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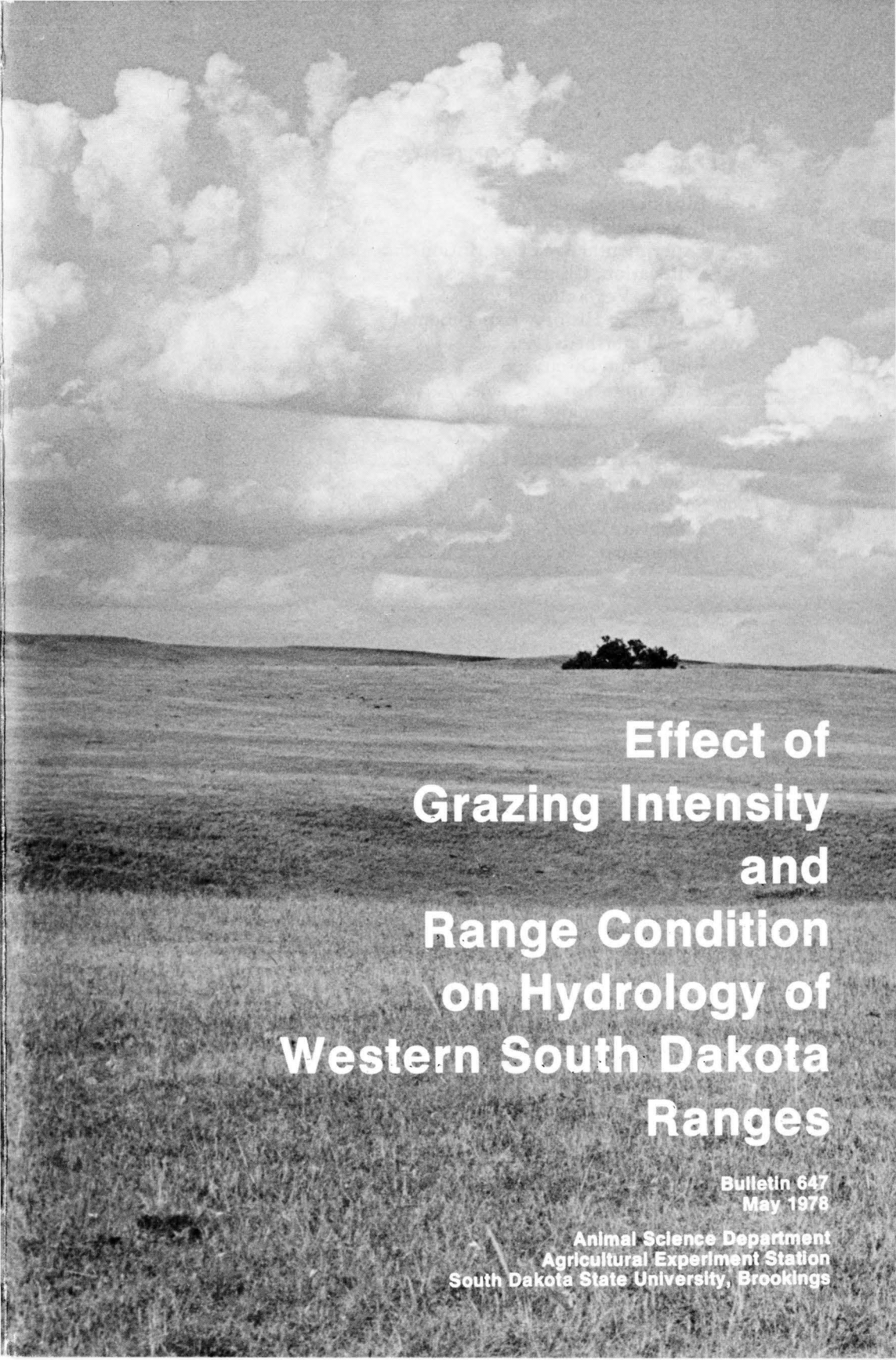
c. L. Hanson

A. R. Kuhlman

J. K. Lewis



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CONTENTS

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Effect of Grazing Intensity and Range Condition on Hydrology of Western South Dakota Ranges

By
Clayton L. Hanson, Armine R. Kuhlman, and James K. Lewis[1]

Introduction

Range livestock production is a primary industry in the Northern Great Plains. Efficiency of operation is important in this industry because of current low livestock prices, coupled with the high cost of necessary inputs. *Proper stocking rate is the most important single factor affecting sustained net returns from South Dakota rangeland.* Stocking rates which are too light result in lowered income. In contrast, heavy grazing results in a damaged resource and poorer range condition. Summarized here are 10 years of a continuing study, initiated in 1963 on experimental pastures of the Range and Livestock Experiment Station, Cottonwood, South Dakota. This study at the South Dakota State University Agricultural Experiment Station facility investigated effects of grazing intensity and range condition on water runoff and water economy of a western South Dakota range.

Review of Literature

Grazing Intensity and Range Condition

Grazing intensity studies have been conducted on predominantly ordinary uplands of the Northern Great Plains at Manyberries, Alberta (cows and calves 1932-37, Clarke et al., 1947; ewes and lambs 1951-70, Smoliak et al., 1972); Miles City, Montana (cows and calves 1932-46, Reed and Peterson, 1961; yearling ewes 1936-41, Woolfolk, 1949; cows and calves 1948-57, Houston and Woodward, 1966); Mandan, North Dakota (two-year-old steers 1915-35, and yearling steers 1936-40, Sarvis, 1941; moderate and heavy grazing continued to the present); Ardmore, South Dakota (two-year-old steers 1919-36, Black et al., 1937, Black and Clark, 1938); Cottonwood, South Dakota (cows and calves 1942-51, Johnson et al., 1951; cows and calves 1952-59, Lewis et al., 1956; steers 1960-67, Lewis et al., 1964, 1968); Antelope Range (near Buffalo), South Dakota (ewes and lambs 1951-69, Gartner et al., 1965). Results from the sheep studies at Manyberries and Antelope Range and the cattle studies at Cottonwood and Mandan are incomplete.

In all of these studies, as well as those from other regions, different stocking rates were imposed on relatively homogeneous pastures with similar soils and vegetation. Although all factors were not measured in each study and some researchers expressed variant opinions, certain general patterns emerged from past grazing studies (Lewis, 1969).

Plant species most palatable to the particular kind of grazing animal during the grazing season are grazed closely and repeatedly (overutilization), and taller plants are grazed more heavily than shorter ones. Overutilization is greatest on convenient areas, like those near water, bedgrounds, and loafing areas. Thus, the amount of vegetation and then the amount of mulch covering the soil is reduced. The microclimate becomes drier

[1]Agricultural engineer, Northwest Watershed Research Center, Agricultural Research Service, USDA, Boise, Idaho; Botanist, USDA (retired); and Associate professor, Animal Science Department, South Dakota State University, Brookings, South Dakota.

and more severe; soil is trampled and puddles when wet; water-infiltration is decreased; runoff is increased, causing man-made drought; and thus, wind and water erosion can occur. These processes can be observed in operation on millions of acres of range in the world where too many animals are placed on the range for too long (overstocking).

The taller, more palatable, less grazing-resistant and less drought-resistant species (decreasers) are weakened and made less competitive. They are replaced by those species that escape grazing or are more grazing- and more drought-resistant (increasers). Plant species escape grazing because of either their low palatability, height (very short or tall), and spines, or because their growth is completed (or nearly so) before grazing begins. If overutilization continues, these increaser species may be replaced by those more able to withstand or escape grazing, by exotic species, or by those originally present only on disturbed areas (invaders).

Continued overstocking leads to continued overutilization, which in turn leads to an overgrazed condition where the microclimate, vegetation, soil, animal communities, and suitability for livestock grazing have been altered by grazing too heavily (Dyksterhuis, 1958).

The concept of range condition as the state of health of a range has been developed into a quantitative measure of overgrazing, or the degree of disturbance by grazing, by Dyksterhuis (1949). In this method, range condition is defined as the percentage of the original, or climax, vegetation for a certain range site. Thus, botanical composition is used as an indicator of the status of the entire ecosystem.

At the Range and Livestock Experiment Station, Cottonwood, South Dakota, pastures which were grazed heavily, moderately, or lightly from 1942 through 1967 were rested in 1968, and grazed at different rates in 1969 to adjust range condition. From 1970 through 1972, replicated pastures in low-fair, low-good, or high-good range condition were grazed with yearling steers for proper use. In 1973 and 1974, these pastures were grazed at the same stocking rate and at the same season (early May to about November 1). Steer gains per head and per acre were slightly lower in low-fair than in high-good range condition pastures and utilization was slightly higher at the same stocking rate (Lewis et al., 1975). In 1971, total forage intake and nutritional value of the steer diets were similar from pastures in low-fair and high-good range condition (Rodgers and Lewis, 1975).

Above-ground vegetation began growth earlier and maintained more vegetation throughout the season on areas in high-good than on areas in low-fair or low-good range condition. However, weights of roots and crowns were greater from low-fair and low-good than from high-good range condition, because of the greater root:shoot ratio of the two shortgrasses common buffalograss[2] *(Buchloe dactyloides)* and blue grama *(Bouteloua gracilis)* which dominated the pastures in low-fair and low-good range condition. Total productivities (above- and below-ground) did not widely differ. However, more forage was available for grazing from high-good than from low-fair or low-good range condition (Lewis et al., 1971; Dodd et al., 1974).

Water Intake Rate

Infiltration rate is the rate at which water passes through the soil surface. *Percolation* is the rate at which water moves through the soil. *Soil water intake,* as measured over time, is influenced by both infiltration and percolation rates.

Water intake rate on ranges has been studied by many investigators (Branson et al., 1972). The most extensive study analyzed the results of 670 simulated rainfall tests, using the raindrop applicator on nine range soil groups in the six Northern and Central Great Plains states over a 13-year period (Rauzi et al., 1968). Simulated rainfall was applied at rates rapid enough to produce runoff. Since intake rates were markedly lower

[2] Scientific names of grasses follow Hitchcock and Chase (1951). Common names follow Beetle (1970).

for the second 30 minutes of rainfall application than for the first, they were the values used in data analyses. For all plots, the combined weight of live and dead vegetation (including mulch) was the most important factor affecting water intake rate, followed by soil structure of the first horizon, and then by soil texture of the second horizon. On clayey range soil groups, like those at the Cottonwood Range and Livestock Experiment Station, the three most important predictors of water intake rate were the combined weight of vegetation and mulch, the sum of the soil structure indices, and the sum of the soil thickness indices of the three horizons. Other predictors tested were percentage bare ground, sum of the texture indices, and sum of the boundary indices for the three horizons. These six predictors accounted for 46% of the variation in water intake for the second 30 minutes on the clayey range soil group. Water intake rates were lowest for the range sites with fine-textured, dispersed soils and highest for those with coarse-textured soils. Water intake rates were highest on areas with the greatest amount of vegetation and mulch and with the best surface soil structure.

Heavy grazing decreased water intake rate as a result of grazing and trampling, which decreased the weight of standing vegetation and mulch, and reduced non-capillary pore spaces (Duley and Domingo, 1949; Reed and Peterson, 1961; Rauzi and Hanson, 1966). In 1964, at Cottonwood, simulated rainfall was applied for 1 hour in three tests in each of four replicates of watersheds grazed heavily, moderately, or lightly. Water intake rates for the heavily and moderately grazed watersheds were 41% and 63% as great as those for the lightly-grazed watersheds. About 16 hours later, simulated rainfall was applied for another hour on the same plots. Water intake rates for the heavily and moderately grazed watersheds were 41% and 55% as great as those for the lightly grazed watersheds (Rauzi and Hanson, 1966).

Runoff

Runoff occurs when the precipitation rate exceeds the water intake rate. Very few studies have measured runoff from differentially grazed areas.

On ponderosa pine grasslands grazed at different intensities on the Manitou National Forest near Colorado Springs, Colorado, runoff was two and three times as great, for moderately and heavily grazed pastures, respectively, as for an ungrazed one (Dunford, 1949). In western Colorado, at Badger Wash, pastures winter-spring grazed by cattle and sheep on salt-desert-shrub range were compared with ungrazed ones. After the first 2 years, runoff from the grazed ranges was 43% greater than that from the ungrazed (Lusby, 1970). In contrast, on chaparral range in the Sierra Ancha Experimental Forest in Arizona, spring-fall grazing by horses and cattle at 40% or 80% utilization of perennial grasses did not increase runoff (Rich and Reynolds, 1963), however, perennial grasses made up only 9% to 18% of the vegetative ground cover. Furthermore, 80% to 88% of the annual runoff occurred in winter; whereas, in the South Dakota studies, summer runoff predominated.

Another of the major rangeland runoff experiments in the United States is the one reported in this bulletin. Data from this study were published previously by Sharp et al., 1964; Hanson et al., 1970, 1972, 1975; and Woolhiser et al., 1970. Data from the first 10 years of this experiment were summarized by Hanson et al. (1975).

Experimental Area Description

Location

The Range and Livestock Experiment Station is in Jackson County, South Dakota about 2 miles east of Cottonwood and about 75 miles east of Rapid City at latitude 43°58' N and longitude 101°52' E (Figure 1) at an elevation of 2414 feet. The Experiment Station is part of the watershed of Cottonwood Creek, a tributary of Bad River.

Climate

Weather records for the area were begun at the Experiment Station Head-

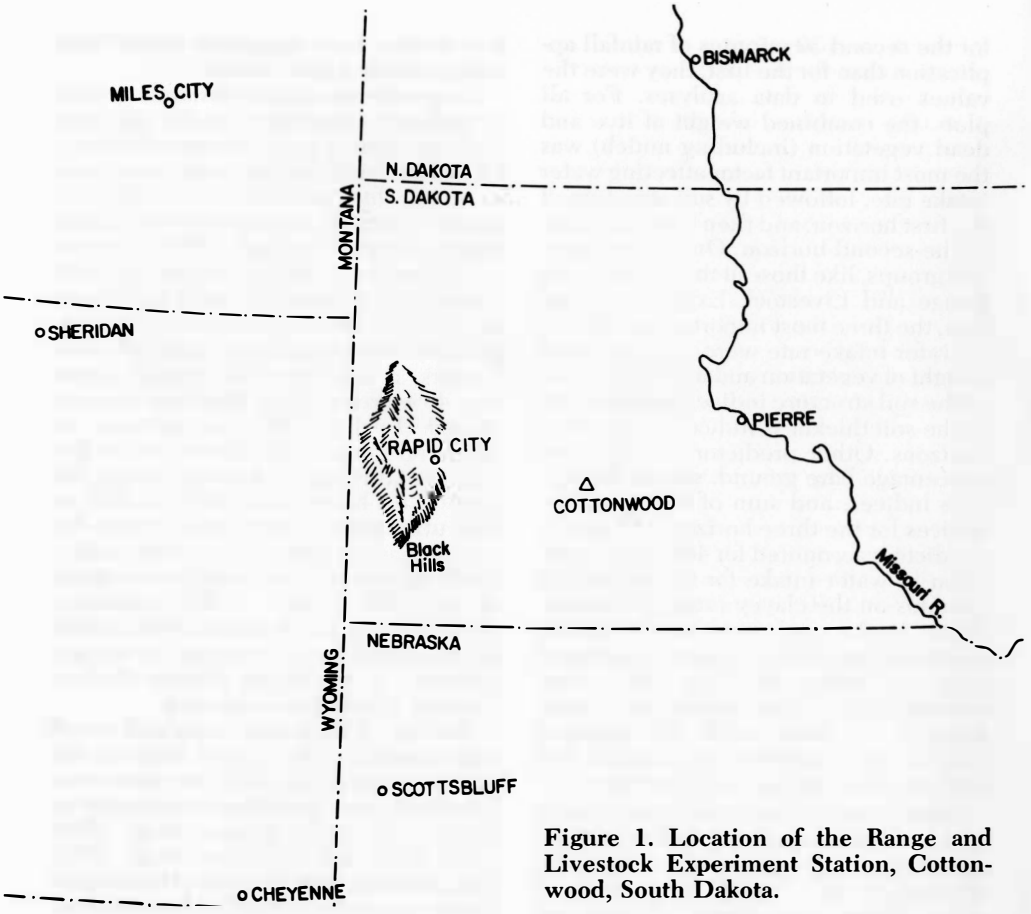


Figure 1. Location of the Range and Livestock Experiment Station, Cottonwood, South Dakota.

