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Ecology and Management of Annual Rangelands Series: Mediterranean Climate

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Ecology and Management of Annual Rangelands Series

Part 1: Mediterranean Climate

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Ecology and Management of Annual Rangelands Series Technical Editor: Melvin George

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Mediterranean-type climates can be found along the west side of continents in mid-latitudes (from 30° to 50°N and 30° to 40°S), commonly in a belt of prevailing westerly winds (fig. 1). Shrub-dominated plant communities that are adapted to summer drought and periodic fire are common in Mediterranean climates. In Chile and Spain these Mediterranean-type shrub communities are called matorral; in France they are called *maquis;* and in Italy, *macchia.* In South Africa they are known as *fynbos* and in southwest Australia, *kwongan.* In California they are known as chaparral and are often mixed with or adjacent to oak-woodlands and annual grasslands. The structure and dynamics of these California plant communities will be further described in Vegetation Change and Ecosystem Services (ANR Publication 8545).

During summer, regions with a Mediterranean climate are dominated by subtropical high-pressure cells, with dry, sinking air capping a surface marine layer of varying humidity and making rainfall impossible or unlikely except for the occasional thunderstorm. During winter, the polar jet stream and associated periodic storms reach into the lower latitudes of the Mediterranean zones and bring rain, with snow at higher elevations. As a result, areas with this climate receive almost all their precipitation during their winter season and may go anywhere from 4 to 6 months during the summer without significant precipitation.

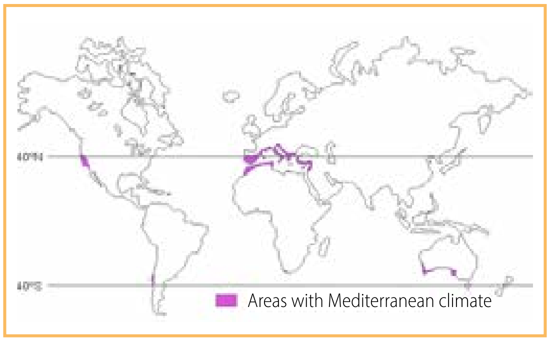

Figure 1. Location of Mediterranean climates.

These Mediterranean-type climates are classified under the Köeppen climate classification system (Kottek et al. 2006) as "Cs." The "C" stands for warm temperature climates, where the average temperature of the coldest months is 64°F. The "s" stands for a dry season in the summer. In the winter, the Mediterranean climate is mild and moist, with most precipitation coming from October through May. During the summer, it is very hot and dry. The normal annual temperature range is between 30° and 100°F. Most of this biome only gets about 10 to 17 inches of precipitation. However, rainfall in California ranges from less than 19 inches in southern desert areas to greater than 100 inches on the north coast. On average, foothill oak-woodland precipitation ranges from 15 to 32 inches. Winter precipitation is primarily the result of cold fronts that move across the Pacific Northwest and northern California. The frequency of these storms decreases from north to south.

LOCATION AND DISTRIBUTION

Orographic and elevational effects influence the location and distribution of precipitation

Table 1. Area of annual rangeland vegetation types

Ecosystem - *million acres*	**Area**
Oak woodlands	**7.4**
blue oak/foothill pine	3.6
blue oak woodland	2.8
coast oak woodland	0.9
Annual grasslands	**7.1**
Chaparral	**15.1**
chamise/redshank chaparral	10.1
coastal scrub	0.65
mixed chaparral	1.3
montane chaparral	0.2

in the annual rangelands. The Coast Range creates a rain shadow effect on the west side of the Sacramento and San Joaquin Valleys and restricts summer fog intrusion from the Pacific Ocean, accentuating the gradient of summer temperatures between the coast and the Central Valley. Precipitation increases with elevation in the Sierra Nevada and the Coast Range mountains. Soils derived from diverse parent materials and complex topography further contribute to the diversity of the annual rangelands and their productivity (Menke 1989).

California's Mediterranean-type rangelands include the oak woodlands, annual grasslands, and chaparral. According to the California Wildlife Habitat Relationships Database (Mayer and Laudenslayer 1988), there are more than 29 million acres of oak woodlands, annual grasslands, and chaparral (table 1).

