Chapter 1 Mediterranean Climate

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Introduction

Mediterranean climate types can be found along the west side of continents in mid-latitudes from 30° to 50° N and 30° to 40° S latitudes, commonly in a belt of prevailing westerly winds (Figure. 1.1). Shrub communities are common in the Mediterranean climate type. In Chile and Spain these Mediterranean shrub communities are called ***matorral***, in France it is called ***maquis*** and in Italy, ***macchia***. In South Africa it is known as ***fynbos*** and in southwest Australia ***kwongan***. In California they are known as ***chaparral*** and are often mixed with oak woodland and grasslands.

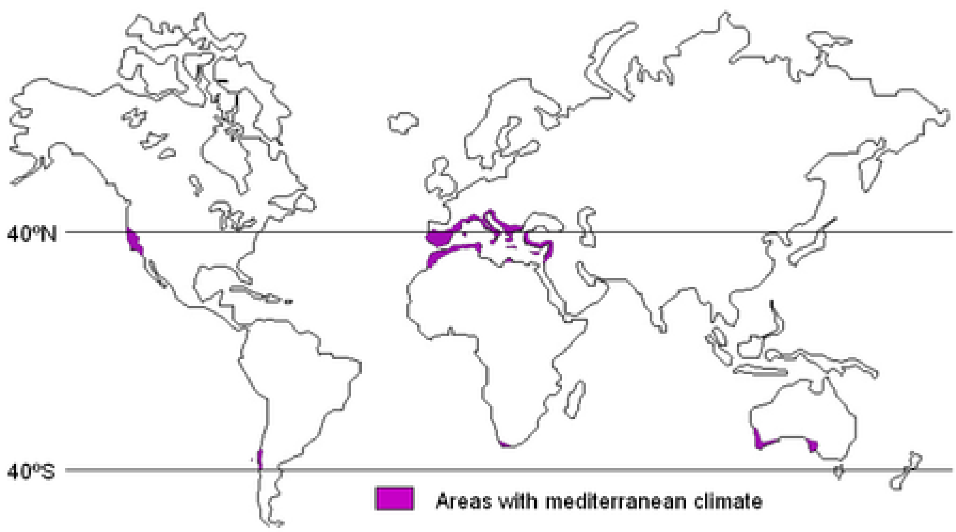

Figure 1.1. Location of Mediterranean climates

During summer, regions of 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, while during winter the polar jet stream and associated periodic storms reach into the lower latitudes of the Mediterranean zones, bringing rain, with snow at higher elevations. As a result, areas with this climate receive almost all of their precipitation during their winter season, and may go anywhere from 4 to 6 months during the summer without significant precipitation.

These Mediterranean climate types 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 (17.8° C) The "s" stands for a dry season in the summer. In the winter the Mediterranean climate, is mild and moist. During the summer it is very hot and dry. The normal annual temperature range is between 30° and 100° F (-1° and 38° C). Most of this biome only gets about 10-17 inches (25-43 cm) of rain. However, rainfall in California ranges from less than 19 inches (25 cm) in southern desert areas to greater than 100 inches (250 cm) on the north coast. On average foothill oak-woodland precipitation ranges from 15 to 32 inches (38 to 81 cm). Most rain comes in the winter. 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 in the annual rangelands. The Coast Range creates a rainshadow effect on the westside 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 (11.7 million ha) of oak woodlands, annual grasslands and chaparral (Table 1.1). The herbaceous understory of these rangelands is dominated by annual grasses and forbs that invaded California during European colonization. California's annual rangelands occur in an intermittent ring around the Central Valley and at lower elevations in the coast mountains and foothills (Figure. 1.2).

