FLUCTUATIONS IN THE ANNUAL VEGETATION OF CALIFORNIA

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The herbaceous vegetation of some 25,000,000 acres of California range lands is dominated by annual plants. This carpet of vegetation is often referred to as the "annual type." It constitutes the vegetation of extensive valley and foothill grassland areas and forms the ground cover under the more open woodland and chaparral types.

Under the influence of such factors as arid climate and variable weather, of livestock grazing and other treatment, this annual-plant cover undergoes changes that are both swift and erratic in comparison with the more stable perennial plant associations. Wide variations often occur from year to year in composition and volume. Moreover, such variations are the rule, not the exception. These fluctuations have long been recognized; but comparatively few attempts have been made to measure them. Since 1934, data on their occurrence and magnitude have been obtained in connection with the general program of range investigations at this station, since they bear directly on livestock production and watershed management. Illustrative examples are discussed in this paper. Supporting data were gathered on (1) the San Joaquin Experimental Range, an area of 4,500 acres in the woodland type in the foothills of Madera County; (2) a 40-acre outpost of the Experimental Range, also in the woodland type; and (3) a range reconnaissance of approximately 9,500,000 acres of the San Joaquin Valley, based on 2,570 sample plots distributed in 14 counties.

Extent and Character of California's Annual-Plant Communities

The annual types cover most of the untilled plains and foothills of the Sacramento and San Joaquin Valleys, a large portion of the south Coast Ranges and part of the north Coast Ranges, as generalized in figure 1. They lie chiefly in the Lower and Upper Sonoran life zones. Areas in the Mohave Desert and in the Great Basin extension into eastern and northeastern California are not shown or included in this discussion, for they represent a somewhat different condition.

The climate prevailing in the annual-type area is characterized by the prevalence of wet winters and dry summers. The precipitation, largely in

[1] Maintained by the United States Department of Agriculture at Berkeley, California, in cooperation with the University of California.

the form of rain, usually begins in October or November and ends in April or May. Rainfall is thus distinctly seasonal. About two-thirds of the rain falls in the four months from December through March. Very light showers may occur from May to September. The yearly precipitation ranges from less than 10 inches up to 40, and varies widely from place to place and from

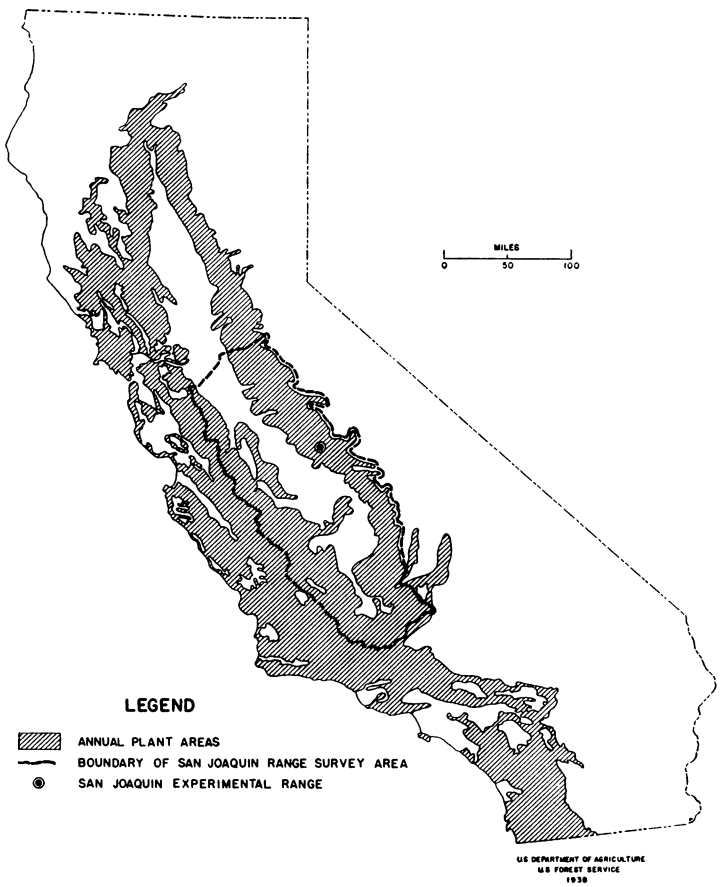

FIG. 1. California range areas in which annuals are generally dominant in the herbaceous cover. Included in this generalized territory are local saltgrass areas dominated by perennials, also dense woodland and chaparral areas in which annuals are negligible.

season to season. Winter temperatures may fall slightly below freezing for short periods. Summer temperatures in the Great Valley are relatively high, often exceeding 105° F. for several days in succession. Along the coastal areas the temperatures are more moderate. The relative humidity during the dry season is generally low, except near the coast. High wind velocities are rare.

