Water Intake and Runoff as Affected by Intensity of Grazing

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Highlight

Water intake rates on differentially grazed rangeland watersheds were nearly linear with the heavily grazed watershed having the lowest and the lightly grazed watershed the highest rate. Annual runoff was greatest from the heavily grazed watersheds and least from the lightly grazed. Storm characteristics were a factor in the production of runoff.

Grazing-intensity studies on native rangeland at many locations have been conducted primarily to obtain basic information from vegetative and livestock responses. Other information of value has also been obtained.

Sharp et al. (1964) obtained basic hydrologic data at Cottonwood, South Dakota, from small rangeland watersheds grazed lightly, moderately, and heavily. Johnston (1962), Rauzi (1963), and Rhoades et al. (1964) made water-intake studies on native pastures differentially grazed for 20 years or more. Basic soils information was obtained (Rhoades et al. 1964) from pastures differentially grazed. Thus the grazing-intensity studies have and are yielding additional information beyond what was originally planned.

Production of kind and amount of native herbage for a given soil type is influenced largely by the amount and distribution of precipitation. In turn, the water-intake rates may be influenced by management, surface, and subsurface soil conditions, the kind and amount of vegetal cover present, and intensity of rainfall (Rauzi and Kuhlman, 1961).

The study reported herein was conducted at the Cottonwood Range Field Experiment Station, Cottonwood, South Dakota. Purpose was to evaluate effects of grazing intensities and vegetal cover on water-intake rates. Some additional soil properties, thought to be of importance, were also measured.

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Study Area and Procedure

The small rangeland watersheds used in this study were situated on pastures grazed lightly, moderately, and heavily since 1942. Research results have been reported on by Johnson et al. (1951) and Lewis et al. (1956). Cattle stocking rates have averaged 3.25, 2.42, and 1.35 acres/AUM (animal unit month) for the light, moderate, and heavy grazing, respectively.

Vegetation is considered mixed prairie. Principal shortgrass species are blue grama *(Bouteloua gracilis)*, buffalograss *(Buchloe dactyloides)*, Sandberg bluegrass *(Poa secunda)*, and needleleaf sedge *(Carex eleocharis)*. Midgrasses include western wheatgrass *(Agropyron smithii)*, green needlegrass *(Stipa viridula)*, needle and thread *(Stipa comata)*, and little bluestem *(Andropogon scoparius)*.

Soils on the study area have been classified as Pierre-Promise association. These soils are modertely deep and underlain by Pierre shale. Surface soils are friable silty clay on silty clay loam. Subsurface cracking may be more pronounced than surface cracking as these soils dry.

Wavy gilgai microrelief, a succession of microvalleys and microridges that run with the slope, are present throughout the watersheds and have been described by White and Bonestall (1960). Our preliminary studies indicate that the rate of water intake may be affected by the microrelief, but in this study we made no attempt to evaluate such an effect.

We are indebted to the South Dakota Agricultural Experiment Station and the Cottonwood Range Field Experiment Station for use of the pasture areas, which are a part of long-time grazing studies conducted by the South Dakota Agricultural Experiment Station at Brookings.

Watershed-study areas on each of the three differentially grazed pastures were established in 1962. Within each 8-acre watershed site in each pasture, four contiguous watersheds approximately 2 acres in size were constructed (Sharp et al. 1964). The soil and aspect of the three sites were very nearly the same. The slope was nearly the same and averaged 7.8, 7.6, and 7.9%, respectively, in the lightly, moderately, and heavily grazed pastures.

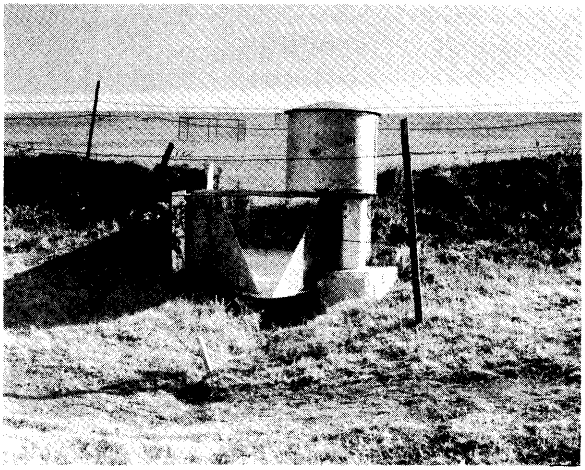

Fig. 1. H-type flume with stage recorder to measure runoff from small rangeland watersheds.