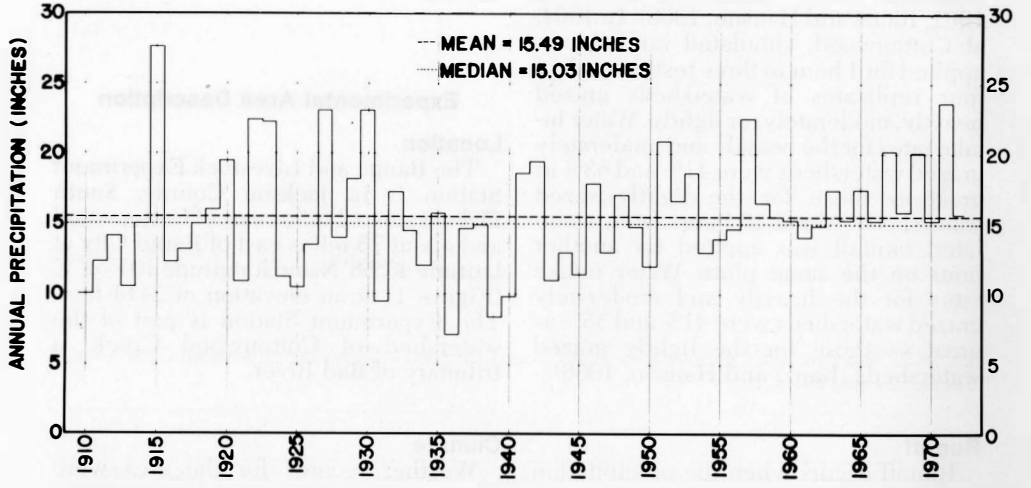


Figure 2. Annual precipitation, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1910-1972.

quarters in June 1909. Average annual precipitation for the 63 years (1910-72) was 15.49 inches, with a standard deviation of 3.83 inches. The median annual precipitation was only 15.03 inches, since there were more years below the mean than above it (Figure 2). There were 10 years with more than 20 inches of precipitation, but only 5 years with less than 10 inches. The wettest year on record, 1915, had 27.62 inches of precipitation, while the driest year, 1936, had only 7.13 inches; a ratio of 3.87:1.

When mean annual precipitation values were grouped into periods (Table 1), an analysis of variance showed the periods were significantly different ($P < 0.05$). The driest period, 1931-40, was 3.10 inches below the mean. The wettest period was 1963-72, during which the runoff study was conducted. Average annual precipitation during this period was 2.10 inches above the mean, which was similar to the 1920-30 period, but significantly wetter than the 1951-62 period, which was 0.88 inch above the long-term mean. During the runoff study, only 3 years were below the mean, and the driest year was only 0.23 inch below. Of the seven above-average years, five were more than 1.8 inches, three were more than 4.5 inches, and one was 8.1 inches above the mean.

June had the greatest mean monthly precipitation (3.01 inches), and December the least (0.36 inch), see Table 2. This precipitation distribution was typical of the Northern Great Plains, with the greatest amounts in May, June, and July, and the least during the winter months. Cycles of several years of dry or wet springs and dry or wet summers were not uncommon. Average precipitation during the growing season (April-September) accounted for 79% of the annual total.

Based on the 1910-67 precipitation records, Spuhler et al. (1971) stated that 1 inch or more of rainfall in 1 hour may be expected about once a year, 2 inches or more in 1 hour may be expected about once in 12 years, and 2.5 inches in 1 hour about once in 50 years. A 24-hour rainfall of 2 inches or more may be expected about once in 3 years, and 3 inches or more about once in 8 years.

Average annual class-A pan evaporation was about 55 inches, of which 79% evaporated from May through October, while average annual reservoir evaporation was about 39 inches (Spuhler et al., 1971). Precipitation:evaporation was

Table 1. Mean annual precipitation, departure from the mean, and standard deviation by years, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1910-72.

Period	Years	Mean	Departure	Standard Deviation
		Inches		
1	1910-19	14.59c*	-0.90	4.98
2	1920-30	16.95ab	+1.46	5.02
3	1931-40	12.39d	-3.10	3.48
4	1941-50	14.77c	-0.72	3.17
5	1951-62	16.37b	+0.88	2.91
6	1963-72	17.59a	+2.10	2.77
All	1910-72	15.49	—	3.83

* Means with the same letter do not differ significantly at the 5% level.

Table 2. Mean monthly precipitation, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1910-72.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Inches												
0.42	0.39	0.72	1.80	2.83	3.01	1.88	1.55	1.17	0.94	0.42	0.36	15.49

0.28, typical of semiarid, temperate grasslands.

Hailstorms can be expected two or three times per season in this area, especially during June. The mean annual snowfall is 24 inches, with at least 1 inch of cover about 36 days per year (Spuhler et al., 1971).

July is the warmest month, with a mean daily temperature of 74.7° F, and January the coldest, with a mean daily temperature of 19.1° F (Table 3). The maximum temperature of 116° was recorded in July 1910, and the minimum of -42° F in January 1916. The frost-free season averaged 126 days.

Soils

A soil survey by the Agricultural Experiment Station was completed by Dr. E. M. White in 1960, but has not been correlated and published.[3] Burford (1972) reported some details of geology and soils of the watersheds.

Topography of the research pastures lying south of Cottonwood Creek is rolling. Soils of the ordinary uplands are formed from Pierre shale of the upper Cretaceous period. Higher ridges have some remains of the Foxhills and Chadron formations that have been nearly eroded away.

The upland soils are Ustertic Camborthids of the family of very-fine montmorillonitic, mesic soils with slow to very slow permeability. The soils of the watersheds are predominantly Kyle silty clay with small amounts of Samsil silty clay on the upper slopes. Kyle silty clays on the station are included in the Clayey Range Site, Western South Dakota Guide Area, Land Resource Area 60-5 (Soil Conservation Service, 1969).

[3] Copy available from author, Plant Science Department, South Dakota State University, Brookings, SD 57007.

Vegetation

The Station is in the Mixed Prairie of the Northern Great Plains, where native vegetation is a mixture of cool-season and warm-season species, as well as short- and medium-height species.

Clayey range sites in top range condition, during average years, are dominated (60%-65% by weight) by two cool-season midgrasses, western wheatgrass *(Agropyron smithii)* and green needlegrass *(Stipa viridula)* with an understory (35%-40%) principally composed of two warm-season shortgrasses, common buffalograss *(Buchloe dactyloides)* and blue grama *(Bouteloua gracilis)*, and cool-season, short-growing needleleaf sedge *(Carex eleocharis* Bailey), with several minor grasses, forbs, a few shrubs and succulents. In years with favorable fall and/or spring precipitation, especially after spring drought, the cool-season annual grass, Japanese brome *(Bromus japonicus)*, can comprise 5% to 8% of the vegetation. In average years, cool-season grasses begin growing in early to mid-April, are ready for grazing in early May, make maximum growth during early June, produce seedstalks in mid-June and mature seed in July to early August. These grasses become dormant or grow slowly during midsummer and grow again in fall, if soil water is adequate. Warm-season grasses on this site begin growth in mid- to late May and make

Table 3. Average daily maximum, minimum, and mean temperatures, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1910-1967*

Average Daily	Jan	Feb	Mar	April	May	June	July	Aug	Sept
Max.	32.5	36.4	46.0	60.8	70.9	81.2	90.8	89.2	78.5
Min.	5.7	9.3	19.2	31.6	42.3	52.6	58.7	56.1	45.5
Mean	19.1	22.8	32.6	46.2	56.6	66.9	74.7	72.6	62.0

* Data from Spuhler, et al., (1971) in degrees F.

maximum growth in midsummer, if soil water is available. They become dormant or grow slowly with the advent of cooler weather in the fall or with soil water exhaustion, which is typical in late summer.

In dry springs, the cool-season midgrasses decrease and the warm-season shortgrasses increase, which also occurs with continued overutilization, even in good years. This change is especially dramatic when grasses are overutilized during years with dry springs. Clayey range sites in high-poor to low-fair range condition are dominated (often 80%-90% by weight) by common buffalograss, blue grama, and needleleaf sedge, often with only minor amounts of other species. In years with wet falls and/or springs, when clayey range sites in high-poor to low-fair range condition are rested, deferred or grazed lightly, Japanese brome may constitute 50% of the vegetation, if an adequate seed source is available.

Grazing History

From 1942 through 1950 experimental replicated native pastures with similar soils, in predominantly good range condition, were grazed heavily, moderately, or lightly for a 7-month season (May through November) with cows and calves at a fixed stocking rate (Johnson et al., 1951). During these years, range condition decreased to fair under heavy grazing, remained in good under moderate, and improved to low-excellent under light grazing. From 1951 through 1959, these pastures were grazed from May through October by cows and calves (except by two-year-old heifers in 1953) with a flexible stocking rate to achieve end-of-season utilization levels of greater than 55%, 40% to 50%, and less than 35% for heavy, moderate, and light grazing, respectively (Lewis et al., 1956). During this period, range condition decreased to low-fair or high-poor under heavy grazing, to low-good or remained in good range condition under moderate grazing, and remained in low-excellent under light grazing.

Japanese brome was observed on the pastures for the first time in 1951 and increased in geometric progression after wet falls with favorable springs from 1953 through 1955. This grass composed up to 50% of the weight of the vegetation in some drainageways in lightly-grazed pastures in 1956.

From 1960 through 1967, the pastures were grazed for a similar season and to similar degrees of use with yearling steers (Lewis et al., 1964, 1968). With five consecutive dry springs and with falls wet enough to produce vigorous early Japanese brome growth, western wheatgrass decreased to about 15% of the vegetation in a permanent exclosure and in some areas of the lightly-grazed pastures. Range condition declined to low-good, high-fair, and high-poor, respectively, for the lightly, moderately, and heavily grazed pastures in 1963. With the advent of normal or above-normal spring precipitation, western wheatgrass recovered rapidly under light grazing, but more slowly under moderate grazing. All pastures were rested in 1968, and grazed differentially in 1969 to adjust range condition. From 1970 through 1972, the pastures were in high-good, low-good, and low-fair or high-poor range condition, respectively, and were grazed for full use by yearling steers (Lewis et al., 1975).

Oct	Nov	Dec	Annual
66.0	48.5	36.4	61.4
33.4	20.2	10.2	32.1
49.7	34.3	23.3	46.7

Experimental Watersheds

The watersheds were established in 1962 on typical areas in pasture 4, 5, and 6 (Figure 3) that had been grazed heavily, moderately, and lightly and were in high-poor, fair, and good range condition, respectively. In each pasture, four contiguous watersheds, about 2 acres each, were separated by building low earthen dikes. The slopes of the four watersheds averaged 7.9%, 7.6% and 7.8%, respectively in the low, medium,

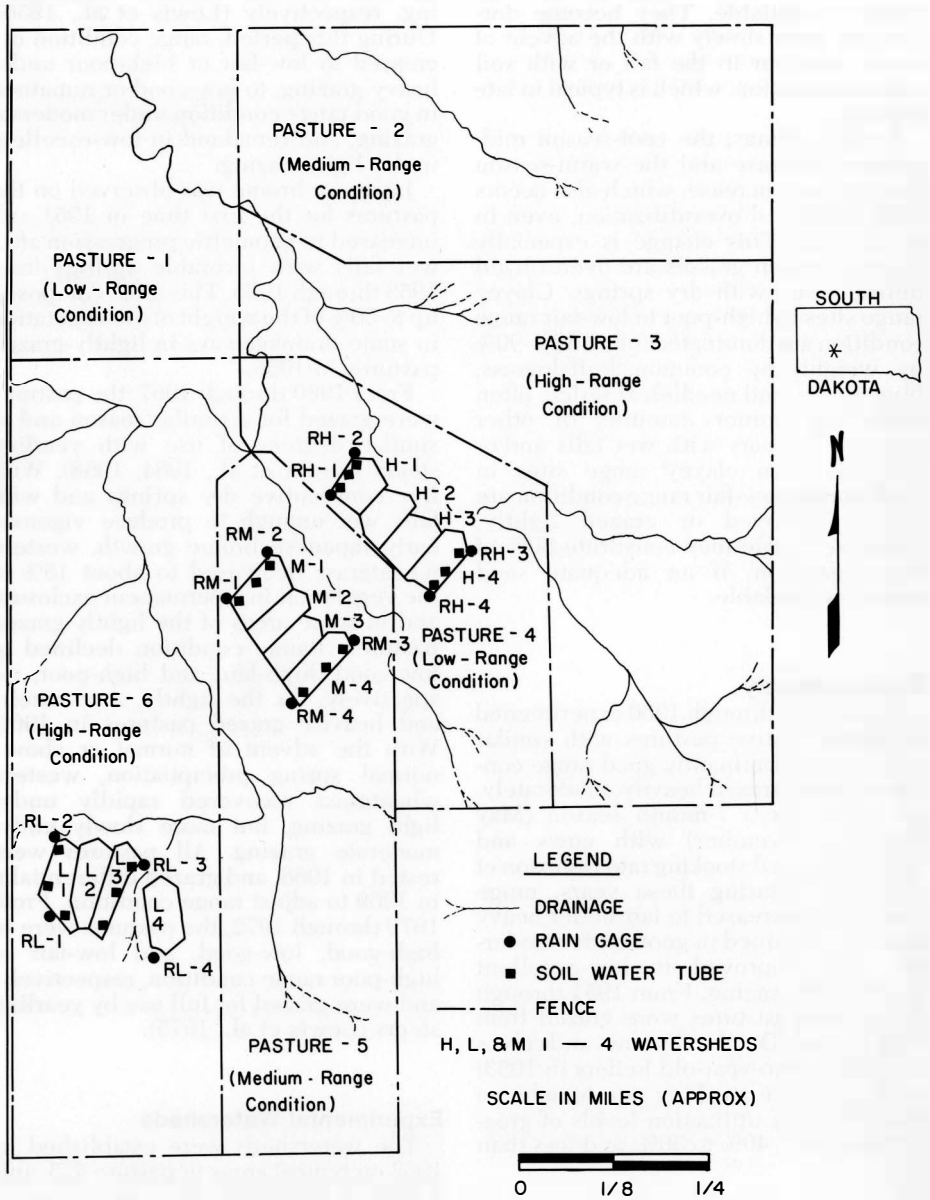


Figure 3. Location of experimental pastures and watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

and high range condition pastures. (These watersheds will be referred to as the low, medium, and high watersheds.) Each set of watersheds had a northeast aspect. Soils were predominantly Kyle silty clay with a small amount of Samsil silty clay on the upper slopes. The low and high watersheds were about ¼ mile on either side of the medium watersheds. Runoff was measured by 2-foot H-type flumes and FW-1 water-stage recorders (Figure 4). Four 8-inch recording rain gauges measured precipitation on each set of watersheds (Figure 5). A neutron probe with scaler was used periodically to measure soil water from mid-April through October at six locations on each set of watersheds.

