Effects Of Seeding And Grazing On Infiltration Capacity And Soil Stability Of A Subalpine Range In Central Utah[1]

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Highlight

Seven years after disking and seeding to grass, main effects were: decreased organic matter and capillary porosity in the surface soil, greater soil bulk density, and decreased plant and litter cover. Seeding did not significantly affect infiltration or soil stability. Grazing during the previous four years decreased plant and litter cover and noncapillary soil porosity, but increased capillary porosity in the surface soil and decreased infiltration and soil stability.

Some mountain rangeland in Utah has been artificially seeded to control overland flow and erosion, or to improve the forage resource, or both. Many other areas will be similarly treated in the future. Because these lands are highly susceptible to erosion where vegetation has been depleted or destroyed, it is important to learn the effects of site preparation—including disking or plowing and seeding—on infiltration capacity and soil stability. For the same reason, the effects of various methods and intensities of grazing should also be evaluated.

This paper reports results of a study of the effects of seeding and of grazing on a cattle grazing unit in the subalpine zone of the Wasatch Plateau in central Utah. The main objectives of this study were to determine: (1) the persisting effects of seeding on infiltration capacity and soil stability, (2) the effects, on infiltration capacity and soil stability, of cattle grazing on the seeded range and on comparable unseeded range, and (3) the role of soil and cover characteristics in these effects.

Description of Study Area

The study area is in the head of Lowry and Logger Forks of Manti Canyon where 435 acres of the most level and accessible portions of a 1,000-acre fenced cattle grazing unit were disked and seeded to adapted grasses in the fall of 1952.

The elevation of the area varies from 9,500 to 10,000 feet. Average annual precipitation is about 32 inches of which 24 inches or more is in the form of snow. Precipitation during the 3-month growing season is highly variable but averages

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only about 5 inches. Precipitation of individual summer storms is usually light, rarely exceeding 1 inch, but a storm having a total of 1.36 inches of rain and a maximum 10-minute rainfall intensity of 2.58 inches per hour has been recorded on a nearby area.

Soils of this area are predominantly silty clay loams derived from limestone and shales. The soil mantle contains varying amounts of rock and varies in depth from a few inches to more than 5 feet.

Prior to 1952, the vegetation was predominantly low-value forbs characteristic of subalpine rangeland depleted of its climax vegetation by many years of livestock grazing. For the past 50 years or more, the study area had been grazed by cattle, a class of livestock that tends to select grasses and certain forbs. As a result, most of the grasses and desirable forbs were grazed out on the more accessible areas. Dominant species on the area at the time it was seeded in 1952 were: western yarrow *(Achillea lanulosa)*, sweetsage *(Artemisia discolor)*, sticky geranium *(Geranium viscosissimum)*, Rydberg penstemon *(Penstemon rydbergi)*, Douglas knotweed *(Polygonum douglasi)*, and dandelion *(Taraxacum officinale)*.

As a result of the 1952 seeding, vegetation in the treated area is now composed mostly of palatable grasses. Meadow foxtail *(Alopecurus pratensis)* and smooth brome *(Bromus inermis)*, both introduced species, are the most prevalent. The other two introduced grasses, timothy *(Phleum pratense)* and orchardgrass *(Dactylis glomerata)* and a seeded native grass, mountain brome *(Bromus carinatus)*, are also relatively abundant. Dandelion and geranium have persisted as the most abundant forbs but no longer dominate the area.

In 1955, 3 years after seeding, Orr (1957) made a preliminary study of the effects of seeding on this unit. At that time, average forage production was much greater on seeded plots than on unseeded plots but differences in soil stability, infiltration capacity, soil bulk density, and ground cover were generally found to be insignificant.

