Using Growing-Season Precipitation to Predict Crested Wheatgrass Yields

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Highlight

Forage available for use by livestock varies with the season in which ranges are used. Specific precipitation patterns accounted for 87% or more of the variation in forage yields of crested wheatgrass grazed at different seasons in the Front Range of Colorado. Rainfall in April determined forage yields of ranges grazed in the spring; May and July rainfall determined forage yields for fall-grazed ranges. Expected forage yields and stocking rates can therefore be predicted from precipitation measurements.

Frequently, one or two specific environmental factors exert major influence on plant growth. If these factors can be isolated from one another, reliably measured, and related to plant growth, then growth can be predicted simply by measuring the environmental factors. Throughout the western United States, studies have shown herbage production is often closely correlated with or largely controlled by precipitation.

In the desert Southwest, Nelson (1934) noted that height growth of black grama *(Bouteloua eriopoda* Torr.) was largely in response to current summer rainfall but more than one growing season with good rainfall was needed to improve vigor or alter the number and size of grass tufts. Lister and Schumacher (1937) found that density (basal area) and flowerstalk height of three important range grasses on the Santa Rita Experimental Range were significantly correlated with precipitation. They used a method based upon 15 months of precipitation to statistically predict changes in the above factors if more or less than the average moisture were received. They recognized too, that distribution of this moisture in different seasons resulted in one or the other of the species being favored.

For semiarid ranges in the Intermountain Region, several workers (Craddock and Forsling, 1938; Hutchings and Stewart, 1953; Blaisdell, 1958) obtained significant correlations between precipitation and herbage yields. Sneva and Hyder (1962) devised a method for estimating yields and stocking rates for these ranges based on adjustments from median yields and crop-year precipitation. They suggested the method should be useful for predicting median yields, both long-term and annual, on rangelands in much of the West. Their system, however, does not take into account yields at various periods within a growing season.

Springfield (1963), for seeded range in New Mexico, found that between 61 and 94% of the variation in forage yields of crested or desert wheatgrass *(Agropyron desertorum* (Fisch.) Schult.) was attributable to antecedent precipitation. Under a medium rate of grazing, a correlation coefficient of 0.97 was obtained between forage production and October-through-May precipitation. He pointed out, though, that to predict stocking rates for an upcoming season, a manager needs a basis for estimating yields before the end of May. Thus he suggested using a weaker relationship, between forage production and October-through-March precipitation. He cautioned that this estimate served only as a rough guide for developing management plans in advance of the grazing season and was subject to considerable error.

Current prediction methods are for an average or range in expected herbage for forage production for an entire growing season based upon either crop-year or antecedent precipitation. These predictions are usually adequate for estimating long-term stocking rates or benefits from a range improvement practice such as seeding, but they generally neglect "effective production"—herbage that is available for use at a particular time rather than at plant maturity or peak production. The present paper outlines a statistical approach that was found successful for estimating forage production and stocking rates on crested wheatgrass ranges grazed at different seasons in the Front Range of Colorado.

Study Area and Methods

Crested wheatgrass ranges in the current study were seeded in 1946 at the Manitou Experimental Forest, 28 miles northwest of Colorado Springs. The Forest is at an elevation of approximately 8,000 ft. Annual precipitation at the headquarters station averages 15.5 inches, with about 10.8 inches falling during the growing season from April through August. Soils of the study site are alluvial, and have been derived primarily from outwash material of Pikes Peak Granite. They generally have moderate amounts of organic matter, and are porous and well drained; they are classified as sandy loams.

Grazing Treatments.—From 1948 to 1956, the crested wheatgrass range was grazed lightly or not at all. In 1957, six pastures, each 3.3 acres, were fenced and grazed by yearling heifers at different seasons. Two areas were grazed in the spring from approximately April 25 to June 10, two in the fall from September 1

[1] *Forest Service, U. S. Department of Agriculture, with headquarters at Fort Collins in cooperation with Colorado State University.*

to about October 15, and two pastures were grazed both spring and fall each year. Animals were turned on the spring pastures when maximum leaf lengths of crested wheatgrass plants averaged approximately 3 inches.

