Annual Range Forage Production

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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 (HREC), and UC Sierra Foothill Research and Extension Center (SFREC) (Figure 1) has allowed researchers to describe seasonal and annual variation 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.

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.

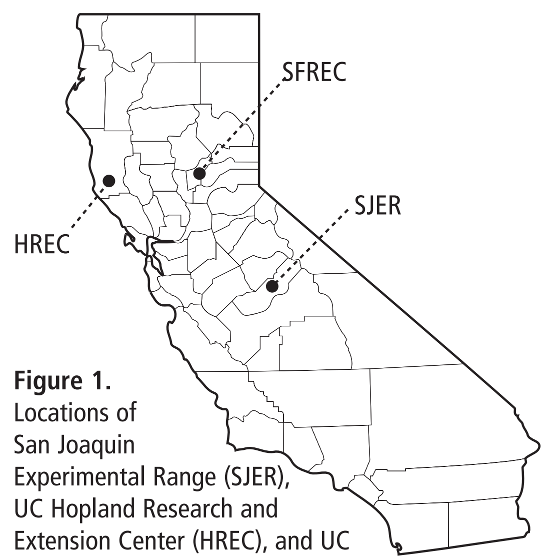

Figure 1. Locations of San Joaquin Experimental Range (SJER), UC Hopland Research and Extension Center (HREC), and UC Sierra Foothill Research and Extension Center (SFREC).

WEATHER-RELATED INFLUENCES

The new fall growing season (break of season) begins when rains start the 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 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 con-

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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 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	Oct 23	Nov 7	600*	Feb 1	700†	May 1	2000‡
Warm, wet fall, average winter and spring	B	Oct 1	Nov 7	1000	Feb 1	1100	May 1	3000
Cold, wet fall, average winter and spring	C	Oct 23	Oct 23	—	Feb 1	300	May 1	1000
Dry fall, average winter and spring	D	Nov 15	Nov 15	—	Feb 1	300	May 1	1000
Average fall, cold winter, average spring	E	Oct 23	Nov 7	600	Feb 1	300	May 1	1500
Average fall, mild, winter average spring	F	Oct 23	Nov 7	600	Feb 1	1000	May 1	3000
Average fall, short winter, early spring	G	Oct 23	Nov 7	600	Jan 15	700	May 1	3000
Average fall, long winter, late spring	H	Oct 23	Nov 7	600	Apr 1	700	May 1	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).

tinues 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. 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 16-year period at SFREC (Table 2). Two years of 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 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 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 losses may occur (Figure 2 E). Forage production is greater during mild winters (Figure 2 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.

Table 2. 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 avg.
1979-80	Oct. 20				500	1300		1670	60%
1980-81	Nov. 30				350	1385		2560	91%
1981-82	Sep. 24				550	1357		2770	99%
1982-83	Sep. 17				800	2142		4630	165%
1986-87	Sep. 18				204	810		1486	53%
1987-88	Oct. 23				214	793		1071	38%
1988-89	Nov. 8			694				2527	90%
1990-91	Nov. 25			162		691		2565	92%
1991-92	Oct. 26		383					2984	107%
1992-93	Oct. 21			367	631	2260		4696	168%
1993-94	Oct. 15				410	1282		2767	99%
1994-95	Oct. 4		547		569	1521	3074	3213	115%
1995-96	Dec. 7		350	664	950	1075	3089	4123	147%
1996-97	Oct. 25		623	583	1590	2827	3201	3201	114%
1997-98	Oct. 8	280		341	438	956	2073	2797	100%
1998-99	Sep. 27		211	254	316	604	1463	1746	62%
Average	Oct. 20		423	438	579	1357	2580	2800	100%

* 0.5 inches of precipitation in one week is a germinating rain.

Rapid spring growth begins with the onset of warming spring temperatures, longer days, and higher light intensities (Figure 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. 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.

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

	Date									
Year	**Dec 1**	**Jan 1**	**Feb 1**	**Mar 1**	**Apr 1**	**May 1**	**Jun 1**	**Jul 1**	**Aug 1**	**Sept 1**
1997–98	88	132		574	1532	2977	3643	4050	4218	4351
1998–99	49	80			122	753	2690	3082	3148	3229

SITE-RELATED INFLUENCES

The available water for plants depends mainly on rainfall, but it is also affected by soil depth, soil texture, aspect, and topography. Annual plants depend primarily on the moisture available in the top 1 foot 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 faster than north-facing slopes. Production curves illustrated in Figure 2 may differ for adjacent sites and for south- and north-facing slopes.