The treated area was not grazed in 1953, but was lightly

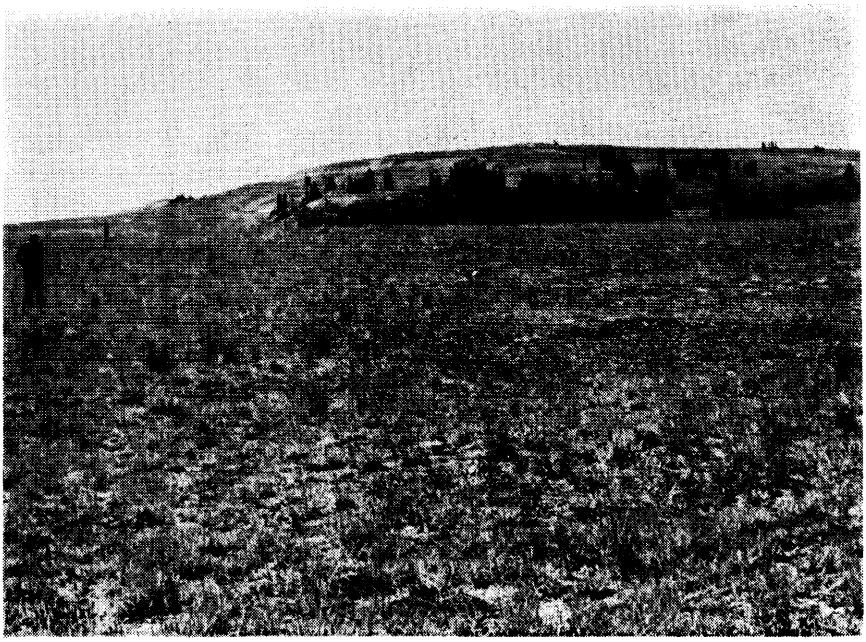

FIGURE 1. Site 5. This gently sloping site is typical of most of the lower portions of the study area. Plot slope gradients range from 1 to 9 percent.

FIGURE 2. Site 6 in foreground. This area has been heavily used by cattle before and after seeding. Its sparse vegetation and compacted soil are representative of the poorest conditions to be found on the study area. Plot slope gradients range from 1 to 6 percent.

grazed by cattle in 1954. During the period from 1955 through 1958, grazing use averaged about 0.5 a.u.m. per acre, a level of use considered to be moderate for this range. During this period some parts of the range were more heavily grazed than others, thus several degrees of grazing intensity prevailed. This area is usually not grazed until early September when the vegetation is fully developed and the major summer storm season is past. Field measurements reported here were made during August 1959, prior to current season grazing.

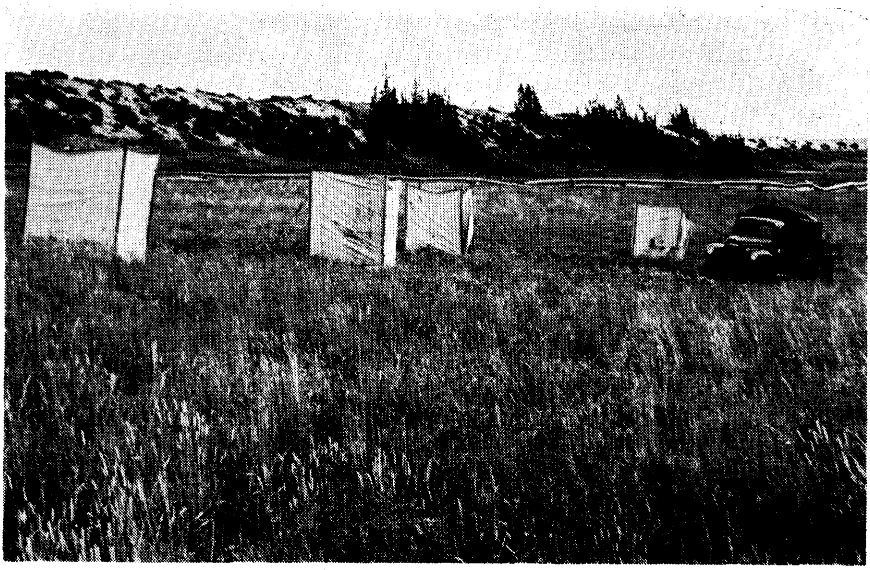

FIGURE 3. Site 8. This is the steepest (9- to 23-percent slope) but most productive site studied. It typifies much of the west-facing slope of the range. The four tentlike objects shown are windbreaks set around infiltrometer plots to reduce the effects of wind on the application of simulated rain.