The herbaceous understory of these rangelands is dominated by annual grasses and forbs that invaded California during European colonization (see *Ecological History,* ANR Publication 8541). California's annual rangelands occur in an intermittent ring around the Central Valley and at lower elevations in the coastal mountains and foothills (fig. 2).

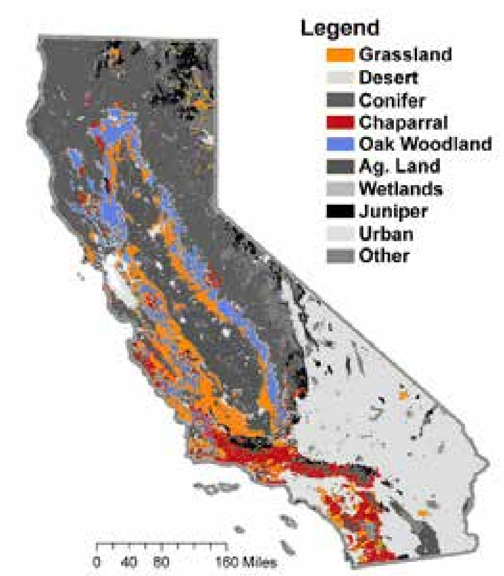

Figure 2. Distribution of annual grasslands, oak woodlands, and chaparral that make up California's annual rangelands.

The oak woodlands form a transition zone between the annual grasslands that surround the agricultural Central Valley and the mixed coniferous forest at higher elevations. The annual grasslands occur at lower elevations and in lower rainfall zones in this intermittent ring around the valley. A transition occurs from annual grasslands to oak woodlands, with increasing elevation and rainfall. Blue oak savanna is often adjacent to the annual grasslands and Central Valley, giving way to oak woodlands with more tree species and a shrub layer as elevation and rainfall increase. Oak woodlands in the Coast Range are commonly adjacent to or intermixed with annual grasslands, chaparral, or other shrub-dominated communities. These plant communities often occur in a mosaic. Chaparral occurs in several

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Figure 3. Blue oak (A), interior live oak (B), and coast live oak (C) on California's annual rangelands.

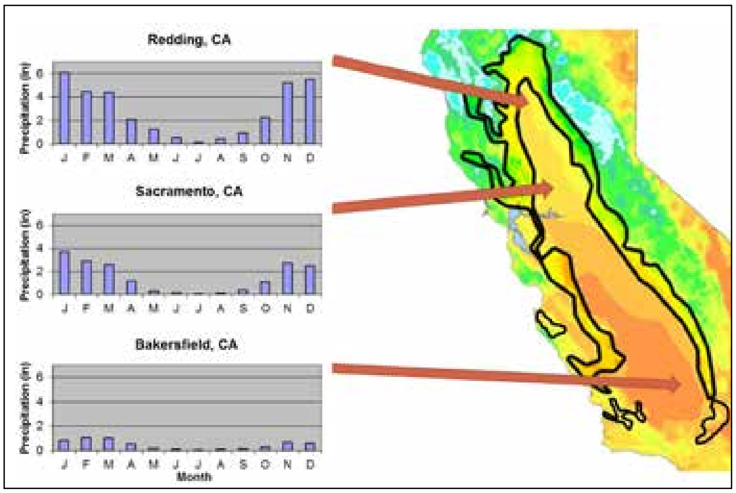

Figure 4. Precipitation decreases from north to south.

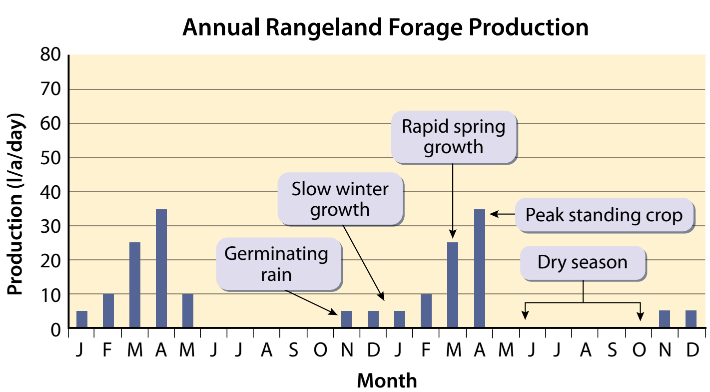

Figure 5. The growing season starts with the first germinating rains in the fall and ends when soil moisture is depleted at the beginning of the dry season.

forms in the coastal range and Sierra Nevada mountains.