By a very general classification, the annual-type area may be subdivided into three broad types of vegetation: treeless "grassland," woodland, and chaparral.[2] Grassland areas occupy the heart of the Sacramento and San Joaquin Valleys and much of the Coast Ranges. Bordering the grassland, and chiefly above it (fig. 2), lies the woodland zone which intermingles with and grades into chaparral. In turn the chaparral merges into the conifer belt above it.

The preponderance of annuals in the ground cover in these types is indicated by figures from the extensive reconnaissance of the San Joaquin Valley,

FIG. 2. An example of the "annual types"—the transition between grassland and woodland in the foothills of the San Joaquin Valley. Blue oak, *Quercus douglasii,* and interior live oak, *Quercus wislizenii,* may be seen in the background. Annual plants dominate the herbaceous cover in both types.

in 1934. To cite three examples, annuals comprised 94 per cent of the herbaceous cover in the grassland areas, 98 per cent in the woodland, and 93 per cent in the more open chaparral. Perennials are comparatively abundant, however, in some parts of the region diagrammed in figure 1, for example, in rather extensive valley areas where saltgrass is important, and locally in the Coast Ranges where bunchgrasses are prevalent.

Surprising also is the extent to which the native vegetation over vast areas in California has been replaced by plants introduced from the Old World. The reconnaissance of the San Joaquin Valley further revealed that introduced plants (mostly annuals) constituted 63 per cent of the herbaceous vegetation

[2] This paper is chiefly concerned with the more open phases of woodland and chaparral—not the dense phases which support comparatively little herbaceous growth.

in the grassland types, 66 per cent in the woodland, and 54 per cent in chaparral. Some of the most important introduced species from the standpoint of abundance are *Erodium cicutarium* (20% of total herbaceous cover) and *E. botrys* (14%), *Bromus hordeaceus* (9%), *B. rubens* (9%), *B. arenarius* (2%), *Avena barbata* (2%), *Bromus rigidus* (1%), and *Medicago hispida* (1%). *Hordeum murinum, H. gussoneanum, Avena fatua, Festuca myuros,* and other minor or rare species comprise an additional 1 per cent.[3]

The annual types are further characterized by the tremendous number of individual plants in the herbaceous cover, and the large number of species.

TABLE I. *Composition of herbaceous vegetation in six grazed pastures, San Joaquin Experimental Range, 1938*

No.	Species	Composition[1]	No.	Species	Composition
		Per cent			Per cent
1	*Bromus hordeaceus*	17.2	21	*Navarretia viscidula*	.7
2	*Erodium botrys*	15.8	22	*Pterostegia drymarioides*	.6
3	*Festuca megalura*	10.3	23	*Trifolium ciliatum*	.6
4	*Lotus americanus*	5.1	24	*Avena barbata*	.6
5	*Trifolium microcephalum*	5.1	25	*Trifolium tridentatum*	.5
6	*Trifolium variegatum*	4.1	26	*Gilia tricolor*	.5
7	*Hemizonia virgata*	3.1	27	*Filago gallica*	.4
8	*Lupinus bicolor*	2.8	28	*Montia perfoliata*	.4
9	*Juncus bufonius*	2.6	29	*Lotus strigosus*	.3
10	*Bromus rubens*	2.1	30	*Linanthus filipes*	.3
11	*Lotus subpinnatus*	1.2	31	*Eremocarpus setigerus*	.3
12	*Plagiobothrys nothofulvus*	1.2	32	*Lupinus benthami*	.3
13	*Godetia* spp.	1.2	33	*Tillaea erecta*	.3
14	*Daucus pusillus*	1.1	34	*Lupinus formosus*	.3
15	*Silene gallica*	1.0	35	*Pentstemon breviflorus*	.2
16	*Bromus rigidus*	.9	36	*Plantago erecta*	.2
17	*Centaurea melitensis*	.9	37	*Erodium cicutarium*	.2
18	*Cerastium viscosum*	.8	38	*Calandrinia caulescens*	.2
19	*Baeria chrysostoma*	.7	39	*Medicago hispida*	.2
20	*Hypochoeris glabra*	.7	40	*Layia pentachaeta*	.2
				Other species	14.8
				Total	100.0

[1] Composition based on density.