Results and Discussion

Precipitation

Seasonal and annual precipitation at the headquarters and on the watersheds were recorded for the study period (Table 4, Appendix Tables C1-C10). Mean annual precipitation (1963-72) on the watersheds was 15.04 inches, but at headquarters was 17.65 inches. During the study period, annual precipitation at the headquarters exceeded the long-term mean (1910-72) by 2.16 inches. The proportion of the precipitation received at different seasons was similar at the headquarters and on the watershed. Pasture precipitation can be predicted from headquarters precipitation by the following equation:

$$Y = .044 + 0.816\,X \qquad (1)$$

where Y is the monthly precipitation on the watersheds and X is the monthly precipitation at headquarters. This equation accounted for 92.7% of the variation in monthly amounts of precipitation on the watersheds over the 10-year study period.

The cause of this difference is not understood. However, the headquarters gauge is protected by a tree shelterbelt on the west and north, which was established in the spring of 1942 (South Dakota Agricultural Experiment Station, 1943), by buildings on the east, and by some trees to the south. In contrast, the watershed gauges were not protected

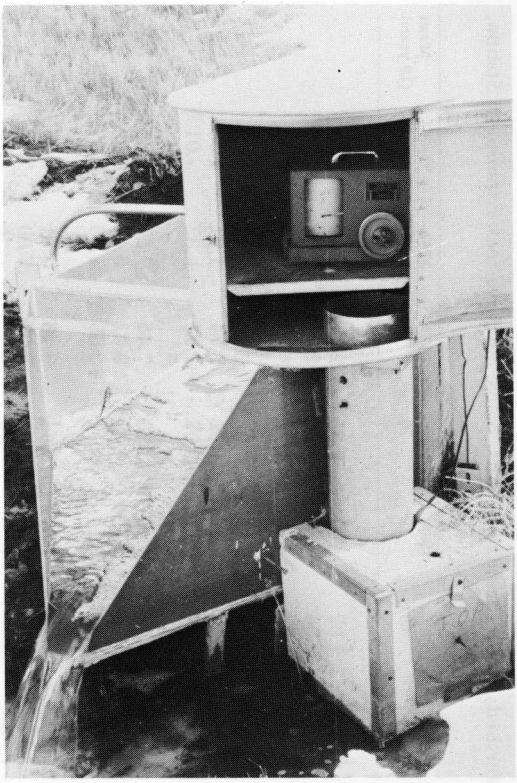


Figure 4. H-type flume with stage recorder measuring snowmelt runoff from one high range condition watershed, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Figure 5. Recording rain gauge, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Table 4. Precipitation (inches) by season on the experimental watersheds and at the headquarters, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963-72.

Season	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	Mean (9 years)	Mean (10 years)
Fall, (S,0),												
Range*	-	1.81	.15	1.84	3.66	1.92	.57	2.31	2.17	4.69	2.12	-
HQ	-	2.06	.17	2.12	4.04	2.04	.67	3.28	2.71	7.66	2.75	-
Dev.†	-	-.05	-1.94	+.01	+1.93	-.07	-1.44	+1.17	+.60	+5.55	+.64	-
Winter (N,D,J,F),												
Range	-	.33	.89	1.24	1.18	1.15	2.13	.96	2.58	1.12	1.29	-
HQ	-	.53	1.12	1.90	1.21	1.17	2.10	1.52	2.74	1.91	1.58	-
Dev.	-	-1.06	-.47	+.31	-.38	-.42	+.51	-.07	+1.15	+.32	-.01	-
Spring (M,A,M),												
Range	6.24	5.60	7.47	3.90	6.19	3.25	4.46	3.53	7.46	7.25	5.45	5.53
HQ	7.49	6.73	7.76	4.23	6.58	3.93	6.46	4.89	9.01	6.41	6.22	6.35
Dev.	+ 2.14	+1.38	+2.41	-1.12	+1.23	-1.42	+1.11	+.11	+3.66	+1.06	+.87	+1.06
Summer (J,J,A),												
Range	6.52	7.04	4.95	5.68	7.22	9.25	7.57	5.44	3.46	5.51	6.24	6.26
HQ	6.88	7.54	5.85	5.57	10.37	9.94	8.43	5.59	3.97	7.20	7.16	7.13
Dev.	+.44	+1.10	-.59	-.87	+3.93	+3.50	+1.99	-.85	-2.47	+.76	+.72	+.69
Cool Season‡												
Range	-	7.74	8.51	6.98	11.03	6.32	7.16	6.80	12.21	13.06	8.86	-
HQ	-	9.32	9.05	8.25	11.83	7.14	9.23	9.69	14.46	15.98	10.55	-
Dev.	-	+.27	.00	-.80	+2.78	-1.91	+.18	+.64	+5.41	+6.93	+1.50	-
Spring plus Summer,												
Range	12.76	12.64	12.42	9.58	13.41	12.50	12.03	8.97	10.92	12.76	11.69	11.79
HQ	14.37	14.27	13.61	9.80	16.95	13.87	14.89	10.48	12.98	13.61	13.44	13.48
Dev.	+2.58	+2.48	+1.82	-1.99	+5.16	+2.08	+3.10	-1.31	+1.19	+1.82	+1.65	+1.69
Vegetation Year§												
Range	-	14.78	13.46	12.66	18.25	15.57	14.73	12.24	15.67	18.57	15.10	-
HQ	-	16.86	14.90	13.82	22.20	17.08	17.66	15.28	18.43	23.18	17.71	-
Dev.	-	+1.37	-.59	-1.67	+6.71	+1.59	+2.17	-.21	+2.94	+7.69	+2.22	-
Calendar Year												
Range	15.34	13.53	15.35	14.28	16.66	14.60	15.81	12.70	18.01	14.11	15.01	15.04
HQ	17.37	15.35	17.35	15.26	20.18	15.86	20.05	15.26	23.59	15.68	17.62	17.60
Dev.	+1.88	-.14	+1.86	-.23	+4.69	+.37	+4.56	-.23	+8.10	+.19	+2.13	+2.11

* Mean of 12 rain gauges, four on each set of watersheds. Record began January 1, 1963.
† Deviation of precipitation at headquarters from the 1910-72 mean
‡ Previous fall and winter plus spring
§ Previous September through August

Table 5. Average basal cover on the watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963, 1965-72.*

Watershed Range Condition	Grasses				Forbs		Mulch, Rock, Bare	
	Mid		Short					
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
	Percent							
Low	1	0-2	76	59-84	1	0-7	22	13-41
Medium	15	5-22	53	39-68	5	1-10	27	18-51
High	26	22-30	31	25-40	5	1-9	38	33-52

* Mean of four watersheds and 125 points/watershed.

from the wind. The headquarters gauge is on a broad terrace of Cottonwood Creek, whereas the watershed gauges are on rolling uplands about 1½ miles distant.

Vegetation and Mulch

Basal Cover

Percent of basal cover was determined from point transects in late July in 1963, and from 1965 through 1972. There were four point transects with 125 points/grazing treatment.

Shortgrasses (common buffalograss plus blue grama) had the highest mean basal cover for the study period, varying from 76% on the low to 31% on the high watersheds, respectively (Table 5, Appendix Table A1). Midgrasses accounted for 1% of the basal cover on the low and 26% on the high watersheds. Forbs accounted for 1% to 5% of the basal cover on all watersheds. Mulch, rock, and bare soil accounted for 22%, 27%, and 38% of the basal cover on the low, medium, and high watersheds, respectively. The various basal cover percentages on each watershed varied considerably between years. All watersheds had the lowest total percent basal cover in 1966, when April through July was very dry.

Weight of Standing Crop, Mulch

The weights of standing crop and mulch were sampled each year in late July, at approximately the time of peak standing crop by clipping, at ground level, four unprotected plots along each of five transects. The residue was separated in the laboratory into mid- and shortgrasses (including sedges and Japanese brome), forbs, and mulch. Each year's standing crop included only vegetative growth for that year. Standing dead vegetation from previous years was considered mulch. An analysis of variance was conducted, assuming that the watersheds were comparable before 1942. Means were separated, using the Duncan Multiple Range Test (LeClerg et al., 1962).

Standing crops of grasses were 553, 499, and 698 lb/acre, and total of vegetation and mulch was 1,844, 2,008, and 3,338 lb/acre (oven-dried weight) from the low, medium, and high watersheds, respectively (Table 6, Appendix Table A2).

Table 6. Standing crop of grasses, forbs, and mulch on the watersheds in late July 1963 through 1972*, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Watershed Range Condition	Grasses			Forbs	Mulch	Total Vegetation & Mulch
	Mid	Short	Total			
	lb/acre, oven-dried					
Low	9	544	553a	21	1270	1844a
Medium	114	385	449a	68	1441	2008a
High	404	294	698b	161	2479	3338b

* Means with the same letters in the same column do not differ significantly at the 5% level.

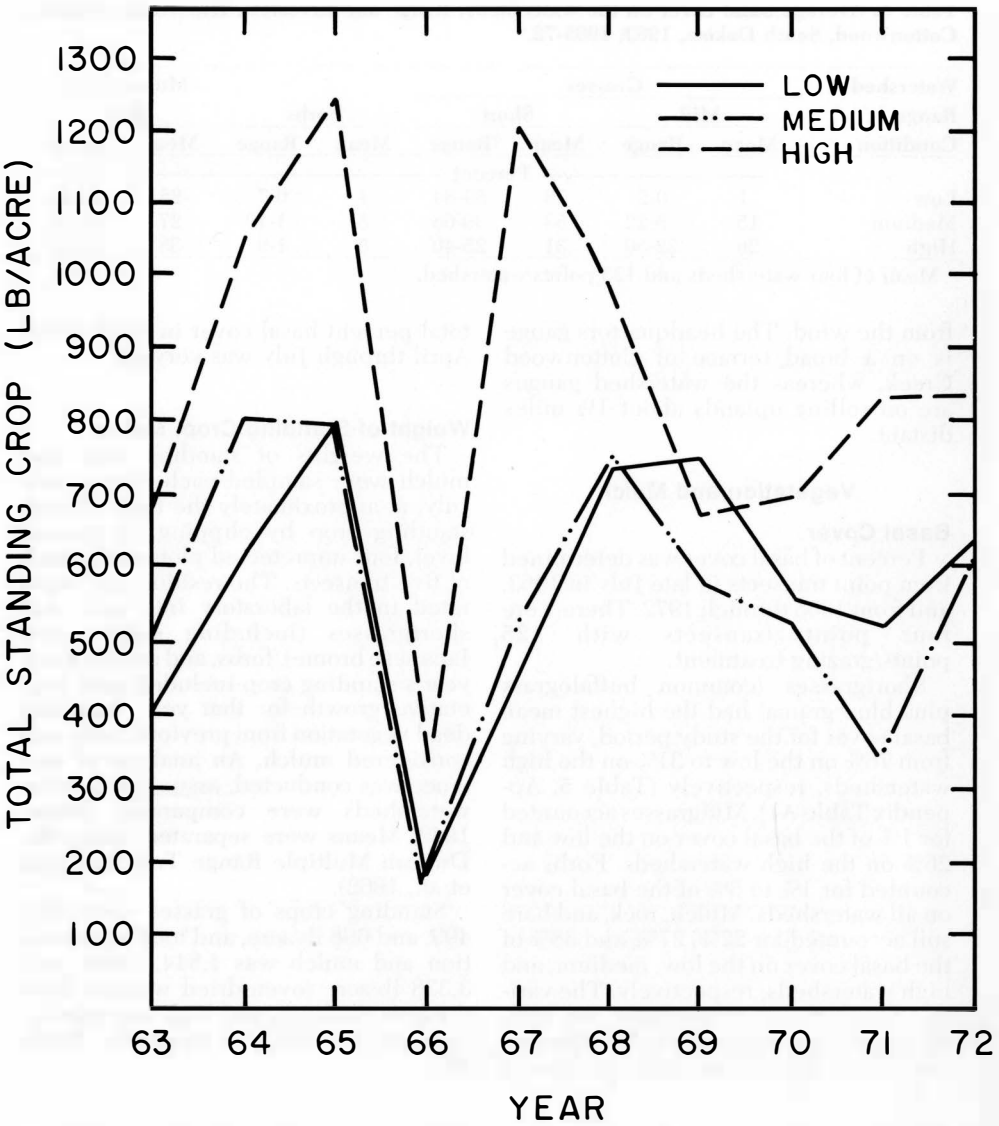


Figure 6. Total standing crop of vegetation on watersheds in different range condition classes, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963-72.

Both standing crops of grass and total vegetation and mulch from the high watersheds were significantly greater ($P < 0.05$) than those from the other watersheds (Table 6). The low watersheds had the least and the high watersheds the greatest amount of midgrasses, forbs, and mulch.

The standing crop varied considerably between years, with weights for all treatments lowest in 1966 (Figures 6 and 7) and highest in 1965, when an average of 8.46 inches of precipitation was received on the watersheds in May and June, following a year with similar conditions (Table 4, Appendix Tables B1-B3

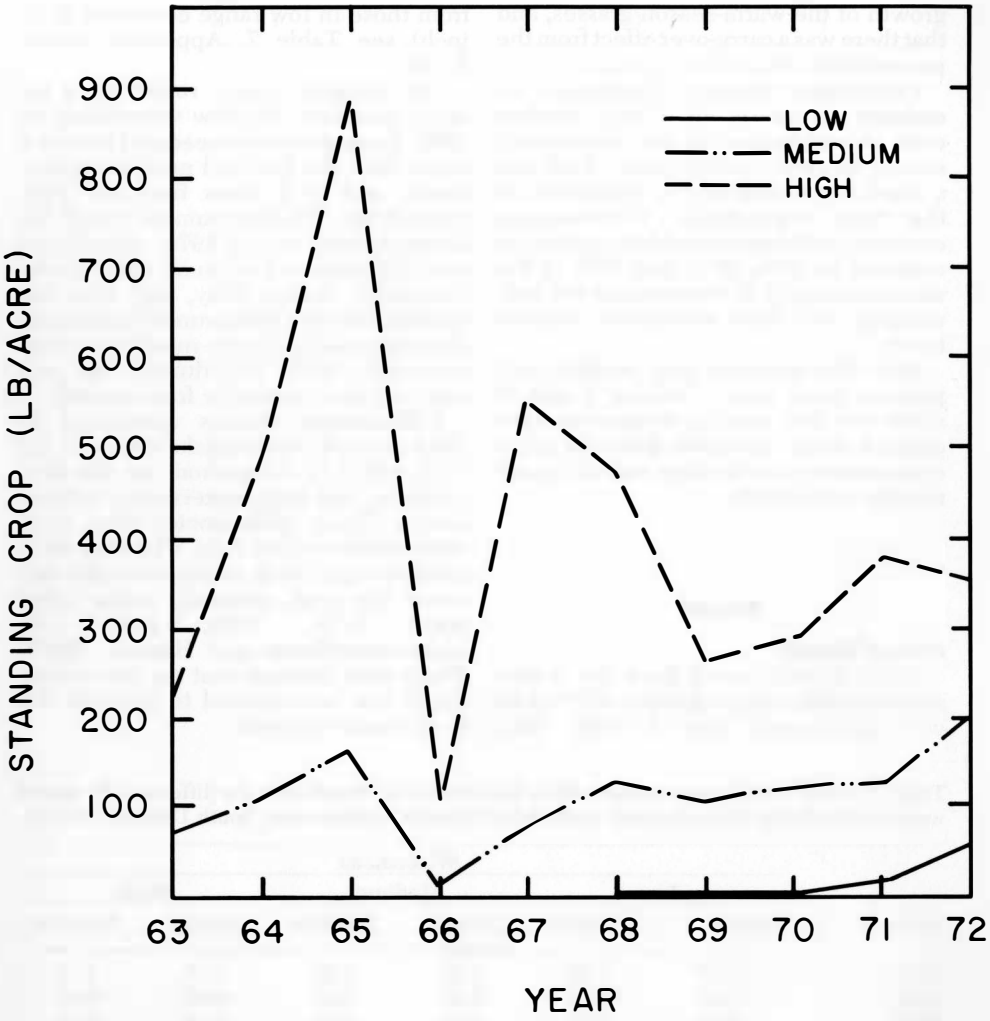


Figure 7. Standing crop of midgrasses on watersheds in different range condition classes, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963-72.

and C1-C10).