Oak woodlands in the Sierra Nevada foothills are dominated by blue oak and interior live oak. Oak woodlands in the Coast Range foothills are dominated by coast live oak or blue oak or both (fig. 3). Valley oak and canyon live oak may also occur in these foothill ecosystems.

WEATHER AND FORAGE PRODUCTION

Four factors—precipitation, temperature, soil characteristics, and plant residue—largely control forage productivity and seasonal species composition. Precipitation and temperature control the timing and characteristics of four distinct phases of forage growth: break of season, winter growth, rapid spring growth, and peak forage production (George et al. 2001). Management decisions may be guided by these patterns—and as the season progresses, patterns become set, and the outcome becomes more predictable. Precipitation in the annual rangelands decreases from north to south (fig. 4) and increases with elevation. Foothill oak woodlands generally occur at an elevation of 200 to 2,300 feet.

In California, the amount of annual precipitation varies greatly within and between years. Additionally, start and end dates of the rainy season are variable. The new fall growing season (break of season) begins when rains start the germination of stored seed (table 2). Young annual plants then grow rapidly if temperatures are warm (60° to 80°F) but more slowly if cooler temperatures prevail (40° to 50°F) (George et al. 1988b). Little growth occurs during winter, when temperatures are low (40°F or less). Rapid spring growth commences with warming conditions in late winter or early spring. Rapid growth continues for a short time until soil moisture is exhausted. Peak standing crop occurs at the point when soil moisture limits growth or when plants are mature (fig. 5). Table 2 and figure 6 describe an average weather pattern and seven variations that can result in greater or less than average forage production, based on weather

Table 2. Influence of normal weather variations on timing of seasonal dry matter (DM) forage production in California's annual rangeland ecosystem

Weather pattern	Curve in fig. 2	Break of season date	Onset of winter growth		Onset of rapid spring growth		Peak standing crop	
			Date	*DM (lb/ac)*	*Date*	*DM (lb/ac)*	*DM (lb/ac)*	*DM (lb/ac)*
average fall, winter, and spring	A	Oct 23	Nov 7	600*	Feb 1	700†	May 1	2,000‡
warm, wet fall, average winter and spring	B	Oct 1	Nov 7	1,000	Feb 1	1,100	May 1	3,000
cold, wet fall, average winter and spring	C	Oct 23	Oct 23	—	Feb 1	300	May 1	1,000
dry fall, average winter and spring	D	Nov 15	Nov 15	—	Feb 1	300	May 1	1,000
average fall, cold winter, average spring	E	Oct 23	Nov 7	600	Feb 1	300	May 1	3,000
average fall, mild winter, average spring	F	Oct 23	Nov 7	600	Feb 1	1,000	May 1	3,000
average fall, short winter, early spring	G	Oct 23	Nov 7	600	Jan 15	700	May 1	3,000
average fall, long winter, late spring	H	Oct 23	Nov 7	600	Apr 1	700	May 1	1,500

Notes:

*Forage production from break of season to onset of winter growth (Oct. 23–Nov. 7 in this example).

† Forage production from break of season to onset of rapid spring growth (Oct. 23–Feb. 1 in this example).

‡ Forage production from break of season to peak standing crop (Oct. 23–May 1 in this example).

