of 2,4,5-T was superior to the ester of 2,4-D.

6. Dilution of 2,4-D amine with water gave no advantage in effectiveness. It increased the time necessary for making effective application and added to the bulk of material to be carried.

7. An abrupt increase in effectiveness took place between October 6 and November 4. The increase in effectiveness in November appears to have been associated with an increase in soil moisture and a decrease in air temperature. The trees remained sensitive throughout the winter and spring months.

LITERATURE CITED

AREND, J. L. AND L. L. COULTER. 1953. Chemical frill girdling for pine release in lower Michigan. Down to Earth. 8 (4): 2-4.

EMRICK, WALTER E. 1953. An easy way to kill your bull (digger) pines. Univ. California Ext. Service Leaflet (Madera County): 1-9.

EMRICK, W. E. AND O. A. LEONARD. 1954. Delayed kill of interior live oak by fall treatment with 2,4-D and 2,4,5-T. Jour. Range Mangt. 7: 75-76.

GODDARD, RAY E. 1954. Killing small undesirable hardwoods by use of the Cornell tool. Down to Earth 10 (2): 5.

HARRIS, G. H. 1926. The activity of apple and filbert roots especially during the winter months. Proc. Amer. Soc. Hort. Sci. 23: 414-422.

LEONARD, O. A. 1952. Result of a cut-surface experiment on interior live oak. Research Rept., 13th Western Weed Control Conference: 53-54.

MCCULLY, W. G. AND R. A. DARROW. 1952. Control of post and blackjack oaks with growth-regulator herbicides. Proc. Fifth South. Weed Conf. 137-140.

PEEVY, F. A. 1954. Woody plant control in Southern Forests. Proc. Seventh South. Weed Conf. 261-264.

ROBERTS, E. G. 1954. Frilling with and without the application of 2,4,5-T in hardwood control. Proc. Seventh South. Weed Conf. 294-296.

SWEZEY, A. W. 1953. A report of preliminary investigations of the treatment of riparian trees with 2,4-D and 2,4,5-T by basal techniques. Res. Rept. Western Weed Control Conf. 42-43.

WEINTRAUB, R. L., J. H. REINHART, R. A. SCHERFF AND L. C. SCHISLER. 1954. Metabolism of 2,4-dichlorophenoxyacetic Acid. 3. Metabolism and persistence in dormant plant tissue. Plant Physiol. 29: 303-304.

Ecology of California Grasslands

H. H. BISWELL

Professor of Forestry, University of California, Berkeley, California

West of the Sierra Nevada Divide in California are 17.5 million acres which contribute 80 percent of the forage for domestic livestock grazing on the State's wildlands. The area includes two vegetational types—the *grass* of 10 million acres and the *woodland-grass* of 7.5 million acres (Fig. 1). Another 25 million acres or so of wildlands in California are also grazed by livestock, but comprise only 20 percent of the forage. These acres include the chapparal type, coastal sagebrush, woodland, timber and meadow types of the mountains, portions of the desert, and the Great Basin sagebrush type east of the Sierra Nevada Divide. In addition to the wildlands, California has about 1,000,000 acres of irrigated pastures with high grazing capacity—up to three animal units per acre per month for seven months of the year.

Grass and woodland-grass ranges are used primarily for domestic livestock production, and problems in management center around this activity. A majority of the other wildlands, however, have other primary values, such as watershed, wildlife and other recreation, or timber production. The grass and woodland-grass ranges usually can be managed to the maximum for livestock, but on the other lands proper consideration must be given to the various uses, and problems in grazing are often complex and difficult (Talbot and Sampson, 1948).

The grass and woodland-grass ranges occur mainly in the plains and foothills of the San Joaquin and Sacramento valleys (Fig. 2). The grass type adjoins the valleys and is surrounded by the woodland-grass (Wieslander and Jensen, 1946). West of the grasslands are the Coast Range Mountains and the Pacific Ocean, and on the east are the Sierra Nevada Mountains. In a few places the grass type adjoins the ocean.