In 1967, the peak standing crop on the high watersheds weighed only slightly less than the peak value of 1965, but was relatively lower on the other watersheds (Figure 6). April through June of this year was very wet, while July and August were dry, thus favoring the midgrasses, which dominated the high watersheds (Figure 7).

Summer precipitation in 1967, 1968, and 1969 was substantially above normal, and total standing crop increased on the low watersheds each year. In 1969, with a relatively dry spring following a very dry spring in 1968, the total standing crop on the low watersheds was greater than that on the high, mainly due to a decrease in the weight of cool-season midgrasses. These data indicate that favorable spring precipitation was needed for good growth of the cool-season grasses, that favorable summer precipitation was needed for good

growth of the warm-season grasses, and that there was a carry-over effect from the precipitation of previous years.

Cool-season western wheatgrass accounted for nearly all of the standing crop of midgrasses on the watersheds, except for green needlegrass, which was a small percentage of the vegetation on the high watersheds. Warm-season common buffalograss and blue grama accounted for 90%, 90%, and 95% of the standing crop of shortgrasses on the low, medium, and high watersheds, respectively.

Both the standing crop weights and percent basal cover (Tables 5 and 6) show that the grazing treatments have created three distinctly different plant communities on the three sets of experimental watersheds.

Runoff

Annual Runoff

Mean annual runoff from the watersheds in high range condition (0.59 inch) was significantly less ($P < 0.05$) than from those in low range condition (0.91 inch) see Table 7, Appendix Tables B1-B3.

The greatest annual runoff (1.79 inches) was from the low watersheds in 1963. Annual runoff exceeded 1 inch in 4 years from the low and medium watersheds, and in 2 years from the high watersheds. The least annual runoff, for all treatments, was in 1970, when there was 0.06 inch or less on all watersheds. Generally, March, May, and June accounted for most of the runoff from any of the watersheds. March runoff was from snowmelt, while that during May and June resulted primarily from rainfall.

Infiltrometer studies conducted in 1964 showed 1-hour intake rates of 1.11, 1.73, and 2.73 inches/hour for the low, medium, and high watersheds, respectively. These infiltrometer runs were made on dry soils in July. When the infiltrometer was left in place overnight and rerun the next morning, intake rates were 0.51, 0.69, and 1.26 inches/hour(Rauzi and Hanson, 1966). These data indicate that the low watersheds can be expected to produce the most summer runoff.

Table 7. Annual and summer season (May 14-October 31) runoff from the differentially grazed watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963-72.

	Watersheds					
	Low		Medium		High	
Year	Annual	Summer	Annual	Summer	Annual	Summer
	Inches					
1963	1.79*	1.79	1.59	1.59	1.17	1.17
1964	0.68	0.66	0.28	0.28	0.05	0.05
1965	0.13	0.13	0.14	0.14	0.12	0.12
1966	1.66	0.16	1.36	0.01	1.51	0.00
1967	1.42	1.21	0.81	0.79	0.62	0.54
1968	0.40	0.40	0.20	0.20	0.02	0.02
1969	1.22	0.32	1.16	0.07	0.75	0.03
1970	0.03	0.00	0.06	0.00	0.01	0.00
1971	0.88	0.20	1.24	0.14	0.88	0.09
1972	0.81	0.58	0.88	0.56	0.84	0.59
Mean	0.91a†	0.55(1)‡	0.77 a,b	0.38(2)	0.59b	0.26(2)
Standard Error	0.06	0.04	0.06	0.04	0.06	0.04

* Mean of four watersheds.

† Annual means with the same letter do not differ significantly at the 5% level.

‡ Seasonal means with the same numbers following in parentheses do not differ significantly at the 5% level.

Summer Season Runoff (May 14 - October 31)

The summer season was considered to be from May 14 through October 31, because no runoff due to snowmelt occurred during this period. Mean summer season runoff from watersheds in low range condition (0.55 inch) was significantly greater ($P < 0.05$) than from those in medium (0.38 inch) or high (0.26 inch) range condition (Table 7). Summer runoff was greatest in 1963, when the low range condition watersheds produced 1.79 inches, and lowest in 1970, when there was no runoff. The low watersheds had the most runoff in 8 out of 10 years, while the high watersheds had the least 8 out of 10 years. In 1965, the medium watersheds produced the most runoff, but the difference among the three watersheds was only 0.02 inch. In 1972, the high watersheds yielded the most summer runoff, but there was only a difference of 0.03 inch among all watersheds.

The effect of different grazing intensities and range condition classes can be demonstrated by the number of runoff events during the months of July, August, September, and October over the 10-year period. On the low watersheds, runoff occurred during each of these months—three in July, two in August, and one each in September and October. From the medium watersheds, runoff occurred only four times—twice in July, once in August, and once in October. On the high watersheds only one small runoff event occurred in July (Appendix Tables B1-B3).

For the 10 summer seasons, there were 35, 26, and 21 runoff events with 0.01 inch or greater from the low, medium, and high watersheds, respectively. Runoff from the low watersheds came from short, intense storms as well as long-duration storms. Most of the runoff from the high watersheds occurred from large storms following wet periods. These data suggest that runoff from high watersheds may exceed that from watersheds in lower range condition if soil water is near maximum.

Least-squares regression was used to develop a set of equations that could be used to predict runoff from a storm event during the summer season. The basic equation was:

$$RO = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad (2)$$

where:

RO = storm event runoff (inches)
X_1 = 30-day antecedent precipitation (inches)
X_2 = 5-day antecedent precipitation (inches)
X_3 = total storm event precipitation (inches)
X_4 = maximum 10-minute precipitation intensity (inches/hour)
b_0, b_1, b_2, b_3, b_4 = model coefficients.

The different runoff model coefficients (Table 8) indicated how the graz-

Table 8. Runoff volume coefficients (b_0 - b_4) and coefficients of determination (R^2) for the three sets of watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Watershed Range Condition	b_0	b_1	b_2	b_3	b_4	R^2
Low	-0.528	0.112	0.046	0.243	0.080	0.67
Medium	-0.437	0.050	0.046	0.247	0.037	0.61
High	-0.470	-0.091	0.125	0.239	-0.012	0.74

b_0 = intercept
b_1 = 30-day antecedent precipitation coefficient
b_2 = 5-day antecedent precipitation coefficient
b_3 = total storm precipitation coefficient
b_4 = maximum 10-minute precipitation intensity coefficient

ing treatments affected the runoff regime.

Coefficient b_1 (30-day antecedent precipitation) was inversely proportional to range condition (0.112 for the low, 0.050 for the medium, and -0.091 for the high watersheds), probably because in most years the previous 30-day precipitation produced more cool- than warm-season vegetation, and thus decreased runoff on the high watersheds. This is because generally the amounts of precipitation and runoff were greatest in May and June, when cool-season grasses grew the most because of available water and cooler air temperature. The warm-season vegetation on the low watersheds responded to both precipitation and warm temperatures. The 5-day antecedent precipitation coefficient (b_2) showed greater runoff in response to increasing amounts of 5-day precipitation on the high watersheds, indicating that when the high watershed surface soil became wet, the runoff to precipitation ratio increased; whereas on the other watersheds the runoff amounts were not as affected. There were several possible reasons for this, one was that the high watersheds had a more open vegetation stand at the ground and the low watersheds had a dense shortgrass sod. The infiltration rate was greater on the high than on the low watersheds, which suggested that infiltration rate would decrease proportionately more on the high than the low watersheds.

The maximum 10-minute intensity coefficient (b_4) suggested that the low and medium watersheds respond to high intensity precipitation more than the high watersheds, as was observed in peak runoff rates (which will be discussed later) and the number of runoff events. This precipitation intensity response is most likely due to the open stand of cool-season grasses with more mulch on the high watersheds, as compared with the dense sod cover of warm-season grasses on the low watersheds.

The low R^2 values (0.61-0.74) indicated that there were numerous other variables that were interacting in the runoff regime. However, runoff was significantly ($P < 0.01$) related to the selected independent variables. These equations may be useful in generating runoff values for hydrologic modeling studies, since data for each of the variables are accessible.

Peak runoff rates, as affected by grazing intensities, were based on the maximum rate during each runoff event considered (Figure 8). The low watersheds had the highest runoff rates and the high watersheds the lowest. The maximum rates recorded were 3.89, 1.65, and 0.50 inches/hour from the low, medium, and high watersheds, respectively. These maximum rates were all recorded during 1963, when there were two 3-inch rainfalls within 16 days of each other. The low range condition watersheds had seven runoff events above 0.50 inch/hour, while the medium had only one, and the high equalled this value only once.

The same least-squares procedure used previously was employed to develop peak runoff rate prediction equations. The basic equation was:

$$RP = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad (3)$$

where:

RP = peak runoff rate (inches/hour)
X_1 = 30-day antecedent precipitation (inches)
X_2 = total storm event precipitation (inches)
X_3 = maximum 10-minute precipitation intensity (inches/hour)
X_4 = month of year (January = 1; December = 12)
b_0, b_1, b_2, b_3, b_4 = model coefficients.

In general, coefficients b_1 through b_3 decreased as range condition increased, which is what would be expected with increasing range condition (Table 9). Month of the year, b_4, had a negative effect on runoff, which decreased as range condition increased, indicating that as the season progressed from spring to late summer the same storm events would have increasingly lower peak runoff rates, probably because antecedent soil water was lower as the season advanced. This effect seemed to be less important in high than low range condition. The R^2 values for Equation 3 (Table 9) were not high, accounting for only 61% to 69% of the variation in peak runoff rate, but peak runoff was signific-

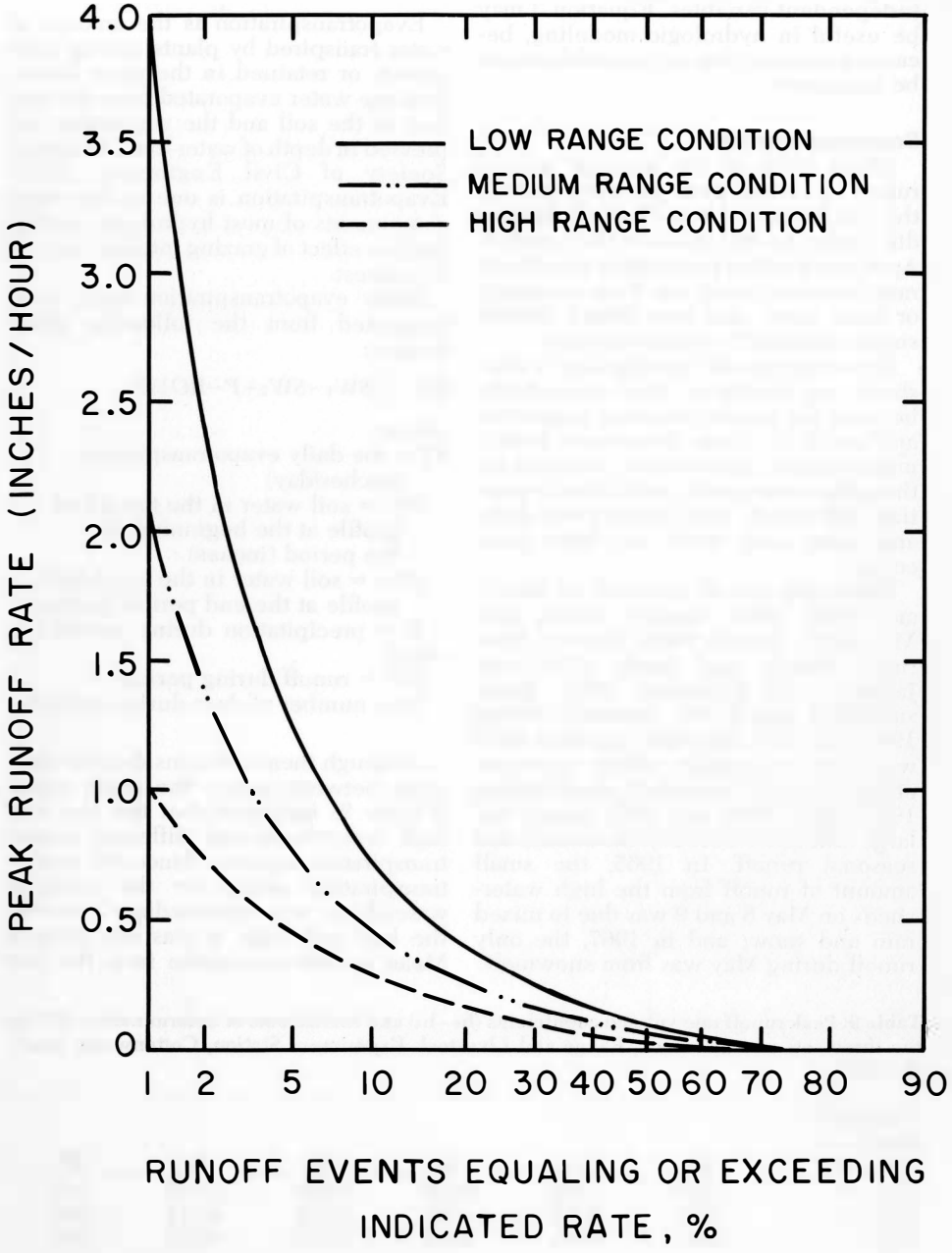


Figure 8. Summer season (May 14-October 13) runoff rate curves, Range and Livestock Experiment Station, Cottonwood, South Dakota, 1963-72.

antly ($P < 0.01$) related to the selected independent variables. Equation 3 may be useful in hydrologic modeling, because necessary data are available or can be generated.

Snowmelt Runoff

About 50% of the average annual runoff occurred from January through the first 13 days of May (Table 7, Appendix Tables B1-B3). Some of the runoff in April and the first part of May was due to rain; however, most was from snowmelt or from snow and rain mixed. March snowmelt runoff was the greatest.

Snowmelt runoff from the high watersheds was similar to other watersheds, because the greater standing vegetation and mulch on these watersheds held a more uniform snow cover; whereas on the other watersheds, with less vegetation and mulch, there were more drifts and some areas with very little snow cover.