Table 1.1 Area of annual rangeland vegetation types

Ecosystem	**Area** (million acres)
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	0.6
Mixed chaparral	1.3
Montane chaparral	0.2

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. There is a transition 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 woodland types 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

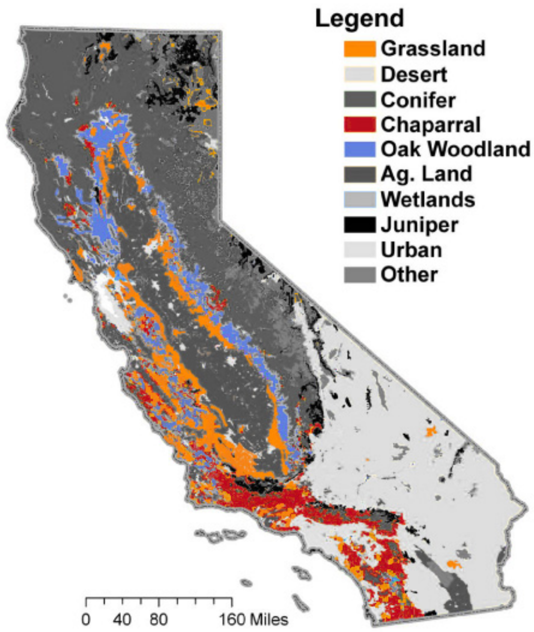

Figure 1.2. Distribution of annual grasslands, oak-woodlands and chaparral that make up California's annual rangelands.

grasslands, chaparral or other shrub dominated communities. Oak-woodlands, annual grassland and chaparral communities often occur in a mosaic. Chaparral occurs in several forms in the coastal range and Sierra Nevada Mountains.

Sierra Nevada foothill oak-woodlands are dominated by blue oak and interior live oak. Coast Range foothill oak-woodlands are dominated by coast live oak and/or blue oak (Figure 1.3). Valley oak and canyon live oak may also occur in these foothill ecosystems.

Figure 1.3. Blue oak (top), Interior live oak (center) and Coast live oak (bottom) on California's annual rangelands.

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. The climate of the annual rangelands is Mediterranean, with precipitation falling primarily between October and May, mostly as rain (Figure 1.4). The dry season averages 6 months but may range from 2 to 11 months. Precipitation in the annual rangelands decreases from north to south and increases with elevation. Foothill oak-woodlands generally occur at an elevation of 200 to 2300 feet (61 to700 m).

In California annual precipitation amounts vary 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 1.2). Young annual plants then grow rapidly if temperatures are warm (60° to 80°F, 15.6° to 26.7°C) but more slowly if cooler temperatures prevail (40° to 50°F, 4.4° to 10°C) (George 1988b). There is little growth during winter when temperatures are low (40°F, 4.4°C) 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 (Figure 1.5). Table 1.2 and Figure 1.6 describe an average weather pattern and seven variations that can result in greater or less than average forage production, based on weather and forage production records kept at 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 1.3).

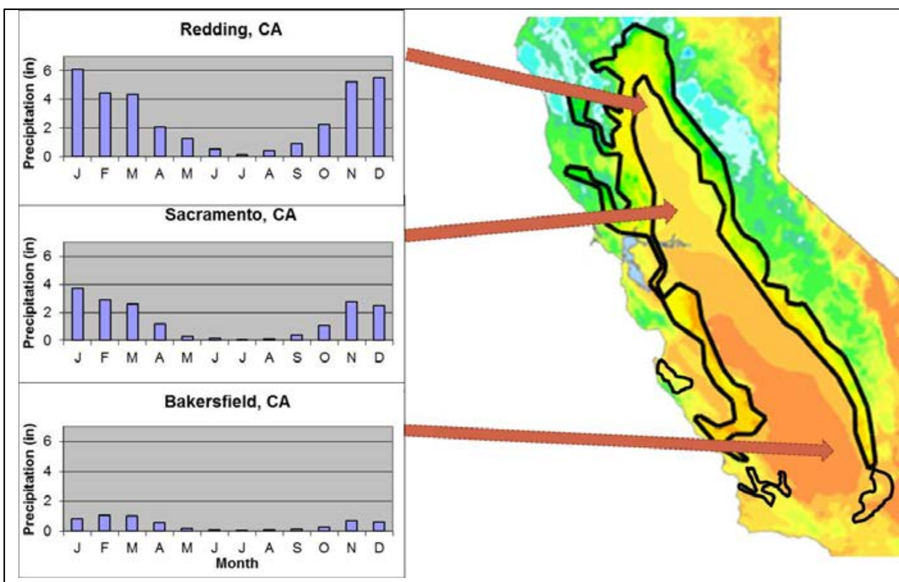

Figure 1.4. Precipitation decreases from north to south.