FIGURE 4. Site 9 in foreground. The soil on this gently sloping terrace is shallow and stony. Slope gradients of plots range from 4 to 8 percent. Site 8 is in the center to the right of the cloud shadow.

Study Sites.—When the grazing unit was seeded in 1952, 10 study sites were selected and a ½-acre area at each site was left unseeded. Forty infiltrometer plots were established on four of these sites: 12 on Site 5, eight on Site 6, 12 on Site 8, and eight on Site 9. Photographs of these four sites are presented in Figures 1-4. At each site, half of the plots were located on the unseeded area and the other half on adjacent seeded range. In each instance, one-half of the plots were caged to prevent grazing, thus providing four separate treatment conditions (unseeded-ungrazed, unseeded-grazed, seeded-ungrazed, and seeded-grazed), with 10 infiltrometer plots on each.

Measurements

Measurements of infiltration and soil stability were obtained with a Rocky Mountain infiltrometer (Dortignac, 1951). The infiltrometer plot frames are 30.5 inches long and 12 inches wide. They are equipped with trough gages to measure the rainfall application rate and collector troughs to catch runoff and sediment (Fig. 5). Approximately 3 inches of artificial rain was applied to each of the 40 plots in 50 minutes at a rate of 3.6 inches per hour. To minimize variation in surface soil moisture, each plot was prewet the day before the test run with 0.6 inch of water and covered with a tarpaulin until the infiltration test was made. The amount of simulated rain applied and the amount of runoff from each plot were measured at 5-minute intervals during the 50-minute test. All runoff from each plot was collected and the suspended sediment was filtered out and its ovendry weight determined.

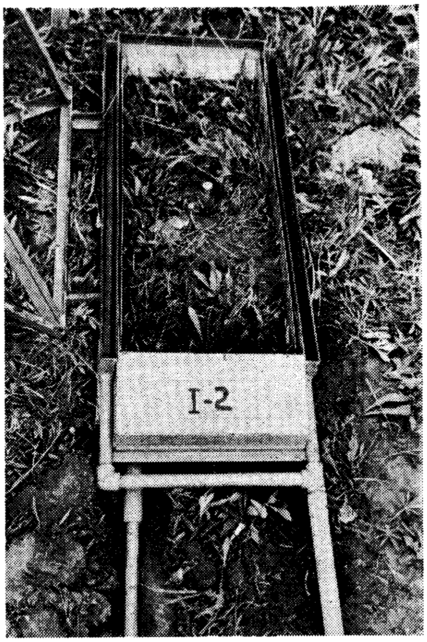

FIGURE 5. Study plot with plot frame and trough gages installed. The pipe on the left delivers plot runoff and the pipe on the right delivers trough gage catch. Plot size is 30½ by 12 inches.

Density of cover protecting the soil surface was measured by the point method (Levy and Madden, 1933) immediately prior to the infiltration test. Density is the proportion of the ground surface protected by cover, expressed as a percentage. The percentage of first strikes by the point analyzer on live vegetation is termed "live plant cover." The percentage of first strikes on live vegetation and litter (unincorporated organic material) is termed "organic cover." "Protective cover" is the percentage of first strikes on live vegetation, litter, and stone. Thus, organic cover includes live plant cover plus litter, and protective cover includes organic cover plus stone.

Two or three days after the infiltration test, all live vegetation was clipped from the plot flush with the soil surface and placed in cloth bags. Litter was also collected in a cloth bag. Vegetation and litter were weighed after air-drying in a warm room for 2 weeks.

