Title
Rangeland Management Series: Annual Range Forage Production

Authors
Becchetti, Theresa
George, Mel
McDougald, Neil
et al.

Publication Date
2016

DOI
10.3733/ucanr.8018

Peer reviewed

University *of* California
Agriculture and Natural Resources

ANR Publication 8018 | January 2016
www.anrcatalog.ucanr.edu
UC PEER REVIEWED

THERESA BECCHETTI, UC Cooperative Extension Livestock, Range, and Natural Resources Advisor, Stanislaus and San Joaquin Counties; **MEL GEORGE,** UCCE Rangeland Management Specialist Emeritus, Department of Plant Sciences, UC Davis; **NEIL McDOUGALD,** UCCE Livestock, Range, and Natural Resources Advisor Emeritus, Fresno and Madera Counties; **DENNIS DUDLEY,** USDA NRCS Rangeland Specialist, Madera, California; **MIKE CONNOR,** Superintendent (retired), UC Sierra Foothill Research and Extension Center, Browns Valley; **DUSTIN FLAVEL,** Superintendent, UC Sierra Foothill Research and Extension Center, Browns Valley; **CHARLES VAUGHN,** Staff Research Associate, UC Hopland Research and Extension Center, Hopland; **LARRY FORERO,** UCCE Livestock, Range, and Natural Resources Advisor, Shasta and Trinity Counties; **BILL FROST,** Associate Vice President, UC Division of Agriculture and Natural Resources; **SCOTT ONETO,** UCCE Farm Advisor, Amador County; **ROYCE LARSEN,** UCCE Livestock, Range, and Natural Resources Advisor, San Luis Obispo County; **KARL STRIBY,** USDA NRCS Rangeland Specialist, Templeton, California; **JOSH DAVY,** UCCE Livestock, Range, and Natural Resources Advisor, Tehama, Glenn, and Colusa Counties; **MORGAN DORAN,** UCCE Livestock, Range, and Natural Resources Advisor, Napa, Solano, and Yolo Counties; and **GARY MARKEGARD,** UCCE Livestock, Range, and Natural Resources Advisor (retired), Humboldt and Del Norte Counties.

RANGELAND MANAGEMENT SERIES
Annual Range Forage Production

California's foothill rangelands make up the primary forage source for the state's range livestock industry (FRRAP 1988). Forage productivity in California's annual rangelands varies greatly from season to season and from year to year. While predicting the productivity of these annual rangelands has been an elusive research objective, analysis of long-term forage production data from the San Joaquin Experimental Range (SJER), UC Hopland Research and Extension Center (UC HREC), and UC Sierra Foothill Research and Extension Center (UC SFREC) (fig. 1) has allowed researchers to describe seasonal and annual variations of this forage resource (Murphy 1970; Pitt and Heady 1978; Pendleton et al. 1983; George et al. 1988a, 1988b, 1989). The descriptions and data in this publication will help range managers identify potential forage gaps, fine-tune grazing plans, and develop contingency plans for drought.

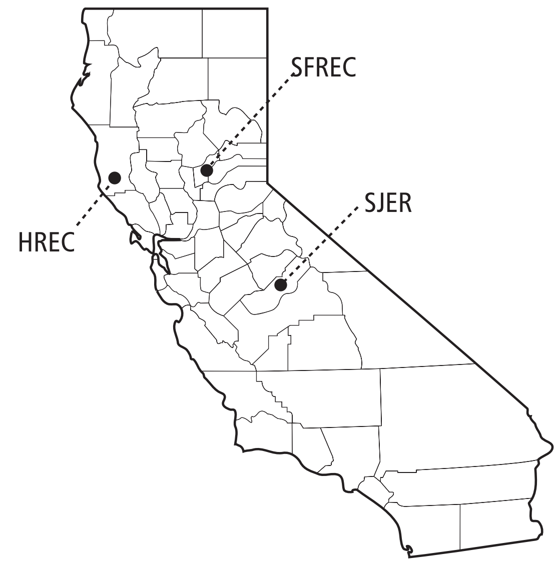

Figure 1. Locations of San Joaquin Experimental Range (SJER), UC Hopland Research and Extension Center (UC HREC), and UC Sierra Foothill Research and Extension Center (UC SFREC).

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. Management decisions may be guided by these patterns, and as the season progresses patterns become set and the outcome becomes more predictable.

Table 1. Influence of normal weather variations on timing of seasonal dry matter (DM) forage productivity in California's annual grassland ecosystem

Weather pattern	Curve shown in figure 2	Break of season date	Onset of winter growth		Onset of rapid spring growth		Peak standing crop	
			Date	DM	Date	DM	Date	DM
				lb/ac		lb/ac		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	1,500
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

*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).