As examples of extreme populations, estimates since 1933 of the dominant forb *Erodium botrys* reveal up to 13,000 young plants per square meter, and as high as 220,000 of *Festuca* on areas dominated by annual species of this genus. The large number of species is illustrated by the San Joaquin Valley range reconnaissance, in which 346 forbs and 79 grasses were recorded; and this number represents only a part of the total number occurring in that large territory.

Some of the most common herbaceous species found in the annual types are given in table I. Although the data in this table are restricted to a description of the composition of the vegetation cover in six large pastures on the

[3] Nomenclature follows Jepson's Manual of Flowering Plants of California.

Experimental Range, most of the species listed are common to large areas of the annual types in other parts of California. It is of interest that only 12 species make up 70 per cent of the ground cover, although 109 species were recorded and many others occurred in insignificant amounts.

Fluctuations in Composition and Yield

The annual-plant cover is unstable and variable to a surprising degree. Percentages of individual species move back and forth along the scale of relative abundance, from year to year. The amount of vegetation produced annually and the dates of greening and of drying likewise vary. Pronounced changes in aspect occur, both from season to season and during a given season. The species composition not only is different from year to year, but, under complete protection from livestock and rodents, striking shifts in composition can be brought about in two years' time or less; and, by a change in treatment, these trends may be arrested—even partially reversed—in a single season. It is with such fluctuations that the following discussion is concerned.

Fluctuations in grazed pastures. The results of yearly inventories of the vegetation in grazed pastures on the Experimental Range (see fig. 1 for location) indicate that the herbaceous cover is ever changing. In connection with these inventories, noticeable variations in species composition were observed from year to year. The relative yield of herbage also changed. Some of the more conspicuous and significant composition changes are illustrated in table II by 12 species which were selected from table I.

Table II. *Changes in herbaceous composition in six grazed pastures, San Joaquin Experimental Range*

No.	Species	Composition percentage		
		1936	1937	1938
1	*Erodium botrys*	40.6	34.3	15.8
2	*Bromus hordeaceus*	19.4	30.6	17.2
3	*Festuca megalura*	16.9	9.3	10.3
4	*Avena barbata*	2.8	4.2	.6
5	*Bromus rigidus*	1.4	3.3	.9
6	*Lotus americanus*	1.2	.6	5.1
7	*Hemizonia virgata*	.6	.2	3.1
8	*Juncus bufonius*	.5	.5	2.6
9	*Plagiobothrys nothofulvus*	.4	2.4	1.2
10	*Trifolium microcephalum*	.4	.3	5.1
11	*Lupinus bicolor*	.1	.2	2.8
12	*Lotus subpinnatus*	.1	.1	1.2
	All other species	15.6	14.0	34.1
	Total	100.0	100.0	100.0

Twelve species made up from 66 to 86 per cent of the vegetation in the pastures. Figures for each of the numerous species comprising the 14 to 34 per cent designated as "all other species" also fluctuated, but the recorded differences were small and may have been less than the errors of measurement.

These data are based on square-foot plots distributed at random (at the rate of one per acre in 1936 and 1937, and one to two acres in 1938) on 1,440 acres.

Fluctuations in fenced exclosures. Sharp fluctuations in herbaceous vegetation induced by extremes in treatment are illustrated by the 5-year story obtained from livestock and rodent exclosures at an outpost of the Experimental Range, in the woodland type. These exclosures, one 10 acres in size excluding livestock, and one 50 feet square excluding rodents also, were fenced in 1933. Systematic estimates and measurements of vegetation were recorded in 1933, 1935, 1937 and 1938 at approximately the same growth stage (maximum development) on three plots, one in each of these two exclosures and one in an adjoining grazed pasture. The comparative estimates are summarized in table III. Grazing on plot No. 3 was close and fairly uniform from 1933 to 1936, moderate in 1937, and very light in 1938.