After vegetation and litter were removed from each plot, duplicate soil samples were taken at 0- to 2-, 2- to 4-, and 4- to 6-inch depths with a 240-cc core sampler. The moisture content of the soil was near field capacity when these samples were taken. Noncapillary and capillary porosities of these cores were measured by the method of Leamer and Shaw (1941). The cores were ovendried to determine bulk density. Organic matter contents of these cores and of an additional sample from the surface inch of each plot were measured by the dichromate method (Peech, et al., 1947).

Analysis and Results

The data were subjected to variance analyses to determine how seeding and grazing affected: infiltration capacity, the amount of sediment eroded, and measured cover and soil characteristics. Differences in these effects were considered significant when their probability of being real was at least 95 percent, and were considered highly significant at a probability of 99 percent.

Retention.—The difference between total applied rainfall and total plot runoff measured during the 50-minute application period of simulated rainfall is a measure of the ability of the site to retain storm precipitation temporarily rather than yielding it immediately as overland flow. This difference is termed "retention" in this report and consists of infiltration, interception by vegetation, depression storage, and evaporation. Average retention by treatments was:

Unseeded-ungrazed ....2.31 inches
Unseeded-grazed 1.84 inches
Seeded-ungrazed 2.25 inches
Seeded-grazed ......1.58 inches

The differences in retention between grazed and ungrazed plots were highly significant. Inasmuch as the plots had not yet been grazed during the year these measurements were made, the reduction in retention on the grazed plots is attributed to the cumulative effects of grazing during previous years. Differences in retention between seeded and unseeded plots were not significant.

Sediment Production. — Sediment eroded during the 50-minute application of simulated rain averaged as follows:

Unseeded-ungrazed 173 lb/a
Unseeded-grazed ......840 lb/a
Seeded-ungrazed ......453 lb/a
Seeded-grazed ....987 lb/a

The grazed plots produced an average of 600 pounds per acre more sediment than did the ungrazed plots, a highly significant difference. Differences in sediment production between seeded and unseeded plots were not statistically significant.

Cover Characteristics.—Cover characteristics are known to influence runoff and erosion. Consequently, they were measured on the study plots to determine in what manner and to what degree they had been affected by seeding and grazing. Average cover and air-dry weights of plants and litter are presented by treatments in Table 1.

Live plant cover was greater on unseeded plots than on seeded plots, whether grazed or ungrazed, the differences being highly significant. The differences in organic cover and in total cover were not so great as the difference in live plant cover but, nevertheless, were significant. It may be concluded that after 7 years, the seeding treatment on this area has not provided cover equaling that of native vegetation on unseeded plots.

The difference in live plant cover between grazed and ungrazed plots was significant and the difference in protective cover was highly significant. Grazing appears to have caused less reduction in live plant cover

Table 1. Cover characteristics of Manti Canyon study plots 7 years after seeding.

		Unseeded		Seeded	
	Units	Ungrazed	Grazed[1]	Ungrazed	Grazed[1]
Live plant cover	Percent	58.4	49.0	42.7	35.7
Organic cover	do.	84.6	70.3	72.6	63.0
Protective cover	do.	85.0	70.6	73.9	63.1
Grass weight	lbs./acre	217	159	1,118	861
Forb weight	do.	1,496	1,124	334	325
Vegetation weight	do.	1,713	1,283	1,452	1,186
Litter weight	do.	2,206	1,745	2,106	1,628

[1] Moderately grazed (about 0.5 a.u.m. per acre per year) during previous 4 years.

Table 2. Percentage of ground covered by live plants on test plots in Manti Canyon 7 years after seeding.