Weather-Related Influences

The new fall growing season (break of season) begins when rains start germination of stored seed. (table 1). Young annual plants then grow rapidly if temperatures are warm (60° to 80°F [15.6° to 26.7°C]) but more slowly if temperatures are cooler (40° to 50°F [4.4° to 10°C]) (George 1988b). There is little growth during winter's lower temperatures (40°F [4.4°C] or lower). Rapid spring growth commences as the weather gets warmer in late winter or early spring. Rapid growth continues for a short time, until soil moisture is exhausted. Peak standing crop occurs either when the soil moisture level limits growth or when the plants are mature. Table 1 and figure 2 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). Patterns of slow and rapid fall, winter, and spring growth have been documented over a 31-year period (1979–80 to 2013–14) at UC SFREC (table 2). Two years' data from Humboldt County contrast normal and cold spring growing seasons in an annual grassland with a long growing season (table 3).

Break of season follows the first fall rains that exceed 0.5 to 1 inch (1.25 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. Filaree (Erodium spp.), one of the few exceptions to the rule, 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. 2 A–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 may be lost because of frost damage to new growth, drying by cold winds, and frost heaving (Laude and Berry 1957; Heady 1958) (see fig. 2 E). Forage production is greater during mild winters (fig. 2 F). A short winter growth period or none at all may occur if there is a late break

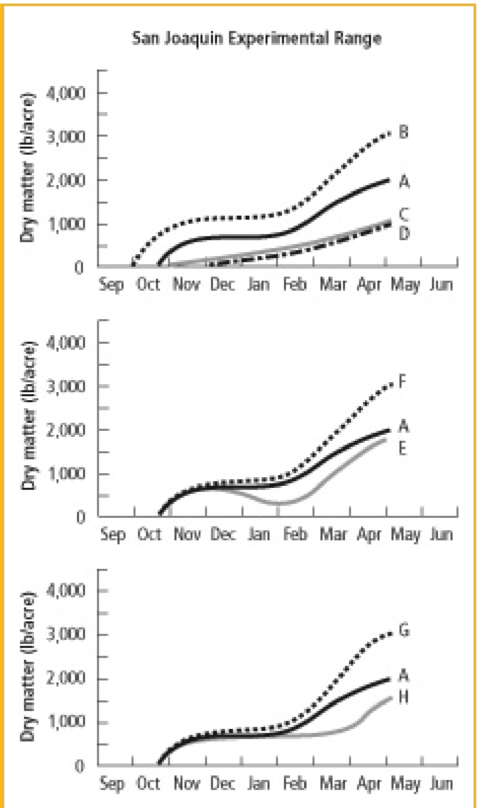

Figure 2. Range forage production curves (A–H in table 1) showing influences of eight different weather patterns.

Table 2. Monthly and annual forage production (lb/ac) for 31 growing seasons at the UC Sierra Foothill Research and Extension Center

Year	Date of germinating rain*	Dec 1	Jan 1	Feb 1	Mar 1	Apr 1	May 1	Peak crop	Peak % of average
		- - - - - - - - - - - - - - - -			*lb/ac*			- - - - - - - - - - - - - - - -	
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%**

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. 2 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 3).

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. 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. Residue decreases about 7 percent per month during the dry season (Frost et al. 2005).

The date of peak standing crop on a single site may vary widely from year to year and with different species compositions. Peak standing crop comes earlier in years when filaree dominates the species composition than in years when grass dominates. In some years and on some sites, summer-growing annuals contribute significant additional growth. Grasses tend to dominate during years with well-distributed or greater-than-normal precipitation and when high levels of residual dry matter are present. Grasses may also dominate in years when germinating rains arrive early and fall-winter precipitation is above average and well distributed. Filaree years coincide with low-rainfall years or years when residual dry matter is low (Pitt and Heady 1978). Drought, heavy grazing, and fire often result in a filaree-dominated understory. Following a fire, filaree may dominate the site for up to three years (Parsons and Stohlgren 1989; Becchetti et al. 2011). Medusahead (Taeniatherum caput-medusa), barbed goatgrass (Aegilops triuncialis), and yellow starthistle (Centaurea solstitialis) invasions may occur on some sites, especially on deep clay soils and sites further north with higher rainfall.

Table 3. Season forage production (lb/ac) for two growing seasons on a ridge 400 feet above sea level and 2 miles east of Cape Mendocino, in Humboldt County

Year	Dec. 1	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	Jun. 1	Jul. 1	Aug. 1	Sept. 1
	lb/ac									
1997–98	88	132		574	1,532	2,977	3,643	4,050	4,218	4,351
1998–99	49	80			122	753	2,690	3,082	3,148	3,229

Site-Related Influences

The amount of soil water available for plants depends mainly on rainfall, but it is also influenced by soil depth, soil texture, aspect, and topography. Annual plants depend primarily on the moisture available in the top 1 foot (30 cm) of soil. Filaree and summer annual forbs may make considerable use of water at greater depths.

