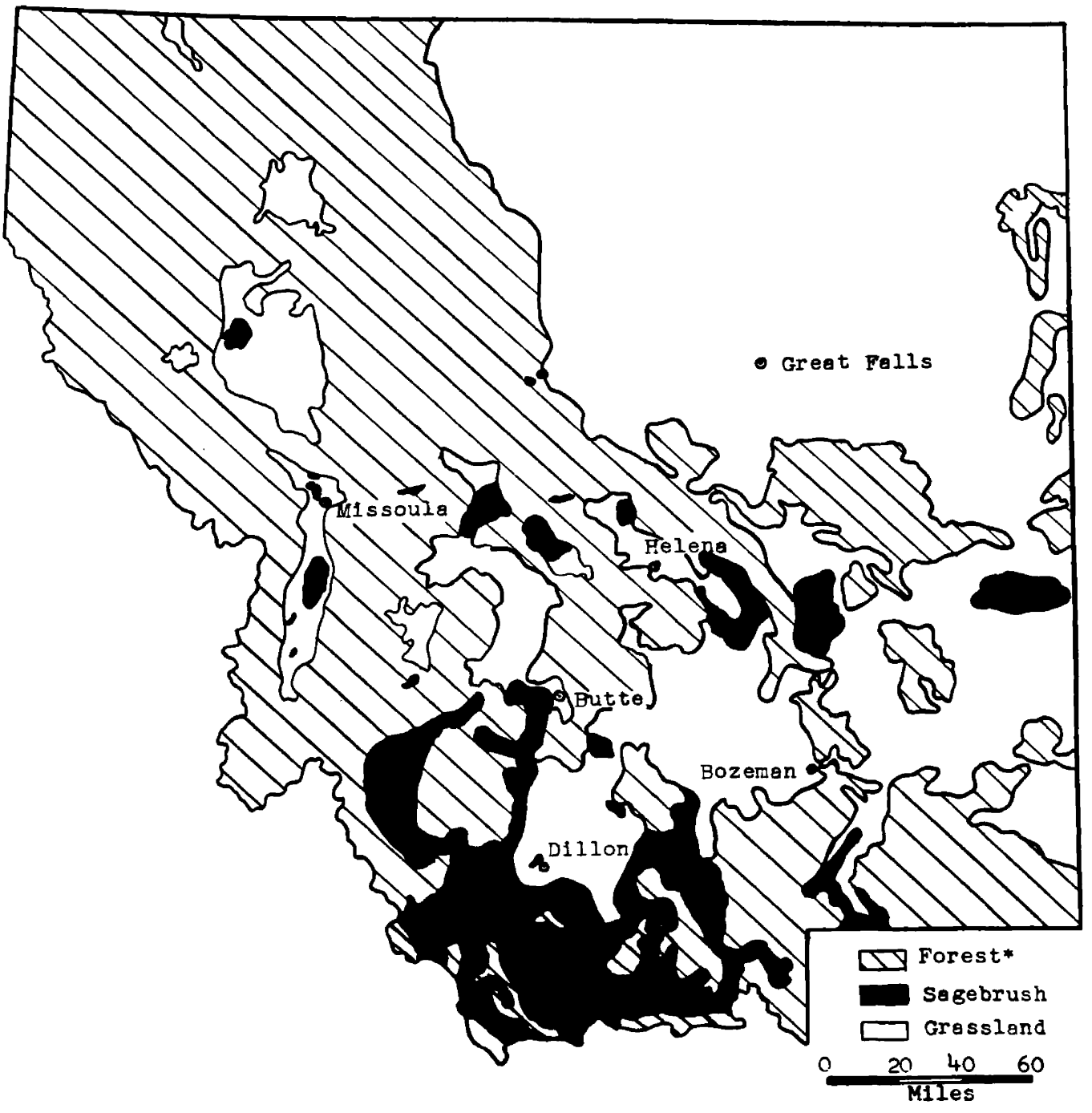
Sagebrush (Artemisia tridentata Nutt.) in varying degrees of density covers large areas in several sections of the State. In western Montana, dense isolated stands of sagebrush occur near Lonepine, Gardner Creek, Missoula, Stevensville, Greenough, Helmville, Lincoln, Townsend, Helena, Butte, White Sulfur Springs, Barber, Sheridan, and in Rochester Creek near Twin Bridges. Many other sagebrush areas, ranging in size from a few plants to several acres, also occur. The largest continuous area of sagebrush in the State extends from the Big Hole Battlefield National Monument on the west, thence southeastward through the Centennial Valley to the west boundary of Yellowstone Park (fig. 1).

Very little herbaceous forage is produced under dense stands of sagebrush (Blaisdell 1953)[1]. Although sagebrush produces a considerable volume of annual growth, it is little used by livestock. That these sagebrush areas differ in forage production from adjacent sagebrush-free grasslands is of considerable economic significance.

In addition to the lesser amounts of usable feed produced on these areas, the sagebrush stands may become so dense that they present a serious obstacle to the movement of livestock-- especially sheep. Loss of both sheep and lambs in such areas may become serious. Pulling of the fleece by the stiff limbs of the mature or dead plants may materially reduce its value. Because of the difficulty of control of the herd and the reduced visibility, losses due to coyotes and other predators may be increased.

Protection of the soil, always most important in pastoral management, may be seriously affected in sagebrush areas. The lesser amounts of the fibrous-rooted perennial grasses and the consequent reduction in

[1] Literature cited.



SAGEBRUSH DISTRIBUTION

WESTERN MONTANA

* Forest type from Forest Service (1952).

surface litter permits greater runoff and soil loss and lesser retention of soil moisture.

Before recommendations are made for management, control or removal of these stands, it is necessary to evaluate the ecological position of the species in Montana. Land managers face a different problem where sagebrush occurs in a grassland climax than where sagebrush itself is climax. When eliminated from a climax grassland, sagebrush would not ordinarily be expected to reinvade where the climax vegetation is properly maintained. In a sagebrush-grass climax, however, control and management would probably be aimed at maintaining a relatively open stand of sagebrush with a complementary stand of vigorous grasses. Finally, accurately judging range condition requires an understanding of sagebrush's ecological position in the range vegetation.

The occurrence of sagebrush in areas of apparently diverse environmental conditions has naturally led to much interest in its ecological position. Montana, lying across the northern fringe of its range, offers an excellent opportunity for the study of the factors limiting its distribution. The many discrete areas of sagebrush ranging in size from a few acres to several townships permit the isolation of environmental factors to a degree not possible in the Great Basin to the south. Furthermore, its distribution in western Montana made it possible to study the ecology of the species from an academic as well as a purely economic standpoint.

It is the purpose of this study to determine, insofar as possible, the factors governing the distribution of these sagebrush areas in western Montana.

REVIEW OF LITERATURE

The Western Range Report (Forest Service 1936) indicates that the present 96,500,000 acres of sagebrush land has increased from a pre-settlement area of not more than 90,000,000 acres. Presumably this extension of its range has occurred into grassland types both within its original boundaries and in peripheral areas.

Clements (1928), Stoddart and Smith (1943), Weaver and Clements (1938) and Sampson (1952) have reported the climax position of sagebrush in the arid or semi-arid areas of the Great Basin approximating the 10 inch or lower rainfall belt. Thornthwaite (1931) lists sagebrush as climax in the semi-arid microthermal area where precipitation deficiency occurs at all seasons. Later, in his discussion of grassland climates (Thornthwaite 1952) he indicates that sagebrush generally occurs under lower moisture conditions than tall, mixed, or shortgrass prairie, in areas of almost continuous moisture deficit, ".....where only the widely spaced desert vegetation of sagebrush and greasewood can survive the periods of low soil moisture content." The 90,000,000 acres of its original range listed in the Western Range Report (Forest Service 1936), however, would necessarily place at least some of its range in areas of higher rainfall. The reports of Fremont (1846 , Hayden (1871) and other explorers indicate the primitive occurrence of sagebrush in areas of considerably higher rainfall. Oosting (1948) considers sagebrush climax ".... in the northern part of the Great Basin or at high altitudes." Pechanec and Stewart (1949) report that good to excellent sagebrush-grass range has not seriously changed since settlement, and produces from two thirds to all of its potential forage. They indicated that few sagebrush seedlings occurred on improving ranges, but were

numerous on degenerating sagebrush-grass ranges. Piemeisel (1938) considered a combination of sagebrush and grass to be the highest type of vegetation to be expected in the natural revegetation of certain cleared sagebrush lands in the northern Great Basin. Blaisdell (1953) reports:

> "Although there may have been considerable local variation from heavy stands of sagebrush to almost pure grassland, the major part of the present sagebrush-grass type was probably an open stand of sagebrush with some other shrubs, beneath which thrived a vigorous stand of perennial grasses and forbs."

When occurring outside of the Great Basin, sagebrush has been listed as a climax dominant (Eggler, 1941; Daubenmire, 1942, 1946), as a minor component of the climax association (Stoddart 1941) and as subclimax or disclimax (Clements 1928; Weaver and Clements 1938; Stoddart and Smith 1943; Morris 1945; Tisdale 1947; Sampson 1952; and Cooper 1953).

Daubenmire (1940), in his study of the Agropyron bunchgrass prairie of southeastern Washington reports the affinity of sagebrush for sandy soils and stream terraces. Stewart, Cottam and Hutchings (1940) in a study of the salt desert plant associations of western Utah report that sagebrush may send roots 80 to 90 cm. deep in usually porous soils, rarely penetrating soils with over 1,000 ppm. salt. The Range Plant Handbook (Forest Service 1937) indicates that sagebrush does not generally occur on soils of granitic origin.

Clements (1934, 1936), Weaver and Clements (1938), Clements and Shelford (1939), Stoddart (1941), Stoddart and Smith (1943), Morris (1945), Tisdale (1947), Lommasson (1948), Sampson (1952), Blaisdell (1953), and Peterson (1953) have reported significant changes in sagebrush distributional patterns due to disturbance of fire or grazing. Humphrey (1945) discusses the sagebrush type as follows:

> "..... Extensive range areas in the Pacific Northwest that now have a big sagebrush aspect were at one time largely covered by perennial grasses. A gradual breakdown of this cover under poor grazing methods reduced competition for moisture, seeds of the sagebrush were trampled into the ground by the hooves of grazing animals, and the type changed from grassland to sagebrush.
>
> Other extensive areas, largely where precipitation was less or moisture conditions less favorable, were sagebrush-covered when the first white man saw the region."

Cooper (1953) in a recent study on the effect of grazing treatment on a sagebrush community near Tensleep, Wyoming, found that, when released from heavy grazing pressure, in eight years sagebrush was reduced from a 50 per cent coverage to 10 per cent, while in an adjacent pasture with no change in grazing practice the sagebrush composition was unchanged. Daubenmire (1940), however, found no significant change in sagebrush distribution due to these factors in the Agropyron bunchgrass prairie of southeastern Washington.

Eggler (1941), in his study of primary succession on volcanic deposits in southern Idaho, indicated that a change in relative density might occur in the present sagebrush-grass type under complete protection from fire and grazing, but that the type would not change from sagebrush to grass. He described several small relict areas, one of which was separated from any fire or grazing disturbance by approximately one mile of lava, where almost pure stands of bunchgrass occur. These areas, however, he considered atypical.

Craddock and Forsling (1938) found that overgrazing tends to result in a pure stand of sagebrush, whereas complete protection tends to permit grass to become at least equally as important as sagebrush in the climatic climax. Daubenmire (1942) reports:

> "..... The influence of heavy grazing upon the savanna-like Artemisietum tends to eliminate first the large forbs and

> grasses, and then the smaller plants, so that under extreme grazing the ground between the shrubs becomes almost barren of vegetation. . . . Under continued grazing and in the absence of fire, there is a tendency toward the development of a biotic climax consisting of a nearly pure stand of Artemisia tridentata."

Booth (1947), working on the effect of competition between grass and sagebrush on sagebrush growth and reproduction, found that in his study area in south central Montana sagebrush seedlings were unable to maintain themselves against grass competition in unused or lightly used areas. Sagebrush reproduction, he found, was characteristic of disturbed areas only.