Break of season follows the first fall rains that exceed 0.5 to 1 inch (1.27 to 2.5 cm) 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 survive 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 (Figure 1.6 A–D).

Table 1.2. Influence of normal weather variations on timing of seasonal dry matter (DM) forage production in California's annual rangeland ecosystem.

Weather Pattern	Curve in Figure 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)	Date	DM (lb/ac)
Average fall, winter and spring	A	23 Oct	7 Nov	600*	1 Feb	700†	1 May	2000‡
Warm, wet fall, average winter and spring	B	1 Oct	7 Nov	1000	1 Feb	1100	1 May	3000
Cold, wet fall, average winter and spring	C	23 Oct	23 Oct	—	1 Feb	300	1 May	1000
Dry fall, average winter and spring	D	15 Nov	15 Nov	—	1 Feb	300	1 May	1000
Average fall, cold winter, average spring	E	23 Oct	7 Nov	600	1 Feb	300	1May	1500
Average fall, mild winter, average spring	F	23 Oct	7 Nov	600	1 Feb	1000	1 May	3000
Average fall, short winter, early spring	G	23 Oct	7 Nov	600	15 Jan	700	1 May	3000
Average fall, long winter, late spring	H	23 Oct	7 Nov	600	1 Apr	700	1 May	1500

*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).

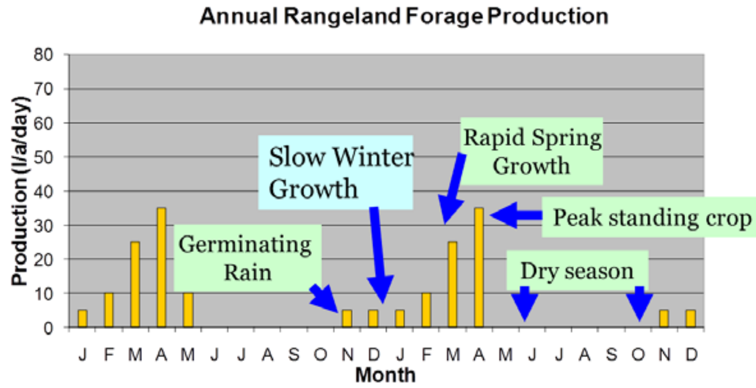

Figure 1.5. The growing season starts with the first germinating rains in the fall and ends when soil moisture is depleted at the beginning of the dry season.

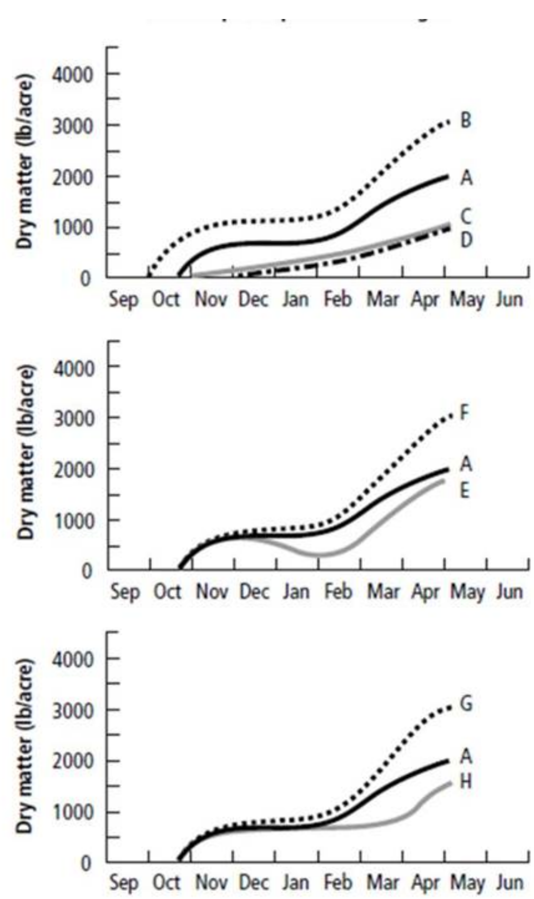

Figure 1.6. Range forage production curves (A–H in Table 2) showing influences of eight different weather patterns.