Soil type

Clay soils hold moisture and provide a buffering effect when rains are widely spaced, and as a result the rapid growth period in such soils may be longer than in others. These soils typically occur in swale areas that collect additional moisture from runoff. Conversely, upland slopes tend to be drier because of high runoff and lighter-textured soils. Aspect is also a factor since south-facing slopes dry more quickly than north-facing slopes. Production curves as illustrated in figure 2 may differ for adjacent sites and for south- and north-facing slopes.

Fertility

California soils vary tremendously in their fertility. Nitrogen (N) is generally the most limiting nutrient in California's annual rangeland soils, but most soils are also deficient in phosphorus (P), sulfur (S), or both. Because phosphorus and sulfur are commonly deficient, they must be included in the fertilizer mix for the nitrogen to be effective (Jones and Woodmansee 1979). Nitrogen fertilizer tends to support grass domination of the species composition. Addition of nitrogen, phosphorus, and/or sulfur increases winter forage and can result in a two- to three-fold increase in annual forage production, resulting in increased carrying capacity and livestock weight gain per acre (Martin and Berry 1970). The amount and distribution of rainfall and temperature influence the effectiveness of nitrogen fertilization. Nitrogen fertilization is usually effective between 12 and 30 inches (30 and 75 cm) of rainfall. Areas with less rainfall are too dry for a fertilizer response. Leaching in areas above this range makes nitrogen fertilization less effective (Martin and Berry 1970). Where legumes are present, phosphorus and sulfur can increase forage and animal production per acre without the addition of nitrogen (Murphy et al. 1973).

Soil pH

Species composition of legumes is influenced by soil pH. Annual grassland soil pH values range from acidic to alkaline. Acidic soils tend to occur in high-rainfall areas, whereas alkaline soils tend to occur in drier southern areas. Soil pH values may vary from 4.5 in high-rainfall zones to 8.5 in lower-rainfall zones. True clovers such as subterranean *(Trifolium subterraneum)* and rose clover *(Trifolium hirtum)* tend to be adapted to neutral to acid soils, while annual medics (*Medicago* spp.) tend to be better adapted to neutral to basic soils (Murphy et al. 1973).

Residue and Grazing Influences

Residual dry matter, the dry forage component remaining at the beginning of the new growing season (end of the dry season), is a major manageable factor governing productivity and composition. Residue, acting as a mulch, influences germinating plants and soil organic matter. To maintain desired forage production, therefore, it is useful to set minimum residue standards (see Bartolome et al. 2006). These standards vary from 100 pounds of dry matter per acre (112 kg/ha) to 2,100 pounds per acre (2,352 kg/ha), depending on rainfall zone, slope, and canopy cover. Retaining residue in excess of established standards does not enhance total forage productivity, but it may be desirable in terms of other management objectives.

A small amount of residue in fall encourages a greater presence of several species: Silver European hairgrass *(Aira caryophyllea),* turkey mullein *(Eremocarpus setigerus),* quakinggrass *(Briza minor),* nitgrass *(Gastridium ventricosum),* filaree (*Erodium* spp.), burclover *(Medicago polymorpha),* and clovers (*Trifolium* spp.). A greater amount of residue in fall encourages dominance by wild oats (*Avena* spp.), soft chess *(Bromus hordeaceus),* medusahead *(Taeniatherum caput-medusae),* barbed goatgrass *(Aegilops triuncialis),* and ripgut grass *(Bromus diandrus).* Some range managers attempt to reduce medusahead and barbed goatgrass by managing for low residue levels. Grasses can shade out other species, so grass most often dominates when residue builds up due to favorable weather or light grazing pressure. Grazing opens the canopy, increasing the occurrence of legumes and other forbs. On a moderately utilized range, livestock do not graze heavily enough to make complete use of the available forage; for this reason, a patchwork of grasses and forbs is apparent. Site factors such as soil depth, aspect, and canopy contribute to this patchwork pattern of species and standing crop.

Monitoring Forage Production

Large year-to-year fluctuations in forage production are characteristic of California's annual rangelands (Bartolome et al. 2007). To document these annual differences, researchers have recorded annual measurements of production in the late spring since the 1930s. Annual forage production is currently being estimated at more than 70 sites in the Sierra Nevada foothills and the Coast Range. With the advent of USDA drought assistance programs, this production data has become important in the decision of whether to declare drought in particular areas. Data from many of these monitoring sites were used in George et al. (2010) to critique the USDA methodology for drought determination.