METHODS AND PROCEDURES

Because of its highly diverse pattern of climate, topography, vegetation, soils, and history of use western Montana was chosen as the general study area. The study area extended east as far as the eastern boundary of Wheatland County, at approximately the 109th meridian. Elevations in the study area ranged from 3,000 feet near Missoula to approximately 9,000 feet at the summit of the Gravelly Range.

In mapping the generalized distribution of sagebrush throughout western Montana, every available source of reliable information was used. The final boundaries of the sagebrush type, however, were drawn during field trips to the various areas concerned (fig. 1). In addition to the sagebrush types listed on the map, several large areas with a definite grassland aspect contained scattered sagebrush plants, although these were not numerous enough to dominate the type. Examples of this are the grasslands around Bozeman and the area north and east of Lewistown.

Local type maps were drawn to show in detail the relation of sagebrush to various soil factors, topography, grazing and fire. These were drawn with plane table, aerial photos, or by pacing and compass.

In selecting paired areas for intensive study, only those pairs differing in a single apparent characteristic were chosen. Thus, north exposure was arrayed against south exposure to evaluate topographic influences, and these in turn against uplands and swales; heavy grazing was compared with conservative grazing or non-use; light soils were compared with heavy soils; and chernozem, chestnut and brown soils were compared with each other.

Analysis of the Physical Environment

Weather Bureau precipitation records, while not a satisfactory index of moisture at any particular site even within a few miles of the station, were nevertheless effective in establishing the seasonal pattern of precipitation in the sagebrush and grassland areas (fig. 2).

Local variations in site were often observed within a few feet of each other, generally due to the effects of slope, exposure, drainage, protection or exposure to wind, or other factors. Frequently these observed differences were striking enough to effect a change in soil zone.

Thorne and Peterson (1949), following the work of Schreiner and Brown (1939), have shown the relationship between organic matter content and major soil zones. Using the nitrogen-carbon ratio method of determining organic matter, they found that the surface six inches of soil in chernozems contained 3 to 6, chestnuts 2 to 4, brown soils 2 to 3, gray desert soils 1 to 2, and red desert soils 0.5 to 1 per cent organic matter. This served as a basis for local evaluation of soil zones.

In this evaluation, per cent organic matter was plotted against the nearest comparable Weather Bureau station precipitation. In order to reduce the error caused by the effect of slope, exposure and microclimate, extreme sites, either xeric or mesic, were discarded. No measure of the reliability of the curve was made, although it is believed that values taken from the smoothed curve are representative of the broad soil zones (fig. 3).

Analysis of Soils

Soil samples were taken from 33 sites throughout the study area.

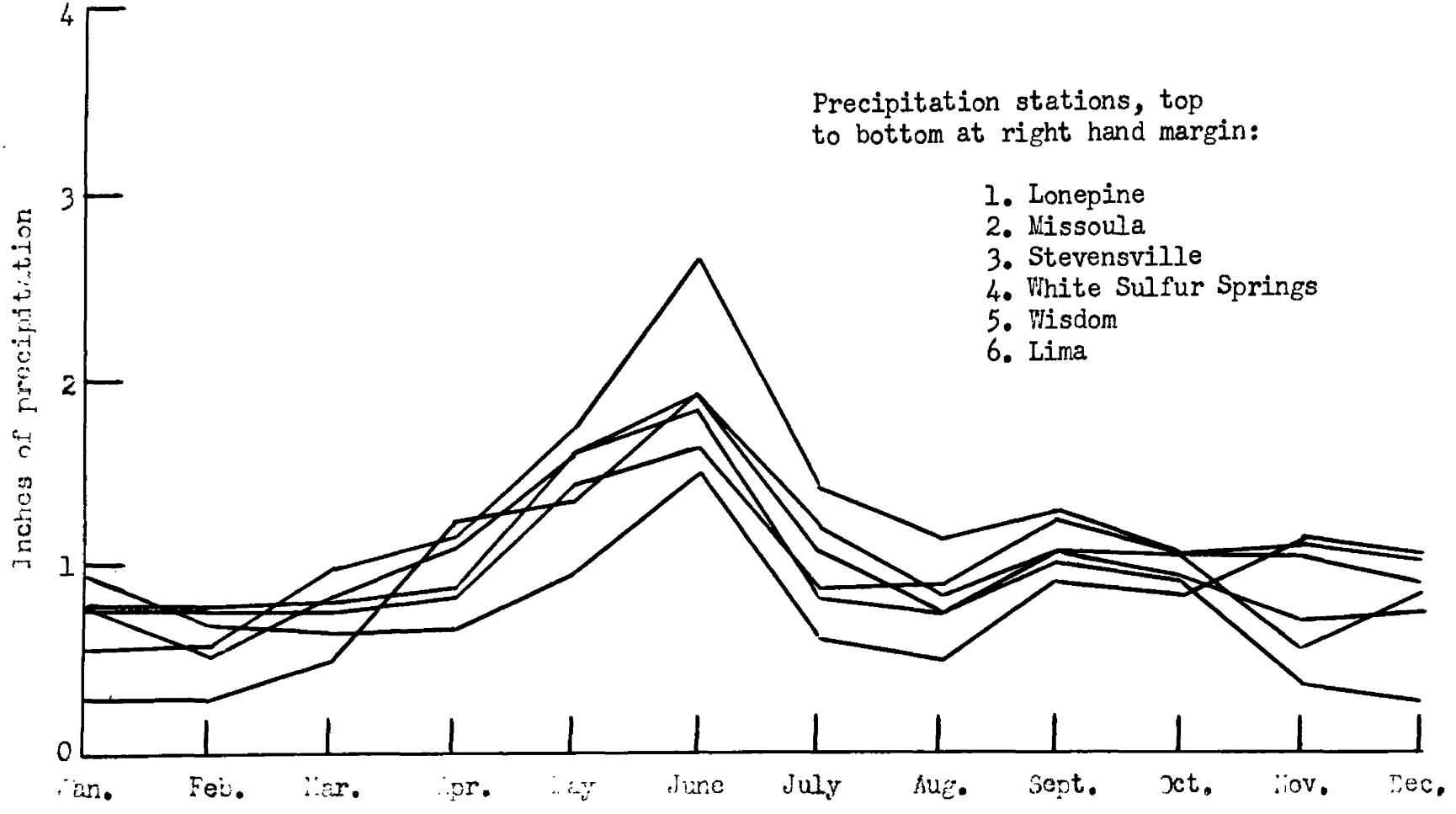
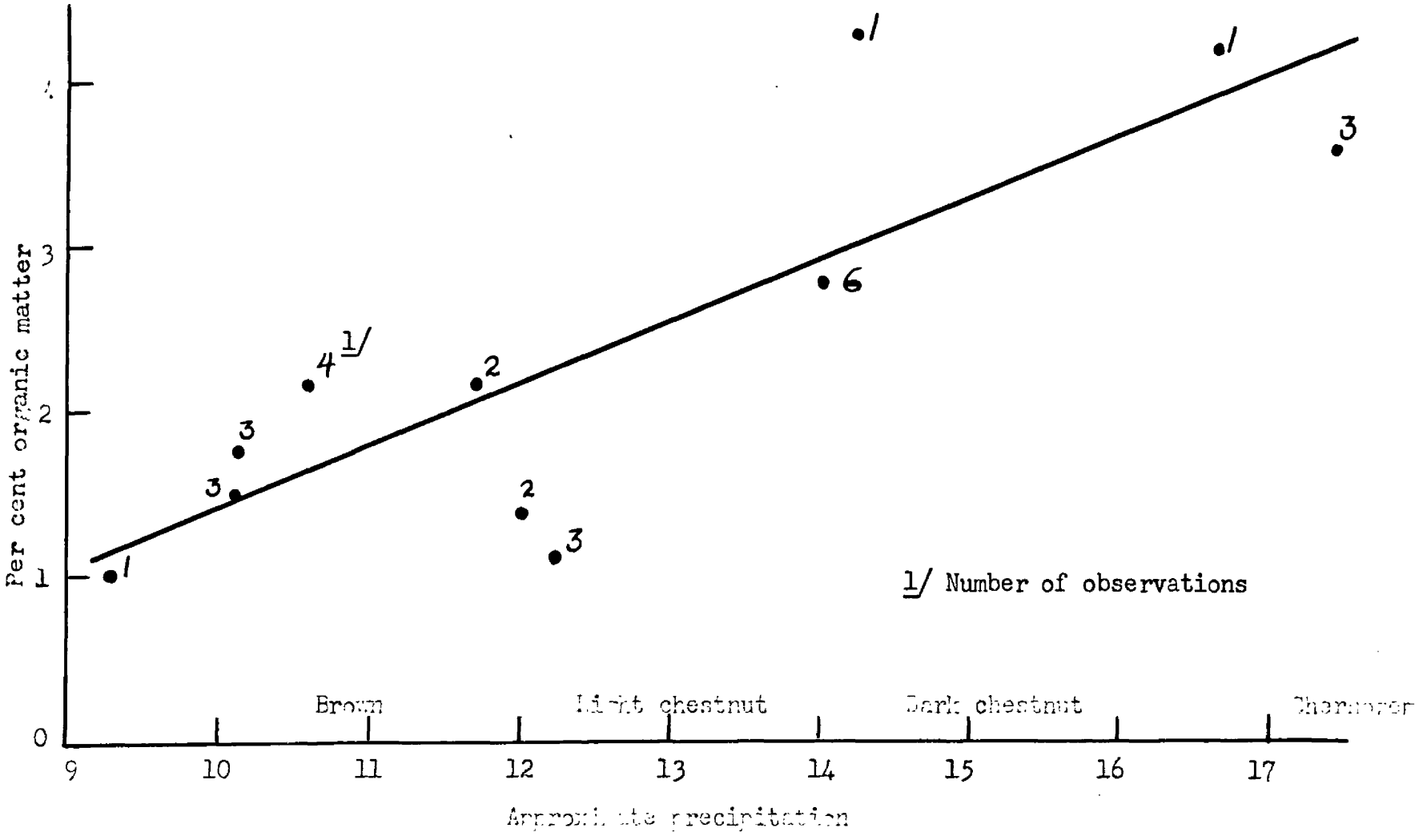


FIGURE 2

SEASONAL PATTERN OF PRECIPITATION

ON WESTERN MONTANA RANGE LANDS


Per cent organic matter
0
1
2
3
4
9
10
11
12
13
14
15
16
17
Brown
Light chestnut
Dark chestnut
Chernozem
Approximate precipitation
1/ Number of observations

11

Of these, 16 were paired grass to sagebrush, and 6 were paired light stand of sagebrush against dense stand of sagebrush. The balance of the soil samples were singles--no reasonably similar site with a significantly different floristic composition could be found in the vicinity.

A composite soil sample was taken from at least two holes at depths of 0 to 6 inches, 6 to 12 inches, and 12 to 24 inches, corresponding roughly to the three soil horizons. The portions used for soil moisture determinations were placed in air-tight aluminum canisters, which were weighed immediately upon return to the University. The soil moisture samples averaged 350 grams.

Soil moisture samples were taken only if the paired samples were taken on the same day. Soil moisture readings were not attempted after early July.

Mechanical analysis of the soils was made by the hydrometer method (Bouyoucos 1951). Salinity was determined by the Solu-Bridge Soil Tester, Industrial Instruments, Inc. (Merkle and Duncle 1944); pH was determined by the Beckman pH Meter. Organic matter was determined by the Cenco-Wilde colorimetric method (Wilde 1942). All tests other than mechanical were run in duplicate.

Analysis of Vegetation

Vegetation was analyzed by the line intercept method (Canfield 1941; Hormay 1949). Fifty foot line transects were used.

In place of the more cumbersome age-frequency determinations, the more rapid height-frequency analysis was used. This was based on the assumption that height is correlated with age in sagebrush as in

most other plants. The correlation of height with age in three typical sagebrush communities is illustrated in Figure 4.

Ten-foot diameter circular plots were used in the height-frequency analysis. The plots were established at 50 or 100 foot intervals along randomly established lines. Only those plants whose center stem fell within the circumference of the plot were tallied.

Throughout the study, botanical nomenclature followed Hitchcock (1950) for all grasses, and Davis (1952) for all other plants.

