Water-Intake Studies on Range Soils at Three Locations in the Northern Plains[1]

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The ability of rangelands to absorb and store rain water is of great importance in the production of range forage, maintenance of stock water, and control of runoff and erosion. Every effort should be made to improve or maintain the storage ability of these lands. This is especially important in western arid and semi-arid areas where moisture is the limiting factor in forage production.

Some of the more important physical factors affecting absorption and storage of water include soil and rainfall characteristics, amount of surface cover, and type of management prevalent on the areas (Duley and Domingo, 1949; Lassen *et al.*, 1952; Osborn, 1952). Rainfall retention is proportionally higher with good vegetative cover protecting the soil because this leads to higher water-intake rates (Osborn, 1952; Rauzi 1956; Rauzi and Zingg 1956).

Water-intake studies using a truck-mounted infiltrometer (Figure 1) were conducted during the summer months of 1956 at three locations in western North Dakota and at four locations in Montana (Rauzi, 1956). Fenceline comparisons forming a contrast were utilized and a total of 40 plots were studied.

Objectives of this study were (a) to determine the effect of different kinds and amounts of grass cover on the ability of a soil to absorb water, and (b) to obtain a relative water-intake rating for major soil types under varying vegetative covers.

Methods and Materials

Simulated rainfall was applied to a circular area of approximately 13 square feet by use of a mobile infiltrometer. The test plot for water-intake measurements was 2 feet square and located in the center of the area receiving rainfall (Figure 2). Under this arrangement, the test plot was relatively free from the influence of lateral water movement. Water-intake rate was measured as the difference between the rate of applied rainfall and the rate of measured runoff. Surface detention, retention, absorption, and interception by vegetation and mulch material are included in the measured intake but usually are negligible after the first 15 to 30 minutes of the test.

Intensity of rainfall on the test plot varied from 3.00 to 4.50 inches per hour. Rainfall was applied to each plot for a 1-hour period and the amount of runoff was determined at 15-minute intervals which permitted evaluation of water intake by 15-, 30-, 45-, or 60-minute periods. Rate of water intake during the second 30-minutes was found to be more stable than during earlier periods and was believed to be more nearly typical of conditions during an actual storm. This value was used along with intake rate during the fourth 15-minute period for all statistical analyses.

All standing vegetation in the test plot including previous years' growth was clipped at ground level one or two days after the test. This material was bagged, air-dried, and weighed, and the yield computed in pounds per acre. All mulch material on the test plot was collected and yield determined in the same manner.

Data for different range-condition classes encountered were grouped into two categories: ex-

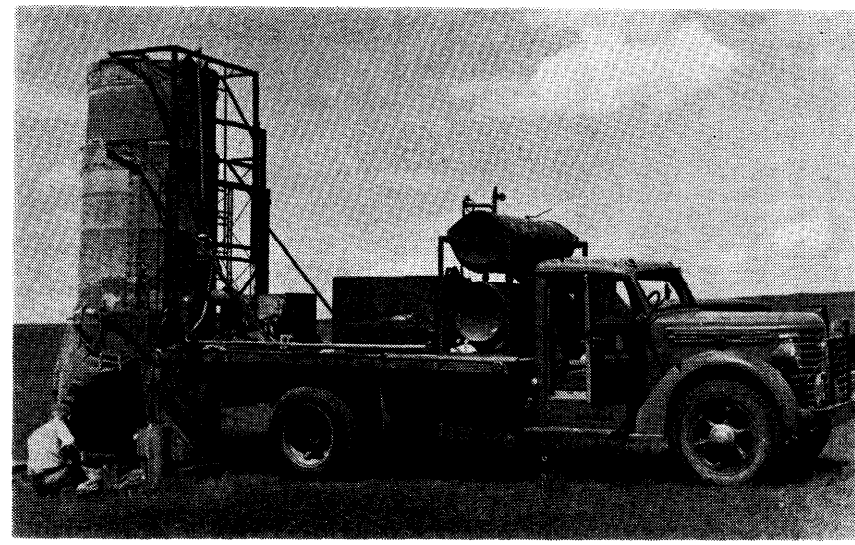

FIGURE 1. Mobile raindrop applicator used to determine water-intake rates on rangelands.

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FIGURE 2. Two by two foot square plot exclosure with runoff spout attached as used in this study. The burlap on the spout is to absorb simulated rainfall to prevent splash into the plot.

cellent and good ranges were grouped as "high" and fair and poor ranges as "low." Range conditions and soils descriptions were obtained from Soil Conservation Service technicians in the areas studied.