Snowmelt runoff occurred in March and April 1966; January, March, and May, 1967; March, 1969; January, February, March, and April, 1971; and January and February, 1972. Some snowmelt runoff also occurred during 1964 and 1970. The only runoff in 1970 was from snowmelt, which averaged about 0.03 inch. Snowmelt runoff during 1966, 1967, 1969, and 1971 caused the large difference between the annual and seasonal runoff. In 1965, the small amount of runoff from the high watersheds on May 8 and 9 was due to mixed rain and snow; and in 1967, the only runoff during May was from snowmelt.

Evapotranspiration

Evapotranspiration is the amount of water transpired by plants during their growth or retained in the plant tissue, plus the water evaporated from the surface of the soil and the vegetation, expressed in depth of water lost (American Society of Civil Engineers, 1973). Evapotranspiration is one of the major components of most hydrologic models and the effect of grazing intensity on it is of interest.

Daily evapotranspiration rates were computed from the following water budget:

$$ET = (SW_1 - SW_2 + P - RO)/D$$

where:

ET = the daily evapotranspiration (inches/day)
SW_1 = soil water in the top 4-foot profile at the beginning of the period (inches)
SW_2 = soil water in the top 4-foot profile at the end period (inches)
P = precipitation during period (inches)
RO = runoff during period
D = number of days during period.

Although there was considerable variation between years, the mean curve (Figure 9) indicated that the low and high watersheds had different evapotranspiration regimes. Since the evapotranspiration curve for the medium watersheds was intermediate between the low and high, it was not plotted. Mean evapotranspiration from the low

Table 9. Peak runoff rate volume coefficients (b_0 - b_4) and coefficients of determination (R^2) for the three sets of watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Watershed Range Condition	b_0	b_1	b_2	b_3	b_4	R^2
Low	-0.087	0.168	0.403	0.290	-0.125	0.62
Medium	0.245	0.086	0.172	0.152	-0.112	0.69
High	-0.024	0.001	0.108	0.011	-0.007	0.61

b_0 = intercept
b_1 = 30-day antecedent precipitation coefficient
b_2 = total storm precipitation coefficient
b_3 = maximum 10-minute precipitation intensity coefficient
b_4 = month of year coefficient

watersheds for the 10-year period was 0.045 inch/day the first of May, increased to 0.13 inch/day by mid-June, remained constant to mid-July, decreased through the last of September and then remained constant at 0.015 inch/day from the end of September through October 15. On the high watersheds, evapotranspiration was 0.07 inch/day the first of May, increased to a maximum of 0.14 inch/day during mid-June, and then decreased to a minimum of 0.035 inch/day by the last of August. Daily evapotranspiration increased again in September to 0.044 inch/day by the end of September, then decreased slightly by October 15.

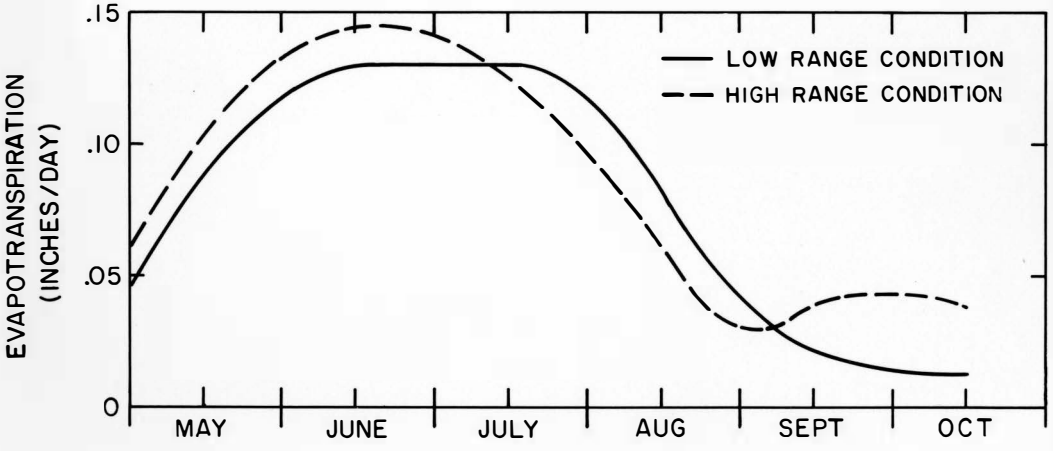
The difference in evapotranspiration regime between the two sets of watersheds was apparently due to differences in botanical composition. The warm-season species (predominantly common buffalograss and blue grama), which dominated the low watersheds, began growing later in the season than did the cool-season species (predominantly western wheatgrass), which dominated the high watersheds. The warm-season species, thus, had water available later into the summer (Figure 10).

When fall precipitation occurred, warm-season grasses were not able to utilize this water because of lower temperatures; however, cool-season species did utilize the fall precipitation for growth (Figure 9). This effect was also noticeable in the soil water in the 4-foot soil profile in September, when the low range condition watersheds averaged almost 2 inches more soil water than did the high watersheds (Figure 10).

Soil Water

Total soil water by treatment, date, and depth are shown in Appendix Tables D1-D9. The 10-year means by date for the 4-foot profile are shown in Figure 10. The different kinds of vegetation on each set of watersheds exhibited very different water-use patterns. Soil water was generally about the same for each treatment in early May and then rapidly decreased on the high watersheds beginning in June, as cool-season grasses utilized more water from the profile, reaching a minimum in early September, then increasing about 0.50 inch by the end of October. At the end of October, the low watersheds had about 1 inch more water in the profile than did the high watersheds. The soil-water regime

Figure 9. Average daily evapotranspiration (1963-72) from the low and high range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.



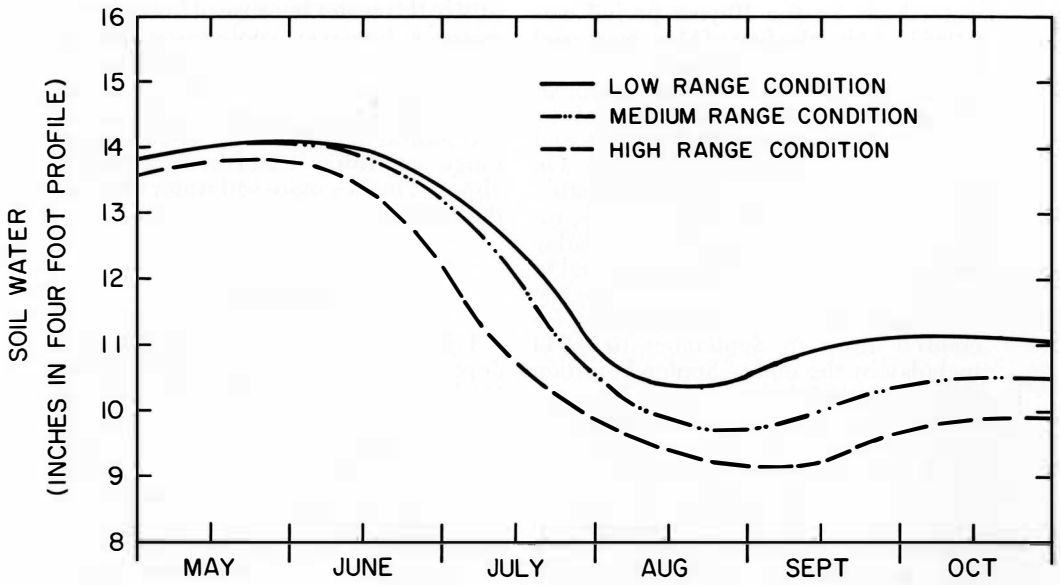


Figure 10. Mean soil water (1963-72) in the upper 4 feet of the soil in the low, medium, and high range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

on the medium watersheds was similar to the low until late June and then followed a course intermediate between the high and low.

The soil water curves showed that the cool-season grasses utilized water early in the season and again in the fall; whereas, the warm-season species utilized water during the warm months and then did not use water in the fall, even if it were available, because of the low temperatures.

SUMMARY

Western South Dakota range hydrologic studies at the Range and Livestock Experiment Station, Cottonwood, showed that grazing intensity and subsequent changes in range condition affected the standing crops of mid- and shortgrasses, forbs and mulch, as well as both annual and summer runoff regimes.

Standing crops of vegetation and mulch averaged 1,844, 2,008, and 3,338 lb/acre in late July on the low, medium, and high range condition watersheds, respectively. Botanical composition on these watersheds varied from almost a pure stand of shortgrasses (primarily warm-season common buffalograss and blue grama) on the low, to a mixture of shortgrasses and midgrasses (primarily cool-season western wheatgrass) on the high range condition watersheds.

The mean annual runoff was 0.91, 0.77, and 0.59 inch from the low, medium, and high range condition watersheds, respectively. The annual runoff was approximately twice the mean summer season runoff of 0.55, 0.38, and 0.26 inch. This indicated that snowmelt or rain and snow mixed caused about 50% of the mean annual runoff. Peak runoff rates were greatest on the low range condition and least on the high range condition watersheds.

Daily evapotranspiration rates were different on the low and high range condition watersheds. The shortgrasses on the watersheds in low range condition had lower evapotranspiration rates early in the growing season, but the maximum rate continued later into the summer before decreasing. The daily rates on watersheds in high range condition were higher early in the spring, reached the highest overall rates, and then decreased earlier in the season. When water was available, the cool-season grasses on the high range condition watersheds used water again in the fall; whereas the warm-season shortgrasses did not.

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Appendices

TABLE A1. Basal cover, 1963 and 1965-72 on the watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Year	WATERSHEDS											
	Low Range Condition[1]				Medium Range Condition				High Range Condition			
	Grasses		Forbs	Mulch, Rock, Bare	Grasses		Forbs	Mulch, Rock, Bare	Grasses		Forbs	Mulch, Rock, Bare
	Mid	Short[2]			Mid	Short			Mid	Short		
	%				%				%			
1963	0	74	0	26	17	59	1	23	29	31	3	37
1965	T[3]	84	T	16	11	68	3	18	30	34	2	34
1966	0	59	0	41	5	39	5	51	22	25	1	52
1967	0	63	7	30	14	45	10	31	23	40	2	35
1968	1	80	1	18	18	53	6	23	26	35	6	33
1969	1	81	0	18	22	54	5	19	29	30	5	36
1970	T	78	T	22	12	60	3	25	24	25	7	44
1971	2	79	2	17	17	54	4	25	27	30	6	37
1972	2	83	2	13	19	43	6	32	28	29	9	34
Mean	1	76	1	22	15	53	5	27	26	31	5	38

1/ Average of four watersheds and 125 points/watershed.
2/ Includes sedges and annual bromes.
3/ Trace.

TABLE A2. Standing crop of grasses, forbs, and mulch on the watersheds in late July, 1963-72, Range and Livestock Experiment Station, Cottonwood, South Dakota

YEAR	WATERSHEDS																	
	Low Range Condition[1]						Medium Range Condition						High Range Condition					
	Grasses			Forbs	Mulch	Total	Grasses			Forbs	Mulch	Total	Grasses			Forbs	Mulch	Total
	Mid	Short[2]	Total				Mid	Short	Total				Mid	Short	Total			
	lb./acre, oven-dried						lb./acre, oven-dried						lb./acre, oven-dried					
1963	T[3]	410	410	1	642	1053	73	398	471	20	1407	1898	227	394	621	57	2202	2880
1964	T	616	616	8	1504	2128	110	582	692	110	1586	2388	487	415	902	150	3317	4369
1965	T	816	816	0	1136	1952	162	556	718	82	1554	2354	894	245	1139	112	3535	4786
1966	T	171	171	8	1619	1798	16	108	124	61	1678	1863	106	106	212	134	3305	3651
1967	T	404	404	60	1008	1472	81	283	364	174	1325	1863	553	266	819	390	2082	3291
1968	3	713	716	22	1167	1905	132	529	661	91	1035	1787	473	371	844	139	2143	3126
1969	3	724	727	29	1535	2292	108	460	568	29	1386	1983	265	338	603	79	1714	2396
1970	3	552	555	14	1677	2246	122	381	503	24	1422	1949	295	286	581	121	1906	2608
1971	20	513	533	3	1129	1665	128	199	327	22	1375	1724	382	282	664	176	2194	3034
1972	65	522	587	66	1278	1931	208	350	558	68	1641	2267	354	239	593	250	2391	3234
Mean	9	544	553[a][4]	21	1270	1844[1]	114	385	499[a]	68	1441	2008[1]	404	294	698[b]	161	2479	3338[2]

1/ Mean of four watersheds and four samples/watershed.
2/ Includes sedges and annual bromes.
3/ Trace.
4/ Means with the same superscript are not statistically different from each other at the 5% level of significance.

TABLE B1. Summary of monthly and annual precipitation and runoff, low range condition watersheds, 1963-72, Range and Livestock Experiment Station, Cottonwood, South Dakota.

	Precipitation[1/]												
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Inches												
1963	.41	.21	.27	1.03	5.11	3.89	1.99	.35	1.05	.74	.03	.11	15.19
1964	.13	.04	.40	2.75	2.44	5.11	.97	1.19	.14	T	.05	.56	13.78
1965	.29	.03	.46	1.65	5.29	3.01	.90	1.04	1.27	.55	.28	.50	15.27
1966	.16	.33	2.24	1.25	.52	1.20	1.49	2.97	2.95	.75	.39	.25	14.50
1967	.32	.34	.47	3.62	2.15	6.35	.25	.65	1.65	.28	.17	.51	16.76
1968	.29	.17	.10	1.56	1.46	6.46	1.04	1.81	.49	.08	.34	.73	14.53
1969	.23	.86	.31	1.60	2.52	2.12	4.64	.61	1.23	1.13	.10	.32	15.67
1970	.37	.18	.58	1.85	.97	1.10	3.03	1.36	1.74	.45	.74	.27	12.64
1971	.61	1.10	.24	3.63	3.60	1.37	.54	1.71	2.87	1.81	.76	.16	18.40
1972	.15	.13	.45	2.19	4.74	1.43	3.02	1.30	.30	.33	.27	.16	14.47
Mean	.30	.34	.55	2.11	2.88	3.20	1.79	1.30	1.37	.61	.31	.36	15.12

1/ Mean of four rain gages.
2/ Mean of four watersheds.

Runoff[2/]												
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Inches												
---	---	---	---	1.32	.31	.16	---	---	---	---	---	1.79
---	---	---	.01	.04	.59	.04	---	---	---	---	---	.68
---	---	---	---	.12	.01	---	---	---	---	---	---	.13
---	---	1.49	.01	---	---	---	.08	.08	---	---	---	1.66
.14	---	.04	---	.03	1.21	---	---	---	---	---	---	1.42
---	---	---	---	---	.40	---	---	---	---	---	---	.40
---	---	.90	---	.02	---	.30	---	---	---	---	---	1.22
---	---	---	.03	---	---	---	---	---	---	---	---	.03
---	.39	.28	.01	.11	---	---	.01	---	.08	---	---	.88
.04	.19	---	---	.58	---	---	---	---	---	---	---	.81
.02	.06	.27	.01	.22	.25	.05	.01	.01	.01	---	---	.91

TABLE B2. Summary of monthly and annual precipitation and runoff, medium range condition watersheds, 1963-72, Range and Livestock Experiment Station, Cottonwood, South Dakota.