Analysis of Past Use

Of the many factors influencing sagebrush distribution, history of past use was most difficult of determination. Whenever possible, ranchers, early residents, or occasionally Forest Service and Soil Conservation Service personnel were questioned about early use of the area. The separation of current use from past use was especially difficult in view of the lack of permanent records. For example, a Palouse Prairie bunchgrass community found in the relict fenced right-of-way of the Milwaukee Railroad in Grass Valley, although fenced since about 1908, may have been heavily utilized in the 20 years prior to that date. Other areas now lightly used almost certainly have been overutilized in times past, as evidenced by invasion patterns of undesirable plants-- particularly *Bromus tectorum*, *Salsola kali*, *Schedonnardus paniculatus*, *Aristida* spp., *Chrysothamnus* spp. and *Gutierrezia sarothrae*. Healing gullies and other evidence of past erosion were considered indicative of previous excessive disturbance-- generally due to grazing. Although less frequent, some currently

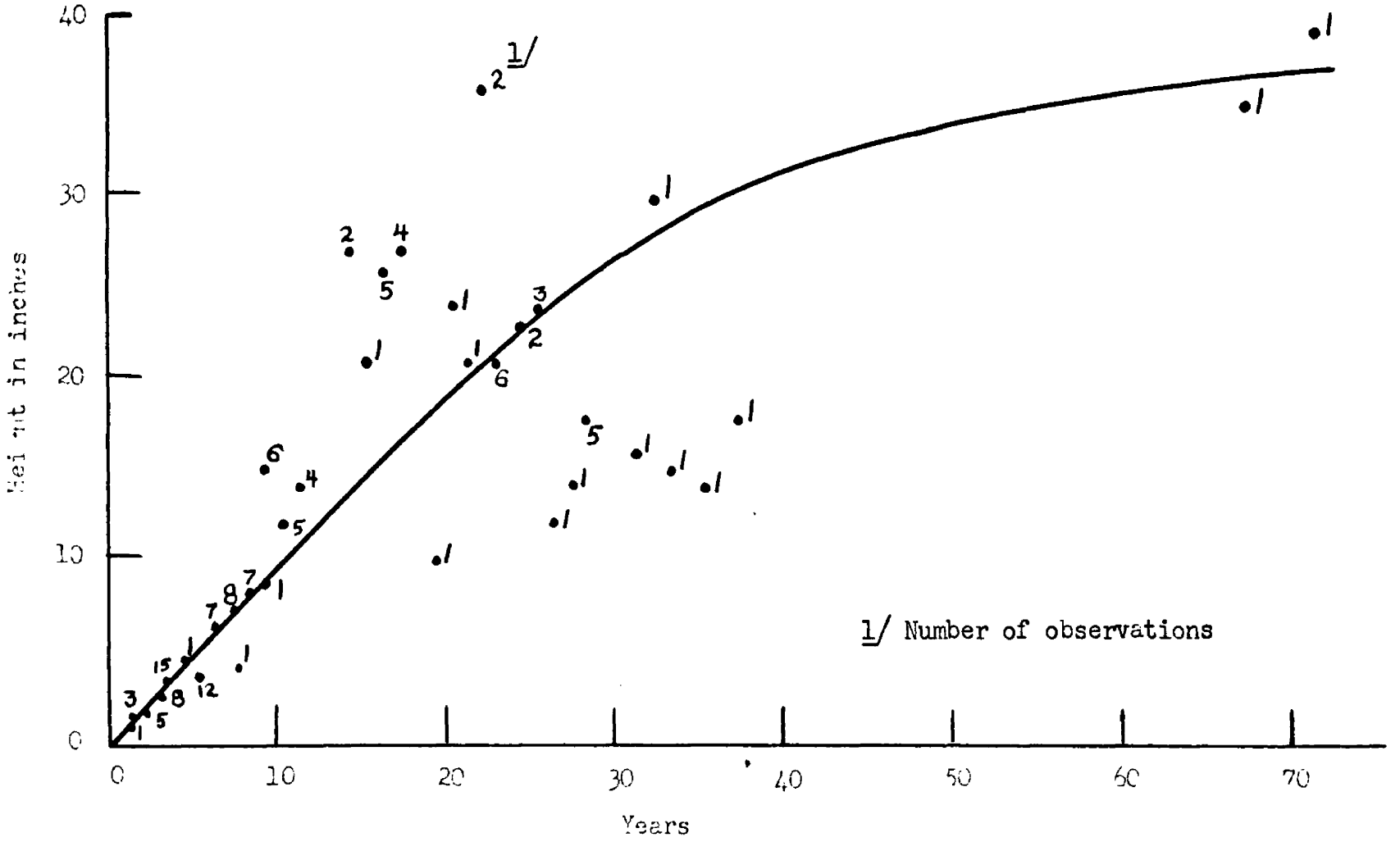


FIGURE 4

SAGEBRUSH WEIGHT RELATIONSHIP ON

UPLAND SOILS AT MISSOULA, DILLON AND HORSE PRAIRIE

heavily grazed areas gave evidence of earlier conservative grazing, as evidenced by the low amounts of noxious plants coupled with a high density of desirable forage plants of low vigor. Heavy current utilization was generally evident in such cases.

Description of Study Areas

As it was obviously impractical to study in detail the floristics of every sagebrush area in the western part of the State, several areas were singled out for intensive study. Ease of comparison of a small number of environmental factors such as grazing, soils, soil moisture, etc. was the first consideration in the choice of these areas.

Because of their small size and isolated nature, as well as their proximity to the University, several sagebrush communities in the intermountain valleys of western Montana were chosen for intensive study.

Missoula County. A small community of sagebrush occurred in Grass Valley approximately five miles west of Missoula at an elevation of 3,100 feet. The surrounding range was typical Palouse Prairie, with Agropyron spicatum, Festuca idahoensis and F. scabrella as the major dominant grasses, depending on site. In the swales and moist lowlands, Agropyron smithii and Elymus canadensis were common. Stipa comata was found generally on sandy sites, and Bouteloua gracilis was absent.

Two pastures, differing only in intensity of grazing and its results, were chosen for comparison. They were separated only by a fenced highway.

A somewhat smaller sagebrush community was found on Butler Creek, some seven miles northwest of the Grass Valley sagebrush type. The Butler Creek sagebrush occurred at a somewhat higher elevation, and

...a slightly more mesic flora. The two areas were completely isolated from each other by grasslands.

Another sagebrush community, substantially smaller than the other two, was found on Blanchard Flat near the junction of the Blackfoot and Clearwater Rivers northeast of Missoula.

Sanders County. The northwesternmost area of sagebrush encountered in the present study was found in the vicinity of Hot Springs and Lonepine. This community, covering several sections, bordered alkali flats at its lower altitudes, ranging upward to the ponderosa pine-Douglas fir type. Soils ranged from brown at the lower elevations of the sagebrush to chestnut near the boundary of the timber type.

Ravalli County. An extensive area of sagebrush covering almost two townships was found between the towns of Lolo and Stevensville east of the Bitterroot River. A relict fence corner on the Hagen Ranch within the type was used as a basis for comparing the present flora with what was probably the original cover.

Powell County. A small area of sagebrush was found east of Lincoln on dark chestnut soil. Soil samples and photographs of the area were taken, but no floristic study was made. A sharp line of demarkation was found between sagebrush and grassland (fig. 5).

A large area of sagebrush was found on the upper Blackfoot near Helmville, extending, although more or less broken, into the Nevada Creek valley and the abandoned town of Finn. In this area, sagebrush seemed to be confined almost entirely to the area east of the Blackfoot River. Several relict areas were found in this locality, as well as several pastures showing different degrees of grazing use. Soils within this community were chestnuts.

Beaverhead County. The largest area of sagebrush found was in Beaverhead County. This area, extending from the vicinity of the

FIGURE 5

SAGEBRUSH OCCURRENCE ON DARK CHESTNUT SOIL NEAR LINCOLN

Sagebrush ends at an old fence line near Lincoln, Powell County. Note sagebrush in gully in foreground surrounded by a vigorous stand of Festuca scabrella, F. idahoensis and Agropyron spicatum.

Big Hole Battlefield through the southern ends of Madison and Gallatin Counties, covers a linear distance of approximately 150 miles. This sagebrush community--or series of communities--is associated with several distinct vegetative types, ranging from the mixed prairie near Dillon through the Palouse Prairie to the sub-alpine Festuca association near the summit of the Gravelly Range. Brown, chestnut and chernozem soils were represented in this series of sagebrush communities.

Broadwater County. A horseshoe-shaped area of sagebrush was found northeast, southeast and southwest of Townsend, although none was found in the dry trench running northwestward toward Helena. Soils in this sagebrush type were generally browns and light chestnuts and were generally derived from limestones, shales and other sedimentary rocks. The associated grasslands were generally dominated by Agropyron spicatum or Stipa comata.

Silver Bow County. An extensive area of sagebrush was found near Butte, extending southward across the continental divide (with minor interruptions) to join the major sagebrush type west and south of Dillon. Near Butte, sagebrush was found to occur on light chestnut soils of granitic origin. Several large areas of Chrysothamnus spp., from which sagebrush was virtually absent, were found adjacent to dense stands of sagebrush.

Soil samples and photographs were taken in several other areas during field mapping of the type. Among these were the areas on the Smith River near White Sulfur Springs, on Rochester Creek near Twin Bridges, in Dead Man Basin near Barber in Wheatland County, and near Pray in Park County.

FIELD AND LABORATORY RESULTS

Insofar as possible, sagebrush occurrence, composition, and density were studied with respect to climatic influences, soil factors, and history of use, or various combinations of these factors.

Climatic Influences

That extensive stands of sagebrush can grow under a wide range of precipitation is evidenced by its range extending from northern New Mexico and Arizona to Montana and southern British Columbia. Sagebrush extends from the area of winter moisture in the Great Basin north into the spring-fall precipitation area of the Palouse Prairie and eastward into the summer rainfall areas of the Great Plains[2].

In western Montana sagebrush may be found in precipitation zones varying from less than 10 to more than 20 inches, ranging from the winter-rainfall areas of the western intermountain valleys to the summer-rainfall area of the eastern plains. Seasonal distribution, then, is not a seriously limiting factor.

The wide altitudinal range of sagebrush--1,500 feet to 9,000 feet(Sampson 1952)--as well as its latitudinal range indicates a high degree of tolerance to temperature extremes. In western Montana, the altitudinal range of sagebrush varies from approximately 3,000 feet in Grass Valley west of Missoula to more than 8,500 feet at the summit of the Gravelly Range. Sagebrush occurs in the cool moist areas of the upper Blackfoot, White Sulfur Springs, Wisdom, and the Cliff Lake-Hebgen Lake sections of the State as well as throughout the hot dry and

[2] Climate and Man. U. S. Dept. Agr. Yearbook of Agriculture. 1941.

cool dry areas of southern Montana. However, frequently sagebrush is absent from what appears to be the driest portions of these areas. Whereas sagebrush tends to occur in small isolated areas ranging in size from a few plants to stands occupying several sections in the cooler moister areas to the north, it extends in the south in a more or less continuous band from the Big Hole to Yellowstone Park.

Influence of Soil Factors

In order to place the broad soil zones on a reasonably quantitative basis, the organic matter content in the surface six inches was plotted against the nearest Weather Bureau precipitation records for each type studied. Because of the highly dissimilar moisture relations on xeric south slopes and moist swales, these were disregarded, as the organic matter content of these soils would probably place them in a soil zone normally found under several inches higher or lower precipitation. Even in plotting the upland soils, however, considerable variation was encountered in individual soils, probably due largely to the minor differences in microclimate, exposure, and the difference in precipitation between the Weather Bureau station and the soil sampling site (fig. 3).

Soil texture, apparently, plays but a minor part in limiting sagebrush distribution (fig. 6). Moderate to dense stands of sagebrush were found on all textural grades ranging from sandy loams to clays on brown, chestnut and chernozem soils (fig. 7). The difference between sagebrush and adjacent grassland sites, as indicated by paired soil samples, could not be attributed to soil textural class (Table I).

