

2005

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Recommended Citation

Smart, Alexander J.; Gates, Roger N.; and Dunn, Barry H., "Spring Drought Effects on Rangeland Forage Yield from Clayey Ecological Sites in Western South Dakota" (2005). *South Dakota Beef Report, 2005*. Paper 24.
http://openprairie.sdstate.edu/sd_beefreport_2005/24

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Spring Drought Effects on Rangeland Forage Yield from Clayey Ecological Sites in Western South Dakota¹

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BEEF 2005 - 23

Summary

Understanding the historical influence of seasonal precipitation, especially spring precipitation, and stocking rate on forage yield would be desirable for planning purposes. The objectives of this study were to examine the historical precipitation pattern and how it influenced forage yield on pastures that were stocked at light, moderate, and heavy stocking rates for 15 years at the Cottonwood Range and Livestock Research Station in western South Dakota. Weather data from 1909 to 2004 at the station were analyzed to determine the frequency of occurrence of below (≤ 75 of mean), normal, and above normal ($> 125\%$ of mean) spring precipitation (April, May, June). Additional data from the station provided for an examination of the relationships between weather and forage yield from pastures grazed at three stocking rates. Forage yield and precipitation data were collected from 1945 to 1960 from pastures continuously grazed from May to November at 0.25, 0.40, and 0.60 AUM/acre. Analysis of variance was used to test influence of spring precipitation (spring drought and non-spring drought) and stocking rate (light, moderate, and heavy) on forage yield. Below normal, normal, and above normal spring precipitation occurred 29, 48, and 23% of the time, respectively. Forage yield in spring drought years was 420 lb/ac less ($P < 0.01$) than in non-spring drought years. Lightly stocked pastures had 38 and 71% more ($P < 0.01$) forage than moderate and heavily stocked pastures. Spring droughts reduced forage yield ($P < 0.01$) in light, moderate, and heavily stocked pastures by 20, 27, and 35%, respectively. Forage yield from lightly stocked pastures during spring droughts was similar to heavily stocked pastures in non-spring drought

years. Our study indicates that spring precipitation should guide stocking rate decisions made during the growing season. Light and moderate stocking rates reduce the impact of spring drought on forage yield more than heavy stocking rates.

Introduction

Anticipating low rainfall and having the flexibility to respond has been common advice from rangeland management professionals and ranchers who have successfully weathered previous droughts. Properly managing rangeland resources requires an acceptance that droughts occur and willingness to plan based on this certainty. The Society of Range Management (1974) glossary stated that drought is "prolonged dry weather, generally when precipitation is less than three-quarters of the average annual amount". However, annual precipitation may not be related to yield because the distribution does not always overlap the growing season. In the northern mixed-grass prairie of the Great Plains the amount of spring precipitation during April, May, and June is the most important indicator of current year's forage production (Smart et al., 2005). Johnson et al. (1951) recognized this phenomenon and also noticed that summer precipitation was below 75% of normal 6 out of 7 years. Since the warm-season grasses on these ecological sites consisted mainly of shortgrasses, such as blue grama and buffalograss, late summer rainfall did little to increase growing season forage production because the cool-season forages had already produced the majority of their biomass for that year. In Heitschmidt's (2004) review of results from 15 experiments in the northern Great Plains, 91% of the annual forage was produced by July 1. An historical data set from the Cottonwood Range and Livestock Research Station provided for an examination of the relationships between weather and forage yield from pastures grazed at three stocking rates. The objectives of this study were to

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examine the historical precipitation pattern and how it influenced forage yield on pastures that were stocked at light, moderate, and heavy stocking rates for 15 years.

Materials and Methods

Site Description

This study was conducted at South Dakota State University's Range and Livestock Research Station near Cottonwood, South Dakota. The research station is located in the Northern Great Plains mixed-grass prairie, approximately 75 miles east of Rapid City, SD. Topography of the research station is gently sloping with long, rolling hills and relatively flat-topped ridges. Long-term average annual precipitation from 1909 to 2002 is 16 inches, 77% of which falls between April and September (USDC 2004). Predominant soil of the experimental pastures is clay developed over the Pierre shale formation. Predominant ecological site classification is Clayey. Vegetation is typical of a mixed-grass prairie. Dominant species on native pastures are the cool-season mid-grass, western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love) and warm-season shortgrasses, blue grama (*Bouteloua gracilis* [H.B.K.] Lag. Ex Griffiths) and buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.).