	Precipitation[1/]												
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Inches												
1963	.32	.21	.30	1.03	4.78	4.15	1.88	.38	.97	.80	.03	.13	14.98
1964	.12	.04	.41	2.69	2.47	5.10	.98	1.22	.15	T	.07	.54	13.79
1965	.31	.04	.40	1.58	5.56	3.01	.86	1.06	1.24	.62	.29	.48	15.45
1966	.17	.34	2.17	1.17	.51	1.27	1.47	2.91	3.01	.61	.42	.18	14.23
1967	.32	.33	.47	3.65	2.19	6.41	.25	.69	1.58	.33	.18	.57	16.97
1968	.30	.18	.10	1.87	1.46	6.34	1.06	1.80	.48	.08	.34	.89	14.90
1969	.32	.82	.36	1.57	2.62	2.00	4.88	.65	1.15	1.23	.12	.29	16.01
1970	.40	.21	.64	2.03	1.03	1.09	2.96	1.37	1.72	.48	.76	.31	13.00
1971	.68	1.27	.27	3.71	3.50	1.24	.53	1.57	2.83	1.91	.66	.14	18.31
1972	.17	.15	.47	2.14	4.69	1.29	2.94	1.27	.28	.36	.35	.24	14.35
Mean	.31	.36	.56	2.14	2.88	3.19	1.78	1.29	1.34	.64	.32	.38	15.19

1/ Mean of four rain gages.
2/ Mean of four watersheds.

Runoff[2/]												
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Inches												
---	---	---	---	1.00	.58	.01	---	---	---	---	---	1.59
---	---	---	---	.01	.27	---	---	---	---	---	---	.28
---	---	---	---	.14	---	---	---	---	---	---	---	.14
---	---	1.35	---	---	---	---	.01	---	---	---	---	1.36
.01	---	.01	---	---	.79	---	---	---	---	---	---	.81
---	---	---	---	---	.20	---	---	---	---	---	---	.20
---	---	1.09	---	.01	---	.06	---	---	---	---	---	1.16
---	---	---	.06	---	---	---	---	---	---	---	---	.06
.09	.64	.36	.01	.13	---	---	---	---	.01	---	---	1.24
.02	.30	---	---	.56	---	---	---	---	---	---	---	.88
.01	.09	.28	.01	.19	.18	.01	T[1/]	---	T[1/]	---	---	.77

TABLE B3. Summary of monthly and annual precipitation and runoff, high range condition watersheds, 1963-72, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Year	Precipitation[1/]												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Inches												
1963	.41	.29	.31	1.23	4.66	4.60	1.94	.39	1.17	.70	.04	.12	15.86
1964	.14	.06	.43	2.82	2.39	4.88	.53	1.14	.15	T	.07	.40	13.01
1965	.29	.03	.37	1.52	5.60	2.91	1.03	1.01	1.27	.58	.27	.44	15.32
1966	.13	.33	2.13	1.12	.59	1.31	1.51	2.91	3.02	.65	.30	.10	14.10
1967	.28	.30	.38	3.43	2.20	6.05	.26	.76	1.59	.32	.17	.51	16.25
1968	.25	.17	.09	1.64	1.48	6.27	1.08	1.89	.50	.08	.34	.57	14.36
1969	.28	.68	.27	1.61	2.52	2.04	5.11	.67	1.06	1.13	.11	.28	15.76
1970	.33	.17	.46	1.98	1.05	1.20	2.69	1.54	1.72	.39	.71	.23	12.47
1971	.51	.55	.15	3.77	3.52	1.31	.55	1.54	2.82	1.83	.65	.12	17.32
1972	.13	.13	.41	2.04	4.64	1.07	2.91	1.31	.28	.28	.16	.15	13.51
Mean	.27	.27	.50	2.12	2.87	3.16	1.76	1.32	1.36	.60	.28	.29	14.80

1/ Mean of four rain gages
2/ Mean of four watersheds.

Runoff[2/]												
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Inches												
---	---	---	---	.15	1.02	---	---	---	---	---	---	1.17
---	---	---	---	---	.05	---	---	---	---	---	---	.05
---	---	---	---	.12	---	---	---	---	---	---	---	.12
---	.10	1.41	---	---	---	---	---	---	---	---	---	1.51
---	---	.02	---	.06	.54	---	---	---	---	---	---	.62
---	---	---	---	---	.02	---	---	---	---	---	---	.02
---	---	.72	---	---	---	.03	---	---	---	---	---	.75
---	---	---	.01	---	---	---	---	---	---	---	---	.01
.04	.51	.24	---	.09	---	---	---	---	---	---	---	.88
---	.25	---	---	.59	---	---	---	---	---	---	---	.84
T	.09	.24	T	.10	.16	T	---	---	---	---	---	.59

TABLE C1. 1963 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	.00	.00	.00	.00	.00	.03	.00	.00	.63	.00	.00	.00
2	.00	.00	.07S	.00	.09	.36	.30	.00	.00	.00	.00	.00
3	.00	.00	.00	.02	.00	.00	.00	.00	.11	.00	.00	.00
4	.00	.00	.00	.00	.00	.02	.10	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00	.09	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.63	.06	.00	.00	.00	.00	.02S
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.13	.00	.00
8	.02S	.00	.00	.03	.00	.03	.00	.00	.00	.00	.00	.00
9	.24S	.02S	.00	.03	.00	.02	.00	.00	.00	.00	.00	.00
10	.01S	.03S	.00	.49	.20	.00	.00	.00	.00	.00	.00	.00
11	.02S	.00	.03S	.00	.44	.00	.00	.00	.00	.00	.03	.00
12	.00	.00	.00	.00	.20	.00	.00	.00	.00	.00	.00	.04S
13	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.03	.12	.00	.00	.00	.00	.00
15	.00	.00	.00	.08	.06	2.87	.00	.00	.00	.00	.00	.00
16	.02S	.00	.08S	.00	.00	.00	.00	.00	.00	.00	.00	.03S
17	.00	.00	.03S	.00	.00	.00	.02	.00	.04	.00	.00	.04S
18	.00	.00	.02S	.00	.00	.00	.00	.00	.02	.39	.00	.00
19	.00	.00	.00	.04	.00	.00	.00	.00	.00	.04	.00	.00
20	.00	.03S	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00
21	.00	.00	.00	.00	.00	.00	.00	.00	.17	.00	.00	.00
22	.00	.01S	.00	.08	.00	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00	.00
24	.00	.00	.07	.00	.00	.05	.00	.00	.00	.00	.00	.00
25	.00	.10S	.00	.00	.63	.00	.00	.00	.00	.00	.00	.00
26	.00	.00	.00	.03	.21	.00	.07	.05	.00	.00	.00	.00
27	.00	.02S	.00	.13	.00	.00	.51	.00	.00	.00	.00	.00
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
29	.00	---	.00	.04	.00	.00	.67	.23	.00	.00	.00	.00
30	.01S	---	.00	.00	2.95	.00	.03	.00	.00	.20	.00	.00
31	.00	---	.00	---	.00	---	.00	.00	---	.04	---	.00
TOTAL	.32	.21	.30	1.03	4.78	4.15	1.88	.38	.97	.80	.03	.13

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C2. 1964 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.00	.00	.00	.12	.15	.00	.00	.00	.00	.00	.03S
2	.00	.00	.00	.01S	.72	.00	.02	.00	.00	.00	.00	.10S
3	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.02S
4	.00	.00	.01S	.00	.00	.00	.00	.00	.00	.00	.00	.02S
5	.00	.00	.07S	.00	.05	.15	.00	.00	.00	.00	.00	.02S
6	.00	.00	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00	.16	.12	.00	.00	.00	.00	.00
8	.00	.00	.01S	.00	.10	1.20	.00	.29	.00	.00	.00	.00
9	.00	.00	.00	.00	.00	.00	.63	.00	.00	.00	.00	.00
10	.00	.00	.00	.00	.27	.00	.00	.00	.00	.00	.00	.00
11	.02S	.00	.00	.00	.05	.00	.01	.00	.00	.00	.00	.00
12	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00
13	.00	.00	.00	.00	.00	.38	.00	.02	.00	.00	.00	.00
14	.00	.00	.00	.00	.00	.19	.00	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.65	.35	.00	.00	.00	.00	.00	.01S
16	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.00	.08S
17	.00	.00	.00	.00	.00	.68	.00	.00	.00	.00	.00	.00
18	.00	.01S	.00	.00	.00	.46	.00	.00	.00	.00	.00	.00
19	.00	.01S	.00	.00	.00	.00	.00	.17	.15	.00	.00	.00
20	.00	.00	.32S	1.40	.00	.00	.00	.00	.00	.00	.00	.00
21	.00	.00	.00	.15	.00	.88	.00	.49	.00	.00	.00	.00
22	.06S	.01S	.00	.00	.00	.14	.00	.07	.00	.00	.00	.00
23	.04S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08S
25	.00	.00	.00	.15	.00	.00	.00	.00	.00	.00	.04S	.18S
26	.00	.00	.00	.84	.00	.00	.00	.00	.00	.00	.01S	.00
27	.00	.01S	.00	.12M	.00	.00	.00	.16	.00	.00	.01S	.00
28	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.01S	.00
29	.00	.00	.00	.00	.20	.06	.20	.00	.00	.00	.00	.00
30	.00	---	.00	.00	.00	.25	.00	.00	.00	.00	.00	.00
31	.00	---	.00	---	.30	---	.00	.00	---	.00	---	.00
TOTAL	.12	.04	.41	2.69	2.47	5.10	.98	1.22	.15	.00	.07	.54

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C3. 1965 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.00	.00	.00	.00	.49	.00	.00	.00	.00	.00	.00
2	.00	.00	.01S	.06	.00	.12	.00	.00	.00	.00	.00	.00
3	.00	.00	.03S	.00	.00	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.01	.00	.42	.00	.00	.04	.00	.00	.00
5	.00	.00	.00	.45S	.00	.05	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00	.12	.02	.00	.00	.00	.00
7	.00	.00	.00	.00	.02	.00	.00	.23	.02	.00	.00	.00
8	.00	.00	.00	.00	.81	.00	.03	.00	.00	.00	.00	.00
9	.00	.00	.02S	.03	.37M	.00	.42	.00	.00	.00	.00	.00
10	.00	.00	.00	.08M	.00	.03	.04	.00	.00	.00	.00	.23S
11	.00	.00	.00	.21M	.00	.60	.00	.00	.00	.00	.06S	.25S
12	.00	.00	.00	.00	.00	.02	.00	.00	.08	.00	.00	.00
13	.00	.00	.00	.00	.09	.00	.00	.14	.00	.00	.00	.00
14	.19S	.00	.00	.00	1.75	.00	.00	.00	.01	.00	.00	.00
15	.00	.00	.00	.00	.26	.00	.00	.00	.02	.00	.00	.00
16	.00	.00	.00	.06S	.00	.05	.00	.00	.25M	.00	.00	.00
17	.00	.00	.06S	.08S	.00	.04	.00	.00	.00	.00	.04S	.00
18	.00	.00	.00	.00	.00	.08	.08	.00	.00	.44	.00	.00
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.18	.00	.00
20	.00	.02S	.00	.00	.09	.00	.00	.12	.00	.00	.00	.00
21	.00	.02S	.00	.00	.00	.00	.00	.47	.00	.00	.00	.00
22	.00	.00	.03S	.00	.30	.00	.00	.00	.00	.00	.00	.00
23	.04S	.00	.00	.53M	.57	.14	.07	.00	.00	.00	.00	.00
24	.00	.00	.02S	.07S	.74	.20	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.00	.27	.29	.00	.08	.00	.00	.19S	.00
26	.00	.00	.00	.00	.08	.14	.00	.00	.00	.00	.00	.00
27	.02S	.00	.09S	.00	.00	.00	.00	.00	.04	.00	.00	.00
28	.00	.00	.14S	.00	.14	.27	.00	.00	.49	.00	.00	.00
29	.04S	---	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
30	.02S	---	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
31	.00	---	.00	---	.07	---	.00	.00	---	.00	---	.00
TOTAL	.31	.04	.40	1.58	5.56	3.01	.86	1.06	1.24	.62	.29	.48

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C4. 1966 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr.	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.00	.00	.00	.00	.00	.45	.00	.00	.00	.00	.06S
2	.00	.00	.14S	.07	.00	.03	.00	.00	.00	.02	.00	.05S
3	.00	.00	1.70S	.13	.00	.00	.00	.00	.00	.22	.00	.00
4	.00	.00	.00	.03	.00	.27	.00	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.04	.00	.00	.00	.00	.00	.00	.20S	.00
8	.00	.16S	.00	.00	.15	.00	.00	.00	.00	.00	.00	.00
9	.00	.08S	.00	.00	.01	.00	.00	.10	.00	.02	.00	.00
10	.00	.00	.00	.00	.04	.07	.00	.00	.00	.00	.00	.00
11	.00	.00	.00	.04	.30M	.00	.00	.00	.00	.00	.00	.00
12	.00	.00	.00	.35M	.00	.00	.00	.29	.00	.00	.00	.00
13	.00	.00	.00	.00	.00	.00	.66	.00	2.46	.12S	.00	.00
14	.00	.03S	.00	.00	.00	.00	.04	.00	.00	.23S	.00	.00
15	.00	.03S	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00
16	.02S	.00	.00	.26	.00	.00	.00	.00	.30	.00	.00	.00
17	.00	.04S	.05S	.00	.00	.04	.00	.00	.00	.00	.00	.00
18	.00	.00	.00	.03S	.01	.00	.00	.07	.00	.00	.00	.00
19	.07S	.00	.00	.00	.00	.00	.00	2.31	.00	.00	.00	.00
20	.03S	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.00
21	.00	.00	.11S	.00	.00	.00	.14	.00	.00	.00	.00	.07S
22	.00	.00	.17S	.00	.00	.70	.00	.00	.00	.00	.00	.00
23	.03S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
24	.01S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
26	.00	.00	.00	.14	.00	.00	.00	.00	.04	.00	.15S	.00
27	.00	.00	.00	.08	.00	.00	.00	.00	.00	.00	.00	.00
28	.01S	.00	.00	.00	.00	.00	.07	.00	.00	.00	.00	.00
29	.00	---	.00	.00	.00	.00	.00	.00	.07	.00	.00	.00
30	.00	---	.00	.00	.00	.16	.00	.00	.09	.00	.07	.00
31	.00	---	.00	---	.00	---	.11	.10	---	.00	---	.00
TOTAL	.17	.34	2.17	1.17	.51	1.27	1.47	2.91	3.01	.61	.42	.16

S = Snow; M- Rain and Snow mixed; All other precipitation is rain.