Climate

The climate of this area is the Mediterranean type, characterized by wet, mild winters and long, hot, dry summers (Fig. 3). It is diverse, being affected by the Coast Range Mountains which influence the air and cloud movements, and by the Pacific Ocean which has moderating effects in certain areas.

Precipitation usually begins in October or November and ends in April or early May, with about two-thirds falling from December through March. It varies in amount from about 6 inches, in the foothills surrounding the southern tip of the San Joaquin Valley and along its west side, to about 40 inches in certain portions near the Coast. From May through September there may be little or no precipitation, a desirable state of affairs from the stockman's viewpoint. At that time the forage is dry and might be leached of its soluble nutrients even by light

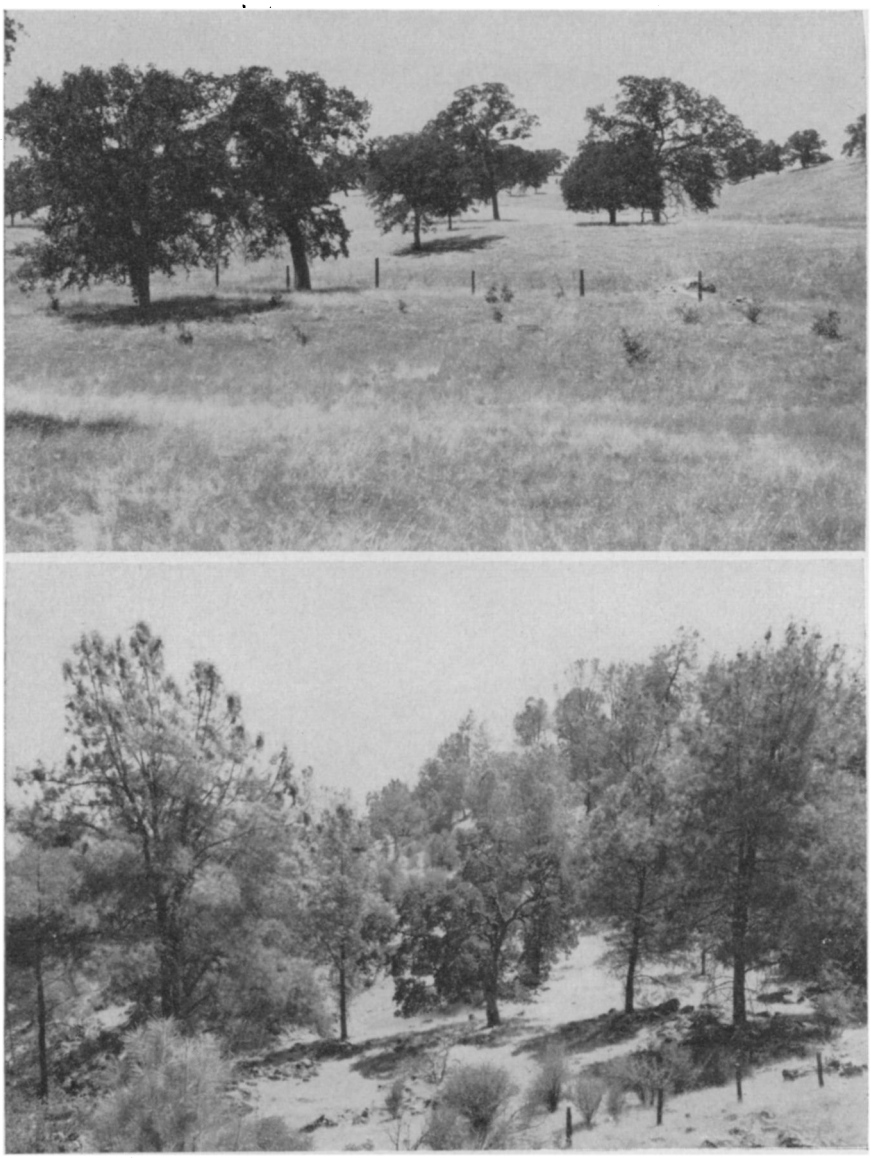

FIGURE 1. *Upper.* Grass type range grading into woodland-grass in background, as indicated by scattered blue oaks. On west-facing slope of central Sierra Nevada foothills at 500 ft. elevation. *Lower.* Woodland-grass range at the same location at 1,000 ft. elevation.