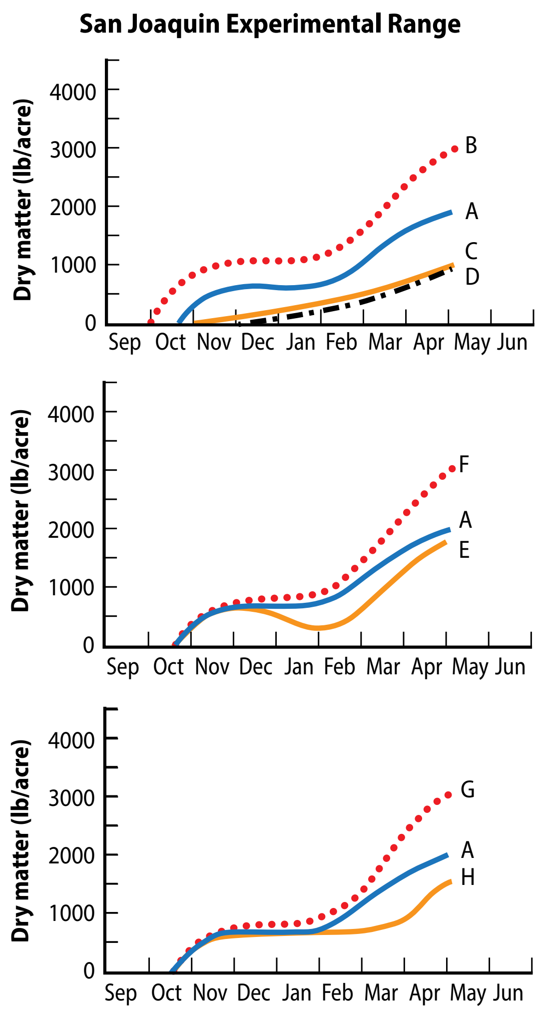

Figure 6. Range forage production curves (A–H in table 2) showing influences of eight different weather patterns.

and forage production records kept at the San Joaquin Experimental Range (SJER) (George et al. 1988a, 1988b, 1989, 2001). Patterns of slow and rapid fall, winter, and spring growth have been documented since 1980 at the University of California Sierra Foothill Research and Extension Center in Yuba County (table 3).

Break of season follows the first fall rains that exceed 0.5 to 1 inch during a 1-week period (Bentley and Talbot 1951). This may occur at any time from September 15 until January 1 (George et al. 1988a). Early false breaks may occur in summer or early fall, but plants that emerge then may not survive until the true break. Taprooted filaree (*Erodium* spp.) is one of the few exceptions that often survives a false break. The timing of the break dramatically affects forage production because earlier rains usually coincide with warmer temperatures, resulting in rapid fall growth and a longer fall growing season (fig. 6A–D).

The winter growth period begins as fall growth slows, due to cooling temperatures, shorter days, and lower light levels. Forage growth may be sparse during this period, and dry matter losses may occur (fig. 6E). Forage production is greater during mild winters (fig.

6F). A short winter growth period or none at all may occur if there is a late break of season. Under those circumstances, almost no new growth is apparent in the fall.

Rapid spring growth begins with the onset of warming spring temperatures, longer days, and higher light intensities (fig. 6G and H). Normally this period begins between February 15 and March 15, when average weekly temperatures exceed 45°F. The length of the rapid spring growth period varies considerably in California, from as little as 1 month in dry southern regions to more than 3 months in wetter coastal regions (see table 2).

Peak forage production occurs at the end of rapid spring growth (peak standing crop), which can come as early as April 1 in the southern San Joaquin Valley or as late as May 25 on the north coast. A late date for peak standing crop means adequate rains will be needed in April or early May. The date of peak standing crop on a single site may vary widely across years and according to species composition. In years when filaree dominates,

Table 3. Monthly and annual forage production (lb/ac) for 16 growing seasons at the UC Sierra Foothill Research and Extension Center