To meet objectives of a more comprehensive study the pastures received heavy use. At all seasons the plants were grazed to a 1-inch stubble height, or approximately 80% use of the forage by weight. Production and utilization were estimated by the paired plot-difference method, with 12 plot pairs in each pasture. In years of high production, during the spring, plots were clipped and cages moved one to several times during the grazing period. In years of low production and in the fall, plots were harvested once immediately after grazing ended. Stocking rates for each seasonal treatment were computed in terms of yearling heifer-days of grazing per acre. Precipitation was measured at the headquarters weather station, approximately 0.5 mile from the pastures at a comparable elevation and exposure.

Analysis.—Previous work with several seeded species at Manitou, which involved analysis of various combinations of monthly precipitation, has shown that from 65 to 90% of the annual variation in forage yield results from fluctuations in April-through-August precipitation.[2] Because precipitation during each of the 5 months did not appear to contribute equally to forage yields, particularly when the ranges were grazed on a seasonal basis, "effective production" was analyzed for its dependence on monthly precipitation within the 5-month period. The analysis was made following the method described by Quenouille (1952). The premise of this approach is to select from a large number of independent variables only those which contribute significantly to the dependent variable through stepwise regression testing.[3]

Results and Discussion

Effective Forage Production in Relation to Precipitation.—Precipitation was quite variable during the 8-year study period. As shown in Table 1, April-through-August precipitation ranged from 6.36 to 16.25 inches, well above and below the study period mean of 10.45 inches. Wide extremes in individual months were also common. For example, April precipitation has averaged 1.65 inches over 28 years of weather records. In 1957, 2.80 inches were recorded during April, but in 1963 no measurable moisture was received.

Forage production from each of the seasonally grazed ranges showed comparable extremes. For those ranges grazed only in the spring, effective forage production ranged from 1,734 lb/acre in 1957 to essentially 0 in 1963 (Table 1). In comparison, when total precipitation for the 5-month growing season was only 7.83 inches in 1959, production was nearly 200 lb/acre more than in 1961 when growing season rainfall totaled 16.25 inches. Production in 1959 and 1961 on ranges that were grazed only in the fall showed just the opposite relationship, with a difference of 700 lb/acre more forage produced during the wetter year. Thus, effective forage production from ranges grazed at different seasons was controlled by the moisture received during specific months.

On ranges grazed only in spring, 88% of the variation in forage yield was accounted for by the amount of precipitation received in April (Table 2, Equation 1). In 6 of 8 years, plant growth to the 3-inch leaf length criteria used for stocking was not reached until after April 25, and occasionally it was early May before grazing began. Therefore, in a majority of years the first equation in Table 2 could be used to predict effective forage production without any adjustment in stocking date. In an occasional year when plant growth is sufficient for grazing before the end of April, stocking must be delayed a few days. This delay permits some additional plant growth, but provides the necessary data for predicting effective forage yields.

The equation for estimating production in the spring is not appropriate for determining the effective yields on ranges grazed both spring and fall. As shown by Equation 3a in Table 2, spring forage production during this split grazing season depended upon April and May precipita-

Table 1. Forage production from crested wheatgrass ranges at different seasons in relation to April-through-August precipitation, Manitou Experimental Forest.