Locations

Three sites studied in North Dakota were located in Williams County within a 10-mile radius of Williston in a 10- to 14-inch rainfall belt. Fenceline contrasts used were between rangelands rated in excellent and fair conditions (Figure 3). Soil texture was classed as loam. The dominant grasses were western wheatgrass *(Agropyron smithii)*, needle-and-thread *(Stipa comata)*, and blue grama *(Bouteloua gracilis)*.

Two of the four sites in Montana were in McCone County in a 10- to 14-inch rainfall belt. One was located approximately 2 miles northeast of Circle, Montana, and the other approximately 15 miles west of the Wolf Point Bridge, south of the Missouri river. The two sites forming the fenceline contrast were rated in good and fair range condition (Figure 4). Soil texture was classed as silt loam. Western wheatgrass, needle-and-thread, and blue grama were again the dominant grasses. At the time of test this area was extremely dry and growth was very limited.

The other two sites in Montana were in Glacier County in a 15-to 19-inch rainfall belt, one approximately 18 miles northwest of Browning and one approximately 2 miles east of East Glacier. The site northwest of Browning was a fenceline contrast rated excellent and poor. Soil texture was classed as loam. The site east of East Glacier was a fenceline contrast rated excellent and fair. Soil texture was classed as silt loam. Both sites are in the 15- to 19-inch-rainfall belt. Dominant grasses were rough fescue *(Festuca scabrella)*, Idaho fescue *(Festuca idahoensis)*, and wheatgrasses *(Agropyron* spp.). Shrubby cinquefoil *(Potentilla fruticosa)* was found on both the high and low range conditions along with several forbs, both annual and perennial.

Results

Williston, North Dakota Area

In the Williston, North Dakota area average water-intake rate for the three sites during the second 30-minute period of the 1-hour test was 3.02 inches per hour on the high-condition range and 1.14 inches on the low-condition range (Table 1). Average rate during the fourth 15-minute period was 2.88 inches per hour for the high condition range and 0.96 inch on the low-condition range.

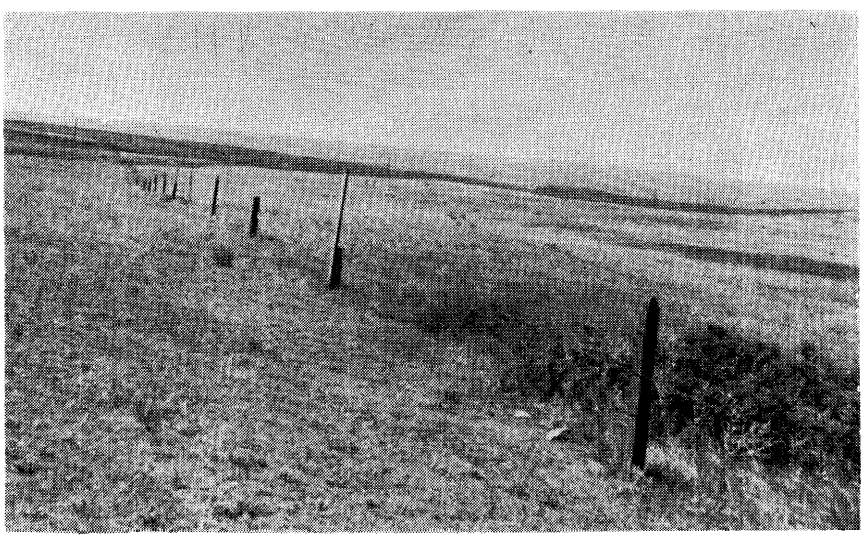

FIGURE 3. Fenceline contrast at North Dakota Site 1, located approximately 6 miles northeast of Williston, N. Dak. The contrast is between range in excellent and in fair condition.

Table 1. Water-intake rate and pounds of forage and mulch per acre on rangelands in high and low range condition for three sites near Williston, North Dakota, 1956.

Site*	Forage		Mulch		Intake Rate during 1-hour Test of			
	Range Condition		Range Condition		Second 30-minutes		Fourth 15-Minutes	
	High	Low	High	Low	High	Low	High	Low
	Lbs. per Acre		*Lbs. per Acre*		*Inches per hour*		*Inches per hour*	
1	3,030	880	2,280	1,070	2.76	1.41	2.64	1.28
2	3,020	650	2,020	1,570	3.11	0.81	2.96	0.56
3	2,410	770	3,280	990	3.19	1.20	3.04	1.00
Average	2,820	770	2,530	1,210	3.02	1.14	2.88	0.96

* Each range condition had three test plots for a total of 6 plots per site.