Year	Germinating rain*	Dec 1	Jan 1	Feb 1	Mar 1	Apr 1	May 1	Peak crop	Peak % of average
1979/80	10/20				500	1,300		1,670	56%
1980/81	11/30				350	1,385		2,560	86%
1981/82	9/24				550	1,357		2,770	93%
1982/83	9/17				800	2,142		4,630	156%
1986/87	9/18				204	810		1,486	50%
1987/88	10/23				214	793		1,071	36%
1988/89	11/8			694				2,527	85%
1990/91	11/25			162		691		2,565	86%
1991/92	10/26		383					2,984	100%
1992/93	10/21			367	631	2,260		4,696	158%
1993/94	10/15				410	1,282		2,767	93%
1994/95	10/4		547		569	1,521	3,074	3,213	108%
1995/96	12/7		350	664	950	1,075	3,089	4,123	139%
1996/97	10/25		623	583	1,590	2,827	3,201	3,201	108%
1997/98	10/8	280		341	438	956	2,073	2,797	94%
1998/99	9/27		211	254	316	604	1,463	1,746	59%
1999/00	10/27	592	807	737	1,040	1,954	3,580	3,580	120%
2000/01	9/2			573	1,082	1,951	3,082	3,082	104%
2001/02	10/30	384	407	385	447	1,475	2,740	2,754	93%
2002/03	12/12	335	567	735	960	1,739	3,386	4,348	146%
2003/04	10/31		596	689	848	1,886	2,831	2,831	95%
2004/05	10/20		482	517	1,077	2,742	4,107	4,410	148%
2005/06	11/7	404	838	983	1,458	2,540	3,858	4,122	139%
2006/07	11/2	229	426	430	609	2,082	2,977	2,977	100%
2007/08	9/30		413	544	531	1,278	1,847	1,847	62%
2008/09	10/4	205	199	284	500	1,117	2,815	2,815	95%
2009/10	10/13	601	641	578	650	1,573	3,176	3,176	107%
2010/11	10/1		502	494	703	1,441	2,941	3,794	128%
2011/12	10/3		412	338	496	566	2,389	2,389	80%
2012/13	10/23	609	533	873	861	1,679	2,881	2,881	97%
2013/14	11/21		52	98	400	1,033	2,218	2,300	77%
Average		**404**	**473**	**515**	**685**	**1,519**	**2,886**	**2,971**	**100%**

Note: *Half an inch of precipitation in 1 week is a germinating rain.

peak standing crop comes earlier than in years of grass dominance. In some years and on some sites, summer-growing annuals contribute significant additional growth after the winter-spring grasses and forbs reach peak standing crop.

Moisture from summer storms, although not normally important for plant growth, leaches nutrients from standing dry forage (Hart et al. 1932) and may speed decomposition. Standing residue frequently shatters into ground litter, especially where filaree is dominant.

Monitoring of range forage production at the San Joaquin Experimental Range (Madera County) and the University of California Sierra Foothill and Hopland Research and Extension Centers has allowed researchers to describe seasonal and annual variation in forage production (Murphy 1970; Pitt and Heady 1978; Pendleton et al. 1983; George et al. 1988a, 1988b, 1989, 2001 and 2010). In total, range forage production has been monitored by the University of California and the U.S. Department of Agriculture at 75 foothill locations in the Sierra Nevada and Coast Range (table 4; and link to appendix A, following the

Table 4. Elevation, production, sample size (n), and frequency of forage losses exceeding 50 percent of average forage production at 75 locations in California's annual rangelands

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50% of average
1	SJER	Madera	2,229	2,496	78	11
2	HREC	Mendocino	2,399	2,686	60	3
3	Hawes Ranch	Shasta	1,498	1,677	40	8
4	SFREC	Yuba	2,971	3,327	30	10
5	Ione	Amador	4,049	4,534	18	6
6	Paloma	Amador	3,458	3,872	13	8
7	Sutter Creek	Amador	3,877	4,341	18	6
8	Copperopolis	Calaveras	3,801	4,256	18	6
9	Keystone	Calaveras	3,532	3,955	6	0
10	Mountain Ranch	Calaveras	5,027	5,629	17	6
11	El Dorado	El Dorado	3,827	4,285	17	6
12	Latrobe	El Dorado	2,146	2,403	18	22
13	Arburua	Merced	849	951	4	50
14	Balvar	Merced	2,542	2,847	3	0
15	Conosta	Merced	1,523	1,705	4	0
16	Los Banos	Merced	1,846	2,067	4	25
17	Milsholm	Merced	1,559	1,746	4	0
18	Onell	Merced	2,247	2,516	4	0
19	Peckham	Merced	1,495	1,674	4	0
20	Quinto	Merced	1,759	1,970	3	33
21	Wisflat	Merced	639	716	4	45
22	Adelaida	San Luis Obispo	4,066	4,553	14	21
23	Bitterwater	San Luis Obispo	2,101	2,353	11	45
24	Cal Poly	San Luis Obispo	5,672	6,352	4	0
25	Camatta	San Luis Obispo	1,486	1,664	14	29
26	Cambria	San Luis Obispo	7,016	7,857	14	7
27	Carrizo	San Luis Obispo	3,066	3,433	14	21
29	Huasna	San Luis Obispo	4,970	5,565	14	14
30	Morro Bay	San Luis Obispo	3,563	3,990	14	7