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 (Figure 1.6 E). Forage production is greater during mild winters (Figure 1.6 F). 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 (Figure 1.6 G and H). Normally this period begins between February 15 and March 15, when average weekly temperatures exceed 45°F (7.2°C). 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 (Table 1.2).

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, peak standing crop will come earlier than in years of grass dominance. In some years and on some sites, summer-growing annuals contribute significant additional growth.

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, and 2001 and 2010). In total range forage production has been monitored by University of California and U.S. Department of Agriculture at 75 foothill locations in the Sierra Nevada and Coast Ranges (Table 1.4, Becchetti et al 2016).

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) 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, California the average annual precipitation since 1935 is 19 in. with a range of 9 to 32 in. (48 cm with a range of 23 to 81 cm) and average forage production is about 2229 lb/a (2496 kg/ha) but has ranged from less than 800 lb/a (896 kg/ha) to more than 4500 lb/a (5040 kg/ha). While average precipitation often results in average productivity, near average production can also occur in low rainfall years (e.g. 1967-68) or in high rainfall years (e.g. 1955-56, 1940-41, 1957-58, 1994-95 (Figure 1.7). Likewise below average precipitation often results in

Table 1.4. Mean annual production at peak standing crop, number of years of data, and number of years when production was less than 50 percent of average for 75 sites in the 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

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50 % of average
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
28	Creston	San Luis Obispo	1,064	1,191	5	40
29	Huasna	San Luis Obispo	4,970	5,565	14	14
30	Morro Bay	San Luis Obispo	3,563	3,990	14	7
31	Pozo	San Luis Obispo	3,151	3,528	5	20

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50 % of average
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	2041	2286	7	0
44	Belgarra	W. Fresno	1804	2020	15	20
45	Delgado	W. Fresno	829	928	15	40
46	Exclose	W. Fresno	993	1112	14	43
47	Grazer	W. Fresno	1117	1251	15	27
48	Whiterock	Merced	1372	1536	7	0
49	Hornitos	Merced	1915	2144	6	0

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50 % of average
50	Auburn v.r.l	Mariposa	1866	2090	5	0
51	Auburn loam	Mariposa	1633	1829	5	0
52	Daulton	Mariposa	2594	2905	6	0
53	103	SJStan	1564	1751	5	20
54	275	SJStan	1247	1396	3	67
55	123	SJStan	1092	1223	6	17
56	125	SJStan	1780	1993	6	17
57	255	SJStan	913	1022	6	17
58	401	SJStan	1678	1879	6	33
59	101	SJStan	1958	2193	6	33
60	505	SJStan	1196	1339	6	50
61	601	SJStan	573	642	6	33
62	611	SJStan	784	878	6	50
63	Kimball	Tehama	2423	2713	9	22
64	Newville	Tehama	838	938	9	11
65	Toomes	Tehama	521	583	9	0
66	Rio Vista	Solano	5185	5806	7	0
67	Benecia Hills	Solano	4001	4480	7	0
68	Carneros	Napa	5085	5694	6	17

Location number	Location name	County	Mean annual production (lb/ac)	Mean annual production (kg/ha)	Years of data	Years less than 50 % of average
69	Rutherford	Napa	3454	3868	6	0
70	North Berryessa	Napa	5225	5851	6	17
71	Wooden Valley	Yolo	2408	2696	5	0
72	Upper Willow Slough	Yolo	2325	2604	6	0
73	Brooks	Yolo	3094	3465	6	0
74	Guinda	Yolo	1900	2128	5	0
75	Hungry Hollow	Yolo	2392	2679	6	17

low annual forage production but may result in above average productivity (e.g. 1969-70). This demonstrates that timing of precipitation can have a strong influence on yearly production.