Sagebrush was found to occur on soils varying in pH from

FIGURE 6A

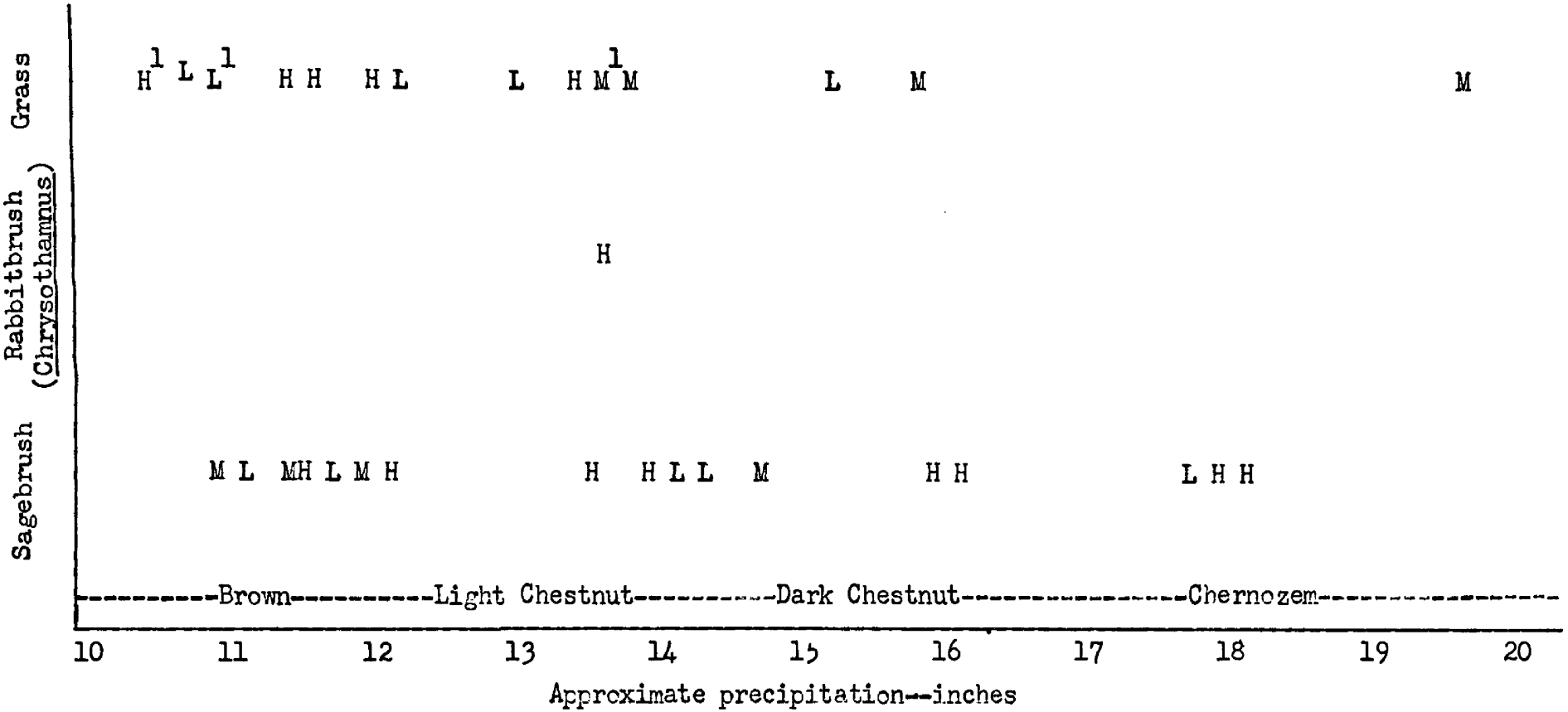
SAGEBRUSH GROWING ON COARSE, GRAVELLY SOIL

BLACKFOOT RIVER NEAR GREENOUGH

FIGURE 6B

SAGEBRUSH GROWING ON FINE TEXTURED SOIL

BLACKFOOT RIVER NEAR GREENOUGH



1 Letters H, L and M indicate an observed occurrence on heavy, light, or medium textured soil. Heavy soils include clays, clay loams and silty clay loams; light soils include sands and sandy loams; medium textured soils include sandy clay loams, loams and sandy clays.

FIGURE 7

DISTRIBUTION OF VEGETATION

BY SOIL TYPE AND TEXTURE CLASS

TABLE I

PAIRED SOIL SAMPLES

Location	Soil No.	Text. Class[1]		% Organic[1]		pH		PPM Salinity		% Moisture	
		Grass	Sage	Grass	Sage	Grass	Sage	Grass	Sage	Grass	Sage
Hagen Ranch	4,[2] 5a[3]	sand	sandy	1.0	1.2	6.5	6.6	min.[4]	min.	11.5	11.1
	b		loam			6.4	7.2	min.	180	11.2	13.6
	c					6.5	8.4	320	420	11.7	11.6
Grass Valley	1, 8a	clay	clay	1.5	1.5	7.3	7.1	560	200	19.8	19.1
	b					8.0	7.8	320	980	22.5	19.0
	c					7.8	8.0	4,800	3,700	16.9	15.1
Helmville	11, 33a	sandy	sandy	1.7	1.6	6.2	6.5	min.	100		20.5
	b	loam	loam			6.9	6.8	440	min.		16.4
	c					7.7	8.0	500	380		11.7
Lonepine (Alkali flat)	14, 13a	clay	clay	0.2	1.4	9.8	8.6	3,800	2,700	10.5	12.1
	b					10.1	8.0	6,800	6,600	13.2	15.1
	c					9.9	8.5	4,200	800	14.5	15.1
Barber	21, 22a	sandy	sandy	2.3	1.2	7.8	7.5	280	200	5.7	6.7
	b	clay	clay			8.0	8.2	320	700	6.9	13.4
	c	loam				8.2	8.4	1,360	1,840	4.8	14.4
Radersburg	24, 23a	clay	sandy	1.6	1.7	8.0	7.2	380	380	9.2	5.2
	b	loam	clay			8.3	8.1	280	460	10.6	9.2
	c		loam			8.7	8.2	640	320	8.9	5.9
Lincoln	30, 31a	loam	sandy	4.5	2.7	6.0	5.9	min.	min.		
	b		loam			6.1	6.2	min.	min.		
	c					6.1	6.4	min.	min.		
Dillon	18, 17a	sandy	loam	1.6	1.3	7.8	6.6	260	240	15.0	6.6
	b	loam				7.8	8.0	900	880	17.3	8.0
	c					7.4	8.1	4,200	1,720	16.2	8.1

1 Texture class and organic matter for 0 to 6 inch soil depths.
2 First number is grassland soil, second is sagebrush soil.
3 a, b and c is 0 to 6, 6 to 12, and 12 to 24 inch soil depths, respectively.

5.9 to 8.6, although the general range was from neutral to slightly acid (fig. 8). On brown or light chestnut soils, sagebrush tended to occur on less alkaline soils than the associated grass types, whereas on dark chestnut and chernozems, sagebrush soil tended to be more alkaline than the associated grass types (fig. 9). While the data for grasslands represents at least two and possibly three grassland associations, the adjacent sagebrush soils were developed under climatic and geologic conditions similar to the adjacent grassland soils.

The tolerance limit of sagebrush with respect to soil salinity has been reported to be approximately 1,000 ppm. (Stewart, Cottam and Hutchings 1940). On one alkali flat near Lonepine, Montana, a considerably higher limit of salinity--6,600 ppm.--was found under a sagebrush stand bordering a saltgrass community (fig. 10). No attempt was made to determine the cause of such high salt tolerance; possibly highly salt-tolerant varieties may occur in the very large Artemisia tridentata genetic complex. This, although representing the highest salinity value, was not unique; three other sites ranging from 1,720 to 3,700 ppm. were found in the study. With one exception representing no significant difference, however, sagebrush grew on soils considerably less saline than the associated grasslands. This was especially noticeable in the low rainfall areas near Lonepine, Dillon and Barber.

An interesting correlation was found between sagebrush and soil moisture (fig. 11). Sagebrush consistently grew on sites with similar or better moisture relations than the associated grasslands. The better moisture relations on such sites were not obvious when due to some compensating factor such as lessened grass competition, rockiness, or sandy soils. Under moderate to light grazing intensity, once established, sagebrush