Annual rangeland forage production monitoring began when USDA Forest Service researchers measured the ungrazed forage standing crop at the SJER in Madera County in the spring of 1936. The project continues today as a cooperative effort of UC Cooperative Extension and the USDA Natural Resources Conservation Service. This is one of the longest-running records of yearly rangeland forage production in the world.

In the 1950s researchers at the UC HREC began to monitor the spring forage standing crop, and in 1979 researchers at the newer UC SFREC began measuring standing crop in the spring and fall. In 1989 the UC SFREC workers began to harvest standing crop on the first of every month if there was new forage present (table 2).

To document drought years as well as normal and above-average production years, several UC farm advisors and USDA NRCS staff members have been monitoring annual forage production on private ranches. Monitoring began on the Hawes Ranch in Shasta County in 1974. During the 1990s, monitoring began in western Fresno County and in several Sierra foothill counties. Since 2000, several sites have been added in Coast Range counties. Since 2000, annual range forage production has been monitored at more than 70 locations in the Sierra Nevada foothills and the Coast Range (see figure 3, the online map at http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=aef4fbf547a34332b92e5216e308d8c5, and appendix A (the Excel download file included with this publication). A few sites have been abandoned due to access problems and changes in grazing management, and new sites are being added.

All of the monitoring sites clip forage at or near peak standing crop in pastures or small plots that have not been grazed that growing season. All locations are managed such that monitoring sites are grazed at least two out of every three years. This requires the use and annual movement of cages or fences to exclude grazing from a particular year's sample site. Forage samples are collected by clipping vegetation to the ground level. The samples are dried and weighed and the resulting numbers are converted to pounds per acre.

Production Comparisons

Annual rangeland forage production differences between locations reflect differences in site capability (table 4 and appendix A). Some coastal and northern sites are very productive when compared with sites in the rain shadow of the Coast Range (George et al. 2010). Year-to-year variation at each site is largely due to the timing and amount of precipitation and prevailing temperatures. Appendix A tabulates the ungrazed standing crop for all of the monitoring sites and also reports average production and highest and lowest production for the years during which monitoring has been conducted.

Long-term production data are valuable for the three research stations because daily weather data that is collected there can be used to determine the effects of rainfall and temperature on annual productivity. Data from the research stations have been analyzed in several studies to determine the influence of precipitation, temperature, and other parameters on seasonal and annual production (Murphy 1970; Pitt and Heady 1978; Pendleton et al. 1983; George et al. 1988a, 1988b, 1989). Precipitation and production relationships developed for UC SFREC were linked to a climate change model in order to forecast the effects of climate change on range forage productivity in the San Francisco Bay Counties (Chaplin-Kramer and George 2013).

The UC HREC began monitoring seasonal production in 1952–53. The average annual production at the site is 2,399 lb/ac (2,686 kg/ha), with a range from 900 to 3,500 lb/ac (1,008 to 3920 kg/ha) (figure 4 and appendix A). The average annual precipitation at Hopland is 35.4 inches (899 mm). The UC SFREC started monitoring productivity in 1979–80 and reports an average annual production of 2,971 lb/ac (3,327 kg/ha) with a low of 1,071 lb/ac and a high of 4,696 lb/ac (1,200 and 5,260 kg/ha) (figure 4 and appendix A). The average annual precipitation at UC SFREC was about 31.5 inches (800 mm). Annual forage production at SJER averages about 2,229 lb /ac (2,496 kg/ha) but has ranged from less than 800 lb/ac to more than 4,500 lb/ac (896 to 5,039 kg/ha) (figure 4 and appendix A). The average annual precipitation at SJER is about 19 inches (483 mm).

While high annual rainfall levels usually result in high annual production levels and low annual rainfall generally results in low annual production, there are exceptions. It all depends on the timing of the rainfall. Average rainfall often results in average productivity, but near-average production can also occur in low-rainfall years (e.g., 1967–68) if rainfall is adequately distributed throughout the year. In high-rainfall years (e.g., 1955–56, 1940–41, 1957–58, 1994–95), productivity may be in the average range if rainfall is not well distributed across the year. Similarly, below-average rainfall