To measure runoff water from naturally occurring rain storms, each watershed is equipped with a 2-foot H-type flume with approach box and FW-1 stage recorder (Fig. 1).

Simulated rainfall was applied with a mobile infiltrometer (Rauzi, 1963) to a circular area of approximately 13 ft^2. The test plot was 2 ft square and located in the center of the area receiving rainfall. Simulated rainfall was applied to the test plots for 1-hour periods at intensities varying from 2.90 to 4.12 inches/hr. A higher intensity of simulated rainfall was required on the lightly grazed watersheds than on the heavily or moderately grazed watershed to obtain runoff early in the test period. Water intake was measured as the difference between the amount applied and measured runoff. The equipment was left in place after the last test of the day. On the following morning a wet run of 1-hour duration was made on the previously wetted plot. Average elapsed time between the dry and wet run was 16 hrs and 40 min. A wet run was made on each replication of each watershed, making a total of four wet runs per watershed.

Three tests were made on each replication for a total of 12 tests on each of the three watersheds. The raindrop applicator was moved to a different replication or watershed daily.

Moisture content of the soil at the time water-intake measurements were made was determined gravimetrically from soil samples taken near each test plot at the 0- to 6- and 6- to 12-inch depths.

All standing vegetation on the test plots, including the previous year's growth, was clipped at ground level after the water-intake measurement was made. The vegetation was separated into the following categories: midgrasses, shortgrasses, annual grasses, sedges, and forbs. All mulch material on the test plot was collected. These materials were air-dried and weighed; yields were then computed. Species composition of each test plot was determined by the vertical point-quadrat method.

Three cores of soil 3.5 inches in diameter and 4 inches long were taken from each grazing treatment in each watershed. Bulk density and pore space (drained between 0 and 70 cm H_20 tension) were determined on each of these cores.[2]

Results and Discussion

Water Intake — Water-intake rates on the watersheds varied with intensity of grazing (Table 1). During the second 30-minute period of the 1-hour test, the water-intake rate on the moderately grazed watershed was nearly twice that on the heavily grazed watershed. Water-intake rate during the second 30-minute period on the lightly grazed

[2] *Determinations made by W. D. Kemper. Soil Scientist, Agricultural Research Service, USDA, and Colorado State University, Fort Collins.*

watershed was nearly four times that on the heavily grazed watershed and over twice that on the moderately grazed watershed. Total water intake during the 1-hr test on the heavily, moderately, and lightly grazed watersheds followed a similar pattern.

On basis of the water-intake data obtained during the second 30-minute period of the 1-hour test, no runoff would occur from a 30-minute storm having an intensity of 2.00 inches on the moderately and heavily grazed watersheds. During the summer months, short-duration, high-intensity rainstorms occur frequently. A 5-minute storm with rainfall intensity of 6.00 inches/hour would produce runoff from most rangelands. A storm of this magnitude can be expected once in 10 years in the study area.

A storm of 1 inch of rainfall during a 30-minute period (2 inches/hr) can be expected in the Cottonwood area once every two years. A storm with an intensity of 4.00 inches/hr for a 30-minute period may be expected once in 25 years (Hershfield 1961).

Soil-moisture content measured on July 12 on the heavily grazed watershed varied from 14 to 26% for the 0- to 6-inch depth. One rain of consequence was recorded during the beginning of the study period. Thereafter, the soils became progressively drier, and after a few days soil moisture was near or below the wilting percentage in the top foot of soil. For this series of tests, no correlations were found between percent soil moisture and water-intake rates.

The comparison of water-intake rates between the dry and wet runs is presented in Table 2. Water-intake rates were markedly reduced on the wet run. Total water intake was slightly less than half that measured for the dry runs. The soils on the wet run had not reached field capacity, but the swelling clays had sealed off the surface cracks. The wet runs showed the same water-intake trend that was shown by the dry runs on the three differentially grazed watersheds. This indicates that the intensity of grazing may have altered the soil structure as well as the kinds and amounts of vegetative cover.