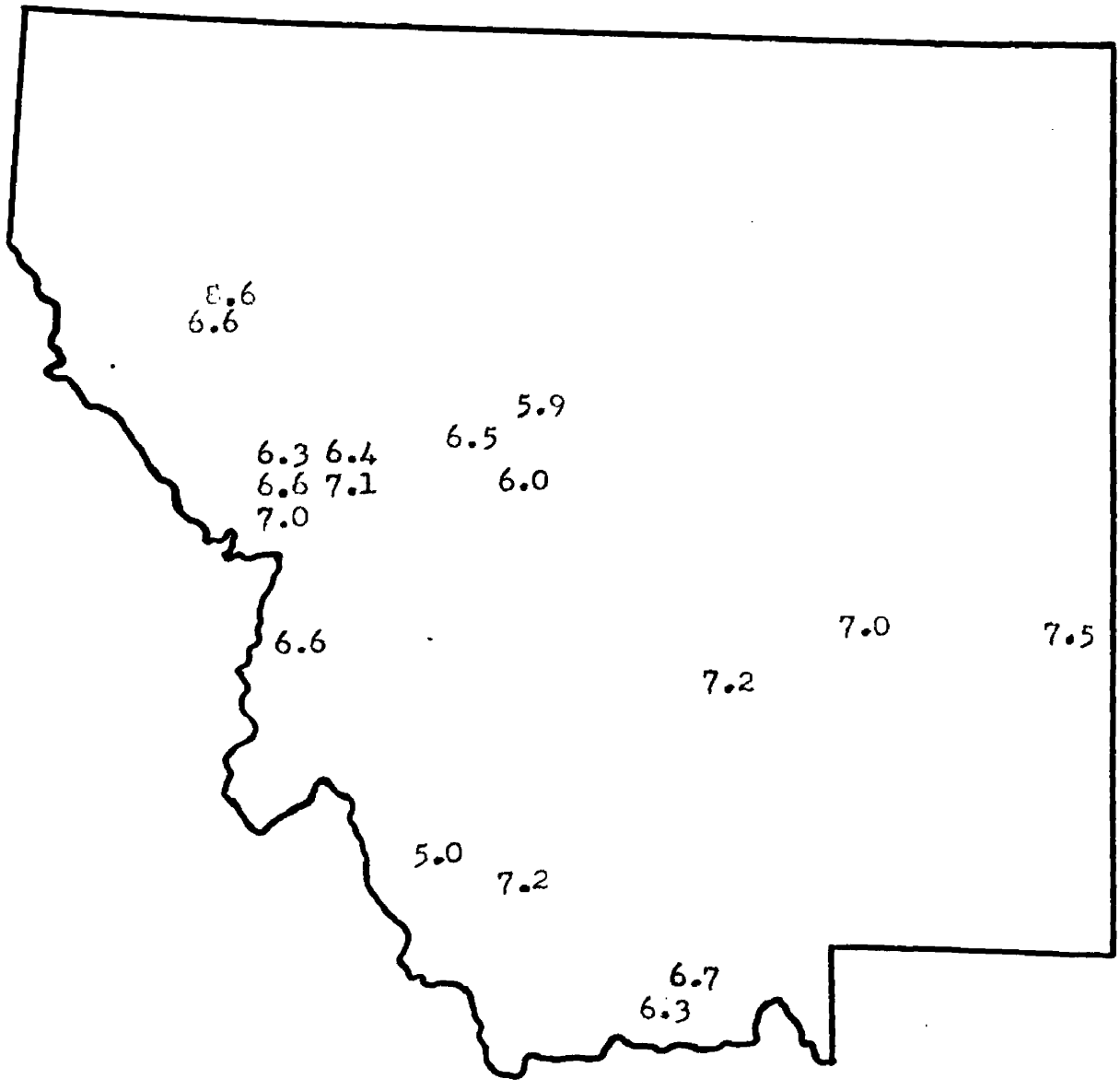


FIGURE 8

pH READINGS IN SAGEBRUSH SOILS,

WESTERN MONTANA

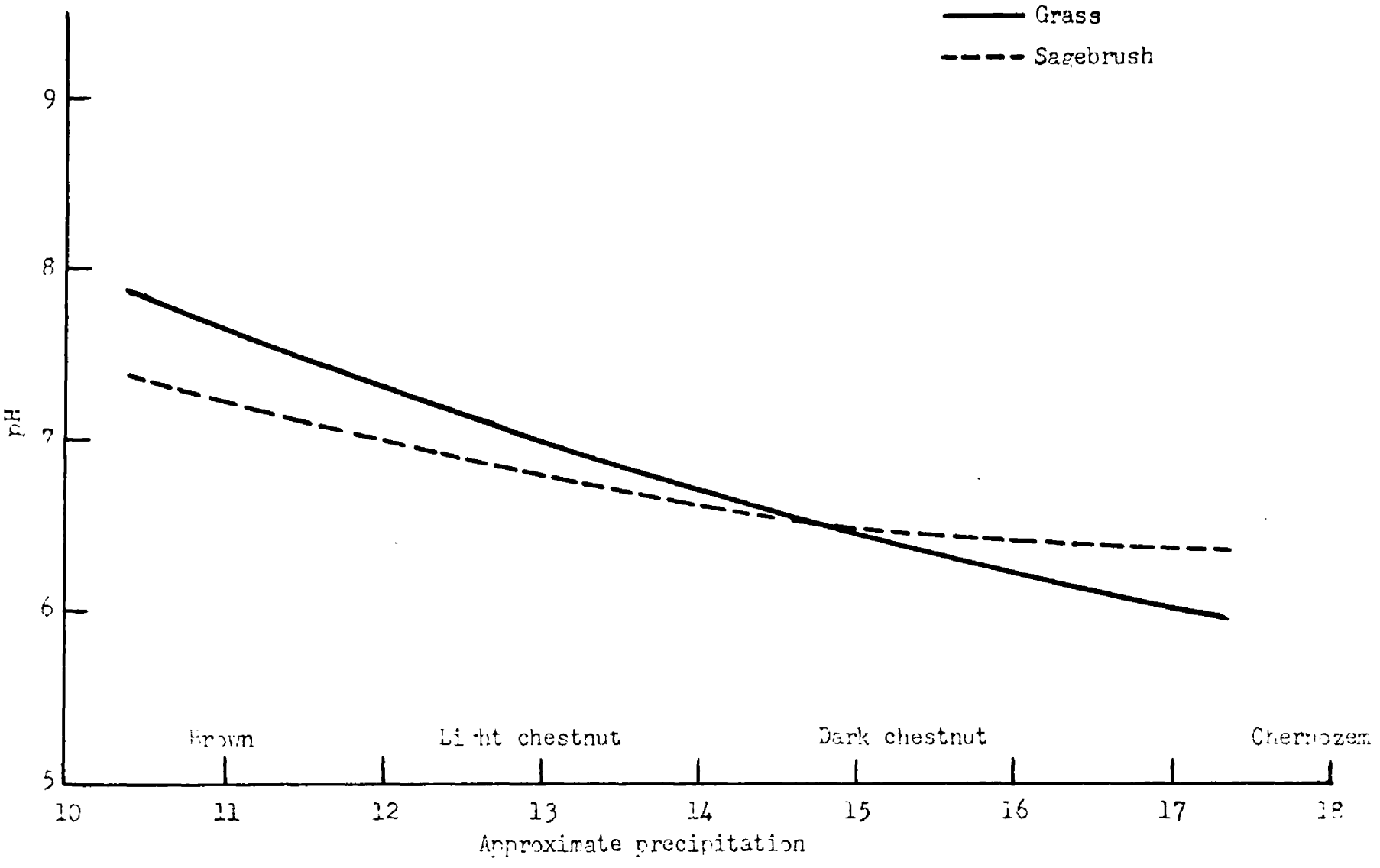
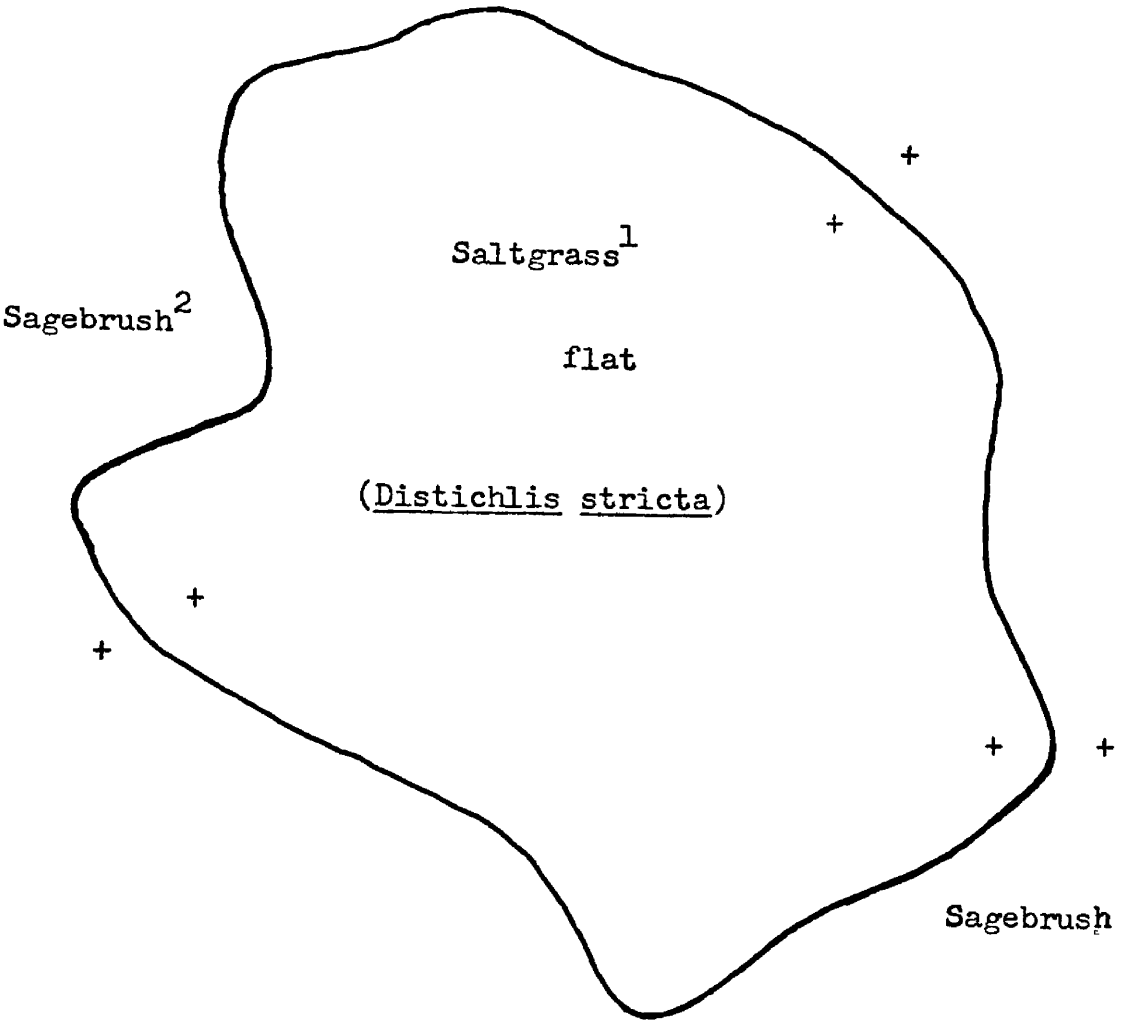


FIGURE 9

GENERAL RELATIONSHIP BETWEEN pH AND SOIL TYPE

OF SAGEBRUSH AND GRASSLAND SOILS



	pH		PPM Salinity	
	(1)Grass	(2)Sagebrush	Grass	Sagebrush
0- 6"	9.8	8.6	3,800	2,700
6-12"	10.1	8.0	6,800	6,600
12-24"	9.9	8.5	4,200	800

\+ Soil sample locations.

FIGURE 10

TOLERANCE LIMITS OF SAGEBRUSH ON AN ALKALINE FLAT

NEAR LONEPINE, MONTANA

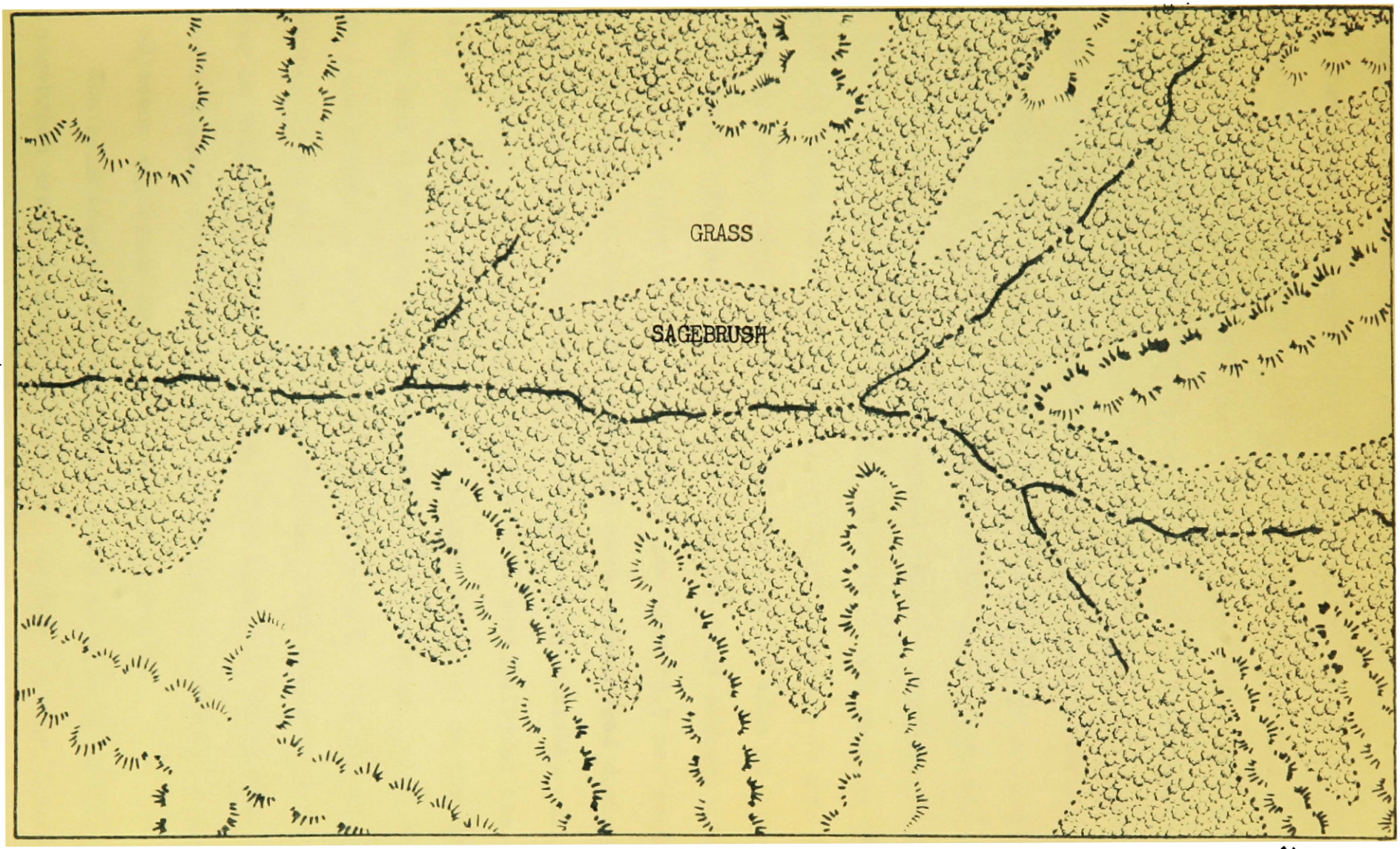


FIGURE 11

SAGEBRUSH DISTRIBUTION IN RELATION TO TOPOGRAPHY

GRASS VALLEY

was generally confined to the more mesic north slopes, swales, or sandy sites throughout much of its range (fig. 12a, b); heavy grazing, with the reduction in grass cover serving in effect to increase the moisture available to sagebrush, permitted the latter to invade more xeric sites than were normally available to it. In two adjacent sagebrush areas in Grass Valley differing only in intensity of grazing use, sagebrush made up 30.8 per cent of the vegetative cover on the mesic north slopes under heavy grazing use, and 29.5 per cent under moderate grazing use. On the xeric south slopes, however, sagebrush in the heavily grazed pasture made up 34.9 per cent of the vegetative cover, whereas sagebrush constituted but 3.7 per cent of the cover in the moderately used pasture (Table II). Within the moderately used pasture, sagebrush occurred on soils whose average moisture content for the first two feet at time of sampling (April 10-22, 1952) was 30.1 per cent; the moisture content of the grass-covered upper slopes of the same pasture averaged 19.7 per cent.