TABLE C5. 1967 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan.	Feb.	Mar	Apr.	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.05S	.00	.00	.12S	.02	.03	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00	.00	.00	.39	.00	.00	.18	.00
3	.00	.01S	.16S	.00	.00	.09	.00	.00	.00	.00	.00	.00
4	.00	.02S	.09S	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	.00	.01	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00
6	.14S	.02S	.03S	.00	.00	.04	.00	.00	.00	.17	.00	.00
7	.08S	.10S	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00
8	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.17S
9	.00	.00	.00	.00	.00	.61	.00	.00	.35	.00	.00	.00
10	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00
11	.00	.04S	.00	.00	.02	1.55	.00	.00	.02	.00	.00	.01S
12	.00	.00	.00	.87	.12	.07	.00	.00	.03	.00	.00	.00
13	.00	.00	.00	.28	.00	.23	.00	.00	.07	.00	.00	.00
14	.00	.04S	.13S	.02	.00	.04	.00	.00	.26	.00	.00	.00
15	.00	.04S	.01S	.00	.08	2.38	.00	.09	.33	.00	.00	.00
16	.03S	.00	.00	.00	.02	.00	.00	.00	.13	.00	.00	.00
17	.02S	.00	.00	.02	.00	.00	.00	.00	.04	.00	.00	.17S
18	.00	.00	.00	.00	.00	.05	.00	.04	.02	.00	.00	.00
19	.00	.00	.05S	.41	.00	.00	.00	.00	.33	.00	.00	.00
20	.00	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00	.09S
21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02S
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	.00	.55	.00	.00	.00	.00	.00	.00
24	.00	.00	.00	.36	.02	.04	.00	.00	.00	.00	.00	.00
25	.01S	.00	.00	.00	.22	.59	.03	.00	.00	.10S	.00	.00
26	.00	.00	.00	.00	.25	.09	.14	.00	.00	.00	.00	.00
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
28	.00	.00	.00	.00	.00	.03	.00	.00	.00	.06	.00	.04
29	.00	---	.00	.02	.15	.00	.00	.00	.00	.00	.00	.02 S
30	.04S	---	.00	1.60M	.96	.03	.00	.03	.00	.00	.00	.05 S
31	.00	---	.00	---	.18	---	.05	.00	---	.00	---	.00
TOTAL	.32	.33	.47	3.65	2.19	6.41	.25	.69	1.58	.33	.18	.57

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C6. 1968 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.11S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07S
2	.02S	.00	.00	.16S	.00	.00	.00	.00	.06	.00	.00	.01S
3	.05S	.00	.00	.84	.00	.00	.01	.00	.03	.00	.00	.00
4	.00	.00	.00	.00	.00	.43	.00	.00	.00	.00	.15S	.00
5	.08S	.00	.00	.00	.05	.19	.00	.00	.00	.00	.02S	.00
6	.00	.00	.00	.00	.07	1.24	.00	.00	.00	.00	.02S	.00
7	.00	.00	.00	.05S	.37	1.17	.00	.00	.07	.00	.03S	.00
8	.00	.00	.00	.02S	.00	.08	.00	.00	.00	.00	.00	.00
9	.00	.00	.00	.00	.00	.46	.00	.41	.00	.00	.07	.00
10	.00	.00	.00	.01S	.02M	.04	.00	.00	.00	.00	.02	.00
11	.00	.04	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.31S
13	.00	.00	.00	.14	.00	.03	.00	.00	.00	.00	.00	.12
14	.00	.00	.00	.00	.00	.00	.00	.56	.00	.00	.00	.00
15	.00	.00	.00	.00	.33	.36	.00	.00	.04	.08	.02S	.02S
16	.00	.00	.00	.00	.01	.00	.00	.00	.19	.00	.00	.02S
17	.00	.00	.00	.00	.02	.00	.00	.30	.00	.00	.00	.00
18	.00	.00	.06S	.00	.09	.33	.00	.10	.00	.00	.00	.00
19	.00	.00	.04S	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	.00	.06S	.00	.00	.00	.11	.00	.00	.00	.00	.00	.02S
21	.00	.00	.00	.46S	.00	.00	.00	.00	.04	.00	.00	.12S
22	.00	.00	.00	.14S	.30	.00	.04	.00	.05	.00	.00	.10S
23	.00	.01S	.00	.00	.03	.65	.00	.03	.00	.00	.00	.00
24	.00	.02S	.00	.00	.00	.63	.97	.00	.00	.00	.00	.00
25	.00	.05S	.00	.00	.00	.22	.00	.00	.00	.00	.01S	.05S
26	.04S	.00	.00	.05	.00	.00	.03	.00	.00	.00	.00	.00
27	.00	.00	.00	.00	.09	.00	.00	.00	.00	.00	.00	.02S
28	.00	.00	.00	.00	.00	.00	.00	.40	.00	.00	.00	.00
29	.00	.00	.00	.00	.00	.40	.00	.00	.00	.00	.00	.03S
30	.00	---	.00	.00	.04	.00	.00	.00	.00	.00	.00	.00
31	.00	---	.00	---	.04	---	.00	.00	---	.00	---	.00
TOTAL	.30	.18	.10	1.87	1.46	6.34	1.06	1.80	.48	.08	.34	.89

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C7. 1969 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar.	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.05 S	.09S	.00	.03	.00	.00	.03	.00	.35	.00	.00
2	.02 S	.00	.06S	.00	.00	.00	.04	.01	.00	.19	.00	.00
3	.00	.00	.00	.00	.11	.00	.00	.00	.00	.04	.00	.00
4	.01 S	.00	.00	.00	.21	.00	.00	.00	.00	.33	.00	.00
5	.03 S	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00	.02S
6	.03S	.00	.02S	.00	.00	.00	.00	.00	.00	.00	.00	.03S
7	.00	.11S	.02S	.07	.00	.03	.00	.00	.00	.00	.00	.02S
8	.00	.00	.00	.79	.00	.00	.00	.00	.00	.00	.00	.00
9	.00	.00	.03S	.02	.00	.00	.08	.00	.00	.06 S	.00	.00
10	.00	.00	.02S	.00	.00	.51	.27	.00	.00	.00	.00	.02S
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04S	.02S
12	.00	.00	.03S	.03	.00	.00	.00	.06	.00	.02S	.00	.00
13	.00	.00	.00	.00	.00	.39	.00	.00	.00	.20S	.02S	.00
14	.00	.25S	.00	.08	.00	.00	.14	.00	.00	.00	.00	.00
15	.02S	.00	.00	.15	1.68	.00	.19	.00	.00	.00	.00	.00
16	.00	.00	.00	.08	.03	.00	.62	.00	.00	.00	.00	.02S
17	.08S	.00	.00	.00	.00	.00	.60	.00	.75	.00	.06S	.00
18	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.00
19	.00	.10S	.04 S	.00	.15	.00	.68	.00	.00	.00	.00	.00
20	.00	.16S	.00	.00	.00	.00	1.99	.00	.00	.00	.00	.00
21	.00	.03S	.00	.00	.29	.03	.00	.00	.00	.00	.00	.02S
22	.05S	.00	.00	.00	.00	.45	.00	.00	.13	.00	.00	.04S
23	.00	.00	.00	.00	.00	.00	.09	.00	.00	.00	.00	.00
24	.00	.00	.00	.00	.00	.51	.00	.00	.01	.00	.00	.00
25	.00	.00	.00	.19	.00	.04	.00	.00	.00	.00	.00	.00
26	.03S	.09S	.04 S	.09	.00	.04	.00	.00	.00	.00	.00	.04S
27	.00	.03 S	.00	.07	.00	.00	.00	.00	.00	.00	.00	.03S
28	.00	.00	.01 S	.00	.00	.00	.00	.03	.00	.00	.00	.01S
29	.05S	---	.00	.00	.00	.00	.00	.45	.00	.01S	.00	.02S
30	.00	---	.00	.00	.00	.00	.00	.05	.26	.03S	.00	.00
31	.00	---	.00	---	.07	---	.10	.02	---	.00	---	.00
TOTAL	.32	.82	.36	1.57	2.62	2.00	4.88	.65	1.15	1.23	.12	.29

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C8. 1970 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.02S	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00
2	.01S	.00	.00	.00	.00	.00	.00	.00	.02	.00	.05S	.00
3	.01S	.02S	.00	.00	.00	.00	.00	.00	.08	.00	.00	.00
4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00	.00	.06	.30	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.01	.00	.00	.25	.14S	.00	.00
7	.00	.00	.00	.00	.05	.00	.03	.00	.74	.08S	.16S	.00
8	.00	.00	.13S	.00	.02	.00	.00	.00	.00	.01S	.24S	.00
9	.00	.00	.26S	.00	.00	.00	1.77	.85	.00	.00	.03S	.04S
10	.00	.00	.00	.00	.17	.07	.00	.00	.00	.00	.01S	.20S
11	.00	.00	.00	.29	.01	.30	.00	.00	.00	.00	.00	.01S
12	.00	.00	.01S	.34	.00	.48	.00	.00	.00	.06S	.00	.02S
13	.00	.03	.02S	.00	.26	.00	.00	.00	.54S	.01S	.05S	.00
14	.00	.00	.02S	.24	.07	.00	.00	.14	.09S	.00	.00	.00
15	.00	.00	.00	.38	.00	.03	.00	.07	.00	.00	.00	.00
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
17	.03S	.09S	.05S	.29	.00	.00	.00	.00	.00	.00	.00	.00
18	.08S	.06S	.03S	.37	.00	.00	.49	.00	.00	.01S	.02S	.03S
19	.00	.01S	.03S	.01	.00	.00	.00	.00	.00	.02S	.00	.00
20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
21	.00	.00	.00	.01	.03	.00	.00	.00	.00	.00	.00	.00
22	.00	.00	.00	.07	.03	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	.00	.00	.61	.00	.00	.00	.00	.00
24	.25S	.00	.00	.00	.08	.19	.00	.00	.00	.00	.00	.01S
25	.00	.00	.02S	.00	.00	.00	.00	.00	.00	.01S	.12S	.00
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02S	.04S	.00
27	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01S	.01S	.00
28	.00	.00	.03S	.03	.00	.00	.00	.00	.00	.03S	.00	.00
29	.00	---	.04S	.00	.02	.00	.00	.00	.00	.08S	.00	.00
30	.00	---	.00	.00	.27	.00	.00	.00	.00	.00	.03S	.00
31	.00	---	.00	---	.02	---	.00	.00	---	.00	---	.00
TOTAL	.40	.21	.64	2.03	1.03	1.09	2.96	1.37	1.72	.48	.76	.31

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C9. 1971 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May.	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.29	.00	.00
2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07	.00	.00
3	.00	.20S	.00	.04S	.14	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	.00	.00	.15	.00	2.17	.00	.00	.00
5	.00	.02S	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00
6	.00	.00	.00	.00	.00	.14	.07	.00	.00	.00	.00	.02 S
7	.00	.00	.00	.00	.00	.00	.00	.00	.18	.00	.00	.12 S
8	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	.00
9	.02S	.00	.00	.00	.03	.08	.00	.00	.00	.00	.00	.00
10	.01S	.04S	.00	.00	.54	.10	.00	.00	.00	.00	.00	.00
11	.05S	.00	.00	.00	.00	.29	.00	.00	.00	.00	.00	.00
12	.01S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	.02S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04 S	.00
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.04 S	.00
16	.00	.00	.00	.00	.12	.13	.00	.00	.00	.15	.23 S	.00
17	.21S	.00	.13 S	.23	.00	.00	.07	.00	.00	1.13	.00	.00
18	.00	.34S	.00	.06	.00	.00	.00	.14	.06	.11	.00	.00
19	.00	.00	.00	1.93	.00	.00	.00	.00	.00	.00	.03S	.00
20	.00	.00	.00	.64	.00	.00	.00	.00	.07	.00	.00	.00
21	.08S	.00	.03 S	.11	.00	.00	.00	.18	.00	.00	.00	.00
22	.00	.00	.03 S	.00	.14	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	1.35	.00	.00	.00	.00	.00	.00	.00
24	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.04	.00	.32	.24	.00	.00	.00	.12S	.00
26	.00	.67S	.05.S	.53	.00	.09	.00	.00	.00	.00	.03S	.00
27	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00	.11S	.00
28	.00	.00	.03 S	.00	.00	.00	.00	.00	.15	.00	.01S	.00
29	.06 S	---	.00	.04	.47	.09	.00	.00	.00	.11S	.03S	.00
30	.16 S	---	.00	.00	.71	.00	.00	1.25	.00	.03S	.02S	.00
31	.06 S	---	.00	---	.00	---	.00	.00	---	.00	---	.00
TOTAL	.68	1.27	.27	3.71	3.50	1.24	.53	1.57	2.83	1.91	.66	.14

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE C10. 1972 Daily precipitation medium range condition watersheds, Range and Livestock Experiment Station Cottonwood, South Dakota.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
						Inches						
1	.00	.02S	.02S	.00	.24	.00	.00	.18	.00	.00	.00	.00
2	.00	.00	.00	.00	.00	.00	.06	.69	.00	.00	.00	.01S
3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04S
4	.00	.00	.00	.00	.00	.00	.02	.00	.00	.00	.00	.09S
5	.00	.00	.00	.00	.00	.00	.00	.08	.00	.20M	.00	.03S
6	.00	.00	.00	.04S	.00	.00	.00	.00	.03	.00	.00	.00
7	.00	.00	.00	.01S	.00	.00	.04	.01	.21	.00	.00	.01
8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01S
9	.00	.01S	.00	.00	.17	.00	.00	.00	.00	.00	.00	.00
10	.00	.00	.00	.03	.75	.06	.00	.00	.00	.00	.00	.00
11	.00	.00	.00	.03	.25	.00	.02	.00	.00	.02S	.18S	.00
12	.00	.00	.04S	.00	.04	.34	.00	.00	.00	.00	.17S	.00
13	.02S	.00	.01S	.28S	.03	.00	.07	.00	.00	.00	.00	.00
14	.00	.00	.08S	.11S	.00	.00	.05	.00	.00	.00	.00	.00
15	.00	.00	.00	.00	.00	.45	.04	.00	.00	.00	.00	.00
16	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00
17	.00	.00	.00	.05S	.00	.04	.38	.00	.00	.00	.00	.00
18	.00	.00	.00	.11S	.21	.01	.00	.00	.00	.00	.00	.00
19	.00	.00	.00	.00	.00	.26	.00	.10	.00	.00	.00	.00
20	.00	.00	.07S	.00	.00	.00	.49	.00	.00	.00	.00	.00
21	.00	.00	.00	.00	.63	.06	.41	.03	.00	.00	.00	.00
22	.00	.00	.00	.00	.23	.00	.02	.00	.00	.00	.00	.00
23	.13S	.11S	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
24	.02S	.01S	.22S	.00	.00	.00	1.05	.00	.00	.00	.00	.00
25	.00	.00	.00	.05	1.37	.07	.00	.00	.00	.00	.00	.00
26	.00	.00	.01S	.49	.19	.00	.00	.00	.00	.00	.00	.00
27	.00	.00	.02S	.53	.53	.00	.23	.00	.00	.00	.00	.00
28	.00	.00	.00	.09	.05	.00	.00	.00	.00	.00	.00	.00
29	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.02S
30	.00	---	.00	.32	.00	.00	.00	.00	.00	.13S	.00	.03S
31	.00	---	.00	---	.00	---	.01	.18	---	.01S	---	.00
TOTAL	.17	.15	.47	2.14	4.69	1.29	2.94	1.27	.28	.36	.35	.24

S = Snow; M = Rain and Snow mixed; All other precipitation is rain.

TABLE D1. Soil water[1/] on the watersheds, 1964, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth	Apr. 2	May 13	May 26	June 12	July 1	July 15	July 31	Sept. 10	Nov. 10
Feet					Inches				
				Low Range Condition					
1	1.95	4.28	4.03	4.75	4.22	3.48	1.95	1.67	1.43
2	2.17	3.06	3.81	3.96	4.42	3.98	2.81	2.53	2.40
3	2.39	2.80	3.05	3.02	3.19		3.01	2.87	2.91
4	2.59	3.29	3.18	3.15	3.16		3.34	3.19	3.26
Total	9.10	13.43	14.07	14.88	14.99		11.11	10.26	10.00
				Medium Range Condition					
1	1.90	4.45	4.08	4.59	4.16	3.06	1.97	1.73	1.46
2	2.24	3.09	3.41	3.78	3.95	3.79	2.76	2.51	2.41
3	2.54	3.07	3.10	3.09	3.16	3.54	3.16	2.96	2.95
4	2.54	2.94	3.11	3.05	3.07	3.98	3.16	3.03	3.18
Total	9.22	13.55	13.70	14.51	14.34	14.37	11.05	10.23	10.00
				High Range Condition					
1	1.75	4.20	3.45	3.78	3.67	2.60	1.50	1.49	1.20
2	2.16	3.42	3.32	3.52	3.84	3.31	2.61	2.38	2.36
3	2.43	2.83	2.92	3.14	3.10	3.12	2.93	2.87	2.87
4	2.56	2.83	2.86	2.92	2.93	2.96	3.11	2.90	2.94
Total	8.90	13.28	12.55	13.36	13.54	11.99	10.15	9.64	9.37

1/ Each value is the mean of six access tubes.