Weather Variables

Precipitation data were collected at the research station headquarters approximately 1 mile from experimental pastures from 1909 to 2004. Spring precipitation was the sum of April, May, and June rainfall. The frequency of years with normal or above normal spring-rainfall that occurred between below normal spring-rainfall years was calculated. The overall mean spring precipitation was calculated over the 95 year period. Spring precipitation was categorized into below normal ($\leq 75\%$ of mean), normal ($> 75\%$ but $\leq 125\%$ of mean), and above normal ($> 125\%$ of mean).

Grazing History

In the late 1930s, an experimental plan was developed by South Dakota State University to collect data on summer grazing of mixed-grass rangeland at three stocking rates (light, moderate, and heavy) at the Cottonwood Station. From 1939 to 1941, rangeland was surveyed, fenced, and water sources were developed to provide two pastures at each stocking rate (Johnson et al. 1951). Pasture

sizes were 180, 133, and 80 acres for light, moderate, and heavy stocking treatments, respectively. From 1942-1960, pastures were stocked at 0.25, 0.40, and 0.60 AUM/acre for light, moderate, and heavy stocking rates, respectively (Lewis et al., 1983). During 1942 through 1950 pastures were grazed from May through November by cows with calves (*Bos taurus* L.) at fixed stocking rates. This grazing pattern resulted in distinct plant communities. In 1951, a put-and-take stocking method was put in place to achieve better control over forage utilization and maintain distinct plant communities. This method entails the use of variable animal numbers during a grazing period or grazing season, with a periodic adjustment in animal numbers to maintain desired degree of defoliation (SRM, 1998). Utilization for the light, moderate, and heavy grazing intensities estimated by visual inspection and by clipping outside and inside protected cages, was targeted at 25, 45, and 65%, respectively. In 1953 pastures were stocked with 2-year old cow-calf pairs. In 1960 yearling steers were grazed on the pastures at the three stocking rates.

Forage Yield

Forage yield data were available for 15 years. From 1942 to 1951, forage yield was estimated in each pasture using three movable grazing exclosures (Johnson et al. 1951). At the beginning of each grazing season, grazing exclosures were relocated to different areas within the pasture to estimate the annual forage yield. Within each exclosure, three 9-ft² plots were hand clipped at crown level using grass shears approximately June 15 and August 15 to estimate peak standing biomass of the cool-and-warm-season forages. Samples were air dried and weighed.

In 1952-1954 forage production was estimated by placing two movable grazing exclosures on each of eight different areas based on soil and topography within each pasture (Lewis et al. 1956). At the beginning of each grazing season, grazing exclosures were relocated to different areas within the pasture to estimate annual forage production. Within each exclosure, three 2-ft² plots were clipped in June and August. In 1952 and 1953, medium height grasses were clipped to a 1 in stubble height and short grasses were clipped to crown height. In 1955 all grasses were clipped just above the first leaf.

Clipped vegetation was dried in a forced air oven at 140°F for 72 hours and weighed.

From 1956 to 1960, 11 to 21 movable grazing enclosures were located on each pasture to estimate forage yield based on soil and topography. As before, enclosures were moved to new locations within each pasture at the beginning of each year. Within each enclosure, two 2-ft² plots were clipped to near ground level with grass shears in June and August to estimate peak standing biomass for cool- and warm-season forages. Clipped vegetation was dried in a forced air oven at 140°F for 72 hours and weighed.

Statistical Analysis

Analysis of variance was used to test the effects of spring precipitation (spring drought and no spring drought), stocking rate (light, moderate, and heavy) and the spring precipitation x stocking rate interaction on forage yield from 15 years of data using SAS (1999). Year was considered replication and pasture was the experimental unit. Mean treatment differences were considered significant at $P = 0.10$ level. Data from 1942-1944 were not included in the analysis because grazing treatment effects had not achieved the desired plant communities until 1945 (Johnson et al. 1951).