Two areas of tree-like sagebrush were encountered during the course of the study, both occurring on deep sandy unstable soils in the beds of creeks, and within four or five feet vertically of the water level. The first, intermingled with willow and alder on the banks of the Red Rock River near Lima, had unbranched sagebrush trunk diameters up to 11.2 inches at six inches above the ground. The second area, in Rochester Creek near Twin Bridges, had sagebrush stems up to 12 feet 2 inches in height (fig. 13). In the first instance, sagebrush on the adjacent uplands averaged from 18 to 20 inches in height; in the second, the adjacent sagebrush averaged 22 inches in height.

The relationship between soil samples of several paired grass and sagebrush areas is shown in Table I. Except for the Lonepine and

FIGURE 12A

SAGEBRUSH LIMITED TO MOIST SWALES AND NORTH EXPOSURES. LIGHTLY GRAZED PASTURE IN GRASS VALLEY

FIGURE 12B

SAGEBRUSH OCCURRENCE IN SWALES

DILLON

TABLE II

COMPOSITION OF TWO RANGES IN GRASS VALLEY NEAR MISSOULA

	Lightly grazed			Heavily grazed		
North exposure	Total intercept[1]	Number of plants[2]	Per cent composition	Total intercept[1]	Number of plants[2]	Per cent composition
Achillea lanulosa	.2	1.5	.4	1.1	9.5	3.2
Agropyron spicatum	27.5	78.5	61.2	16.9	83.0	46.6
Artemisia tridentata	13.2	22.5	29.5	11.2	26.0	30.8
Chrysothamnus lanceolatus	.2	1.0	.4	3.9	11.5	10.7
Koeleria cristata	.7	3.0	1.5	.3	2.0	.8
Phlox sp.	1.0	4.0	2.0	1.9	9.0	5.2
Poa secunda	.6	5.5	1.4	.8	7.0	2.2
Stipa comata	.2	.5	.4			
Vicia americana	1.5	.7	3.2	.2	1.5	.5
Total	45.1		100.0	36.3		100.0
South exposure						
Achillea lanulosa				.2	1.0	.6
Agropyron spicatum	31.3	11.5	88.1	13.1	50.0	48.8
Artemisia tridentata	1.3	5.0	3.7	9.4	20.0	34.9
Chrysothamnus lanceolatus	.9	2.5	2.5	3.6	10.0	13.7
Phlox sp.	1.4	5.5	4.0	.3	2.0	1.0
Poa secunda	.6	5.0	1.7	.3	1.5	1.0
Total	35.5		100.0	26.9		100.0

1 Total for three 50-foot transects.

2 Average for three transects.

Radersburg areas which represent excessively high salinity and pH values, no significant difference can be detected in the soil factors in the several areas.

Influence of Grazing

The search for relict areas or areas showing a significantly different floristic composition on similar sites but under different patterns of use was one of the first problems encountered in attempting to evaluate grazing as a factor in the distribution of sagebrush. Relict or other "fence-line" patterns were found in the Bitterroot Valley, Grass Valley, Hot Springs, upper Blackfoot (three areas), Grasshopper Creek, Dillon, and the Tobacco Root Mountains.

Grass Valley. Two fenced pastures lying on opposite sides of old U.S. 10 between Frenchtown and Missoula were studied in some detail. Pasture A, south of the highway, was lightly to moderately grazed at the time of the study, and gave little evidence of previous overuse. However, Festuca scabrella, a highly palatable indicator species found in a nearby railroad right-of-way, was not found in even the moderately grazed pasture. Pasture B, north of the highway, was heavily used at the time of the study, and gave evidence of previous overuse for a number of years. Many bare areas, the low density and vigor of the perennial bunchgrasses, and the abundance of noxious weeds (especially Grindelia squarrosa) indicated that the current pattern of use was of long standing.

The sagebrush composition on the mesic north slopes of Pasture A and Pasture B showed little variation; sage composed 29.5 percent of the vegetative covering of the north slopes in Pasture A, and 30.8

per cent in Pasture B. In the moderately grazed Pasture A, Agropyron spicatum made up 61.2 per cent, and in the heavily grazed Pasture B, 46.6 per cent of the composition. The difference between the two pastures became more obvious in a comparison of the xeric south slopes; whereas Pasture A had only 3.7 per cent sagebrush, Pasture B had 34.9 per cent on comparable sites (Table II). In addition, Pasture A contained almost twice as much Agropyron spicatum as Pasture B, or an increase of from 48.8 to 88.1 per cent.

A height-frequency analysis of the same two pastures reveals some interesting comparisons. Twenty systematically spaced plots on the upland soils in each pasture gave essentially the same size-class distribution. However, approximately eight times as many sagebrush plants were encountered in the heavily grazed as in the lightly grazed pasture (Table III). On the relatively more mesic sites in this area, sagebrush, once established, was able to maintain itself at a fairly high population level in both the moderately and heavily used pastures; on the drier upland soils, however, sagebrush was reduced to a relatively low population level by the healthy, vigorously competing bunchgrasses on the moderately used pasture.

Another small, disconnected island of sagebrush in the Missoula area was found on Butler Creek, about seven miles airline from the Grass Valley sagebrush type. Analysis of the Butler Creek sage area indicated that the flora there is slightly more mesic, with Festuca idahoensis and F. scabrella (missing from the Grass Valley type) as the dominant grasses (Table IV). The dense but localized sagebrush stand, the presence of old holding corrals, and evidences of past erosion indicated that the area was at one time very heavily used.

TABLE III

HEIGHT-FREQUENCY ANALYSIS OF FOUR SAGEBRUSH AREAS

IN WESTERN MONTANA

Height class inches	Missoula				Centennial Valley				Helmville						Cliff Lake Natural Area	
	Pasture A[1]		Pasture B[2]		Burned		Unburned		Lightly grazed			Heavily grazed				
	No.[3]	%	No.	%	No.	%	No.	%	No.	No.[4]	%	No.	No.[4]	%	No.	%
0- 3	3.4	63.6	29.0	63.8	14.0	81.4	144.0	77.2	29.6		78.3	61.6		77.7	0.6	9.1
4- 6	1.0	17.8	9.2	20.4	3.0	17.4	24.0	12.8	2.2	0.8	5.8	8.6		10.8	0.6	9.1
7- 9	0.6	10.3	3.8	8.4	0.2	1.2	6.0	3.2	2.2	0.2	5.8	1.8		2.3	0.4	6.1
10-12	0.2	3.7	2.0	4.4			3.0	1.6	1.2	0.8	3.2	0.8		1.0	0.4	6.1
13-15	0.1	0.9	0.9	2.0			3.0	1.6	1.6	0.6	4.3	1.4	0.2	1.8	0.2	3.0
16-18	0.2	3.7	0.4	0.7			1.2	0.6	0.6	0.4	1.5	1.2	0.2	1.5	0.4	6.1
19-21			0.1	0.1			2.4	1.2	0.4	0.2	1.1	1.0		1.2	0.2	3.0
22-24			0.1	0.1			1.6	0.9				0.8		1.0	0.8	12.0
25-27			0.1	0.1			1.6	0.9				1.0		1.2	0.4	6.1
28-30												0.8		1.0	1.0	15.1
31-33												0.4		0.5	0.4	6.1
34-36															0.6	9.1
37-39															0.6	9.1
40+																
Total	5.5		45.6		17.2		186.8		37.8	3.0		79.4	0.4		6.6	

1 Lightly to moderately grazed pasture south of Frenchtown road in Grass Valley.

2 Heavily grazed pasture north of Frenchtown road in Grass Valley.

3 Average per 10-foot diameter circular plot. Twenty plots at Missoula, five at all others. Plots systematically spaced on upland soils at 50 foot intervals.

4 Dead plants.

TABLE IV

COMPOSITION OF A SAGEBRUSH AREA ON

BUTLER CREEK NORTHWEST OF MISSOULA

Species	Intercept--feet[1]	Number of plants	Per cent composition
Achillea lanulosa	2.5	12	2.8
Agropyron spicatum	1.8	6	2.0
Antennaria sp.	0.8	2	0.9
Artemisia tridentata	47.8	24	53.5
Aster sp.	0.1	1	0.1
Balsamorhiza sagittata	14.0	26	15.6
Bromus tectorum	0.9	2	1.0
Carex filifolia	0.3	1	0.3
Festuca idahoensis	13.7	48	15.4
F. scabrella	4.1	9	4.9
Koeleria cristata	0.8	4	0.9
Lithospermum sp.	0.3	1	0.3
Lupinus sp.	1.8	6	2.0
Symphoricarpos sp.	0.3	1	0.3
Total	89.2		100.0

1 Total for 150 feet of transect line.

The flora of several heavily used pastures adjacent to the Grass Valley sagebrush type is difficult of explanation in the light of data obtained in this study. The vegetation of one of these areas, a heavily used pasture near DeSmet, was compared with an adjacent relict railroad right-of-way. Agropyron spicatum made up 70.3 perccent of the composition on the relict, with Festuca scabrella 0.6 and Chrysothamnus sp. 5.6 per cent. Sagebrush was not found in the relict area. On the heavily grazed adjacent pasture, Agropyron spicatum made up only 49.5 per cent of the vegetation, Festuca scabrella was absent, sagebrush composition was only 0.2 per cent, but Chrysothamnus sp. increased to 19.5 per cent, thereby apparently taking the place occupied by sagebrush in the Butler Creek and Grass Valley areas (Table V). There was no apparent difference between the DeSmet and Grass Valley soils, both being light chestnuts, the heavy clay soils being in each case of lacustrine origin.

Bitterroot Valley. Two small, separate areas of sagebrush were found near the towns of Victor and Grantsdale. A third area, much larger than the other two, covers approximately two townships in the lower foothills east of the Bitterroot River generally northeast of Stevensville. A relict fence corner, unused for an undetermined number of years, was found in the latter area on the Hagen Ranch.