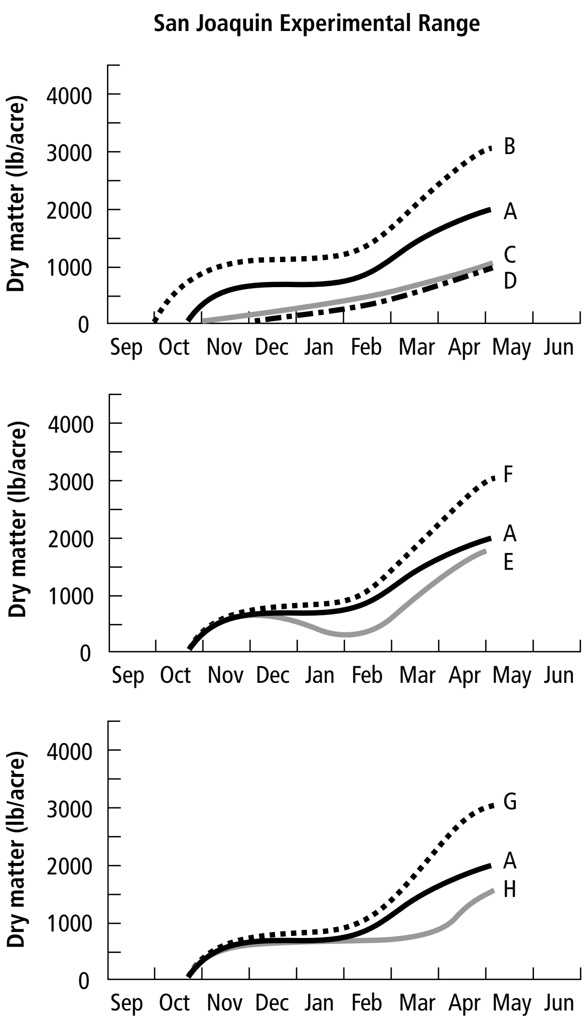

Figure 2. Range forage production curves (A–H in Table 1) showing influences of eight different weather patterns.

Fertility. California soils vary tremendously in their fertility. Nitrogen (N) is generally the most limiting nutrient in California's annual rangeland soils, but phosphorus (P) and sulfur (S) may become secondary limiting factors. Where deficient, addition of N, P, and S can substantially improve range forage productivity (Frost and Duncan 1989).

Soil pH. Species composition of legumes is influenced by soil pH. Annual grassland soil pH values range from alkaline to acidic. Acidic soils tend to occur in high-rainfall areas, whereas alkaline soils tend to occur in drier southern areas; pH values may vary from 4.5 in high-rainfall zones to 8.5 in lower-rainfall zones.

SITE COMPARISONS

Sites vary considerably in their patterns and amounts of annual forage production. One of the longest-running projects to monitor annual forage production is still in progress at SJER in Madera County. Started by the U.S. Forest Service in 1935–1936, the project is continued today by UC Cooperative Extension researchers. Forage production at this site averages about 2,300 lb/ac (2,576 kg/ha) but has ranged from less than 900 lb/ac to 4,500 lb/ac (1,008 to 5,040 kg/ha) (Figure 3). The average annual precipitation at SJER is about 18.7 inches (477 mm).

The UC Hopland Research and Extension Center (HREC) began monitoring seasonal production in 1952–1953 (Figure 3). The average annual production at the site is 2,300 lb/ac (2,576 kg/ha), with a range from 900 to 3,500 lb/ac (1,008 to 3920 kg/ha). The average annual precipitation at Hopland is

