Predicted Forage Yield Based on Fall Precipitation in California Annual Grasslands[1]

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Highlight

The initiation of fall forage growth in the California annual grasslands is dependent upon the first half-inch of effective rainfall. Annual yield of this forage is influenced by the amount of precipitation received by the third week in November. At that time a determination can be made as to whether the expected annual production will be low, medium, or high. A coefficient of correlation value (r = .70), significant at the 1% level, was obtained between yield and total rainfall through November 20.

The forage yields on California annual grasslands differ considerably from one year to the next. A factor contributing to this variation is the date the annual plant seeds begin to germinate. This, in turn, depends upon the timing of the fall precipitation. Early estimates of expected annual forage production would be useful in planning range livestock grazing operations. With our present knowledge, predicting the annual forage yield before the growing season is more than half completed is unreliable.

Forage estimate systems based on precipitation data have been devised for various areas of North America. In the Great Plains region Rogler and Haas (1947) obtained a highly significant correlation coefficient (r = .76) for April–July precipitation and forage yield for the same season on a native sod of mixed prairie type. Stitt (1958) obtained high correlations (r = .67 to .93) between yield and April–May rainfall in a 15-inch rainfall area. Smoliak (1956) reported a highly significant correlation coefficient (r = .859) between yield and May–June precipitation in an Alberta, Canada study. In the Sandhills range type of Nebraska, Dahl (1963) found that the total precipitation in the two previous years had a significant influence on yield of grass during the spring growth period. Further west, in the Rocky Mountain states, Blaisdell (1965) noted that yield was well correlated with total precipitation in the nine-month period immediately preceding the growing season. From yield and precipitation data for semiarid ranges in Oregon, Utah, and Idaho, Sneva and Hyder (1962) developed a method, based on medium precipitation and herbage yield, for range operators to use to forecast herbage production in eastern Oregon.

In South Australia, where climate and vegetation is similar to California, Trumble and Cornish (1936) showed that rainfall at certain periods rather than total annual rainfall determined pasture yield. A high significant correlation between yield and rainfall was strongest for the April–June period (October–December in the northern hemisphere), coinciding with early stages of seasonal growth.

The purpose of this study was to determine if precipitation might be used as a basis for early forecasting of herbage yields on California ranges.

Study Area and Methods

Yield and precipitation data over a 16-year period were available for an annual range at the University of California's Hopland Field Station. This station is located approximately 40 miles inland from the coast at 39° N latitude, in a typical California foothill rangeland area. Average seasonal precipitation is 35 inches. Normally, the growing season starts in the latter part of October and is concluded by late May. In January the mean minimum temperature is 33 F and the mean maximum is 54 F. Average dates of the first and last freezes are November 15 and March 15, respectively (Elford and McDonough, 1963). The grasses are usually dry by mid-May.

The range pastures used were grazed by sheep both before and during the study. The elevation of the pastures varies between 600 and 1200 feet in an area of about 1000 acres. The herbaceous vegetation consists of annual native and introduced grasses and forbs. The more common genera of grasses are *Bromus*, *Festuca*, *Avena*, and *Hordum*. The forbs include *Erodium*, *Trifolium*, *Lotus*, and *Baeria*. The range is also characterized by scattered trees of the *Quercus* genus, both evergreen and deciduous types.

Eleven soil series are represented in the range area, the most prominent being the Sutherlin (Gowans, 1958).

In 1953, six pastures with the most grazing use during the winter–spring growing season, were selected for sampling. Six 0.001-acre exclosures were placed in each pasture. Before the start of each successive growing season, the exclosures were moved to new locations within the area. At the conclusion of the growing season, samples of the dry forage were taken from inside the exclosures.

Precipitation was measured at the 800-foot elevation, using a standard Weather Bureau 8-inch, nonrecording gage. Readings were made daily at 8 AM for the previous 24-hour period.

Discussion and Results

The annual dry weight forage yield during the 16-year study varied from a low of 900 pounds to a high of 3500 pounds per acre. The yields reflect the interaction of temperature, precipitation, and time of germinating rainfall. The seeds of the grassland plants respond readily to moisture, and

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Table 1. Annual yield and accumulated effective precipitation (inches) totals for 1952–53 through 1967–68 growing years. Hopland Field Station.