TABLE III. *Fluctuations in composition under different treatments*

Plot	Treatment	Year	Total		Four most abundant species			
			Forbs	Grasses	*Erodium* spp.	*Bromus hordeaceus*	*Avena barbata*	*Bromus rigidus*
					Per cent of cover			
1	Rodents and livestock excluded	1933	98	2	86	1	T	T
		1935	4	96	3	20	72	4
		1937	1	99	0	10	1	88
		1938	20	80	1	10	10	60
2	Only livestock excluded	1933	99	1	80	T	0	T
		1935	15	85	14	75	10	T
		1937	4	96	2	85	8	T
		1938	20	80	0	55	20	T
3	Grazed by livestock and rodents	1933	98	2	82	T	T	T
		1935	79	21	50	5	T	T
		1937	67	33[1]	50	0	0	T
		1938	43	57[1]	10	24	T	T

T (Trace) = Values less than 1 per cent.
[1] Includes *Juncus bufonius*.

The marked changes that were observed in the forb-grass ratio in only two years are shown graphically in figure 3. Some of these changes from 1933 to 1935, under all three treatments, were of course due to climate; but the replacement of forbs by grasses is significantly greater in the fenced plots, virtually amounting to a reversal in ratio.

Even more striking evidence of the rapid response of this delicately balanced vegetation to extremes of treatment is afforded by the results of careful removal of accumulated old growth by hand from three alternate strips across the rodent exclosure, leaving the intervening strips undisturbed as checks. This was done in October 1936, just before the beginning of the rainy season and the start of new growth. By the following May sharp contrasts were

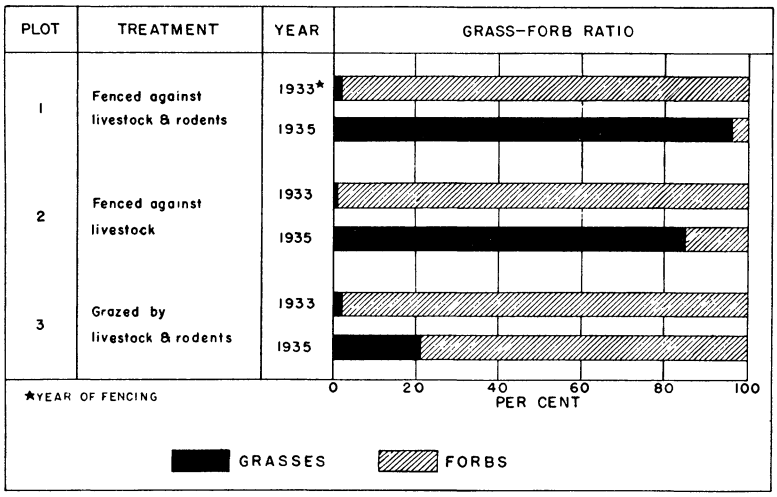

FIG. 3. Comparative replacement of forbs by grasses in two years, under three treatments.

clearly visible from the boundary fence of the exclosure, throughout the length of each division line between strips. These striking differences in composition, by pairs, of cleared and uncleared strips are indicated in figure 4.

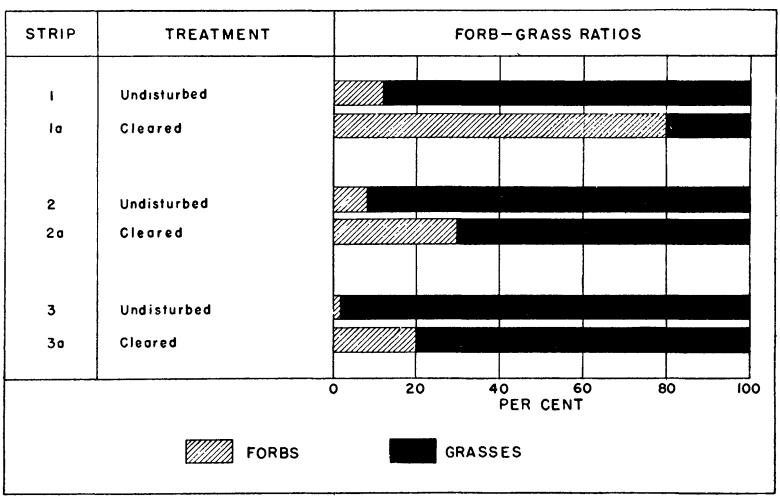

FIG. 4. Increase in forbs from one season's clearing.