In the relict area, sagebrush composed 6.4 per cent, and Agropyron spicatum 51.5 per cent of the vegetation. In the adjacent heavily used pasture, sagebrush composed 47.2 per cent, and Agropyron spicatum 6.2 per cent of the vegetation (Table VI). Poa secunda was common in both pastures. A large amount of dead sagebrush was found in the relict area, some of which was probably killed by a light grass fire two years previous. The fire in this case was so light that even the smaller twigs of the sagebrush were not consumed, evidence of the fire being found

TABLE V

A COMPARISON OF TWO PLANT COMMUNITIES

NEAR DeSMET

Species	Ungrazed[1]			Heavily grazed[2]		
	Intercept --feet[3]	No. of plants	Per cent composition	Intercept --feet[3]	No. of plants	Per cent composition
Achillea lanulosa				2.7	16	6.7
Agropyron spicatum	33.7	136	70.3	20.1	124	49.5
Artemisia tridentata				0.1	1	0.2
Chrysothamnus sp.	2.7	9	5.6	7.9	22	19.5
Festuca scabrella	0.3	3	0.6			
Koeleria cristata	0.1	1	0.2	0.6	4	1.5
Malvastrum sp.				0.6	4	1.5
Phlox sp.	2.4	9	5.0	0.3	2	0.7
Poa pratensis				0.3	2	0.7
P. secunda	8.6	57	17.9	8.0	64	19.7
Vicia sp.	0.2	1	0.4			
Total	48.0		100.0	40.6		100.0

1 South of fence in relict railroad right-of-way.

2 North of fence in heavily grazed pasture.

3 Total intercept for 150 feet of transect line.

TABLE VI

COMPOSITION OF TWO ADJACENT

RANGE AREAS, HAGEN RANCH, STEVENSVILLE

Species	Relict fence corner			Heavily grazed pasture		
	Intercept per 100 feet	Plants per 100 feet	Per cent composition	Intercept per 100 feet	Plants per 100 feet	Per cent composition
Achillea lanulosa	0.2	2.5	1.3	1.2	12.0	6.0
Agropyron spicatum	7.6	36.5	51.0	1.2	11.5	6.0
Artemisia frigida	0.3	2.0	2.0	1.3	6.0	6.5
A. tridentata (living)	1.0	1.0	6.7	9.4	17.0	47.3
A. tridentata (dead)[1]	7.2	5.0				
Bromus tectorum	0.6	6.0	4.0	0.8	7.0	4.0
Chrysothamnus sp. (living)	0.2	0.5	1.3			
Chrysothamnus sp. (dead)[1]	0.8	0.5				
Koeleria cristata	1.1	10.0	7.4	1.0	11.5	5.0
Lewisia rediviva				0.2	2.0	1.0
Lomatium sp.	0.8	7.0	5.4	0.6	5.0	3.0
Lupinus sp.	0.1	1.0	0.7			
Opuntia polycantha	0.1	0.5	0.7			
Poa pratensis	0.7	-	4.7	0.2	-	1.0
P. secunda	1.5	15.5	10.0	3.6	35.0	18.2
Taraxacum officinale	0.1	0.5	0.7			
Tragopogon sp.	0.1	1.5	0.7			
Verbascum thapsis	0.1	0.5	0.7			
Others	0.4	3.5	2.7	0.4	4.0	2.0
Total	14.9		100.0	19.9		100.0

1 Some Artemisia tridentata and Chrysothamnus sp. apparently killed by very light burn two years previous (in 1950). Range grass outside relict area too thin to support fire, hence the sagebrush in heavily grazed pasture unaffected.

mainly on the bark of the dead sagebrush plants and in the crowns of the grass plants. The adjacent heavily grazed range was covered by a grass cover too light to support fire, and hence was unaffected. The area probably burned during a cool, moist period.

Upper Blackfoot Valley. A relict fenced road right-of-way was compared with an adjacent heavily grazed pasture near Brown's Lake north of the Ovando-Helmville road. In the relict area, neither Artemisia tridentata nor A. tripartita was found, while Stipa comata and S. columbiana together made up 56.7 per cent of the vegetation. On the adjacent heavily grazed pasture, Stipa comata and S. columbiana were not encountered in the transects, and Artemisia tridentata and A. tripartita together composed 82.7 per cent of the vegetation (Table VII). Poa pratensis, although comprising but 4.4 per cent of the vegetation in the relict area, made up 14.4 per cent of the vegetation in the heavily grazed pasture, indicating the relatively mesic conditions under which the two species of Artemisia occurred. Both areas were flat and relatively well drained, and there was no obvious site difference in the two areas.

Near Helmville, the vegetative composition of two adjacent pastures differing only in the degree of livestock utilization was compared (fig. 14). In the lightly grazed pasture, sagebrush made up 43.0 per cent of the vegetation, Agropyron spicatum 11.4 per cent, and the highly palatable Festuca scabrella 15.7 per cent. On the adjacent heavily grazed pasture, sagebrush made up 83.0 per cent of the vegetation, while Agropyron spicatum and Festuca scabrella were absent. Festuca idahoensis made up 3.4 per cent of the vegetation under light use, but was missing from the heavy use pasture. The abundance of Poa

TABLE VII

COMPOSITION OF TWO ADJACENT RANGE

AREAS, BROWN'S LAKE, UPPER BLACKFOOT VALLEY

Species	Lightly grazed pasture			Heavily grazed pasture		
	Intercept per 100 feet	Plants per 100 feet	Per cent composition	Intercept per 100 feet	Plants per 100 feet	Per cent composition
Achillea lanulosa	0.1	1.0	0.9			
Antennaria sp.	0.2	2.5	1.9	0.1	1.0	0.6
Artemisia tridentata				12.3	20.0	75.5
A. tripartita				1.2	7.0	7.4
Carex filifolia	0.6	5.0	5.7	0.1	1.0	0.6
Eriogonum sp.	0.2	1.5	1.9			
Geranium viscosissimum	0.2	2.0	1.9			
Koeleria cristata	0.3	3.0	2.8			
Lithospermum ruderale	0.2	0.5	1.9			
Lupinus sericeus	0.1	0.5	0.9			
Poa pratensis	0.6	4.5	5.7	2.3	21.0	14.1
Potentilla sp.	0.1	0.5	0.9			
Solidago sp.	0.6	4.0	5.7	0.3	4.0	1.8
Stipa columbiana	0.6	5.0	5.7			
S. comata	6.6	49.0	62.2			
Others	0.2	1.5	1.9			
Total	10.6		100.0	16.3		100.0

FIGURE 13

TREE-LIKE SAGEBRUSH STAND ON SANDY

SOIL IN ROCHESTER CREEK BASIN

FIGURE 14

MODERATELY AND HEAVILY USED PASTURES

ON WES POLLEY RANCH NEAR HELMVILLE

secunda was relatively unchanged in the two pastures (Table VIII). The textural class of the dark chestnut soils in each pasture was a clay loam. The gentle north slope, generally less than 10 per cent, was similar in the two pastures.

Five 5-foot radius systematically spaced plots were established in each pasture in order to determine the distribution of sagebrush by size classes. As was true in the Grass Valley area, a similar size-class distribution was found in the two pastures. However, approximately twice as many sagebrush plants were found per plot in the heavily grazed as were found in the lightly grazed pasture. Three dead sagebrush plants were found per plot in the lightly used pasture, and only 0.4 dead plants per plot in the heavily used pasture (Table III). Apparently sagebrush was decreasing under light use and remaining relatively stable in the heavily used pasture.

A cemetery relict was found near the town of Helmville (fig. 15). The vegetation within the cemetery fence was composed primarily of Agropyron spicatum, Festuca idahoensis, F. scabrella, Tetradymia sp. and scattered sagebrush plants. Although the area was fenced around 1900, disturbance of the area, primarily through sporadic burning, has occurred. The area, however, was not burned for at least the 10 years prior to 1952.[2]

One half mile east of the Helmville cemetery a fence divided a moderately grazed range from the heavily used area surrounding the cemetery. The heavily grazed sagebrush type was found to contain a sparse cover of small, unthrifty bunchgrasses, including primarily

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[2] Personal communication with Mr. Neil Spieker, Helmville, Montana. June 23, 1952.

TABLE VIII

COMPOSITION OF TWO ADJACENT

RANGE AREAS, HELMVILLE, MONTANA

Species	Lightly grazed			Heavily grazed		
	Intercept per 100 feet	Plants per 100 feet	Per cent composition	Intercept per 100 feet	Plants per 100 feet	Per cent composition
Agropyron spicatum	4.0	25	11.4			
Antennaria sp.	2.9	20	8.3	0.7	6	1.8
Artemisia tridentata	15.1	18	43.0	31.2	38	83.0
Castilleja sp.	0.5	5	1.4	0.2	2	0.5
Cerastium arvense	0.9	7	2.6	1.8	16	4.8
Crepis sp.	0.2	2	0.6	0.2	2	0.5
Erigeron sp.				0.3	3	0.8
Festuca idahoensis	1.2	6	3.4			
F. scabrella	5.5	21	15.7			
Geum triflorum	0.3	2	0.8			
Heuchera sp.				0.1	1	0.3
Koeleria cristata	1.5	13	4.3			
Lupinus sp.	0.1	1	0.3	0.1	1	0.3
Phlox sp.	0.4	3	1.1			
Poa secunda	2.5	20	7.1	2.7	24	7.2
Senecio sp.				0.2	2	0.5
Taraxacum officinale				0.1	1	0.3
Total	35.1		100.0	37.6		100.0

Poa secunda and Koeleria cristata. Agropyron spicatum was rare, and Festuca idahoensis and F. scabrella were absent. The type was estimated to produce less than 100 pounds of air-dry grass per acre per year. The moderately grazed sage-free area east of the fence, on the other hand, had a high density of healthy, vigorous bunchgrasses dominated by Agropyron spicatum, Festuca idahoensis and F. scabrella. A few scattered plants of Tetradymia sp. occurred throughout. Estimated total air-dry grass production was probably seven to eight times as much as the sagebrush type across the fence (fig. 16). No evidence of recent or periodic fires was found in the vicinity.

Dillon. Several relict areas were found in the large sagebrush area adjacent to Dillon (fig. 17 a, b). Soil samples taken on adjacent similar sites indicate no significant soil differences between the grassland and sagebrush types. No floristic analysis was made in this area.

Centennial Valley. Two pastures, separated by a barbed wire fence and a county dirt road, were studied with reference primarily to reinvasion. Pasture A, north of the road, was unburned, while Pasture B, south of the road, was burned in 1947, five years before the present study. Five 5-foot radius circular plots were established systematically in each pasture. The resulting analysis showed a size-class distribution pattern essentially similar to the previous areas studied (Table III). Both areas were moderately grazed at the time of the study, and the very good grass cover in the burned area was effectively competing with the sagebrush reproduction. Approximately eleven times as many sagebrush plants were found per plot on the unburned as on the burned area (fig 18 a, b).

FIGURE 15

RELICT Agropyron STAND IN HELMVILLE CEMETERY

SURROUNDED BY HEAVILY USED SAGEBRUSH RANGE

FIGURE 16

HEAVILY USED SAGEBRUSH RANGE AND MODERATELY USED

Agropyron-Festuca RANGE NEAR HELMVILLE

FIGURE 17A

RELICT ROAD RIGHT-OF-WAY IN OLD SAGEBRUSH STAND NEAR DILLON

FIGURE 17B

HEAVILY GRAZED SAGEBRUSH RANGE AND MODERATELY GRAZED *Agropyron-Stipa* RANGE ON GRASSHOPPER CREEK NEAR DILLON

FIGURE 18A

MATURE SAGEBRUSH STAND AT LAKEVIEW,

CENTENNIAL VALLEY. PHOTOGRAPHED JUNE, 1952

FIGURE 18B

SAGEBRUSH STAND AT LAKEVIEW, BURNED IN 1947

PHOTOGRAPHED JUNE 1952

Cliff Lake Natural Area. The general vegetation of the Cliff Lake Natural Area has been described by Peterson (1953). The relatively open, scattered stands of sagebrush in this moist area are interspersed with a luxurious cover of sedges, grasses, and perennial forbs (fig. 19). The soil in the area is a dark chestnut, deep and apparently fertile. The area has been ungrazed by domestic livestock since 1948, and but lightly grazed in the years previous to that date, due largely to the absence of stock water. The area has burned over in the past, and concentrations of game have undoubtedly occurred in the area from time to time. A height-frequency analysis reveals a striking difference from previous areas. Based on five 5-foot radius circular plots, the size distribution of sagebrush varied from 9.1 per cent in the 0 to 3 inch group to 15.1 per cent in the 28 to 30 inch group (Table III). The small number of young plants in the stand probably indicates a decadent condition in the sagebrush community due, in part, to the competition of herbaceous plants and to the reduction of those factors which permitted the original establishment of the sagebrush colony.

Blanchard Flat. Five separate pastures, differing in intensity of use and in history of use, were studied on Blanchard Flat near the junction of the Clearwater and the Big Blackfoot Rivers in Missoula County. Pastures 1, 3 and 5, representing light to moderately heavy use, had from 52.9 to 75.3 per cent of the vegetation composed of Agropyron spicatum, Festuca idahoensis, and F. scabrella. Sagebrush was not found in any of these pastures. The heavily to very heavily used Pastures 2 and 4 had only 23.0 and 12.7 per cent composition of these three grasses, respectively. The very heavily used Pasture 2

had no sagebrush; the heavily used Pasture 4 had 38.2 per cent of the vegetation in sagebrush (Table IX). Pasture 4, however, was an old sheep bed ground, and was probably much more destructively used in years past. Sagebrush in this area was confined to the vicinity of the old bed grounds and to the one-time heavily used adjacent areas.