rainfall. During the dry summer period the days are mostly clear with maximum temperatures frequently above 105° F. and the relative humidity often 10 to 15 percent and sometimes lower.

Landscape and Vegetation

The grass and woodland-grass types are similar in many respects, but the latter has a landscape of scattered trees and shrubs while the other does not. In the grass type, however, scattered areas of chaparral may be found.

To the casual observer, the landscape of herbaceous vegetation appears remarkably uniform, but it is extremely diverse and composed of hundreds of species in varying amounts. It becomes green soon after the first rains, and the amount of growth is considerable in the fall months if conditions are favorable. During December, January and February, growth is slow because the minimum temperatures are near freezing. With the return of warmer weather in March the growth becomes rapid. The plants mature and dry in late April and early May, with some, but not all, of the perennials staying green slightly longer. From then until the fall rains, the landscape of dry forage is golden brown. Any green herbs are mostly summer weeds and may indicate deteriorated range conditions.

In early March the evergreen shrubs and trees of the woodland-grass type resume growth, and the deciduous plants put out new leaves soon thereafter. The shrubs and trees are green throughout the summer except for certain species, such as poison oak and California buckeye, which drop their leaves in early August.

The plants are all adapted in one way or another to the Mediterranean climate. The annual herbs grow and mature when moisture is plentiful, and are dry during the long, hot summer. The perennial grasses and forbs do likewise, being mainly dry and dormant during summer. Pine bluegrass, for example, dries equally as early as any annual and is completely dormant during the summer. This adaptation gives it an advantage over the annuals because it starts growth in the fall with less precipitation, and makes more rapid initial growth, thus placing it in a better position to compete with surrounding vegetation. The shrubs and trees are deep rooted. Some have small, thick, heavily-cutinized, evergreen leaves; others drop their leaves before the end of the extremely dry summer period.

The herbaceous vegetation is composed mainly of annuals. These and the perennials vary in percentage from place to place. Because of the great abundance of annuals, the grasslands have become known as the annual vegetation type of California (Talbot, *et al.*, 1939). In the foothills east of the San Joaquin Valley, for example, annuals comprise about 98 percent of the plant cover; perennial, grass-like plants (sedges and rushes), 1 to 4 percent; and other perennial grasses and forbs, less than 1 percent (Talbot and Biswell, 1942).

Along the coast, some of the perennials are abundant locally. The annual plant cover fluctuates greatly from year to year, depending on the weather and other growth factors, especially in the more arid portions where even normal rainfall may produce little growth (Talbot, *et al.*, 1939).

The more abundant plants on grass and woodland-grass ranges include the following (alien species indicated by *):

Annual Grasses and Forbs

*Soft chess, *Bromus mollis*
*Ripgut grass, *Bromus rigidus*
*Red brome, *Bromus rubens*
*Slender oat, *Avena barbata*
*Wild oat, *Avena fatua*
*Common foxtail, *Hordeum hystrix*
Foxtail fescue, *Festuca megalura*
*Common ryegrass, *Lolium multiflorum*
*Broadleaf filaree, *Erodium botrys*
*Red-stem filaree, *Erodium cicutarium*
*Bur clover, *Medicago hispida*
Annual clovers, *Trifolium* spp.
*Napa thistle, *Centaurea melitensis*
Tarweed, *Hemizonia* spp.
Spanish clover, *Lotus americanus*
Ground lupine, *Lupinus bicolor*