Table 1. Air-dry herbage and mulch (lb/acre) and rate of water intake (inches/hr) on small native range watersheds grazed heavily, moderately, and lightly. Cottonwood, South Dakota, 1964.

Study Area[1]	Total Herbage	Mulch	Rate of Water Intake: First 30-min.	Second 30-min.	Ave. for 1-hr. period
Heavily grazed	910[c]	456[b]	1.40[c]	0.71[c]	1.05[c]
Moderately grazed	1,345[b]	399[b]	2.16[b]	1.21[b]	1.69[b]
Lightly grazed	1,869[a]	1,100[a]	3.19[a]	2.72[a]	2.95[a]

[1]Twelve test plots on each study area. Means with the same letter superscript are not statistically different from each other at the 0.05 level of significance.

Table 2. Water-intake rates (inches/hr) during first and second 30-minute period and total for 1-hour test for dry and wet runs on watersheds grazed heavily, moderately and lightly. Cottonwood, South Dakota, 1964.

Study Area[1]	Dry Run: First 30-min.	Second 30-min.	Total 1-hr.	Wet Run: First 30-min.	Second 30-min.	Total 1-hr.
Heavily grazed	1.50	0.72	1.11	0.66	0.36	0.51
Moderately grazed	2.26	1.20	1.73	0.84	0.54	0.69
Lightly grazed	3.12	2.34	2.73	1.46	0.96	1.26

[1]Four test plots on each study area.

Vegetal Cover. — Twice as much total herbage was present on the lightly grazed watershed as on the heavily grazed one (Table 1). Only a trace of midgrasses was present on the heavily grazed watershed, whereas nearly 50% of the total herbage on the lightly grazed watershed was midgrasses (Fig. 2).

More dryland sedges were present on the heavily grazed watershed than on the moderately or lightly grazed watersheds. Forb species were more abundant on the moderately grazed watershed than on either the moderate or heavily grazed watershed. Annual grasses, chiefly Japanese brome *(Bromus japonicus)*, were associated with the lightly grazed watershed.

The amount of natural mulch material on the test plots varied with the grazing intensity (Table 1). Natural mulch as defined by Dyksterhuis (1947) is the nonliving plant material on the soil surface. Test plots on the lightly grazed watershed had nearly 2.5 times more mulch than did the heavily grazed watershed and 2.75 times more than the moderately grazed watershed. There was an abundance of buffalograss seed present on the heavily grazed watershed, and this was included in the mulch material collected. The amount of mulch material varied with kind and amount of vegetative cover. Amount of mulch present increased with an increase of midgrasses and Japanese brome.

Species composition on the plots was determined by the vertical point quadrat and by weighing. Blue grama and buffalograss accounted for 97, 80, and 49% of the composition as measured by the point quadrat, and 94, 78 and 41% by weight, for the watersheds grazed heavily, moderately, and lightly, respectively.

Water Intake and Vegetal Cover — Water-intake rate, amount of total herbage, and mulch from the three watersheds