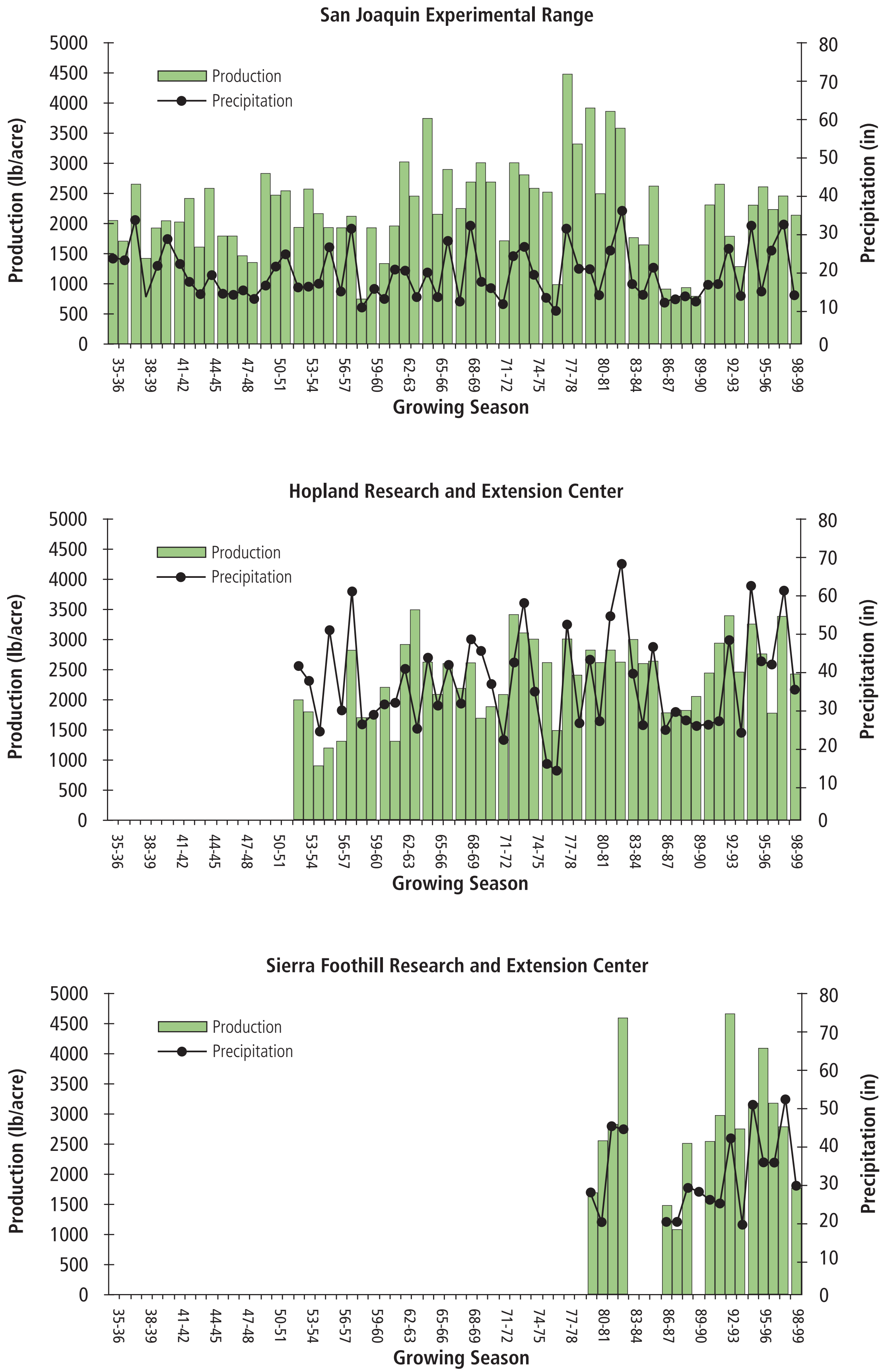

Figure 3. Annual rangeland peak standing crop at San Joaquin Experimental Range (1935–1999), UC Hopland Research and Extension Center (1951–1999), and UC Sierra Foothill Research and Extension Center (1979–1999).

36.8 inches (935 mm). The UC Sierra Foothill Research and Extension Center (SFREC) started monitoring seasonal productivity in 1979–1980 and reports an average annual production of 2,800 lb/ac (3,136 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) (Table 2 and Figure 3). The average annual precipitation at SFREC during this period was about 31.5 inches (800 mm). The average precipitation at SFREC since rainfall records were started in the 1960s is 28.9 inches (734 mm).

Analysis of the long-term data sets from HREC and SJER have shown that peak standing crop is heavily influenced by fall and winter weather variables at the more northerly HREC, while at SJER it is more dependent on spring weather conditions. Studies have shown that fall and winter precipitation, winter temperature, and winter dry period patterns have a strong influence on peak standing crop at HREC while spring precipitation has a strong influence on peak standing crop at SJER (George et al. 1989).