Perennial Grasses

Purple needlegrass, *Stipa pulchra*
Pine bluegrass, *Poa scabrella*
Creeping wildrye, *Elymus triticoides*
Melic grass, *Melica californica*
California oatgrass, *Danthonia californica*
Squirrel grass, *Sitanion hystrix*

Trees and Shrubs

Blue oak, *Quercus douglasii*
Interior liveoak, *Quercus wislizenii*
Buckeye, *Aesculus californica*
Digger pine, *Pinus sabiniana*
Wedgeleaf ceanothus, *Ceanothus cuneatus*
Poison oak, *Rhus diversiloba*
Hollyleaf buckthorn, *Rhamnus crocea*
Manzanita, *Arctostaphylos* spp.

Changes in the Native Grasslands

Great changes in the vegetation of California grasslands have occurred since the first Spanish Missions were established nearly 200 years ago. These have been brought about chiefly by an invasion of alien species—nearly 400 of them on grassland ranges (Robbins, 1940). Some of these are adaptable, aggressive, and widespread

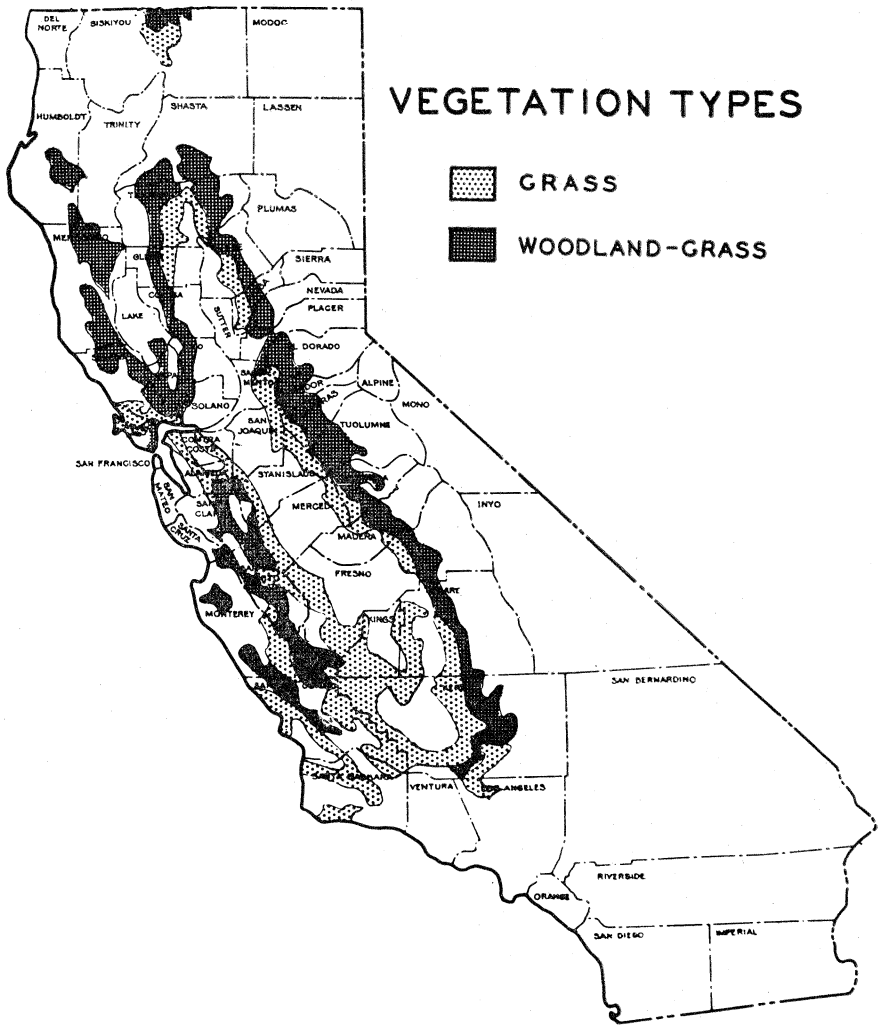

FIGURE 2. Map of California showing distribution of grass and woodland-grass ranges which provide 80 percent of the forage for domestic livestock from the State's wildlands.

while others are more limited. Usually the alien species can be expected to comprise at least 50 percent of the plant cover, but often they account for 90 percent, or even more. A majority of the aliens are annuals, although a few, such as Klamath weed *(Hypericum perforatum)*, are perennial.