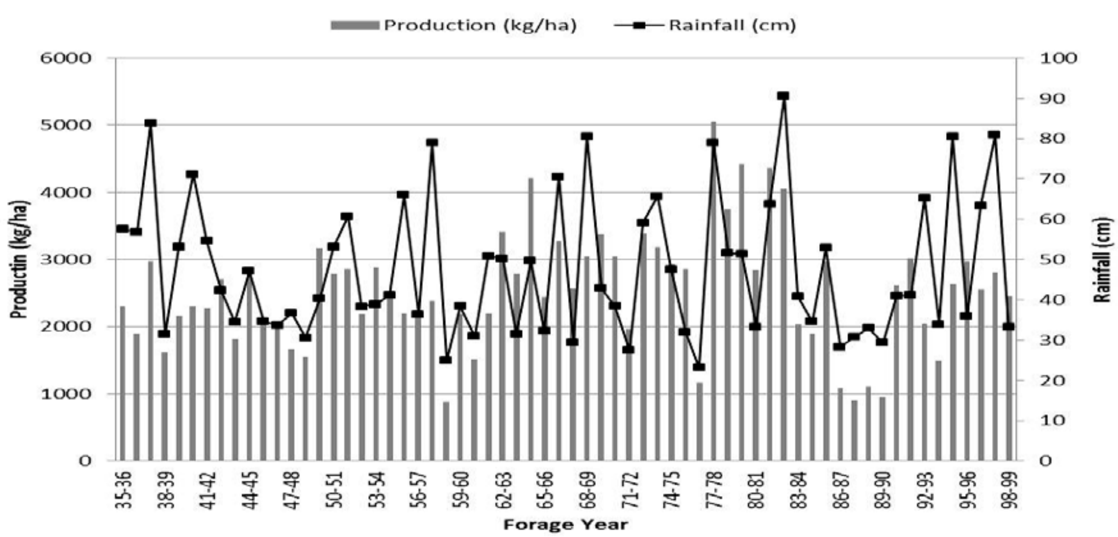

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Figure 1.7. Annual rangeland peak standing crop at San Joaquin Experimental Range (1935–1999)

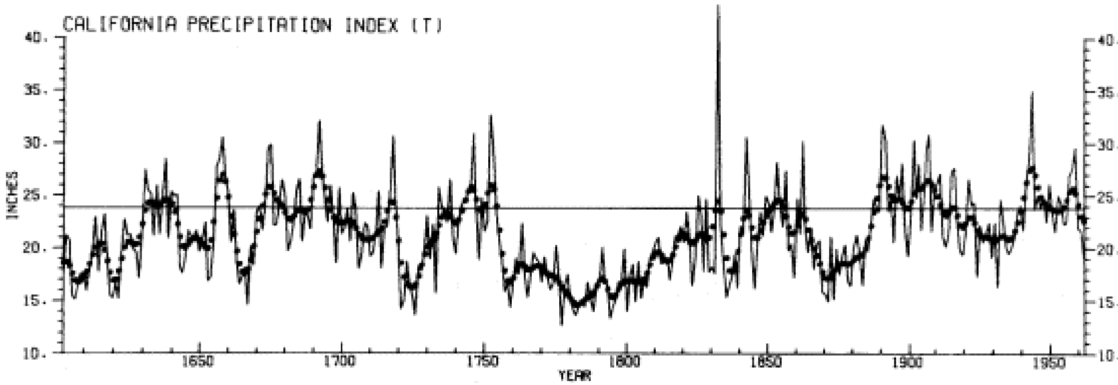

Figure 1.8. Reconstructed statewide precipitation index (in) for California showing an extended dry period from 1760 to 1830.

Drought

According to tree ring records there have been multi-decade dry periods in the past 500 years. These records reveal a major dry period from 1760 to 1820 (Figure 1.8, Fritts and Gordon 1980) and another drought from 1860 to 1885. Severe droughts in 1850-1851 and 1862-1864, 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. 2007).

At least eight multiyear periods of low precipitation have occurred in California since 1900. Droughts that exceed three years are uncommon, though occurrences in the past century include 1929-1934, 1947-1950, and 1987-1992. One of the most memorable examples of drought in California was the two year dry period in 1976 and 1977. Precipitation during each of these calendar years, and during the 1976-1977 water year in particular, was extremely low. In these two consecutive years statewide precipitation was ranked among five lowest ever recorded in California. The 1976-1977 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 reveal that a 50 percent reduction in range forage production rarely occurs north of Sacramento (George et al. 2010, Becchetti et al. 2016). 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 (George et al. 2010).

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Suggested Citation

George, M.R., 2016. Mediterranean Climate. In: M.R. George (ed.). Ecology and Management of Annual Rangelands. Davis, CA: Department of Plant Science. Pgs 1-15.