(continued on next page)

Table 4. Elevation, production, sample size (n), and frequency of forage losses exceeding 50 percent of average forage production at 75 locations in California's annual rangelands *(continued)*

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50% of average
31	Pozo	San Luis Obispo	3,151	3,528	5	20
32	Shandon	San Luis Obispo	3,192	3,574	12	25
33	Soda Lake	San Luis Obispo	1,196	1,339	11	45
34	105	SJ/Stan	2,050	2,296	7	0
35	107	SJ/Stan	3,843	4,303	7	0
36	170	SJ/Stan	3,444	3,857	7	14
37	207	SJ/Stan	2,097	2,348	7	0
38	209	SJ/Stan	1,973	2,209	7	14
39	210	SJ/Stan	2,528	2,831	7	0
40	301	SJ/Stan	2,663	2,982	7	14
41	451	SJ/Stan	2,590	2,900	7	0
42	551	SJ/Stan	1,755	1,965	7	14
43	CyD	SJ/Stan	2,041	2,286	7	0
44	Belgarra	W. Fresno	1,804	2,020	15	20
45	Delgado	W. Fresno	829	928	15	40
46	Exclose	W. Fresno	993	1,112	14	43
47	Grazer	W. Fresno	1,117	1,251	15	27
48	Whiterock	Merced	1,372	1,536	7	0
49	Hornitos	Merced	1,915	2,144	6	0
50	Auburn v.r.l	Mariposa	1,866	2,090	5	0
51	Auburn loam	Mariposa	1,633	1,829	5	0
52	Daulton	Mariposa	2,594	2,905	6	0
53	103	SJStan	1,564	1,751	5	20
54	275	SJStan	1,247	1,396	3	67
55	123	SJStan	1,092	1,223	6	17
56	125	SJStan	1,780	1,993	6	17
57	255	SJStan	913	1,022	6	17
58	401	SJStan	1,678	1,879	6	33
59	101	SJStan	1,958	2,193	6	33
60	505	SJStan	1,196	1,339	6	50
61	601	SJStan	573	642	6	33
62	611	SJStan	784	878	6	50
63	Kimball	Tehama	2,423	2,713	9	22
64	Newville	Tehama	838	938	9	11
65	Toomes	Tehama	521	583	9	0
66	Rio Vista	Solano	5,185	5,806	7	0
67	Benecia Hills	Solano	4,001	4,480	7	0
68	Carneros	Napa	5,085	5,694	6	17
69	Rutherford	Napa	3,454	3,868	6	0
70	North Berryessa	Napa	5,225	5,851	6	17
71	Wooden Valley	Yolo	2,408	2,696	5	0
72	Upper Willow Slough	Yolo	2,325	2604	6	0
73	Brooks	Yolo	3,094	3465	6	0
74	Guinda	Yolo	1,900	2128	5	0
75	Hungry Hollow	Yolo	2,392	2679	6	17

References section at the end of this publication). For further information, see the map at UC ANR's IGIS website, http://ucanr.maps.arcgis.com.

Range forage production is strongly influenced by the amount and timing of precipitation. For the range livestock producer, a normal year is characterized by near average forage production.

High forage yields result from years with early-season (November) rains combined with late-season (April) rains (Murphy 1970; Duncan and Woodmansee 1975). Because 50 to 75 percent of annual rangeland forage production occurs in March and April, spring precipitation has a large influence on total annual forage production. At the San Joaquin Experimental Range in Madera County, the average annual precipitation since 1935 has been 19 inches, with a range of 9 to 32 inches. The average forage production is about 2,229 pounds per acre, but it has ranged from less than 800 pounds per acre to more than 4,500 pounds per acre (fig. 7). While average precipitation often results in average productivity, near-average production can also occur in low-rainfall years (e.g., 1967–1968) or in high-rainfall years (e.g., 1955–1956, 1940–l941, 1957–1958, and 1994–1995). Likewise, below-average precipitation often results in low annual forage production but may result in above-average productivity (e.g., in 1969–1970). This demonstrates that the timing of precipitation can have a strong influence on yearly production.