The aliens came from many areas —Europe, Eastern and Western Asia, South Africa, Australia, South America and other regions of the United States. A majority were probably introduced unintentionally, but others were brought in purposely. Some of these are valuable forage plants, such as bur clover, red-stem filaree and soft chess, but others, such as Medusahead *(Elymus caput-medusa)* and Napa thistle, are among the worst of the weeds.

The introduction of aliens probably began with the Spanish Missions, and has continued to the present day. During the Mission period, 1769-1824, such important aliens as wild oats, bur clover and Napa thistle were introduced (Robbins, 1940). Examples of very recent introductions are halogeton *(Halogeton glomeratus)* and goatgrass *(Aegilops triuncialis)*. The dates of the earliest introductions were determined through studies of plant materials found in adobe bricks from the walls of old buildings, including Missions, whose construction dates were known (Hendry and Bellue, 1936). Dates of later introductions were found

by such means as studies of plant collections and botanical literature.

There is considerable speculation about that portion of the native vegetation which the alien plants displaced. Was it chiefly perennial grasses, or was it native annual plants? There is no final answer to this question because early records were not made. It is possible that both types were displaced in varying degrees in different areas because there are hundreds of native annuals in the California grasslands as well as numerous perennial grasses. Perennials grasses may have decreased greatly along the Coast where conditions are most favorable for them, while native annuals may have formed most of the "lost" portion in such areas as the lower foothills of the western slope of the Sierras. It is possible also that perennial forbs, such as blue dicks *(Brodiaea capitata)*, were more plentiful and have decreased. The blue dicks has a fleshy bulb sometimes sought after by rodents. Hillsides with a plowed appearance have been observed where rodents have dug out bulbs of this species. If rodents have increased with grazing, it is possible that they have played an important role in affecting plant composition.

A few early writings (such as one by Davy in 1902), in describing the stock ranges of northwestern California, present evidence that native perennial grasses, particularly California oatgrass, were dominant and that they were displaced by aliens. Clements (1934) arrived at somewhat similar conclusions through studies of relict areas. In a railroad right-of-way near Fresno, abundant purple needlegrass was found, with the conclusion that this was the dominant grass over hundreds of miles of the San Joaquin Valley in the primitive condition. Recently, however, it has been observed that this particular species may be favored by frequent burning. Since such rights-of-way were burned almost annually at the time Clements made his observations in 1918, it leaves doubt about the value of conclusions derived from studies of these relict areas. On the other hand, Indians may have burned the grasslands at fairly frequent intervals, thereby favoring purple needlegrass. On the grass-covered slopes around Berkeley, vacant lots are burned annually for fire hazard reduction with the result that some now support large amounts of purple needlegrass.