	Unseeded			Disked and seeded		
Species	Un-grazed	Grazed[1]	All	Un-grazed	Grazed	All
Grasses and sedge						
Agropyron trachycaulum	1.7	0.3	1.0	0.7	0.6	0.6
Alopecurus pratensis	0	0	0	7.0	5.4	6.2
Bromus carinatus	.1	0	.1	4.8	1.9	3.3
Bromus inermis	0	0	0	4.7	4.3	4.5
Carex festivella	1.1	.5	.8	0	0	0
Dactylis glomerata	0	0	0	3.3	2.8	3.1
Phleum pratense	0	0	0	3.3	4.4	3.9
Stipa lettermanni	3.6	2.8	3.2	.6	.4	.5
Minor grasses	.1	.8	.4	0	.4	.2
Total grasses and sedge	6.6	4.4	5.5	24.4	20.2	22.3
Forbs						
Achillea lanulosa	2.0	2.7	2.3	0.3	0	0.2
Aplopappus uniflorus	6.5	5.9	6.2	.2	.4	.3
Artemisia discolor	2.2	1.2	1.7	2.7	.7	1.7
Geranium viscosissimum	17.5	13.0	15.2	1.3	5.1	3.2
Penstemon rydbergi	9.0	4.2	6.6	.4	.4	.4
Potentilla filipes	2.0	4.0	3.0	.1	0	.1
Taraxacum officinale	6.3	2.0	4.2	9.4	5.4	7.4
Minor forbs	6.3	11.6	9.0	3.9	3.5	3.6
Total forbs	51.8	44.6	48.2	18.3	15.5	16.9
Total live plant cover	58.4	49.0	53.7	42.7	35.7	39.2

[1] Moderately grazed (0.5 a.u.m. per acre per year) during previous 4 years.

but a greater reduction in protective cover than did seeding.

Table 2 shows the relative abundance of the major grasses and forbs by treatments. Plants of low forage value, such as geranium, plantain goldenweed (*Aplopappus uniflorus*), penstemon, and needlegrass (*Stipa lettermanni*) are much more abundant on the unseeded sites. These species have largely been replaced on the seeded sites with introduced and native grasses of high forage value.

Seeding and grazing both appear to have caused reductions in total vegetation weight, but none of the reductions were significant. The seeded plots have much more grass and fewer forbs than the unseeded ones and, although total production may be less on the seeded plots, the proportion of desirable forage is greater.

Average litter weights were slightly lower on seeded than on unseeded plots. They were also slightly lower on grazed than on ungrazed plots.

Soil Characteristics. — Values of noncapillary porosity, capillary porosity, bulk density, and organic matter content were averaged by seeding and grazing treatments. These average values are shown in Table 3. All significant differences occur in the surface 2 inches of soil. Below 2 inches, most of the differences among treatments are small and none is statistically significant.

In the surface 2 inches of soil, seeding tended to increase noncapillary porosity and decrease capillary porosity, especially on the more compacted sites. However, the differences in noncapillary porosity between seeded and unseeded plots are not significant, whereas the differences in capillary porosity are highly significant. As a consequence of less total pore space and less organic matter, bulk density of the surface 2 inches of soil on

Table 3. Average porosity, bulk density, and organic matter content of soil cores from the Manti Canyon plots 7 years after seeding.

	Unseeded		Seeded	
Depth (in.)	Un-grazed	Grazed	Un-grazed	Grazed
Noncapillary porosity (percent)				
0-2	18.8	15.1	19.6	17.7
2-4	16.2	15.9	16.5	15.4
4-6	15.8	15.3	15.8	14.9
Capillary porosity (percent)				
0-2	42.7	43.9	40.8	42.3
2-4	43.4	41.5	41.5	41.7
4-6	41.1	41.7	41.2	40.7
Bulk density (grams per cc.)				
0-2	0.96	0.99	1.02	1.04
2-4	1.06	1.05	1.05	1.04
4-6	1.10	1.09	1.08	1.10
Organic matter (percent)				
0-1	14.4	15.8	11.0	11.4
0-2	10.2	11.7	8.6	8.4
2-4	9.4	9.7	8.4	8.1
4-6	9.2	9.5	8.2	7.6

seeded plots is significantly greater than on unseeded plots.