Table 4. Production means from each monitoring stie

Location number and name	County	Mean annual production, lb/ac	Years of data	Percentage of years at less than 50% of average
1. SJER*	Madera	2,229	78	11
2. HREC†	Mendocino	2,399	60	3
3. Hawes Ranch	Shasta	1,498	40	8
4. SFREC‡	Yuba	2,971	30	10
5. Ione	Amador	4,049	18	6
6. Paloma	Amador	3,458	13	8
7. Sutter Creek	Amador	3,877	18	6
8. Copperopolis	Calaveras	3,801	18	6
9. Keystone	Calaveras	3,532	6	0
10. Mountain Ranch	Calaveras	5,027	17	6
11. El Dorado	El Dorado	3,827	17	6
12. Latrobe	El Dorado	2,146	18	22
13. Arburua	Merced	849	4	50
14. Balvar	Merced	2,542	3	0
15. Conosta	Merced	1,523	4	0
16. Los Baños	Merced	1,846	4	25
17. Milsholm	Merced	1,559	4	0
18. Onell	Merced	2,247	4	0
19. Peckham	Merced	1,495	4	0
20. Quinto	Merced	1,759	3	33
21. Wisflat	Merced	639	4	45
22. Adelaida	San Luis Obispo	4,066	14	21
23. Bitterwater	San Luis Obispo	2,101	11	45
24. Cal Poly	San Luis Obispo	5,672	4	0
25. Camatta	San Luis Obispo	1,486	14	29
26. Cambria	San Luis Obispo	7,016	14	7
27. Carrizo	San Luis Obispo	3,066	14	21
28. Creston	San Luis Obispo	1,064	5	40
29. Huasna	San Luis Obispo	4,970	14	14
30. Morro Bay	San Luis Obispo	3,563	14	7
31. Pozo	San Luis Obispo	3,151	5	20
32. Shandon	San Luis Obispo	3,192	12	25
33. Soda Lake	San Luis Obispo	1,196	11	45
34. 105	San Joaquin/Stanislaus	2,050	7	0
35. 107	San Joaquin/Stanislaus	3,843	7	0
36. 170	San Joaquin/Stanislaus	3,444	7	14
37. 207	San Joaquin/Stanislaus	2,097	7	0
38. 209	San Joaquin/Stanislaus	1,973	7	14
39. 210	San Joaquin/Stanislaus	2,528	7	0
40. 301	San Joaquin/Stanislaus	2,663	7	14
41. 451	San Joaquin/Stanislaus	2,590	7	0
42. 551	San Joaquin/Stanislaus	1,755	7	14
43. CyD	San Joaquin/Stanislaus	2,041	7	0
44. Belgarra	W. Fresno	1,804	15	20
45. Delgado	W. Fresno	829	15	40
46. Exclose	W. Fresno	993	14	43
47. Grazer	W. Fresno	1,117	15	27
48. Whiterock	Merced	1,372	7	0
49. Hornitos	Merced	1,915	6	0
50. Auburn v.r.l.	Mariposa	1,866	5	0
51. Auburn loam	Mariposa	1,633	5	0
52. Daulton	Mariposa	2,594	6	0
53. 103	San Joaquin/Stanislaus	1,564	5	20
54. 275	San Joaquin/Stanislaus	1,247	3	67
55. 123	San Joaquin/Stanislaus	1,092	6	17
56. 125	San Joaquin/Stanislaus	1,780	6	17
57. 255	San Joaquin/Stanislaus	913	6	17
58. 401	San Joaquin/Stanislaus	1,678	6	33
59. 101	San Joaquin/Stanislaus	1,958	6	33
60. 505	San Joaquin/Stanislaus	1,196	6	50
61. 601	San Joaquin/Stanislaus	573	6	33
62. 611	San Joaquin/Stanislaus	784	6	50
63. Kimball	Tehama	2,423	9	22
64. Newville	Tehama	838	9	11
65. Toomes	Tehama	521	9	0
66. Rio Vista	Solano	5,185	7	0
67. Benecia Hills	Solano	4,001	7	0
68. Carneros	Napa	5,085	6	17
69. Rutherford	Napa	3,454	6	0
70. North Berryessa	Napa	5,225	6	17
71. Wooden Valley	Yolo	2,408	5	0
72. Upper Willow Slough	Yolo	2,325	6	0
73. Brooks	Yolo	3,094	6	0
74. Guinda	Yolo	1,900	5	0
75. Hungry Hollow	Yolo	2,392	6	17

Notes:
*SJER = San Joaquin Experimental Range
†HREC = UC Hopland Research and Extension Center
‡SFREC = UC Sierra Foothill Research and Extension Center