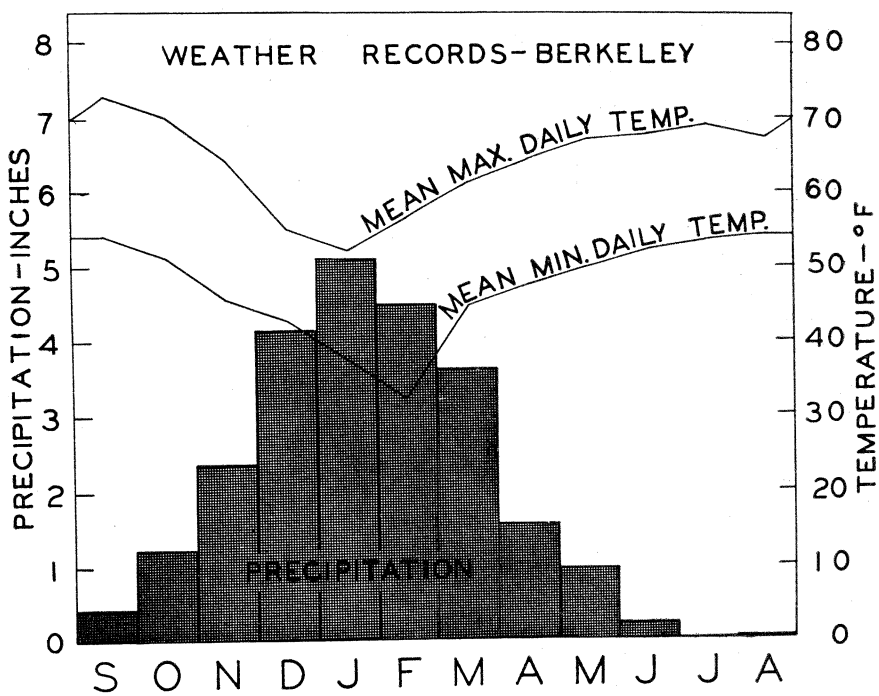

FIGURE 3. Graph of rainfall and temperatures for California grasslands. In the drier areas there may be little or no rainfall for five months of the summer, and the temperatures are considerably higher.

Importance of Soils

Much of the variability in grassland vegetation is related to differences in soils. There are many soil series; even in a square mile there might be a dozen or more. The differences to be expected in plant cover as related to soils are illustrated in Table 1. These data were obtained from a small, rectangular enclosure of less than one acre that crossed two distinct soil series. The centers of the sample plots on the two soils were not more than 100 feet apart.

Such marked differences in composition are not common to all soil series, but may be expected in places where the soils are as different as sandy loams and clays.

There is indication, although nothing very definite, that many grassland soils are gradually losing their fertility under continued cropping. This results in a thinning of the vegetation and an increase in shorter lived and more weedy species. When such areas are fertilized, remarkable changes often take place in the vegetation. For example, in one area common ryegrass and weeds were displaced almost entirely by bur clover. In another area, broadleaved filaree decreased and true clovers increased; in still another, tarweed was largely replaced by bur clover and common ryegrass.

Changes Under Grazing Protection

During the past twenty years a number of protected areas have been studied in order to record changes in vegetation when such areas are not grazed. The rapidity of change depends on rate of accumulation of mulch, weather

and other factors that affect general distribution and growth of plants. An example of change and succession is illustrated in Table 2 from data reported by Talbot, Biswell, and Hormay (1939).

On fertile soils which produce large volumes of forage and mulch, the plant cover is likely to change rapidly toward ripgut grass, a tall and shade-tolerant species with seeds well equipped with barbs that take them down to mineral soil. When protection follows heavy grazing, a common pattern of change is from forbs to soft chess, to slender oat, to ripgut grass. It appears that much of the change in species composition is caused by accumulation of mulch. If the mulch is removed by hand, the plant cover may be set back to the stage of forbs. Where mulch accumulates slowly the changes in plant cover are less rapid, and the vegetation may stay in a relatively low stage of succession for many years. In certain coastal areas, the succession may go farther, and ripgut grass be displaced by creeping wildrye, a perennial grass with strong rhizomes, or by black mustard *(Brassica nigra)*, poison hemlock *(Conium maculatum)*, or other tall growing weeds.

Table 1. Example of differences in botanical composition of California grasslands as related to soils.

Plants	Laughlin sandy loam	Montezuma clay
	Percentage in forage cover.	
Perennial grasses and forbs:		
California oatgrass	1	—
Sheep sorrel, *Rumex acetosella*	7	—
English plantain, *Plantago lanceolata*	4	—
Annual grasses and forbs:		
Ripgut grass	34	2
Silver hairgrass, *Aira caryophyllea*	11	—
Foxtail fescue	11	2
Soft chess	9	2
Common ryegrass	4	20
Slender oat	4	—
Bur clover	4	40
Tarweed, *Hemizonia congesta*	—	23
Others	7	11

Table 2. Example of changes in annual vegetation of areas under protection compared with those under grazing. (1933 was a dry year; the others were normal or above in precipitation.)