TABLE D2. Soil water[1/] on the watersheds, 1965, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth	May 7	May 20	June 9	June 24	July 9	July 22	Aug. 13	Aug. 30	Oct. 1
Feet				Inches					
				Low Range Condition					
1	2.67	3.79	3.91	2.98	2.42	1.97	1.25	1.32	3.46
2	2.90	5.08	5.29	4.99	4.47	3.95	2.86	2.61	3.29
3	2.81	3.60	3.79	3.81	3.99	4.16	3.59	3.10	3.18
4	3.07	3.22	3.30	3.42	3.53	3.77	3.80	3.41	3.43
Total	11.45	15.69	16.29	15.20	14.41	13.85	11.50	10.44	13.36
				Medium Range Condition					
1	2.91	3.94	4.13	2.97	2.08	1.62	1.03	1.17	2.92
2	3.38	4.87	5.22	4.77	4.08	3.45	2.84	2.64	2.87
3	2.98	3.30	3.36	3.44	3.42	3.51	3.33	3.11	3.09
4	2.95	3.01	3.07	3.08	3.19	3.35	3.37	3.19	3.18
Total	12.22	15.12	15.78	14.26	12.77	11.93	10.57	10.11	12.06
				High Range Condition					
1	2.69	3.53	3.71	2.48	1.62	1.26	0.83	0.98	2.33
2	3.57	5.34	5.34	4.77	3.57	2.98	2.50	2.49	2.44
3	2.93	3.44	3.88	3.85	3.77	3.50	3.12	2.92	2.94
4	2.76	2.79	2.76	2.89	2.92	3.00	2.99	2.93	2.94
Total	11.95	15.10	15.69	13.99	11.88	10.74	9.44	9.32	10.65

1/ Each value is the mean of six access tubes.

TABLE D3. Soil water[1/] on the watersheds, 1966, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	April 21	May 5	May 19	June 2	June 22	July 15	Aug. 3	Aug. 29	Sept. 23	Oct. 18	Nov. 1
					Inches						
					Low Range Condition						
1	4.64	3.81	3.79	2.49	1.98	2.49	2.05				
2	3.88	3.82	3.87	3.57	2.97	3.07	2.62				
3	3.14	3.17	3.26	3.30	3.19	3.05	3.05				
4	3.28	3.30	3.36	3.42	3.37	3.44	3.42				
Total	14.94	14.10	14.28	12.78	11.51	12.05	11.14				
					Medium Range Condition						
1	5.27	4.70	3.84	2.48	1.86	2.50	1.82				
2	4.09	4.87	4.24	3.83	3.12	3.02	2.71				
3	3.39	3.66	3.40	3.41	3.29	3.24	3.34				
4	3.11	2.87	3.12	3.26	3.21	3.23	3.20				
Total	15.86	16.10	14.60	12.98	11.48	11.99	11.07				
					High Range Condition						
1	4.69	3.96	3.38	2.12	1.80	2.22	1.68				
2	4.55	5.15	4.46	3.45	2.75	2.66	2.39				
3	3.53	3.70	3.49	3.41	3.22	3.11	2.98				
4	2.91	3.12	2.87	2.95	3.00	2.97	2.95				
Total	15.68	15.93	14.20	11.93	10.77	10.96	10.00				

1/ Each value is the mean of six access tubes.

TABLE D4. Soil water[1/] on the watersheds, 1967, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	Apr. 28	May 9	June 8	June 20	July 7	July 19	Aug. 8	Sept. 22	Oct. 20	Nov. 16
					Inches					
					Low Range Condition					
1	5.04	5.13	4.70	4.54	3.36	2.51	2.22	2.83	2.75	2.14
2	4.31	4.96	4.94	4.98	4.60	4.00	3.04	2.65	2.73	2.54
3	3.03	3.14	3.22	4.23	4.07	4.22	3.69	3.09	3.15	3.11
4	3.27	3.22	3.25	3.29	3.34	3.55	3.34	3.39	3.29	3.28
Total	15.65	16.45	16.11	17.04	15.37	14.28	12.29	11.96	11.92	11.07
					Medium Range Condition					
1	5.47	5.47	4.42	4.80	3.36	2.68	2.17	2.86	2.72	2.16
2	4.29	4.81	4.19	5.52	4.70	3.80	3.01	2.71	2.72	2.63
3	3.13	3.22	3.06	3.87	3.66	3.85	3.46	3.22	3.10	3.05
4	3.05	3.05	2.93	3.08	3.00	3.15	3.01	3.20	3.11	3.01
Total	15.94	16.55	14.60	17.27	14.72	13.48	11.65	11.99	11.65	10.85
					High Range Condition					
1	4.58	4.91	3.99	4.70	3.27	2.39	2.01	2.58	2.47	1.83
2	3.66	4.41	3.88	5.39	4.50	3.37	2.81	2.35	2.45	2.33
3	2.98	3.13	3.03	4.29	3.95	3.86	3.36	2.82	2.94	2.96
4	2.83	2.96	2.92	2.96	2.91	2.93	2.96	2.70	2.91	2.82
Total	14.05	15.41	13.82	17.34	14.63	12.55	11.14	10.45	10.77	9.94

1/ Each value is the mean of six access tubes.

TABLE D5. Soil water[1/] on the watersheds, 1968, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	Apr. 25	May 16	June 10	June 27	July 11	July 26	Aug. 16	Aug. 28	Sept. 11	Oct. 3	Oct. 31
	Inches										
Low Range Condition											
1	5.01	4.36	4.85	5.73	3.49	3.35	2.64	2.55	2.49	2.19	2.08
2	3.54	3.42	4.08	4.71	4.25	3.46	2.78	2.91	2.87	2.61	2.57
3	3.36	3.31	3.44	3.84	3.87	3.69	3.14	3.28	3.19	2.95	2.94
4	3.53	3.39	3.24	3.69	3.45	3.56	3.46	3.48	3.50	3.37	3.38
Total	15.44	14.48	15.61	17.97	15.06	14.06	12.02	12.22	12.05	11.12	10.97
Medium Range Condition											
1	5.63	4.80	5.12	5.63	3.61	3.11	2.72	2.61	2.56	2.39	2.27
2	4.07	3.80	4.68	4.64	4.45	3.58	2.83	2.85	2.88	2.66	2.60
3	3.39	3.25	3.31	3.45	3.87	3.64	3.16	3.27	3.25	3.06	3.10
4	3.19	3.18	2.99	3.17	3.40	3.39	3.12	3.14	3.23	3.00	3.11
Total	16.28	15.03	16.10	16.89	15.33	13.72	11.83	11.87	11.92	11.11	11.08
High Range Condition											
1	5.06	4.03	4.61	4.75	3.21	2.50	2.47	2.28	2.26	2.09	1.94
2	3.09	3.27	4.57	4.18	3.73	2.82	2.56	2.69	2.61	2.31	2.48
3	3.06	2.95	3.15	3.15	3.22	3.10	2.91	2.97	2,90	2.77	2.81
4	3.17	3.17	3.12	3.15	3.15	3.05	2.93	2.99	2.97	2.87	3.00
Total	14.38	13.42	15.45	15.23	13.31	11.47	10.87	10.93	10.74	10.04	10.23

1/ Each value is the mean of six access tubes.

TABLE D6. Soil water[1/] on the watersheds, 1969, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	Apr. 19	May 5	May 23	June 11	July 1	July 15	Aug. 4	Aug. 21	Sept. 4	Sept. 15	Sept. 30	Oct. 16
	Inches											
Low Range Condition												
1	4.46	4.42	4.81	3.26	3.70	2.94	2.44	1.80	1.87	1.67	2.46	3.87
2	2.77	2.82	3.02	2.76	2.91	2.72	2.96	2.20	2.08	2.11	2.36	2.26
3	3.35	3.34	3.30	3.22	3.36	3.27	3.19	2.95	2.82	2.78	2.83	2.75
4	3.44	3.55	3.50	3.51	3.61	3.60	3.49	3.49	3.46	3.45	3.39	3.30
Total	14.02	14.13	14.63	12.75	13.58	12.53	12.08	10.44	10.23	10.01	11.04	12.18
Medium Range Condition												
1	4.51	4.37	4.71	3.46	3.33	2.89	2.63	2.05	2.02	1.84	2.33	3.16
2	3.45	3.36	3.82	3.35	3.26	2.91	3.47	2.70	2.52	2.50	2.57	2.41
3	3.33	3.31	3.46	3.41	3.42	3.41	3.30	3.14	3.06	3.10	3.07	2.98
4	2.97	2.99	3.00	3.02	3.05	3.08	2.98	3.01	2.99	3.00	2.99	2.90
Total	14.26	14.03	14.99	13.24	13.06	12.29	12.38	10.90	10.59	10.44	10.96	11.45
High Range Condition												
1	4.32	4.30	4.53	3.00	2.92	2.52	2.61	1.72	1.65	1.48	1.78	2.89
2	3.46	3.38	3.80	3.23	3.13	2.84	3.69	2.65	2.48	2.41	2.45	2.31
3	3.52	3.56	3.59	3.37	3.51	3.34	3.50	3.30	3.03	3.01	3.02	2.82
4	3.02	3.05	3.07	3.03	3.17	3.18	3.00	3.03	2.99	2.97	2.96	2.81
Total	14.32	14.29	14.99	12.63	12.73	11.88	12.80	10.70	10.15	9.87	10.21	10.83

1/ Each value is the mean of six access tubes.

TABLE D7. Soil water[1/] on the watersheds, 1970, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	Apr. 30	June 9	June 15	July 2	July 20	Aug. 4	Aug. 21	Sept. 4	Sept. 29	Oct. 16
					Inches					
					Low Range Condition					
1	4.42	3.10	3.22	2.24	3.34	2.20	2.42	2.11	2.90	2.77
2	3.78	3.49	3.36	2.59	2.67	2.38	2.40	2.22	2.16	2.14
3	3.24	3.36	3.35	3.26	3.23	3.11	3.01	2.93	2.97	2.95
4	3.33	3.37	3.50	3.51	3.52	3.49	3.54	3.51	3.53	3.45
Total	14.77	13.32	13.43	11.60	12.76	11.18	11.37	10.77	11.56	11.31
					Medium Range Condition					
1	4.61		3.01	2.39	3.06	2.36	2.47	2.25	2.96	2.73
2	4.48		3.55	2.95	2.86	2.77	2.72	2.57	2.61	2.56
3	3.43		3.47	3.37	3.36	3.28	3.19	3.19	3.14	3.05
4	2.90		2.97	2.95	3.07	3.02	3.07	2.92	3.06	2.97
Total	15.42		13.00	11.66	12.35	11.43	11.45	10.93	11.77	11.31
					High Range Condition					
1	4.46		2.80	1.98	2.53	1.95	2.20	1.93	2.56	2.23
2	4.52		3.41	2.76	2.67	2.57	2.68	2.49	2.45	2.44
3	3.98		3.81	3.54	3.37	3.21	3.21	3.13	3.10	3.01
4	2.96		3.06	3.09	3.10	3.10	3.10	3.27	3.13	3.03
Total	15.92		13.08	11.37	11.67	10.83	11.19	10.82	11.24	10.71

1/ Each value is the mean of six access tubes.

TABLE D8. Soil water[1/] on the watersheds, 1971, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth	May 3	May 28	June 15	July 2	July 26	Aug. 10	Sept. 3	Sept. 17	Oct. 5	Oct. 21
Feet	Inches									
Low Range Condition										
1	4.54	4.47	3.91	2.85	2.42	2.04	3.62	4.20	4.19	4.69
2	3.65	3.70	3.66	3.20	2.29	2.10	2.51	2.69	2.66	2.73
3	3.11	3.31	3.42	3.38	3.10	2.97	2.92	2.86	2.95	2.90
4	3.27	3.32	3.32	3.35	3.36	3.27	3.31	3.33	3.31	3.25
Total	14.57	14.80	14.31	12.78	11.17	10.38	12.36	13.08	13.11	13.57
Medium Range Condition										
1	4.56	4.45	3.77	2.69	2.41	2.31	2.97	4.33	3.92	4.48
2	3.93	3.90	3.89	3.18	2.57	2.47	2.44	2.46	2.55	2.61
3	3.11	3.24	3.24	3.10	3.00	2.94	2.92	2.95	2.89	2.89
4	2.93	2.78	2.77	2.77	2.84	2.82	2.88	2.90	2.81	2.78
Total	14.53	14.37	13.67	11.74	10.82	10.54	11.21	12.64	12.17	12.76
High Range Condition										
1	4.43	4.29	3.61	2.47	2.01	1.83	3.23	4.08	3.86	4.17
2	4.45	4.32	4.12	3.16	2.33	2.18	2.29	3.04	2.82	3.17
3	3.36	3.42	3.50	3.33	3.05	3.03	2.94	2.93	2.88	2.86
4	2.84	2.82	2.88	2.91	2.81	2.87	2.85	2.86	2.85	2.80
Total	15.08	14.85	14.11	11.87	10.20	9.91	11.31	12.91	12.41	13.00

1/ Each value is the mean of six access tubes.

TABLE D9. Soil water[1/] on the watersheds, 1972, Range and Livestock Experiment Station, Cottonwood, South Dakota.

Depth Feet	May 18	June 2	June 14	June 28	July 19	July 29	Aug. 12	Sept. 18	Oct. 10
					Inches				
					Low Range Condition				
1	4.55	4.62	3.63	3.36	2.78	4.02	3.71	2.34	2.46
2	4.21	3.87	3.64	3.45	2.80	3.05	2.97	2.30	2.24
3	3.99	3.90	4.12	3.89	3.71	3.64	3.64	3.16	2.84
4	3.34	3.37	3.52	3.47	3.55	3.59	3.48	3.46	3.14
Total	16.09	15.76	14.91	14.17	12.84	14.30	13.80	11.26	10.68
					Medium Range Condition				
1	4.42	4.52	3.53	3.00	2.64	3.66	3.43	2.38	2.12
2	4.45	4.28	4.17	3.79	3.00	3.22	3.21	2.47	2.46
3	3.27	2.95	3.37	3.30	3.27	3.32	3.28	2.93	3.09
4	2.85	2.77	2.90	2.84	2.84	2.85	2.88	2.84	2.75
Total	14.99	14.52	13.97	12.93	11.75	13.05	12.80	10.62	10.42
					High Range Condition				
1	4.38	4.54	3.29	2.96	2.45	3.96	3.31	2.15	1.94
2	4.46	4.51	4.19	3.85	2.86	3.21	3.02	2.09	2.38
3	4.11	4.14	4.40	4.08	3.66	3.78	3.58	3.25	2.90
4	2.99	3.02	3.07	2.99	2.96	3.06	3.01	2.89	2.76
Total	15.94	16.21	14.95	13.88	11.93	14.01	12.92	10.38	9.98

1/ Each value is the mean of six access tubes.

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