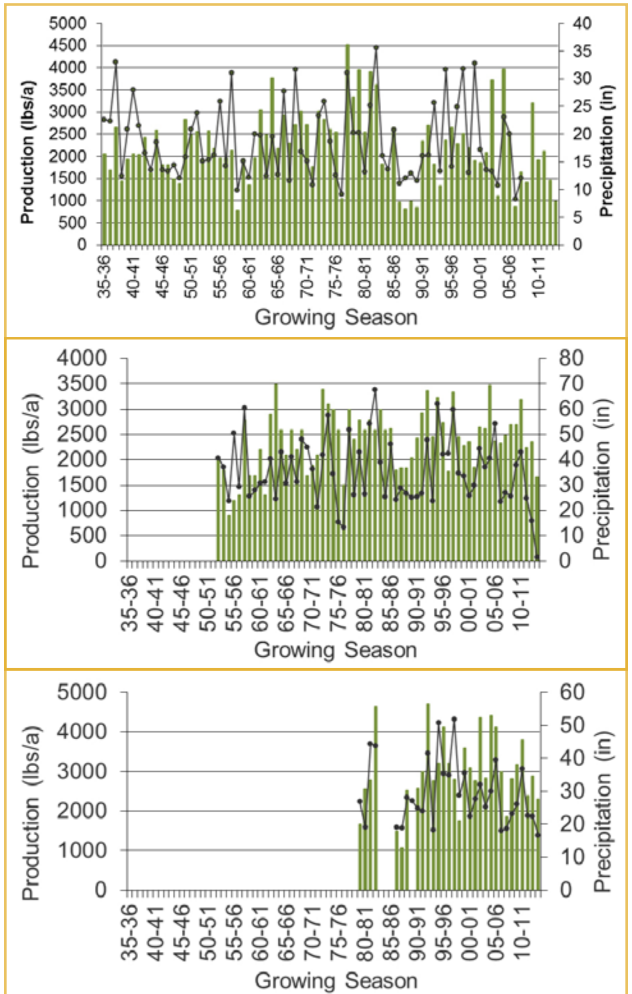

Figure 4. Annual rangeland peak standing crop at San Joaquin Experimental Range (1935–2014), UC Hopland Research and Extension Center (1951–2014), and UC Sierra Foothill Research and Extension Center (1979–2014).

often results in low annual forage production but may result in above-average productivity (1969–70) if it is well distributed.

California's annual rangeland forage production also varies greatly over short geographical distances due to variations in precipitation, soil characteristics, and topography. The coastal areas of a county may have adequate precipitation, but its drier inland locations may have low precipitation and resulting forage reductions in excess of 50 percent. Data from San Luis Obispo County (table 4) reveal that forage reductions of 50 percent or more are less frequent at coastal sites than at inland sites (George et al. 2010).

Dry Years and Drought Years

Prior to the current drought (2014), which started in 2007, 2009, or 2012, depending on the location, there have been at least eight multiyear periods of low precipitation in California since 1900. Droughts that exceed three years are uncommon, though occurrences in the past century include 1928–34, 1947–50, and 1987–92. One of the most memorable examples of drought in California was the two-year dry period in 1976–77. Precipitation during each of these calendar years, and during the 1976–77 water year in particular, was extremely low. In these two consecutive years, statewide precipitation was ranked among the five lowest years on record for California. The 1976–77 drought is notable because of the magnitude of the precipitation deficit and the enormous effect it had on the human population of California. Annual range forage production levels in 1976–77 at SJER, UC HREC and Hawes Ranch in Shasta County, respectively, were 46, 62 and 56 percent of normal.

In 2014, after three consecutive years of below-normal rainfall, most of California was classified as being in extreme or exceptional drought by the U.S. Drought Monitor. Snowpack was well below average, reservoirs were low, and much of the state was placed on water rationing. Hay was expensive, and many ranches reduced their herd size in response to poor range forage production. However, March rains in 2014 boosted annual forage production nearly to average levels in some parts of the state. Forage production in 2013–14 ranged from less than 5 percent of average (at drier sites in the Coast Range) to 75 percent (at more northerly sites). Production for some central Sierra foothill sites exceeded the long-term average during the 2013–14 growing season.

The USDA FSA Noninsured Crop Disaster Assistance Program (NAP) defines drought as a year when forage production is less than 50 percent of average. Appendix A reports the number of years when this criterion was reached on the monitored sites. Because the amount and dependability of precipitation increases from south to north in the state and with increased elevation, the frequency of years with forage production below 50 percent of average varies greatly across the state's Mediterranean-type rangelands. Analysis of annual forage production data from more than 70 locations in California's annual rangelands reveals that a 50 percent reduction in range forage production rarely occurs north of Sacramento (George et al. 2010; Appendix A). However, the frequency of NAP drought years ranges from 25 to 67 percent for several of the monitoring sites in the rain shadow of the Coast Range (e.g., western Fresno County and eastern San Luis Obispo County). During dry years, low forage production levels in the fall and winter increase feed costs for range livestock operations even if rains stimulate forage production to near average levels in March and April, when 50 to 75% of annual production occurs.

Weather Influences on Animal Performance

Weather influences forage intake and animal performance because it influences the quantity and quality of forage available to grazing animals. Mature beef cattle can often be maintained throughout the year with little or no supplementation, especially in more northern areas where the growing season is longer and the dry season shorter. However, during the summer dry season forage quality is inadequate for growing cattle such as stockers and replacement heifers. During the fall and winter, forage quantity and quality may limit the performance of growing cattle. However, seasonal stocker operations are well adapted to annual rangelands because they take advantage of the high-quality forage produced during the spring growing season.