There was an average of 2,820 pounds per acre standing vegetation at the time of test for the three sites rated in high condition and 770 pounds per acre for the sites rated in low condition. Sites rated in high condition had received limited or no use by livestock whereas two of the three sites rated in low condition were being utilized at the time of test and the other site was being rested for the year.

On these three sites the amount of standing vegetation and mulch present was quite uniform within the two range groups. Higher water-intake rates were associated with the better cover conditions, which protected the soil from raindrop impact and thus prevented the sealing of the pore spaces which occurs on bare soil. A storm intensity of between 2.00 and 2.50 inches per hour for a 30-minute period would be expected to occur in this area once in five years (Yarnell, 1935). On the basis of the second 30-minute period of the 1-hour test, rangelands rated in good condition would have sufficient cover to prevent major runoff from such a storm.

McCone County, Montana Area

At the study areas in McCone County, Montana, water-intake rate during the second 30-minute period of the 1-hour test on ranges rated in high condition was 1.41 inches per hour and 0.90 inch on ranges rated in low condition (Table 2). During the fourth 15-minute period of the 1-hour test, ranges rated in high condition had a water-intake rate of 1.36 inches per hour compared to a rate of 0.76 inch on ranges rated in low condition.

Standing vegetation present at the time of test was 1,740 pounds per acre on the high-condition ranges and 620 pounds per acre on the low-condition ranges. Total cover, including mulch material, for the high-condition range was 3,090 pounds per acre and 1,230 pounds per acre on the low-condition range.

There was only 0.51 inch per hour difference between the two conditions during the second 30-minute period. This would tend to indicate that differences between range conditions for these two sites were not very great.

At the time of test the ranges rated in high condition had received little or no use, whereas those ranges rated in low condition were being utilized.

Glacier County, Montana Area

At the Glacier County, Montana sites water-intake rate averaged 2.19 inches per hour during the second 30-minute period of the 1-hour test on the ranges rated in high condition and 0.88 inch for the ranges rated in low condition. During the fourth 15-minute period water-intake rate on the high condition range was 2.04 inches per hour and 0 inch on the low-condition range.

There was an average of 4,130 pounds per acre standing vegetation on the high condition

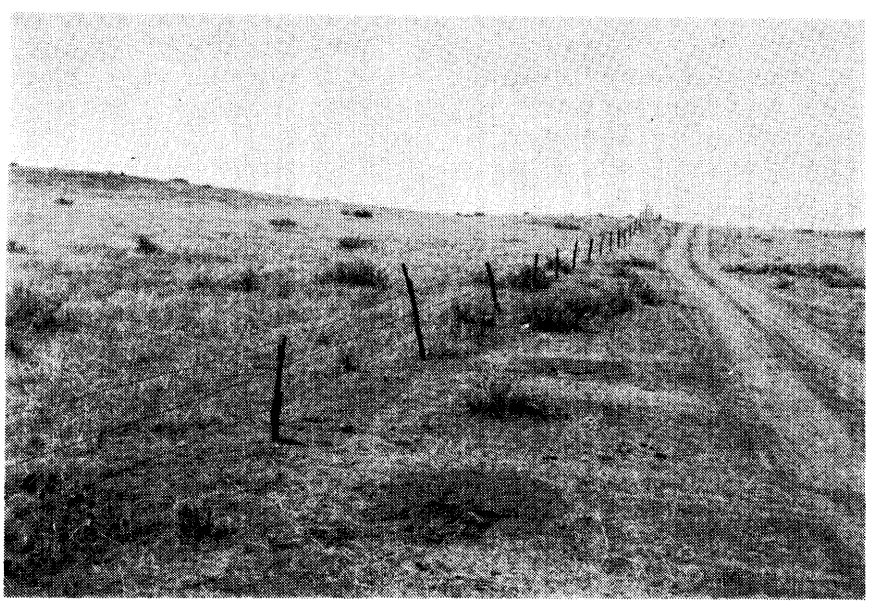

FIGURE 4. Fenceline contrast at Montana Site 2, located approximately 15 miles south of the Wolf Point Bridge, south of the Missouri River. The contrast is between rangelands rated in good and fair condition. Two of the test-plot sites may be noted on the right-hand side of the fence.