Year	Yield group[1]	Yield (lb./acre)	Precipitation Nov. 1	Nov. 5	Nov. 10	Nov. 15	Nov. 20	Nov. 25	Nov. 30	Dec. 31	Jan. 31	Feb. 28	Mar. 31	Apr. 30	May 31	Total season
1954–55	L	900	.7	.7	2.9	6.3	6.6	6.6	6.6	13.5	17.1	19.2	19.7	23.6	23.6	23.6
1955–56	L	1200	.4	.5	.5	1.5	3.1	4.8	4.8	24.2	39.3	47.3	48.2	49.7	50.4	50.5
1956–57	L	1300	3.0	3.1	3.1	3.1	3.1	3.1	3.1	3.8	10.9	19.3	22.9	25.5	29.2	29.3
1958–59	L	1700	0	0	.4	.7	1.4	1.4	1.4	3.1	15.2	23.3	25.0	25.5	25.5	25.5
1959–60	L	1700	2.1	2.1	2.1	2.1	2.1	2.1	2.1	3.5	9.3	18.6	24.3	25.8	28.0	28.0
1961–62	L	1300	.4	.4	.4	.4	1.2	6.9	8.1	12.6	14.1	25.0	29.9	30.5	31.1	31.1
1952–53	M	2000	0	0	0	2.7	2.7	2.7	2.7	19.9	30.8	31.1	35.2	38.3	40.0	40.7
1953–54	M	1800	1.7	1.7	2.9	6.3	6.8	9.1	9.1	9.9	22.4	27.7	33.4	36.1	36.1	37.2
1960–61	M	2200	.8	.8	.9	3.2	3.6	5.2	6.2	14.0	18.5	22.4	28.3	29.8	30.6	30.7
1965–66	M	2100	0	0	.9	5.8	7.6	9.1	9.6	14.5	24.0	27.4	29.1	30.2	30.4	30.6
1967–68	M	2200	2.0	2.1	2.5	3.6	3.7	3.7	4.2	10.5	20.4	25.1	29.7	30.3	31.0	31.1
1957–58	H	2800	9.7	9.7	10.0	10.9	11.2	11.2	11.2	16.9	25.9	45.4	53.0	59.0	59.6	60.4
1962–63	H	2800	9.3	9.3	9.5	9.5	9.6	9.6	11.7	15.7	20.1	25.0	32.0	39.0	40.2	40.3
1963–64	H	3400	3.7	4.8	6.3	8.0	9.4	10.3	10.3	12.8	19.3	19.6	22.2	23.1	23.9	24.4
1964–65	H	2600	3.0	3.5	7.8	9.0	9.0	9.6	10.8	27.0	35.5	36.8	37.8	43.0	43.0	43.0
1966–67	H	2600	0	0	.8	2.5	7.9	9.0	9.5	17.3	27.0	27.4	35.0	39.7	40.1	41.1
Correlation coefficient (r)			.57*	.61*	.63**	.63**	.70**	.61**	.63**	.24	.19	.09	.20	.25	.24	.21

[1] L = Low yield, M = Medium yield, H = High yield.
* = Significant @ 5%.
** = Significant @ 1%.

most of them will germinate after a rain of ½ to 1 inch in the fall (Bentley and Talbot, 1951).

The yields were classed into three groups by a method similar to that used by Caprio (1966). The groups were: low yields, 800 to 1700 pounds; medium yields, 1800 to 2200 pounds; and high yields, 2600 to 3500 pounds. Yields from 6, 5, and 5 years were in the respective groups.

The time of the first precipitation in the fall sufficient to initiate germination was a prime factor in seasonal yield. Generally, if rain started in September, yield was high; but if it started in November, yield was low. Part of this response to early rainfall was the result of the higher temperatures in September and October than in November. The plants naturally grew at a more rapid rate than if germination had started when temperatures were considerably lower. With the high yield group, the rainfall 4 of the 5 years was above average in September and October, and by November 21 had exceeded 8 inches. In the exceptional year, 1966–67, the yield was 2600 pounds per acre, even though September–October precipitation was low. However, by November 20, rainfall was about 8 inches. The high yield in 1966–67 resulted primarily from higher than normal temperatures in December, which caused the growing season to be extended later than usual. In the low and medium yield years, total precipitation by November 20 was always less than 8 inches.

In relating yield to rainfall, especially in late summer or early fall, the effectiveness of the rain, insofar as plant growth is concerned, must be considered. Early precipitation is often insufficient to initiate germination; or, if germination is started, rainfall is not frequent enough, or heavy enough, to sustain growth. In the 1954 season, for example, 0.26 inches of rain was measured on August 30, but no additional rainfall occurred until October 10. The early rain came before germination had taken place, but the amount of moisture was not sufficient to initiate germination.

Total yearly precipitation was adjusted by subtracting the amount of ineffective rain. This value varied from 1.2 inches in the 1955 rainfall year to zero in 1958, 1960, 1961, 1965, and 1968.

The yield–rainfall relationship was most critical in November. At 5-day intervals, starting November 1, the coefficient of correlation values of forage yield to rainfall increased until the highest value ($r = .70$) was obtained on November 20 (Table 1). When the coefficient of correlations were calculated from December to May, the values were much lower, ranging from $r = .24$ to $.09$.

The regression equation for yield vs. precipitation as determined from data of November 20, is $\hat{Y} = 15.25 + 1.49X$, where $\hat{Y}$ = annual forage yield in pounds dry weight per acre and X = effective November precipitation.

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