In 1951, Bentley and Talbot described three seasons (inadequate green forage season, adequate green forage season, and the inadequate dry season) based on the adequacy of annual range forage for weight gain by growing beef heifers (stocker cattle, see fig. 5). The inadequate green forage season begins with the fall germination of stored seed. The onset and length of this period depends on prevailing weather conditions. If the fall/winter period is dry or cold, green forage production will be poor and range supplementation may be necessary to maintain cattle performance. If warm weather coincides with adequate precipitation, forage production will be greater and animal performance will improve. Dry residual forage from the previous growing season, which is commonly available for grazing and provides energy, is low in protein and other vital nutrients (see George et al. 2001b). Leaching that results from precipitation further decreases the nutritional quality of dry residue. The inadequate green forage may contain adequate energy, protein, phosphorus, and vitamin A on a dry-matter basis, but sometimes livestock are not able to consume enough of the forage to meet these nutrient needs because of high forage water content. Growing cattle that graze this forage may end up losing weight; hence the term “inadequate green forage season.”

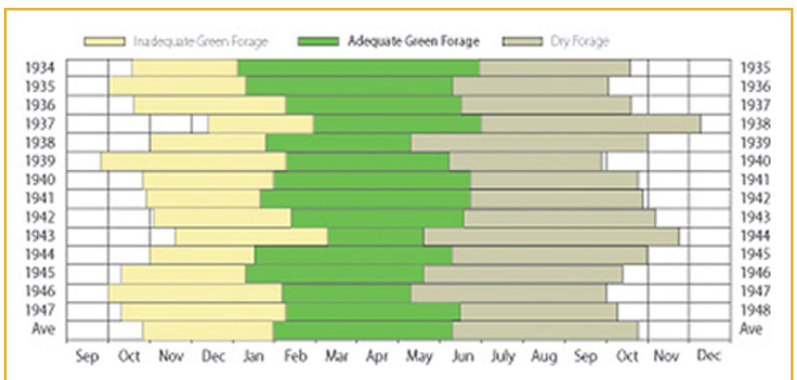

Figure 5. Variations in length of time of the inadequate green forage season, adequate green forage season, and dry forage season at the San Joaquin Experimental Range. *Source:* Bentley and Talbot 1951.

Rapid spring growth commences with warming weather conditions in late winter or early spring. This is also the period when animal performance improves, and is commonly called the rapid spring growth or adequate green forage season. This forage usually is nutritionally adequate for growth, maintenance, reproduction, and gestation. Livestock weight gains are usually greatest during this period. In a study at UC SFREC, Raguse et al. (1988) reported that average daily gains of stocker cattle increased from December to early May and then rapidly decreased.

Rapid spring growth continues for a short time until soil moisture is exhausted. Peak standing crop occurs at the point where soil moisture limits growth or when plants are mature. This period is followed by the summer dry season when the dry forage is a fair energy source but is low in protein, phosphorus, carotene, and other important nutrients (George et al. 2001; George, Nader, and Dunbar 2001). The performance of stocker cattle during this *inadequate dry season* may be poor unless they are provided with feed supplementation. While this forage is inadequate to support growing animals, it is often sufficient to maintain mature beef cattle (Renquist et al. 2005). During the summer dry period it is common practice to provide supplements, transport the stock to high-elevation green feed, or use irrigated pasture.

Conclusion

In summary, while rainfall determines the beginning and end of the growing season, temperature heavily influences the rate of forage production during the growing season. Range managers cannot control the weather, but they can influence productivity and species composition of forage by managing livestock grazing in a way that leaves adequate residual dry matter.

Performance of growing beef cattle is poor on low-quality summer forage. Forage production early in the growing season (fall and winter) is often inadequate to support growing animals, but increased forage quantity and quality during the late winter and in spring support rapid weight gain and serve as the basis for seasonal stocker operations. Mature beef cattle have lower nutritional requirements for most of the year than growing cattle, so they can often be maintained on summer dry forage with little or no supplementation, especially in northern areas where the dry season is shorter. The livestock manager can estimate the frequency of poor forage seasons and years on the basis of long-term data sets and can then use those estimates to assess risk and develop appropriate drought contingency plans.

References

Bartolome J. W., W. E. Frost, N. K. McDougald, and J. M. Connor. 2006. Guidelines for residual dry matter on coastal and foothill rangelands in California. Rangeland Monitoring Series. Oakland: University of California Division of Agriculture and Natural Resources Publication 8092. UC ANR catalog website, http://anrcatalog.ucanr.edu/Details.aspx?itemNo=8092.