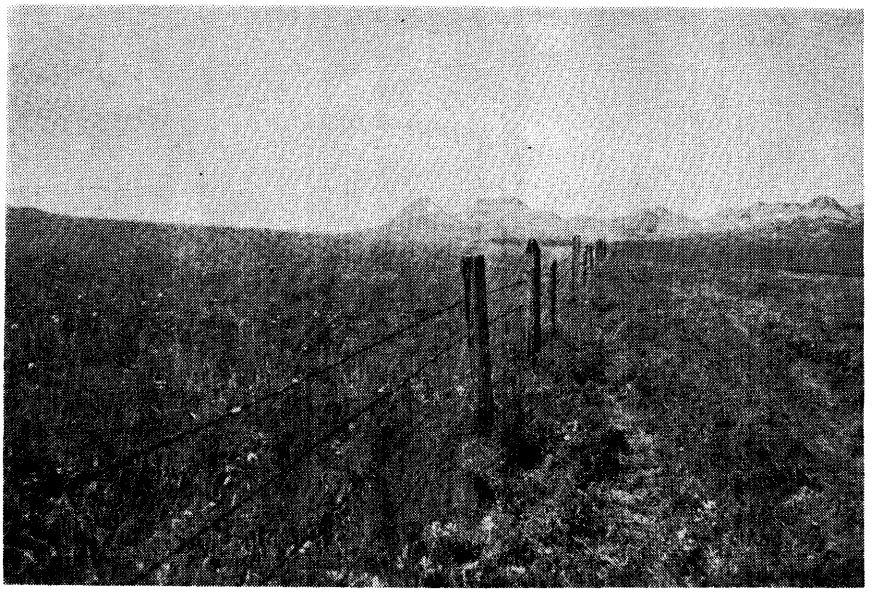

FIGURE 5. Fenceline contrast at Montana Site 4, east of East Glacier. Pasture on the left of the fence is used as winter pasture and rates in excellent condition. The pasture to the right of the fence is rated in fair range condition.

range and 1,870 pounds per acre on the low-condition range at the time of test. Mulch material averaged 5,740 and 2,030 pounds per acre, respectively, for the high and low range condition.

Ranges rated in high condition had received no use from livestock at the time of test, as they are used for winter pasturage. The low-condition ranges were being utilized at the time of test (Figure 5).

Multiple Regression Analyses

The data indicated that forage yield and mulch seemed to be related rather closely to water intake. To test this hypothesis, individual plot data were analyzed by means of multiple regression analysis to determine the degree of association between the variables.

An analysis combining all sites was made using water-intake rate (fourth 15-minute period) as the dependent variable (Y) and forage yield X_1 (tons per acre) and mulch X_2 (tons per acre) as the independent variables. The correlation coefficient for this analysis was $R=0.637$, which showed that the forage yield and mulch accounted for approximately 41 percent of the variation in water-intake rates.

The regression equation ($Ey= 0.2264\ X_1 + 0.0170\ X_2 + 0.14$) was statistically significant at the 0.01 level. Partial correlation coefficients for the independent variables, forage yield, $r = 0.635$, and mulch, $r = 0.456$, indicate that both independent variables contribute significantly to the water-intake rate.

Since total regression accounted for only 41 percent of the variation in water-intake rates, the three different areas (Williston, McCone, and Glacier County) were analyzed separately to determine if a closer association among the variables existed for the individual areas.

Sites in the Williston area had a correlation coefficient of $R = 0.915$, which indicated that variations in forage and mulch yield accounted for 84 percent of the variation in water-intake rate. The regression equation ($Ey = 0.4134\ X_1 + 0.0229\ X_2 + 0.09$) was statistically significant at the 0.01 level. Partial correlation coefficients for the independent variables were for forage yield, $r = 0.914$, and mulch, $r = 0.575$, indicating again that both independent variables contribute significantly to water-intake rates but that forage yield was more closely related to water-intake rates than was mulch.

The two sites in McCone

Table 2. Water-intake rate and pounds of forage and mulch per acre on rangeland in high and low range condition for four sites in Montana, 1956.

Site*	Forage		Mulch Range Condition		Intake Rate during 1-hour Test of Second 30-minutes		Intake Rate during 1-hour Test of Fourth 15-minutes	
	High	Low	High	Low	High	Low	High	Low
	Lbs. per Acre		*Lbs. per Acre*		*Inches per hour*		*Inches per hour*	
				McCone County				
1	1,880	660	1,710	530	1.35	0.79	1.52	0.60
2	1,600	580	990	690	1.47	1.02	1.20	0.92
Average	1,740	620	1,350	610	1.41	0.90	1.36	0.76
				Glacier County				
3	3,890	1,360	5,470	2,970	1.80	0.71	1.56	0.42
4	4,380	2,380	6,000	1,100	2.59	1.05	2.64	1.00
Average	4,135	1,870	5,735	2,035	2.19	0.88	2.04	0.76

* Site 1 has only two test plots on each range condition whereas the other sites had three test plots for each range condition.