Grazing also tended to reduce total pore space of the surface soil but its effect on pore size distribution was opposite to that of seeding: it significantly reduced noncapillary porosity and significantly increased capillary porosity.

Organic matter content of the surface 2 inches of soil was significantly greater on unseeded than on seeded plots, the differences in the surface inch being highly significant. Although differences in the 2- to 4-inch and 4- to 6-inch depths were not statistically significant, they were great enough to suggest that disking may have reduced organic matter below the 2-inch depth as well as in the surface soil. There were no significant differences in soil organic matter content between grazed and ungrazed plots.

The reasons for less soil organic matter on seeded plots are not obvious. It is hypothesized that, by temporarily increasing aeration and by thoroughly mixing accumulated litter into the soil, disking induced more rapid and complete oxidation of litter and humus than normally occurs on undisturbed sites. In the years following seeding, less surface litter was present to contribute organic matter to the soil and organic matter content of the surface soil gradually declined. This aspect of the effects of cultivation of mountain soils should receive further study.

Influence of Soil and Cover Characteristics on Water Retention and Soil Erosion.—Multiple regression analyses of the data revealed that bulk density of the surface 4 inches of soil, noncapillary porosity of the surface 4 inches of soil, and total cover, in combination, accounted for 79 percent of the variance in water retention. Although most of the other measured variables are also significantly correlated with water retention, none explained significant additional variance.

The relation of amount of water retained to soil bulk density and noncapillary porosity is shown in Figure 6. The effect of protective cover is shown separately in Figure 7. Retention is influenced primarily by bulk density, which by itself accounts for 67 percent of the variance, and secondarily by protective cover, which accounts for an additional 9 percent of the variance. Bulk density is an index of porosity, which directly affects infiltration capacity. Noncapillary porosity is important because large pores transmit water more rapidly than small pores. Cover can influence retention in a number of ways, notably by interception of precipitation and protection of the soil surface from puddling by raindrop impact.

The relation of soil eroded to protective cover and soil bulk density is shown in Figure 8. These two variables account for 81 percent of the variance in eroded soil; no significant additional variance is explained by any of the other measured variables. The use of protective cover rather than organic cover yields better relations in both retention and erosion, indicating that stone on the surface of otherwise unprotected soil has a beneficial effect on infiltration and soil stability.

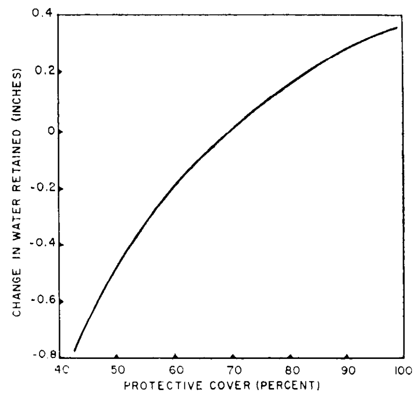

FIGURE 7. Effect of protective cover on amount of water retained by plots during 50-minute simulated rain. The values in Figure 6 can be corrected for variations in protective cover by means of this graph.

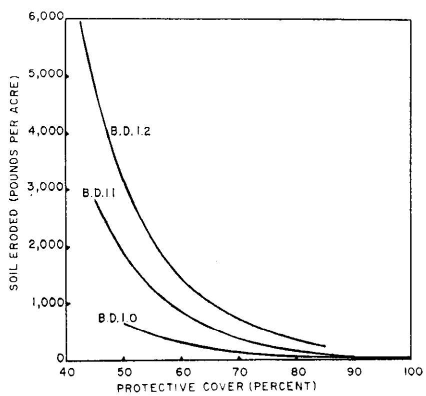

FIGURE 8. Relation of amount of soil eroded from plots during 50-minute simulated rain to bulk density (B.D.) of the surface 4 inches of soil and percent of soil surface protected by plants, litter, and stone.