Year	Precipitation in inches						Forage production in lb/acre			
	April	May	June	July	August	Total	Spring	Fall	Spring plus fall	
							only	only	Spring	Fall
	(x_1)	(x_2)	(x_3)	(x_4)	(x_5)		(y_s)	(y_f)	(y_s')	(y_f')
1957	2.80	3.63	1.10	6.20	1.89	15.62	1734	1894		
1958	1.59	3.75	0.57	1.99	2.28	10.18	1090	1362		
1959	1.50	1.43	1.44	1.22	2.24	7.83	1026	824	575	303
1960	0.72	1.96	0.60	2.69	0.72	6.69	708	926	654	302
1961	1.41	2.09	2.22	5.73	4.80	16.25	838	1525	822	914
1962	1.19	0.65	1.23	1.60	1.69	6.36	676	501	452	126
1963	0.00	0.23	2.37	1.81	8.79	13.20	0	741	0	896
1964	0.45	1.68	1.61	2.09	1.67	7.50	769	758	516	418
Mean	1.21	1.93	1.39	2.91	3.01	10.45	855	1066	505	508

[2] *Currie, Pat O. and Dwight R. Smith. Response of seeded ranges to different grazing intensities in the Ponderosa Pine Zone of Colorado. (In preparation for publication, Rocky Mountain Forest and Range Expt. Sta., U. S. Forest Serv., Fort Collins, Colo.).*

[3] *Computer programs for stepwise regression methods used are available at most statistical service libraries.*

Table 2. Influence of monthly precipitation on forage prooduction of crested wheatgrass ranges grazed at different seasons, Manitou Experimental Forest.

Grazing season	Significant precipitation		Equation number	Regression equation for forage production estimate	R^2	Standard error
Spring only	April	(x_1)	(1)	$\hat{Y}_s = 533.32x_1 + 211.14$	0.88	185
Fall only	May	(x_2)	(2)	$\hat{Y}_f = 198.90x_2 + 143.69x_4 + 263.96$	0.94	136
	July	(x_4)				
Spring plus fall:						
Spring	April	(x_1)	(3a)	$\hat{Y}_s' = 201.36x_1 + 266.95x_2 - 31.41$	0.97	56
	May	(x_2)				
	April[1]		(3b)	$\hat{Y}_s' = 349.76x_1 + 200.00$	0.55	185
Fall	June	(x_3)	(4)	$\hat{Y}_f' = 362.53x_3 + 66.93x_4 - 232.92$	0.87	126
	July	(x_4)				

[1] Equation used for early estimate of forage yields for advance stocking rate information.

tion. Animals usually began grazing on spring-fall ranges in late April or early May; therefore, the ranges were stocked before the necessary production and precipitation data could be taken. To overcome this difficulty, Equation 3b was used to obtain an approximation of early forage yields for spring use on spring-fall ranges. This equation, based on April precipitation, accounted for only 55% of the variation in yield. It provides a conservative estimate of effective production.

Forage yields from crested wheatgrass grazed in the fall can be predicted well in advance. As shown in Equations 2 and 4 of Table 2, precipitation during May and July accounted for 94% of the variation in yields on ranges grazed only in the fall, and June and July precipitation accounted for 87% of the differences for fall yields on ranges grazed both spring and fall. With low standard errors of 136 and 126 lb/acre, respectively, each equation provides reliable estimates of fall forage yields from rainfall measurements.

Effect of Grazing Treatments on Plant Growth.—The monthly precipitation responsible for effective forage production at the different grazing seasons can be related to plant growth as it is influenced by harvesting. As shown below, when plants are grazed only at one season each year, leaf lengths (inches) when spring grazing began were about 0.5 inch longer than they were when plants were grazed at two seasons in the same year.

Grazing Treatment	Leaf Lengths
Spring	2.64
Fall	2.67
Spring-Fall	2.16

On ranges grazed only in the spring, the plants started rapid growth in April because of favorable moisture and associated warm weather. Much of their growth was completed during this month. They were then harvested by early June, but had the remaining summer months to grow and regain vigor. Plant growth during the latter part of the summer did not contribute to actual yield the following year, except that regained vigor allowed the plants to start rapid growth early the following spring.

Plants grazed only in the fall followed much the same development trend except that growth was delayed for a short time. Since the plants were grazed in the fall, the following April moisture was utilized primarily to initiate early plant growth, which contributed little in terms of total yield. Height growth and the bulk of the forage production was made during May, and some plant growth was added during July, which is usually wet.