County had a correlation coefficient of $R = 0.672$ indicating that variation in forage yield and mulch accounted for 45 percent of the variation in water-intake rates. The regression equation ($Ey = 0.1544 X_1 + 0.980 X_2 + 0.13$) was not statistically significant but approached significance at the 0.5 level. Partial correlation coefficients for the independent variables were for forage yield: $r = 0.658$ was significant at the .05 level, and for mulch, $r = 0.592$, approached significance at the .05 level indicating that both independent variables contribute to water-intake rates.

The two sites in Glacier County had a correlation coefficient of $R = 0.803$, which showed that variation in yield and mulch accounted for 65 percent of the variations in water-intake rates. The regression equation ($Ey = 0.1148 X_1 + 0.0864 X_2 + 0.01$) was statistically significant at the 0.01 level. Partial correlation coefficients for the independent variables, forage yield, $r = 0.749$, and mulch, $r = 0.756$, indicate that both of the independent variables contributed significantly to water-intake rates.

Further analysis showed that the three regressions were different and that the three areas represent three distinct populations. When the areas were grouped together, only 41 percent of the variation in water-intake rates was accounted for by variation in amount of forage yield and mulch, but, when analyzed separately, from 45 to 84 percent of the variation was accounted for.

Discussion

These studies on water-intake rates on rangelands emphasize the importance of vegetation and mulch material in increasing the amount of rainfall absorbed by the soil. Dyksterhuis and Schmutz (1947) state that with few exceptions, mulches are the primary factor in determining infiltration of rainwater and in preventing erosion. The pastures rated in low condition had less water intake because too heavy use had decreased the amount of standing vegetation and mulch material, which bared the soil to the sealing action of the raindrops. Duly and Domingo (1949) found that when the grass was clipped and the litter removed, water-intake rates were reduced because of a loss of the surface protection. Trampling by livestock probably contributed to the lower absorption capacity of the soil. Lassen *et al.* (1942) state that the principal effect of soil compaction, so far as soil-water relations are concerned, is the reduction of pore space and increase in soil density. As a result, ranges rated in high condition took in almost three times as much water as did the pastures rated in low condition (Rauzi, 1956).

On two of the three areas studied, analysis showed that the amount of standing vegetation present contributed more to water intake than did the mulch material. Hopkins (1954) working in Kansas found that mulch affected the water-intake rates but was not a controlling factor. Hanks and Anderson (1957) found that destroying the surface mulch by burning substantially decreased water intake on native bluestem pastures in Kansas. In Glacier County standing vegetation and mulch material contributed about equally to the intake rates.

Frequently during the summer months, torrential rains of high intensity but of short duration occur and result in excessive runoff and erosion. This is especially true on those rangelands not protected with a good cover of grass and mulch. Also, that portion of the precipitation that becomes runoff is lost, thereby reducing on-site productiveness. It is therefore important that rangelands be managed so that they are able to absorb the maximum amount of water from torrential rains to increase forage and reduce erosion.

Summary

Water-intake studies were conducted with a mobile infiltrometer on rangelands at three locations in the northern plains. Two of the three areas (Williston, North Dakota, and McCone County, Montana) are in the 10- to 14-inch-rainfall belt. The other area (Glacier County, Montana) is in the 15-to-19-inch-rainfall belt. Fenceline comparisons were made between pastures rated in either a high or low range condition. Soil texture for th sites was either silt loam or loam.

Ranges rated in high condition absorbed almost three times as much water in the form of simulated rain as the low-condition ranges during the fourth 15-minute period of the hour test. Ranges rated in high condition had more standing vegetation and mulch material present at the time of test than did those rated in low condition.

Regression analysis was used to compare variations in water intake with variations in forage and mulch yield. An over-all regression of the three areas indicated that the relationship between water-intake rates and amount of forage yield and mulch was highly significant, but only 41 percent of the variation in water intake was accounted for. Individual regressions for each area were then computed and it was found that from 45 to 84 percent of the variation in water intake was accounted for by mulch and forage yield in the individual areas.

Partial correlation coefficients indicated that on two of the three areas the amount of standing vegetation contributed more to water intake than mulch material. Apparently on these areas the amount of standing vegetation masked the effect of the mulch.

Although significant relationships between water-intake rates and amount of forage yield and mulch were established for all areas, the individual regressions for the different areas show a closer degree of association among the variables and therefore greater accuracy can be obtained from their use.

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