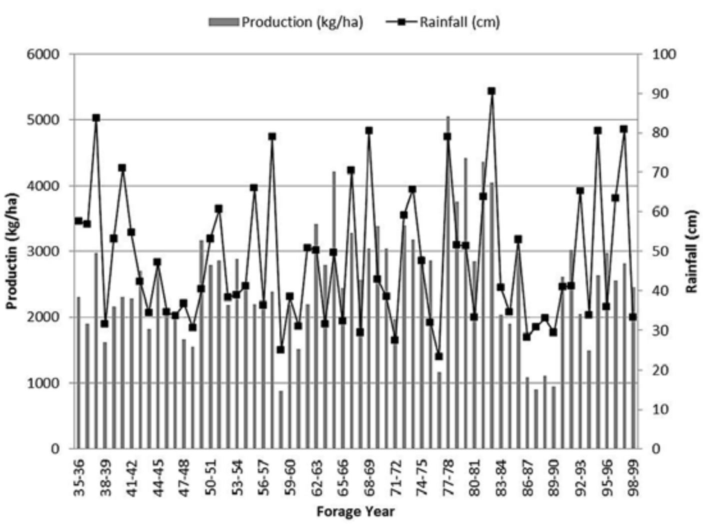

Figure 7. Annual rangeland peak standing crop at San Joaquin Experimental Range (1935–1999).

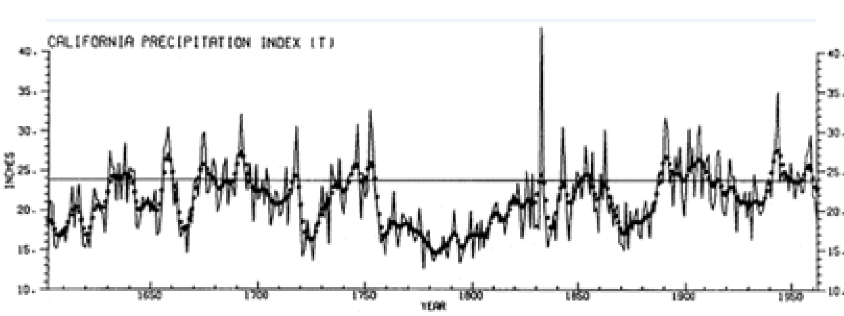

Figure 8. Reconstructed statewide precipitation index (in) for California, showing an extended dry period from 1760 to 1830.

DROUGHT

According to tree ring records, multi-decade dry periods have occurred in the past 500 years. These records reveal a major dry period from 1760 to 1820 (fig. 8) and another drought from 1860 to 1885 (Fritts and Gordon 1980). Severe droughts in 1850 to 1851 and 1862 to 1864, together with other factors, have been implicated in the conversion of the former native perennial grassland to a grassland dominated by annual grasses and forbs (D'Antonio et al. 2006).

At least eight multi-year periods of low precipitation have occurred in California since 1900. Droughts that exceed 3 years are uncommon, though occurrences in the past century include 1929 to 1934, 1947 to 1950, and 1987 to 1992. One of the most memorable examples of drought in California was the 2-year dry period in 1976 and 1977. Precipitation during each of these calendar years, and during the 1976-to-1977 water year in particular, was extremely low. In these 2 consecutive years, statewide precipitation was ranked among the five lowest instances ever recorded in California. The 1976-to-1977 drought is notable because of the magnitude of the precipitation deficit and the enormous effect it had on the human population of California.

In some years poor precipitation results in forage production that is 50 percent or more below average. Because the amount and dependability of precipitation increases from south to north and with elevation, the frequency of years with forage production less than 50 percent of average varies greatly across the state's Mediterranean-type rangelands. Analysis of annual forage production data from 75 locations in California's annual rangelands reveals that a 50 percent reduction in range forage production rarely occurs north of Sacramento (see table 4, Becchetti et al. 2016; appendix A). Forage losses of 50 percent are more common in the rain shadow of the Coast Range, adjacent to the west edge of the San Joaquin Valley.