Treatment	1933	1935	1937	1938	1939
	Percentage in forage cover				
Closed to livestock and rodents:					
Grasses	2	96	99	80	99
Forbs	98	4	1	20	1
Open to livestock and rodents:					
Grasses	2	21	33	57	78
Forbs	98	79	67	43	22

The idea is frequently expressed that perennial grasses will take over under grazing protection. This happens occasionally but not always. In a protected area of fertile soil near Berkeley a stand of 65 percent purple needlegrass decreased to about 10 percent after several years of protection, being crowded out chiefly by ripgut grass which was growing three or four feet tall (Sampson, 1955). In the foothills east of the San Joaquin Valley, pine bluegrass gradually decreased under protection. In another case, sods of several species transplanted into a fertile soil gradually decreased in number. There is evidence that certain of the perennial grasses, such as pine bluegrass and nodding needlegrass *(Stipa lepida)*, increase during periods of drought and also on poor soils where competition from other plants may not be so great as under more favorable conditions.

Influences of Grazing

Botanical composition of the vegetation is influenced both by intensity of grazing and the season during which the range is utilized. Moderate grazing usually gives the densest cover of forage as well as the more desirable species. Light grazing may result in too much ripgut grass for best forage, and heavy grazing may result in summer weeds, such as turkey mullein *(Eremocarpus setigerus)* and tarweeds. The latter change is explained on the basis that the forage crop heavily utilized is unable to use all the soil moisture, and the summer weeds thrive on that which remains in the soil. Moderate grazing results in more growth during winter than does close grazing (Bentley and Talbot, 1951).

A system of grazing management that provides for fairly close grazing in the early spring, followed by light grazing or complete protection as the forage crop matures, usually results in less ripgut grass and summer weeds and a larger volume of the late growing species, such as soft chess, common ryegrass, bur clover and true clovers.

The perennial grasses in the forage cover often increase, or can be maintained, under a system of grazing management that retards the growth and reproduction of annuals but favors that of the perennials. This happens where the annuals are grazed fairly close up to the time of maturity, followed by complete protection to permit the perennials to grow flower stalks and mature seed. California oatgrass, near the Coast, was shown to increase under this system of grazing from 3 percent of the cover to 15 percent in three years. A slight difference in time of maturity of the perennial and that of the annuals made it possible for the perennial to increase under this system of grazing.

Influences of Fire

Grassland fires that consume the dry vegetation and mulch have much the same effect as removing this material by grazing or by hand. Neither method destroys the seed in the ground, nor completely removes all the seed on the surface. The change in composition is usually toward forbs and other species, such as the filarees and bur clover, that do best with little mulch. If grazing should be light preceding fire on areas with abundant mulch and ripgut grass, a great change toward forbs may be expected. On the other hand, if grazing has been close, with an abundance of forbs in the cover, the effects of fire will be slight (Hervey, 1949). An example of responses of annual vegetation to fire is given in Table 3.

Table 3. Example of effect of fire in moderately grazed area near Berkeley, California.

Plant group	Unburned	Burned
	Percentage in forage cover	
Grasses	89	47
Forbs	11	53

Increase in Trees and Shrubs

Throughout the woodland-grass type, trees and shrubs have a tendency to increase in abundance. This increase is greatest where the woodland-grass joins the woodland and timber types. Here growth often becomes thick enough to choke out the herbaceous vegetation. This tendency is also found in certain areas of the grass type, but the problem is minor compared with that in woodland-grass.

Studies have shown that, where seed sources exist, seedlings of the trees and shrubs appear in considerable abundance nearly every spring, but that most of them die before the summer passes.