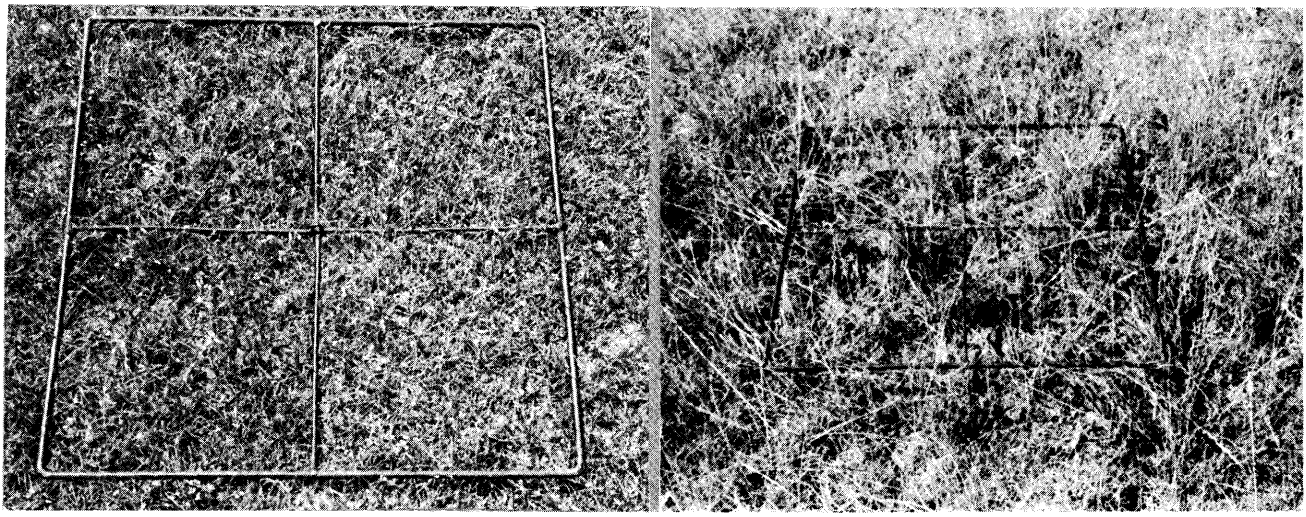

FIG. 2. Comparison of vegetative cover on the heavily grazed (left) and lightly grazed (right) watersheds.

were used in a multiple-regression analysis. Water-intake rate during the second 30-minute period of the 1-hr test was the dependent variable; total herbage and mulch (both in lb/acre) were the independent variables. The correlation coefficient for the multiple regression analysis was 0.845. The analysis showed that total herbage and mulch accounted for 71% of the variation in water intake on the three differentially grazed watersheds. The simple correlation coefficient for water intake and total herbage was 0.734, and was 0.801 for total herbage and mulch material. Both the total herbage and mulch material contributed significantly to the rate of water intake at the 0.01 level. The multiple-regression analysis resulted in the following equation:

$$Y = .0007x_1 + .0013x_2 - 0.26$$

Where Y = water intake (inches/hr)

x_1 = Total vegetal cover (lb/acre)

x_2 = Total mulch (lb/acre)

The regression equation was statistically significant at the 0.01 level of probability.

Bulk Density and Pore Space—Bulk density and pore space (drained from 0 to 70 cm H_2O tension) is shown in Table 3. Differences between soil bulk densities were all highly significant. Pore space of the lightly grazed treatment was significantly larger than in the moderate and heavily grazed treatments at the 0.01 level. The probability that the moderately grazed areas have more pore spaces than the heavily grazed area is about 70% (0.3 level).

Table 3. Effect of grazing intensity on bulk density (g/cc) and pore space (% of total volume).

Grazing Treatment	Bulk density	Pore space[1]
Heavy	1.29	7.7
Moderate	1.24	8.4
Light	1.17	10.6

[1] Pores drained from 0 to 70 cm H_2O tension.

Runoff from Watersheds — Runoff data for 1963 and 1964 are available for the watersheds. Four rainfall-runoff events during 1963 produced the runoff shown in Table 4. The first runoff-producing storm on May 30 followed a period of approximately normal precipitation (Sharp et al. 1964). This high intensity storm produced about 3 inches of rain. The maximum 10-minute rainfall intensities varied from a high of 7.80 inches/hr on the lightly grazed watershed to 4.80 inches/hr on the heavily grazed watershed. An intensity of 7.80 inches/hr for a 10-minute rainfall is approximately equal to a 100-year storm (Hershfield, 1961). Runoff from the heavily grazed watershed was 1.4 times greater than from the moderately grazed watershed and about 9 times greater than the lightly grazed watershed. The second runoff-

Table 4. Precipitation and runoff during 1963 and 1964 on watersheds grazed heavily, moderately, and lightly. Cottonwood, South Dakota.

Year and Grazing Treatment	Inches Precip. Annual	Inches Precip. Runoff Prod.	Runoff-Prod. Precip. % of Ann. Precip.	Inches Runoff	Runoff % of Ann. Precip.
1963					
Heavy	15.19	7.40	48.7	1.77	11.7
Moderate	14.97	7.15	47.8	1.53	10.2
Light	15.86	7.47	47.1	1.39	8.8
1964					
Heavy	13.74	5.82	42.4	.87	6.3
Moderate	13.63	4.19	30.7	.32	2.3
Light	13.02	2.94	22.6	.05	0.4

producing storm of 0.59 inch was on June 6. Runoff from this small storm was the greatest from the heavily grazed watershed and least from the lightly grazed watershed. On June 15 another 3-inch storm occurred and the lightly grazed watershed produced 1.23 inches of runoff which was 2.2 and 4.2 times more runoff than from the moderately and heavily grazed watersheds, respectively. The maximum 10-minute rainfall intensity was 1.4 inches/hr for each of the watersheds. The reason for the high runoff amount from the lightly grazed watershed was probably the previous abundant rainfall resulting in a high antecedent soil moisture (Sharp et al. 1964). The fourth storm, on July 29, was a high-intensity, short-duration storm. The runoff from this storm was greatest from the heavily grazed watershed and least from the lightly grazed.