This diagram emphasizes the occurrence of a consistently greater proportion of forbs on the cleared strips.

Reexamination of these plots in 1938 revealed still further changes, in comparison with 1937, as indicated in table IV.

TABLE IV. *Fluctuations in vegetation on cleared and uncleared strips in rodent exclosure. Figures in each column represent an average of 3 strips*

Year	1937		1938	
Treatment	Uncleared	Cleared in 1936	Uncleared	Cleared in 1936
Density	.33	.50	.43	.82
Species	*Percentage of cover*			
Bromus rigidus	69	31	43	4
Avena barbata	14	20	20	17
Bromus hordeaceus	10	10	3	1
Erodium spp.	5	39	4	13
Lupinus bicolor			15	46
Trifolium spp.			10	14
Other forbs	2		5	5
Total grasses	93	61	66	22
Total forbs	7	39	34	78

The relative effect of clearing, which showed up in 1937, the first growing season after treatment, was still strongly evident in 1938. The relatively higher density of the vegetation on the cleared as compared with the uncleared strips was still pronounced. Also, the ratio of forbs to grasses on the cleared strips continued to be relatively greater than on the uncleared. An additional noteworthy point was the big increase in forbs in 1938 on both cleared and uncleared areas, especially of *Trifolium* spp. and *Lupinus bicolor*. In 1937 these species were either absent or represented by so few individuals that they escaped the observer's eye.

Examples of extreme fluctuations in annuals. Contrasts in the growth of annuals in the grassland type were especially impressive in the southern part of the San Joaquin Valley, in Kern County, in 1934 and 1935. In this locality conditions were very unfavorable to plant growth during the 1933–1934 season, in contrast to the following season during which growing conditions were excellent.

The plant cover on seven .25-acre grassland plots, distributed in five localities, was examined and recorded during the course of the range reconnaissance in 1934. The plots were reexamined in 1935. The results of the two examinations are summarized in table V.

TABLE V. *Consecutive seasonal differences in annual vegetation Kern County*

Locality	Number of plots	Height		Density	
		1934	1935	1934	1935
		Inches		*Per cent*	
Caliente	1	.75	9.0	10	90
Bakersfield	1	.50	3.5	3	40
McKittrick	1	.25	16.0	2	50
Buena Vista Lake	1	.25	5.0	5	60
Lost Hills	3	.44	4.7	3	40
Average		.44	6.8	4	51

The comparative figures in this table illustrate the marked differences in average height and percentage of ground covered by herbaceous vegetation on these plots, from one growing season to the next. The product of height and density, affording a rough index of plant volume, indicates a production of herbage approximately 193 times greater in 1935 than in 1934.

Marked differences in composition of the cover likewise were observed. For example, only 12 species were recorded on the plots in 1934, as compared with twice that number in the following year. In 1934 three species, namely *Erodium cicutarium, Lepidium nitidum* and *Bromus rubens,* made up 97 per cent of the herbaceous cover. In 1935, 15 species were needed to make up this amount. The following comparisons are indicative of the most conspicuous changes in the relative proportion of the species from 1934 to 1935. *Erodium cicutarium* decreased from 70 per cent to 29 per cent. A species of annual composite unrecorded in 1934 made up 13 per cent of the cover in 1935, while an annual fescue increased from 1 to 12 per cent. The relative proportion of *Bromus rubens* and *Lepidium nitidum* did not change significantly, although the yield for these species as well as others was vastly greater in 1935. Fluctuations such as these are not uncommon over a period of years in this locality.

Wide fluctuations in herbaceous vegetation, as outlined in the foregoing pages, hold more than academic interest. Directly related as they are to uncertainties in forage supply and soil cover, they complicate range and watershed management. Thus, as a factor in practical land use they have economic importance.