Bartolome, J. W., W. J. Barry, T. Griggs, and P. Hopkinson. 2007. Valley grassland. In M. G. Barbour, T. Keeler-Wolf, and A. A. Schoenherr, eds., Terrestrial vegetation of California. 3rd ed. Berkeley: University of California Press. 367–393.

Becchetti, T. A., N. McDougald, W. E. Frost, and J. L. Sullins. 2011. Estimating the cost of replacing forage losses on annual rangeland. Range Management Series. Oakland: University of California Division of Agriculture and Natural Resources Publication 8446. UC ANR catalog website, http://anrcatalog.ucanr.edu/Details.aspx?itemNo=8446.

Bentley, J. R., and M. W. Talbot. 1951. Efficient use of annual plants on cattle ranges in the California foothills. USDA Circular No. 370.

Chaplin-Kramer, R., and M. R. George. 2013. Effects of climate change on range forage production in the San Francisco Bay Area. PLoS ONE 8(3): e57723. doi:10.1371/journal.pone.0057723.

Frost, W. E., J. W. Bartolome, and K. R. Churches. 2005. Disappearance of residual dry matter on annual grassland in the absence of grazing. In F. P. O'Mara, R. J. Wilkins, L. 't Mannetje, et al., eds. 2005. XX International Grassland Congress: Offered Papers. Wageningen, The Netherlands: Wageningen Academic Publishers.

FRRAP (California Department of Forestry and Fire Protection, Forest and Rangeland Resources Assessment Program). 1988. California's forests and rangelands: Growing conflict over changing uses. Sacramento: FRRAP.

George, M. R., K. Olson, and J. W. Menke. 1988a. Range weather: A comparison at three California Range Research Stations. California Agriculture 42(1): 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 livestock 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., G. Nader, and J. Dunbar. 2001a. Balancing beef cow nutrient requirements and seasonal forage quality on annual rangeland. Oakland: University of California Division of Agriculture and Natural Resources Publication 8021. UC ANR catalog website, http://anrcatalog.ucanr.edu/Details.aspx?itemNo=8021.

George, M., G. Nader, N. McDougald, M. Connor, and B. Frost. 2001b. Annual rangeland forage quality. Oakland: University of California Division of Agriculture and Natural Resources Publication 8022. UC ANR catalog website, http://anrcatalog.ucanr.edu/Details.aspx?itemNo=8022.

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.

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: University of California College of Agriculture Bulletin 543.

Heady, H. F. 1958. Vegetational changes in the California annual type. Ecology 39:402–416.

Jones, M. B., and R. G. Woodmansee. 1979. Biogeochemical cycling in annual grassland ecosystems. Botanical Review 45:111–144.

Laude, H. M., and L. J. Berry. 1957. Frost injury to range annuals. California Agriculture 11(5): 10, 14.

Martin, W. E., and L. J. Berry. 1970. Effect of nitrogenous fertilizers on California range as measured by weight gains of grazing cattle. Berkeley: California Agricultural Experiment Station Bulletin 846.

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

Murphy, A. H., M. B. Jones, J. W. Clawson, and J. E. Street. 1973. Management of clovers on California annual grasslands. Berkeley: California Agricultural Experiment Station Circular 564.

Parsons, D. J., and T. J. Stohlgren. 1989. Effects of varying fire regimes on annual grasslands in the southern Sierra Nevada of California. Madrono 36:154–168.

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 California. Ecology 59:336–350.

Raguse, C. A., J. L. Hull, M. R. George, J. G. Morris, and K. L. Taggard. 1988. Foothill range management and fertilization improve beef cattle gains. California Agriculture 42(3): 4–8.

Renquist, B. J., J. W. Oltjen, R. D. Sainz, J. M. Connor, and C. C. Calvert. 2005. Effects of supplementation and stocking rate on body condition and production parameters of multiparous beef cows. Animal Science 81: 403–411. doi:10.1079/ASC50950403.

For More Information

To order or obtain ANR publications and other products, visit the ANR Communication Services online catalog at http://anrcatalog.ucanr.edu/ or phone 1-800-994-8849. You can also place orders by mail or FAX, or request a printed catalog of our products from

University of California
Agriculture and Natural Resources
Communication Services
1301 S. 46th Street
Building 478 - MC 3580
Richmond, CA 94804-4600

Telephone 1-800-994-8849
510-665-2195
FAX 510-665-3427
E-mail: anrcatalog@ucanr.edu

Publication 8018

ISBN-13: 978-1-60107-913-8

An electronic copy of this publication can be found at the ANR Communication Services catalog website, http://anrcatalog.ucanr.edu/.

UC PEER REVIEWED

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor for Agronomy and Range Sciences Rachael Freeman Long.

web-1/16-WJC/SB/BG