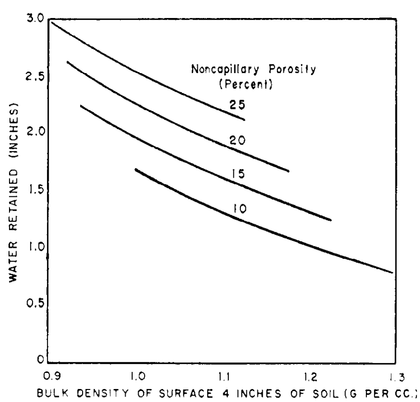

FIGURE 6. Relation of water retained by plots during 50-minute simulated rain to bulk density and noncapillary porosity of surface 4 inches of soil when 70 percent of the soil surface is protected from direct raindrop impact. The numbers on the curves are percentages by volume of noncapillary pore space.

Protective cover is more closely correlated with soil eroded than any other measured variable, but there is a strong interaction between bulk density and cover and their influence on soil erosion. If protective cover exceeds 85 percent, the amount of soil eroded is small, irrespective of bulk density, because the soil is protected from detachment by flowing water and raindrop impact. Conversely, the influence of protective cover at bulk densities of less than 1.0 is not as great as at higher bulk densities because there is little overland flow to detach and transport soil particles. In short, the influence of bulk density is most pronounced at low cover and the influence of cover is greatest at high bulk densities.

Of course, these relations are valid only for conditions similar to those of the study area. For example, studies on the porous, coarse-textured granitic soils of southern Idaho (Packer, 1951) revealed that runoff and soil eroded were dependent almost entirely on density of ground cover and its distribution, and that soil bulk density exerted little influence. However, it is reasonable to expect bulk density to be a greater limiting factor on fine-textured soils such as those in this study.

Requirements for Watershed Protection.—Control of overland flow is requisite to good watershed condition. When appreciable overland flow occurs, soil is eroded and loss of soil can only result in depreciation of range and watershed values. The major goal in managing range-watersheds should be maintenance of the capacity of each site to detain high-intensity precipitation where it falls rather than to yield it immediately as overland flow. Because of the complexity and variability of site conditions, criteria for judging the capacity of a site to do this are yet imperfectly developed.

Reasonable approximations of site conditions required for satisfactory watershed protection on the area studied can be derived from the data obtained in this study. In Ephraim Canyon, 6 miles north of Manti Canyon, records of summer storms have been kept for the past 40 years. During this time, the maximum rainfall intensity recorded for any 10-minute period is 2.58 inches per hour. Study plots that retained at least 2.15 inches of water during 50-minute applications of simulated rain have the capacity to retain an average of at least 2.58 inches per hour and may be expected to retain most, if not all, precipitation falling at this intensity during any 10-minute period. Therefore, it is assumed that plots retaining 2.15 inches or more under study conditions would rarely produce appreciable overland flow under natural rainfall conditions.

On the area studied, bulk density and noncapillary porosity of the top 4 inches of soil, together with total cover, are the most important measured factors affecting the retention of simulated rainfall. Examinations of the data for individual plots revealed that 50-minute retention equaled or exceeded 2.15 inches if any one of the following three conditions existed: (1) bulk density of the surface 4 inches of soil less than 0.97, (2) protective cover at least 85 percent, or (3) noncapillary porosity of the surface 4 inches at least 22 percent. Any one of these conditions would be considered a single protection requirement. However, it is better to consider all three factors in combination when judging watershed condition. The graphs in Figures 6 and 7 may be used to estimate various combinations of bulk density, noncapillary porosity, and protective cover required for a given amount of retention. For example, if bulk density is 1.00 and noncapillary pore space is 15 percent, Figure 6 shows that 50-minute retention is only 2.0 inches at 70-percent cover. Going to Figure 7, we see that retention is 0.15 inch greater if we have 80-percent cover, thus retention is increased to the required 2.15 inches. This illustrates that, in general, protection requirements are less stringent if more than one factor is considered.