Results and Discussion

Weather

The cumulative spring precipitation data for the months of April, May, and June from 1909 to 2004 at the Cottonwood Range and Livestock Station near Philip, SD are presented in Fig. 1. As expected, spring precipitation was highly variable over the 95 years. Below normal ($\leq 75\%$ of mean), normal, and above normal ($> 125\%$ of mean) occurred 29, 48, and 23% of the time, respectively. During the decades of 1910's through 1950's, below normal spring precipitation occurred nearly 40% of the time while only occurring 15% of the time from 1960's to 1990's (Fig. 1).

The occurrence of past events provides insight about what kind of spring-rainfall might be expected given current rainfall patterns. Information about the occurrence of events such as the number of years of favorable spring-rainfall between spring-drought years is an informative use of this historical data. The occurrence and frequency of favorable spring-

rainfall years between spring-drought years were calculated (Table 1). Consecutive spring droughts, which are represented by zero favorable spring-rainfall years between spring-drought years, occurred 33% of the time. Fifty-one percent of the favorable spring-rainfall years lasted from 1 to 4 years. Only 16% of the favorable spring-rainfall years lasted more than 7 years (Table 1). The use of this historical data can be illustrated in the following example. Prior to 2002, favorable spring growing conditions had occurred seven years in a row in at Cottonwood. Expecting an eighth consecutive year of above normal or normal spring rainfall was unlikely based on the historical data. Ranchers and rangeland resource professionals should have been expecting a drought. Realizing that consecutive spring droughts occurred 33% of the time, the risk of reduced forage production was great. Knowing and understanding historic precipitation patterns is a critical first step to a prudent management response.

Impact on Forage Resources

The impact that spring drought can have on forage yield is dramatic. At the Cottonwood Station, forage yield averaged 420 lb/ac less during years with below normal spring precipitation than in normal or above normal years (Table 2). This translates to an average decrease of 0.18 AUM/acre. Stocking higher in normal and above normal spring-rainfall years can result in lower forage carryover into subsequent years, compounding the effects of drought. Stocking for the average forage yield would give the flexibility to hay excess forage in an above spring-rainfall year. Since the majority of the forage is produced by July 1 decisions to de-stock by selling off cattle or weaning early to adjust grazing pressure can be fit into a management plan.

Stocking rate had a greater effect on forage yield than spring drought (Table 2). Forage yield from moderate and heavy stocking averaged 500 and 750 lb/ac less than lightly stocked pastures. In addition, spring droughts reduced forage production on light, moderate, and heavily stocked pastures by 20, 27, and 35%, respectively. Also, during spring droughts, lightly stocked pastures had 1.9 times more forage than heavily stocked pastures. During non-spring drought years, heavily stocked pastures had the same forage yield as did lightly stocked pastures in spring drought years (Table 2). If stocking rates are not adjusted during

drought years, grazing pressure is dramatically increased. The mixed-grass plant community can shift from western wheatgrass dominated to western wheatgrass-shortgrass co-dominant to shortgrass dominated relatively quickly. Johnson et al. (1951) found this happened in less than 5 years. It is also true that plant communities can shift in the opposite direction in years with above normal spring precipitation and lower stocking rates. How long it takes to move from shortgrass dominated to western wheatgrass-shortgrass co-dominant or western wheatgrass dominated plant communities is unknown. The ability to predict forage yield and make appropriate stocking rate adjustments is necessary to sustain plant communities dominated by western wheatgrass. The merits of deferred rotation at proper stocking rates for improving range condition in the Northern Great Plains are well known (Rogler, 1951, Sampson 1951, Smoliak 1960). Klipple and Bement (1961) argued that light grazing is an economically feasible method for improving deteriorated rangeland.