Plants grazed both spring and fall needed April moisture simply to begin growth, and depended on May rainfall to continue rapid growth. After spring grazing, plants initiated additional growth in response to June precipitation, and added to this second-growth stage primarily from the rainfall in July.

Stocking Rates in Relation to Forage Production.—After forage production was estimated in relation to the precipitation received in certain months, the relationships between stocking rates and forage yields were determined by ordinary regression analysis. These stocking rates were closely associated with the amount of forage produced on each seasonal treatment. Correlation coefficients between stocking rates (y) and forage production (x) ranged from 0.94 to 0.99 (Fig. 1).

The pastures grazed both spring and fall provided the most grazing in terms of total yearling heifer days of grazing per acre. For example, at an expected forage yield of 800 lb, pastures grazed only in the spring would support 42.8 days of grazing and those grazed in fall 38.4. Pastures grazed both spring and fall, however, would support 52.9 days of spring grazing at 800 lb of forage plus 35.5 days of fall grazing with 800 lb of regrowth forage.

It was also possible through stepwise regression testing to estimate stocking rates directly from precipitation data. These analyses showed, for example, that on ranges grazed only in the fall, 95% of the variation in the number of yearling heifer days of grazing per acre was attributable to the rainfall received in May and July. This variation and the months accounting for it were almost identical to those for forage yields (Table 2, Equation 2).

Thus it would seem more direct to predict stocking rates from precipitation data. Such predictions may be appropriate where adequate information is available on production, precipitation, and stocking. However, because of differences between sites, plants, classes and kinds of livestock, and management objectives, a stocking-precipitation relationship from one area cannot be recommended for another area without proper testing. Since stocking is a direct function of effective forage production, and only an indirect function of precipitation, the two-step approach is suggested: (1) stepwise regression analysis to estimate effective forage yields, and (2) ordinary regression analysis to determine the particular stocking to be used. For many ranges, these data are already available.

Research Application.—In addition to its usefulness for management purposes, the statistical approach employed provides a tool for minimizing variation in research problems. For example, April-May precipitation in the present study was ineffective for making advance predictions of spring forage yields for stocking purposes on spring-fall ranges. The equation for these months did account for 97% of the variation in yields, however, and provided a means of removing variation due to environment in comparing forage yields between treatments. Also, total animal-days of use for experimental pastures could be predicted and the pastures then stocked accordingly to obtain the desired utilization in a specified period of time. This provides better control in grazing studies where variations in length of grazing periods are frequently a confounding factor in the analysis.