California's annual rangeland forage production also varies greatly over short distances due to variations in precipitation, soil characteristics, and topography. The coastal areas of a county may have adequate precipitation, but drier inland locations may have low precipitation and forage reductions exceeding 50 percent. Data from San Luis Obispo County reveals that forage reductions of 50 percent or more are less frequent at coastal sites than inland sites (George et al. 2010).

REFERENCES

Becchetti, T., M. George, N. McDougald, D. Dudley, M. Connor, D. Flavel, C. Vaughn, L. Forero, B. Frost, S. Oneto, R. Larsen, K. Striby, J. Davy, M. Doran, and G. Markegard. 2016. *Annual range forage production.* Oakland: University of California Division of Agriculture and Natural Resources Publication 8018.

Bentley, J. R., and M. W. Talbot. 1951. Efficient use of annual plants on cattle ranges in the California foothills.Washington, D.C.: USDA Circular 370.

D'Antonio, C. M., S. J. Bainbridge, C. Kennedy, J. W. Bartolome, and S. Reynolds. 2006. Ecology and restoration of California grasslands with special emphasis on the influence of fire and grazing on native grassland species. A report to the David and Lucille Packard Foundation. University of California, Santa Barbara, CA.

Department of Water Resources (DWR). 1993. California's 1987–1992 drought. Sacramento, CA: Department of Water Resources.

Duncan, D. A., and R. G. Woodmansee. 1975. Forecasting forage yield from precipitation in California's annual rangeland. Journal of Range Management 28:327–329.

Fritts, H. C., and G. A. Gordon. 1980. Annual precipitation for California since 1600, reconstructed from western North American tree rings. Sacramento, CA: California Department of Water Resources.

George, M. R., R. E. Larsen, N. M. McDougald, C. E. Vaughn, D. K. Flavell, D. M. Dudley, W. E. Frost, K. D. Striby, and L. C. Forero. 2010. Determining drought on California's Mediterranean-type rangelands: The noninsured crop disaster assistance program. Rangelands 32(3): 16–20.

George, M. R., K. Olson, and J.W. Menke.1988a. Range weather: A comparison at three California range research stations. California Agriculture: 42:30–32.

George, M. R., C. A. Raguse, W. J. Clawson, C. B. Wilson, R. Willoughby, N. K. McDougald, D. A. Duncan, and A. H. Murphy. 1988b. Correlation of degree-days with annual herbage yields and live¬stock gains. Journal of Range Management 41: 193–197.

George, M. R., W. A. Williams, N. K. McDougald, W. J. Clawson, and A. H. Murphy. 1989. Predicting peak standing crop on annual range using weather variables. Journal of Range Management 42(6): 508–513.

George, M. R., J. Bartolome, N. McDougald, M. Connor, C. Vaughn, and G. Markegard. 2001. Annual range forage production. Oakland: University of California. Division of Agriculture and Natural Resources Publication 8018.

Hart, G. H., H. R. Guilbert, and H. Goss. 1932. Seasonal changes in the chemical composition of range forage and their relation to nutrition of animals. Berkeley, CA: California Agricultural Experiment Station Bulletin 543.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World map of the Koppen-Geiger climate classification updated. Meteorologische Zeitschrift 15:259–263.

Mayer, K. E., and W. F. Laudenslayer. 1988. A guide to wildlife habitats of California. Sacramento: State of California, Resources Agency, Department of Fish and Game.

Menke, J. W. 1989. Management controls on productivity. In L. F. Hueneke and H. Mooney, eds., Grassland structure and function: California annual grassland. Dordrecht, Netherlands: Kluwer Academic Publishers.

Murphy, A. H. 1970. Predicted forage yield based on fall precipitation in California annual grasslands. Journal of Range Management 23:363–365.

Pendleton, D. F., J. W. Menke, W. A. Williams, and R. G. Woodmansee. 1983. Annual grassland ecosystem model. Hilgardia 51:1–44.

Pitt, M. D., and H. F. Heady. 1978. Responses of annual vegetation to temperature and rainfall patterns in northern California. Ecology 59:336–350.

APPENDIX A

Annual Production at 75 sites in the Sierra Nevada Foothills and the Coast Range (Becchetti et al. 2016). Double click on paper clip to open Appendix A in Excel.

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