TABLE IX

COMPOSITION OF FIVE PASTURES

ON BLANCHARD FLAT[1]

Species	Pasture 1		Pasture 2		Pasture 3		Pasture 4		Pasture 5	
	Intercept feet[2]	% comp.	Intercept feet	% comp.	Intercept feet	% comp.	Intercept feet	% comp.	Intercept feet	% comp.
Achillea lanulosa	3.6	6.1	3.0	6.3	0.7	1.1	8.3	18.7	1.6	2.3
Agropyron spicatum	25.3	42.9	10.7	22.5	3.4	5.2	4.7	10.6	34.2	49.4
Antennaria sp.			3.0	6.3	2.9	4.5	5.4	12.1	0.7	1.0
Artemisia tridentata							17.0	38.2		
Carex filifolia	2.8	4.7			4.0	6.2	4.0	9.0	1.4	2.0
Chrysopsis sp.			6.1	12.8	0.2	0.3			0.6	0.9
Danthonia unispicata	13.2	22.3	1.0	2.1					15.5	22.4
Erigeron sp.	1.0	1.7			0.3	0.5	1.9	4.3	0.2	0.3
Eriogonum sp.					0.9	1.4				
Festuca idahoensis	0.1	0.2	0.1	0.2	34.2	52.6	0.4	0.9	0.6	0.9
F. scabrella	0.7	1.2	0.2	0.4	11.4	17.5	0.7	1.6	1.9	2.7
Geum triflorum	0.3	0.5	2.9	6.1						
Koeleria cristata	2.7	4.6	1.4	3.0	0.4	0.6	0.6	1.3	2.6	3.8
Phlox spp.	5.9	10.0	2.4	5.1	0.1	0.2	0.7	1.6	7.8	11.3
Poa secunda	0.1	0.2	2.9	6.1			0.2	0.4		
Potentilla spp.	1.0	1.7	2.7	5.7						
Senecio sp.					1.2	1.8				
Solidago sp.	2.3	3.9	11.1	23.4	5.3	8.1	0.6	1.3	2.1	3.0
Total	59.0	100.0	47.5	100.0	65.0	100.0	44.5	100.0	69.2	100.0

1 Pasture 1 SE of Clearwater Crossing on west side of fence (moderately used); Pasture 2 SE of Clearwater Crossing on east side of fence (very heavily used); Pasture 3 opposite sagebrush area toward ranch headquarters on north side of road (lightly used); Pasture 4 in sagebrush area south side of road (heavily used); Pasture 5 SE of Clearwater Crossing north of game range fence (lightly used).

2 For 150 feet of transect in each area.

DISCUSSION

Sagebrush occurs throughout western Montana under a wide range of environmental conditions. It is found on a variety of textural classes of chernozem, chestnut and brown soils under from less than 10 to more than 20 inches of precipitation.

History of use is probably the most important factor affecting sagebrush distribution in western Montana. When plant communities--sagebrush and non-sagebrush-- are grouped by intensity of livestock use, the effect of disturbance becomes more apparent (Table X).

Sagebrush was not found to occur on relict areas or on lightly used ranges within the area studied. It was occasionally found, however, on raw, undeveloped soils or on otherwise disturbed sites within presently lightly grazed or relict areas. Sagebrush often occurred on heavily grazed ranges on chernozem and dark chestnut soils, and on moderately or heavily grazed light chestnut and brown soils. Observation indicated that reduced grazing pressure caused a marked decline in sagebrush dominance. Except in areas of dense sagebrush where few remnant climax grasses remain, or on eroded or undeveloped soils, proper grassland management may be expected to return sagebrush-infested areas to their original grass dominance.

Some heavily grazed areas, while adjacent to sagebrush stands, were not invaded by sagebrush. Examples of this were also found in Grass Valley, Kleinschmitt Flat, Radersburg, and near Butte. Further study may reveal the possible causes of this condition.

While it is generally assumed that sagebrush occupies rather dry sites, it was generally found on more mesic sites than the associated

TABLE X

SAGEBRUSH OCCURRENCE IN WESTERN MONTANA

AS RELATED TO SOILS AND GRAZING USE

Palouse and mixed prairie	Sandy loams to loams		Clay loams to clays	
	Light use	Heavy use	Light use	Heavy use
18 + inches precipitation Chernozems	Lincoln-Festuca, Agropyron Helmville-Festuca, Agropyron	Wisdom-sagebrush		Manger Ranch-sagebrush
12-18 inches precipitation Chestnuts	Barber- Stipa comata	Kleinschmitt- Poa, Koeleria Garden Cr.-Sage-brush Red Rock Lake-sagebrush Lincoln-sagebrush Barber-sagebrush	Blanchard Flat-Agropyron	Finn-sagebrush Frenchtown-sage-brush Deschamps-Chryso-thamnus Blanchard Flat-sagebrush Butler Cr.-sage-brush
Less than 12 inches precipitation Brown soils	Helmville Ceme-tery- Agropyron Hagen Ranch-Agropyron Dillon-Stipa, Bouteloua	Radersburg- sage-brush Helmville, sage-brush Hagen Ranch-sagebrush Dillon-sagebrush	Florence-Agropyron Dillon-Bouteloua, Agropyron	Radersburg-Bouteloua, Agropyron Hot Springs-sagebrush

grass types. This was true near the summit of the Gravelly Range at 8,500 feet elevation, as well as in the drier areas near Missoula and Dillon (figs. 12 a, b and 20).

FIGURE 19

DECADENT SAGEBRUSH STAND

CLIFF LAKE BENCH

FIGURE 20

SAGEBRUSH ON NORTH EXPOSURE, 8,500 FEET ELEVATION

VIGILANTE EXPERIMENTAL RANGE

SUMMARY

All known sagebrush communities in Montana west of the 109th meridian were mapped. Floristic analyses and soil samples were taken at representative locations in sagebrush and adjacent non-sagebrush communities.

Sagebrush and non-sagebrush areas were compared on the basis of soil texture, organic matter, pH and salinity.

Vegetation was analyzed by line transects and height-frequency tables.

Soil, precipitation and elevational differences were not adequate to explain sagebrush occurrence in western Montana.

On the basis of the areas studied, grazing use and other disturbance factors best explain present sagebrush distribution patterns.

Sagebrush was generally found on more mesic sites than associated grassland types.

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APPENDIX

SOIL SAMPLES

Soil No.	Date	Location	Veg.	OM	Text. Class	Moist. %	pH	PPM Salinity
1 a	4-10-52	Missoula	G	1.5	C	19.8	7.3	560
b					C	22.5	8.0	320
c					Si	16.9	7.8	4800
2 a	4-22-52	Missoula	S	4.3	C	35.0	6.6	40
b					C	26.4	6.7	80
c					C	22.6	7.1	460
3 a	4-22-52	Missoula	S	3.5	C	36.8	6.3	370
b					C	28.2	6.3	min.
c					C	25.8	6.4	min.
4 a	4-24-52	Stevensville	G	1.4	LS	11.5	6.9	min.
b					SCL	11.2	7.1	min.
c					SCL	11.7	8.1	320
5 a	4-24-52	Stevensville	S	1.2	SL	11.1	6.6	min.
b					SL	13.6	7.2	180
c					SL	11.6	8.4	420
6 a	5- 6-52	Stevensville	G	1.2	SiCL	18.9	6.1	min.
b					SL	12.5	6.6	220
c					L	16.0	8.0	800
7 a	5- 6-52	Missoula	S	1.7	C	19.5	7.0	280
b					C	18.5	7.8	400
c					C	16.6	7.7	4,800
8 a	5- 6-52	Missoula	S	2.5	C	19.1	7.1	200
b					C	19.0	7.8	980
c					C	15.1	8.0	3,700

Soil No.	Date	Location	Veg.	OM	Text. Class	Moist. %	pH	PPM Salinity
9 a	5- 7-52	Missoula	S	3.5	C	38.0	6.4	160
b					C	23.8	6.5	200
c					C	10.5	7.6	300
10 a	5-13-52	Helmville	G	3.2	L	35.0	6.0	100
b					SCL	34.0	6.1	80
c					SL	24.3	6.6	80
11 a	5-13-52	Helmville	S	1.6	SL	20.5	6.5	100
b					SL	16.4	6.8	min.
c					SL	11.7	8.0	380
12 a	5-16-52	Hot Springs	S	3.0	L	12.5	6.6	min.
b					L	14.5	6.5	100
c					-	----	---	---
13 a	5-16-52	Hot Springs	S	1.4	C	12.1	8.6	2,700
b					C	15.1	8.0	6,600
c					C	15.7	8.5	800
14 a	5-16-52	Hot Springs	G	0.2	SiC	10.5	9.8	3,800
b					C	13.2	10.1	6,800
c					C	14.2	9.9	4,200
15 a	5-23-52	Missoula	G	2.5	L	11.5	6.6	200
b					L	15.0	6.9	200
c					L	12.0	7.5	340
16 a	5-11-52	Wisdom	S	4.2	SL	----	5.9	200
b					SL	----	6.0	min.
c					SL	----	6.1	min.

Soil No.	Date	Location	Veg.	OM	Text. Class	Moist. %	pH	PPM Salinity
17 a	5-13-52	Dillon	S	1.3	L	7.2	6.6	240
b					CL	15.3	8.0	880
c					CL	13.5	8.1	1,720
18 a	5-13-52	Dillon	G	1.6	SL	15.0	7.8	260
b					L	17.3	7.8	900
c					SiL	16.2	7.4	4,200
19 a	5-17-52	Lima	S	2.7	SL	6.7	6.3	min.
b					LS	6.2	6.5	min.
c					SL	9.8	6.9	200
20 a	5-17-52	Lima	G	1.0	S	3.5	6.5	120
b					S	4.0	6.4	min.
c					S	5.7	6.5	min.
21 a	7-29-52	Barber	G	2.3	SCL	5.7	7.8	280
b					CL	6.9	8.0	320
c					CL	4.8	8.2	1,360
22 a	7-29-52	Barber	S	1.2	SC	6.7	7.5	200
b					C	13.4	8.2	700
c					C	14.4	8.4	1,840
23 a	7-30-52	Radersburg	S	1.7	SCL	5.2	7.2	380
b					SCL	9.2	8.1	460
c					SL	5.9	8.2	320
24 a	7-30-52	Radersburg	G	1.6	CL	9.2	8.0	380
b					L	10.6	8.3	280
c					SL	8.9	8.7	640
25 a	7-30-52	Radersburg	G	2.2	SL	----	7.5	400
b					SL	----	8.1	600
c					SL	----	7.1	1,360

Soil No.	Date	Location	Veg.	OM	Text. Class	Moist. %	pH	PPM Salinity
26 a	7-31-52	White Sulfur	S	4.3	CL	----	7.0	400
b					CL	----	7.6	340
c					CL	----	8.0	400
27 a	8-12-52	Missoula	R[1]	2.5	C	----	7.4	380
b					C	----	7.8	460
c					Si	----	7.9	5,200
28 a	8-12-52	Missoula	G	2.3	C	----	7.4	620
b					C	----	8.3	1,920
c					C	----	8.1	2,900
29 a	8-14-52	Helmville	G	3.0	SL	----	6.1	100
b					SL	----	6.6	min.
c					SL	----	7.2	280
30 a	8-14-52	Lincoln	G	4.5	L	----	6.0	min.
b					SL	----	6.1	min.
c					L	----	6.1	min.
31 a	8-14-52	Lincoln	S	2.7	SL	----	5.9	min.
b					SL	----	6.2	min.
c					SL	----	6.4	min.
32 a	8-15-52	Finn	S	2.6	SCL	----	6.0	100
b					C	----	6.9	960
c					C	----	7.6	1,100
33 a	8-15-52	Helmville	G	1.7	SL	----	6.2	min.
b					SCL	----	6.9	440
c					CL	----	7.7	500

1 Rabbitbrush (Chrysothamnus sp.)