The 1963 total annual runoff from the three watersheds grazed heavily, moderately, and lightly was 1.77, 1.53, and 1.39 inches, respectively (Table 4). The proportion of annual runoff to annual precipitation was greatest on the heavily grazed watershed and least on the lightly grazed.

The number of runoff-producing storms during 1964 was 8, 7, and 5, respectively, for the heavily, moderately, and lightly grazed watersheds. A low-intensity storm on April 20 was the only storm during the year that had a rainfall over 1 inch, and runoff occurred only on the heavily grazed watershed. Some runoff occurred on both the heavily and moderately grazed watersheds from a small storm on May 2. The first storm to produce runoff on all the watersheds was on May 15, when approximately 0.62 inch of rain produced 0.03 inch, 0.01 inch, and a trace of runoff on the heavily, moderately, and lightly grazed watersheds, respectively. Four June storms all caused runoff from all three watersheds, the greatest runoff coming from the heavily grazed watershed and the least from the lightly grazed. The last runoff-producing storm was on July 9, when the rainfall on the heavily and moderately grazed watersheds was about 0.63 inch, while the lightly grazed watershed received only 0.18 inch. Probably because of this difference in precipitation, runoff occurred from the heavily and moderately grazed watersheds, but no runoff occurred on the lightly grazed watershed. The 1964 total annual runoff was 0.87, 0.32, and 0.05 inch for the heavily, moderately, and lightly grazed watersheds, respectively (Table 4). The proportion of runoff to annual precipitation was the greatest for the heavily grazed watershed and the least for the lightly grazed.

A few high-rainfall and high-intensity storms during 1963 caused more runoff than a greater number of smaller storms during 1964. Runoff never occurred on any of the watersheds with less than a 0.43-inch rainfall, and runoff always occurred when the rainfall was greater than 0.75 inch. All storms with a maximum 10-minute intensity of 1.80 inches/hr or more produced runoff on all watersheds. During 1963 and 1964 there were seven storms with maximum 10-minute intensities of 1.80 inches/hr or more. These factors indicate that the characteristics of the storms are among the controlling factors in runoff production on any watershed.

There has been no snowmelt runoff since the project was started.

Summary

During July 1964, water-intake studies were conducted on three small differentially grazed rangeland watersheds at the Cottonwood Range Field Experiment Station, Cottonwood, South Dakota. In 1962, the small watersheds were superimposed on pastures grazed lightly, moderately, and heavily since 1942.

Water-intake rates were nearly linear with grazing intensity. Total water intake on the lightly grazed watershed was 2.5 times greater than on the heavily grazed watershed and 1.8 times greater than on the moderately grazed watershed.

Species composition on the test plots on the three differentially grazed watersheds showed marked differences. Blue grama and buffalograss were the dominant species on the heavily and moderately grazed watersheds, accounting for 97 and 80% of the total composition, respectively. Western wheatgrass was the dominant midgrass and Japanese brome the dominant annual grass found almost exclusively on the lightly grazed pasture.

Water-intake rates during wet runs were reduced to nearly half those during dry runs. Water-intake rates from the wet runs showed the same nearly linear trends on the differentially grazed watersheds that were obtained from the dry test runs. The dry and wet runs indicated that not only has the species composition been altered by 22 years of differential grazing but possibly the soil properties have been changed.

Bulk density and pore-space measurements further showed a change in soil properties. Heavy grazing compacted the soil and significantly decreased the pore spaces in the top 4 inches of the soil when compared with light grazing.

Two years' runoff data indicate that, on an annual basis, the heavily grazed watershed produces the most runoff and the lightly grazed watershed produces the least. The data indicate that storm characteristics are a dominant factor in the production of runoff from areas differentially grazed. Thus, management of grazing can decrease

runoff and increase the amount of available precipitation entering the soil for plant use.

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