Implications

At the Cottonwood Station, our study found that below normal, normal, and above normal spring precipitation occurred 29, 48, and 23% of the time. The frequency of 1 to 4 favorable spring moisture years between spring drought years was 51%. Consecutive spring droughts occurred during 33% of the 95-year period. Historical precipitation patterns are a useful guide for planning. Forage yield in moderate and heavily stocked pastures was 72 and 58% less than lightly stocked pastures. Forage yield in heavily stocked pastures was 1.9 times less than lightly stocked pastures during spring droughts. During spring drought, lightly stocked pastures had the same forage yield as heavily stocked pastures in non-spring drought years. Our study indicates that spring precipitation is a useful management tool for stocking rate decisions made during the growing season. Light and moderate stocking rates reduce the impact of spring drought on forage yield more than heavy stocking rates.

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Tables

Table 1. Number and frequency of normal or above normal spring (cumulative April, May, and June) rainfall years between years having below normal spring rainfall at South Dakota State University's Cottonwood Range and Livestock Station from 1909 to 2004.

Normal or above normal spring rainfall years between years having below normal spring rainfall	Times occurred		
	Event	No.	%
	0	9	33
	1	5	18
	2	3	11
	3	4	15
	4	2	7
	5	0	-
	6	0	-
	7	1	4
	8	1	4
	9	1	4
	10	0	-
	11	0	-
	12	0	-
	13	1	4
Total		27	100

Table 2. Forage yield from pastures stocked season-long (May-November) at light, moderate, and heavy stocking rates during years with spring-droughts (≤ 5.7 inches, $\leq 75\%$ of mean) and no spring-droughts (> 5.7 inches) of April through June precipitation from 1945 to 1960 at the Cottonwood Range and Livestock Station near Philip, SD.

Stocking rate ¹	Spring Precipitation (April-June) ²		Mean ³
	Spring drought	Non spring drought	
	----- lb/ac -----		
Light	1590 ^{ab}	2000 ^a	1800 ^j
Moderate	1100 ^{bc}	1510 ^b	1300 ^k
Heavy	840 ^c	1280 ^b	1050 ^k
Mean ⁴	1180 ^y	1600 ^z	

¹Stocking rates for light, moderate, and heavy grazing were 0.25, 0.40, 0.60 AUM/ac, respectively.

²Means within a row and column followed by different letters (a, b, c) are significantly different ($P < 0.10$).

³Means within a column followed by different letters (j, k) are significantly different ($P < 0.10$).

⁴Means within a row followed by different letters (y, z) are significantly different ($P < 0.10$).

Figures

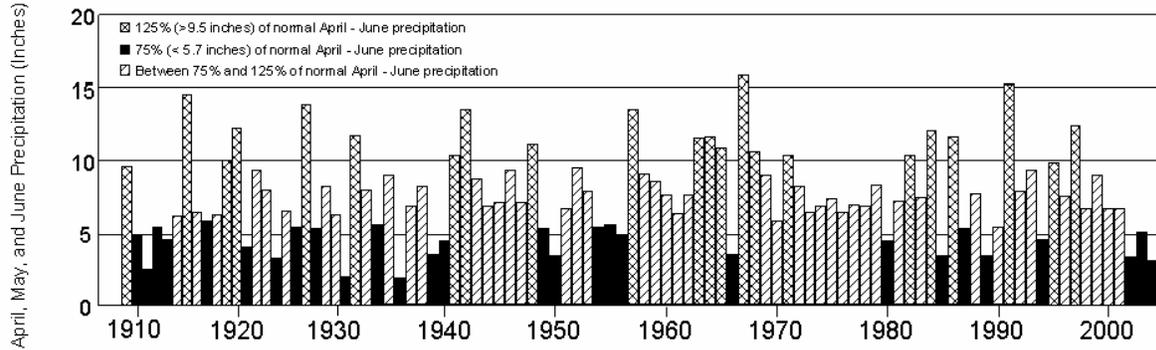


Figure 1. Cumulative precipitation for April, May, and June from 1909 to 2004 for the Cottonwood Range and Livestock Station, located 75 miles east of Rapid City, South Dakota in the mixed-grass prairie. Mean precipitation for April, May, and June is 7.6 inches (USDC 2004).