If bulk density is too great for satisfactory control of overland flow, it is still possible to minimize soil loss by maintaining a dense cover. As shown in Figure 8, soil loss decreases as the percentage of the soil surface protected by plants, litter, and stone increases. A dense plant and litter cover is desirable for its beneficial effects on bulk density and other soil properties. A dense cover also reduces the likelihood of soil compaction.

On range-watersheds like the one studied, grazing tends to reduce protective cover and noncapillary porosity. Grazing on these lands should be limited to a time of year and to a degree of use that will insure that the soil is not compacted nor the cover reduced beyond allowable limits. Where the soil is compacted and the cover reduced to the point that overland flow will occur during high-intensity storms, modification of grazing methods is indicated. On sites where soil is badly compacted or the vegetation depleted, grazing exclusion and cultural treatments to increase cover and noncapillary porosity are necessary to restore these lands for future use.

The watershed protection requirements defined here are only approximate because they are based on rather limited data. Research on a more extensive and comprehensive scale is underway to provide more precise information on vegetal and soil requirements that would be applicable to all subalpine range of central Utah.

Summary and Conclusions

The effects of seeding and grazing on infiltration, soil stability, and a number of vegetal characteristics and soil properties were evaluated on a subalpine cattle range. The study was made on an area that was seeded to grass 7 years previously. Twenty infiltration test plots were located on areas that had been left unseeded for study purposes and 20 plots were located on adjacent seeded range. Half the plots on each area had been moderately grazed during the previous 4 years; wire cages protected the other half from grazing. Prior to current season grazing, each of the 40 plots was subjected to simulated rain for 50 minutes at an intensity of 3.6 inches per hour and the resultant runoff and eroded soil were measured. Cover characteristics and several soil properties were also measured. Variance analysis revealed the significant effects of seeding and grazing.

The surface soil of the seeded plots had significantly less capillary pore space, and had significantly greater average bulk density than the unseeded plots.

Noncapillary porosity tended to be greater on the seeded plots, but not significantly so. Average protective cover on the seeded plots was significantly less than on native plots but vegetation weight and litter weight did not vary significantly. Although average runoff and soil eroded were greater on seeded plots than on native plots, the differences were not significant. Results show that disking and seeding are effective in improving usable forage on subalpine range. Disking can also improve infiltration on compacted sites by increasing noncapillary pore space in the soil, but on sites initially in good condition disking should be used with caution: it can detrimentally affect infiltration and soil stability by reducing protective cover, soil organic matter content, and soil porosity.

On the plots that had been grazed during the 4 years previous to the study, average protective cover was significantly lower than on ungrazed plots. There was less average weight of vegetation and litter on the grazed plots, but the differences were not significant. Bulk density and organic matter content of the surface soil did not vary significantly, but there was significantly less noncapillary pore space and significantly more capillary pore space on grazed than on ungrazed plots. Average runoff and soil eroded from the grazed plots were significantly greater than from the protected plots.

Results of this study indicate that infiltration capacity is influenced primarily by soil bulk density and noncapillary porosity and secondarily by the amount of protective cover afforded by plants, litter, and stone. Soil stability is influenced primarily by the density of protective cover and secondarily by soil bulk density.

It is concluded that disking and seeding on the study area tended to reduce infiltration capacity and soil stability but these reductions are minor and probably temporary. The reductions of infiltration capacity and soil stability induced by grazing are of greater concern. The differences in infiltration capacity and soil stability between grazed and ungrazed plots demonstrate that even moderate grazing can have pronounced residual effects on these factors. Grazing must be carefully managed so that protective cover is not reduced nor soil compacted to the extent that severe summer storms will cause excessive overland flow and soil loss.

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