RESIDUE AND GRAZING INFLUENCES

Residual dry matter, the dry forage component remaining at the 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 UC ANR Publication 21327, *Guidelines for Residue Management on Annual Range*). These standards vary from 200 pounds of dry matter per acre (224 kg/ha) in the south to 1,250 lb/ac (1,400 kg/ha) on north coast steep slopes. The retaining of greater amounts of residue does not enhance total forage productivity, but it may be desirable in terms of other management objectives.

A lower amount of residue in fall encourages higher proportions of the following species: Silver European hairgrass (*Aira caryophyllea*), turkey mullein (*Eremocarpus setigerus*), quakinggrass (*Briza minor*), nitgrass (*Gastridium ventricosum*), broadleaf filaree (*Erodium botrys*), burclover (*Medicago polymorpha*), redstem filaree (*Erodium cicutarium*), and clovers (*Trifolium* spp.).

A high amount of residue in fall encourages dominance by slender wild oats (*Avena barbata*), soft chess (*Bromus hordeaceus*), wild oats (*Avena fatua*), medusahead (*Taeniatherum asperum,* recently changed to *T. caput-medusae* according to Hickman 1993), and ripgut grass (*Bromus diandrus*). 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.

WEATHER INFLUENCES ON ANIMAL PERFORMANCE

In 1951, Bentley and Talbot described three seasons based on the adequacy of annual range forage for beef cattle weight gains (Figure 4). The *inadequate green season* begins with the fall germination of stored seed. Cattle grazing this forage may lose weight, hence the term *inadequate green forage.* The onset and length of this period depends on prevailing weather conditions. If the fall and 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 is commonly available for

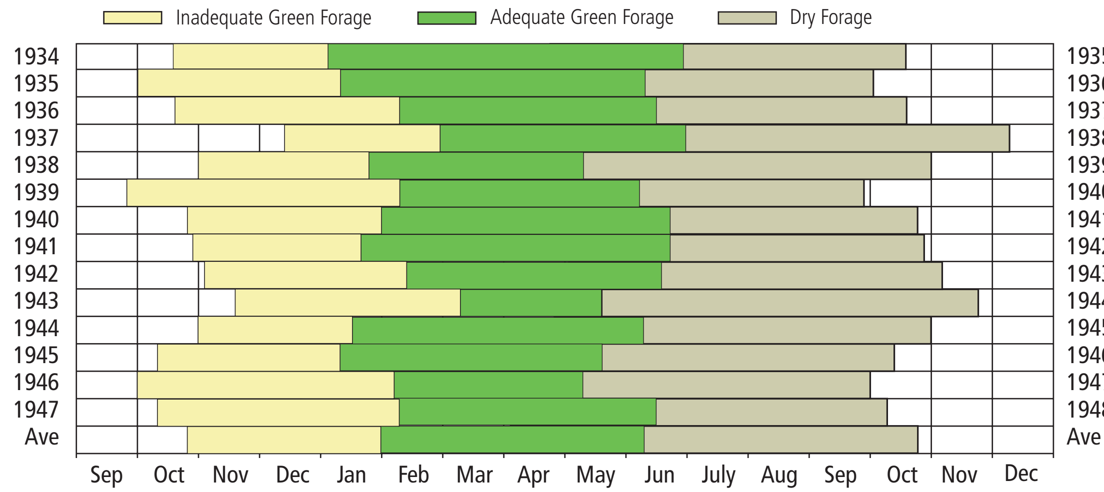

Figure 4. Variations in length of time of the inadequate green forage season, adequate green forage season, and dry forage season at the San Joaquin Experimental Range (Bentley and Talbot 1951).

grazing and provides energy, but it is low in protein and other vital nutrients (see UC ANR Publication 8022, *Annual Rangeland Forage Quality*). Leaching due to 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. On occasion, however, livestock are unable to consume adequate forage to meet their need for these nutrients because of high forage water content.

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 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 forage is a fair energy source but is low in protein, phosphorus, carotene, and other important nutrients. Livestock performance during this *inadequate dry season* may be poor without supplementation. During this summer 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 usually determines the rate of forage productivity during the growing season. Range managers cannot control the weather, but they can influence forage productivity and species composition by managing grazing to leave adequate residual dry matter.

During winter periods of slow forage growth, forage quantity and quality often are inadequate to support cattle weight gains. Forage quality and animal performance both decline rapidly as forage matures and dries following the depletion of soil moisture and the onset of the dry season. The frequency of poor forage seasons and years can be estimated from long-term data sets and can then be used to assess risk and develop drought contingency plans.

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