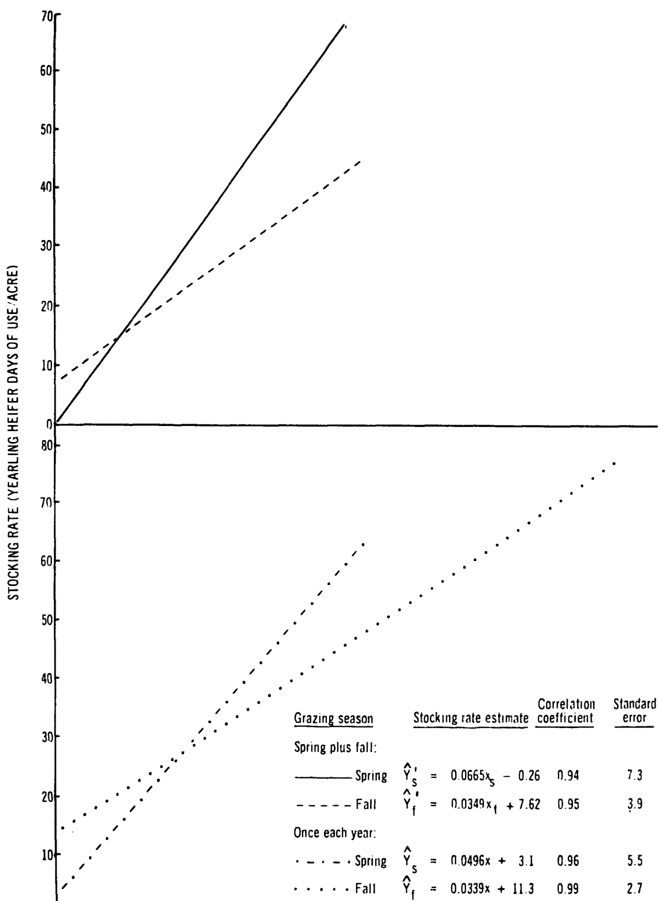

FIG. 1. Stocking rates in relation to forage production for crested wheatgrass grazed only in the spring, fall, or both spring and fall.

Summary

Stepwise regression analyses were made to determine how much influence monthly precipitation (x) during the growing season had on forage yields (y) of crested wheatgrass ranges grazed during spring, fall, and spring-fall seasons in the Front Range of Colorado. Precipitation accounted for 88 to 97% of the differences in yields, and the amounts received during dif-

ferent months or combinations of months determined the effective forage production available for use at each season. Precipitation in April primarily determined forage yields on ranges grazed only in the spring; for ranges grazed only in the fall, May and July rainfall was most useful for predicting yields. When ranges were grazed both spring and fall, April-May precipitation determined spring yields, and June-July moisture determined fall yields. Equations are given for estimating yields of crested wheatgrass grazed during these seasons.

Stocking rates in relation to forage yields during the different grazing seasons were also determined by ordinary regression analysis. Correlation coefficients between stocking rates (y) and effective forage production at each season (x) ranged from 0.94 for spring grazing on spring-fall ranges to 0.99 for ranges grazed only in the fall. It is suggested that comparable relations of production and stocking rates could be worked out from existing data for many of our rangelands. In addition to its use for predicting production from precipitation data, the method is also suggested as a means of accounting for variation in certain types of research studies.

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Seasonal and Growth Period Changes of Some Nutritive Components of Kikuyu Grass[1]

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Highlight

Changes in nutritive constituents of kikuyu grass with regrowth period and season were considered. The hemicellulose fraction of kikuyu grass collected during February and April contained xylose, arabinose, glucose, and galactose regardless of length of regrowth period. Protein decreased while fibrous components and lignin (72% sulfuric method) increased as regrowth was extended. The highest in vitro cellulose digestibility occurred at six weeks regrowth. Grazing rate or clipping practices should influence the value of kikuyu in feeding programs designed to produce acceptable beef from animals slaughtered directly from grass.

[1] *Approved by the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 797.*

Kikuyu grass *(Pennisetum clandestinum* Hochst. ex Chiov.), a native grass of tropical Africa, was introduced in Hawaii from California about 1924. Kikuyu has become one of the major range grasses on the island of Hawaii. The extensive use of this grass appears to be based on its resistance to trampling and grazing, ability to provide ground cover against undesirable brush and especially its ability to adapt to altitudes from sea level to over 5,000 ft. Much less is known, however, concerning the nutritive value of kikuyu grass for fattening cattle on pasture. This is an important consideration since the major portion of the beef produced by the State of Hawaii is grass-fattened only. The term "grass-fattening" as used in Hawaii would mean production of slaughter cattle directly off grass which grade at least high good at approximately two years of age.

Whitney et al. (1939) noted that ranchers were in disagreement as to the nutritive value of kikuyu. Younge and Otagaki (1958) indicated that kikuyu was among the grasses which were too low in protein to meet minimum standards for young growing cattle or for fattening cattle. Ishizaki (1963) showed kikuyu grass harvested in November and December to be of lower digestibility than panicum or paragrass *(Panicum purpurascens* Raddi) harvested during January, March, July, or August. Since the carbohydrates other than crude