Several factors favor the tendency for brush to increase, while others have the opposite effect (Biswell, 1954). In addition, certain factors may cause the brush to change from one type to another. Factors favoring brush increase are: (1) single fires which usually increase germination of brush seeds and prepare seedbeds; (2) close grazing, late in the green forage period, which decreases the capacity of the herbaceous vegetation to deplete the soil of its moisture, which can be used by brush seedlings in summer; and (3) late rains that replenish soil moisture, thus favoring brush seedlings in summer. Retarding factors are: (1) a dense cover of herbaceous vegetation at maturity, which uses all soil moisture; (2) two fires in close succession, the second destroying the brush seedlings that follow the first fire; (3) browsing by deer, sheep and cattle. Factors important in causing changes in brush type are fires and differential browsing. Fires are more detrimental to non-sprouting species than to sprouting; therefore the tendency is for the sprouting plants to increase in proportion to the non-sprouting species. Browsing, of course, is more detrimental to the palatable plants than to the unpalatable. Browsing may not only kill some of the plants individually, but it also decreases competition, thereby favoring the unpalatable species. Thus, combinations of fire and browsing may result in stands of unpalatable sprouting species of little value on range lands.

In recent years, deer populations have increased throughout most of the woodland-grass type. It can be expected that during the next 20 years, with high populations of deer, successions of trees and shrubs will be considerably different than they were in the past 20 years simply because of browsing. For this reason alone, shrubs will have much greater difficulty in becoming established, and are likely to decrease in abundance.

Summary

In California, 17.5 million acres of grass and woodland-grass range provide 80 percent of the grazing on wildlands. These ranges are green in winter and golden brown in summer. The vegetation is nearly all annual, and comprised chiefly of alien species. It appears remarkably uniform to the casual observer but is, in fact, extremely variable, being influenced by differences in soils—of which there are many series and types—grazing use, and occasional fires. In the woodland-grass ranges there is a tendency for woody vegetation to increase.

LITERATURE CITED

BENTLEY, J. R. AND M. W. TALBOT. 1951. Efficient use of annual plants on cattle ranges in the California foothills. U. S. Dept. Agr. Circ. 870. 52 pp.

BISWELL, H. H. 1954. The brush control problem in California. Jour. Range Mangt. 7: 57-62.

CLEMENTS, F. E. 1934. The relict method in dynamic ecology. Jour. Ecol. 22: 39-68.

DAVY, J. B. 1902. Stock ranges of Northwestern California. U. S. Bur. Plant Indus. Bull. 12. 81 pp.

HENDRY, G. W. AND M. K. BELLUE. 1936. An approach to Southwestern agricultural history through adobe brick analysis. Reprinted from Univ. of N. Mexico Bull. The Univ. Press, Albuquerque, N. Mexico.

HERVEY, D. F. 1949. Reaction of a California annual-plant community to fire. Jour. Range Mangt. 2: 116-121.

KADISH, AMRAM. 1955. Vegetation as related to soil type. Unpublished data.

ROBBINS, W. W. 1940. Alien plants growing without cultivation in California. Calif. Agr. Expt. Sta. Bull. 637. 128 pp.

SAMPSON, A. W. 1955. Unpublished data.

TALBOT, M. W., H. H. BISWELL AND A. L. HORMAY. 1939. Fluctuations in the annual vegetation of California. Ecology 20: 394-402.

TALBOT, M. W. AND H. H. BISWELL. 1942. The forage crop and its management. *In* The San Joaquin Expt. Range, Calif. Agr. Expt. Sta. Bull. 663: 13-49.

TALBOT, M. W. AND A. W. SAMPSON. 1948. The range in California. U.S. D.A. Yearbook. U. S. Dept. Agr. 575-582.

WIESLANDER, A. E. AND H. A. JENSEN. 1946. Forest areas, timber volumes and vegetation types in California. Forest Survey Release No. 4, Calif. Forest and Range Expt. Sta., Berkeley, Calif. 66 pp.