Hydrologic and Biotic Effects of Grazing vs. Non-grazing Near Grand Junction, Colorado[1]

GREGG C. LUSBY

Research Hydrologist, U.S. Geological Survey, Water Resources Division, Denver, Colorado.

Highlight

The effect of grazing on the hydrology of salt-desert type rangeland has been studied near Grand Junction, Colorado for the past 14 years. Measurements of precipitation, runoff, erosion, and vegetation have been made in four pairs of watersheds. One of each pair has been grazed by cattle and sheep as is normal in the region, and the other has not been used since the beginning of the study. Measurements made 10 years apart show that all four grazed watersheds have had a slight increase in the amount of bare soil and rock and a decrease in ground cover; cover on ungrazed watersheds has remained essentially unchanged. Runoff in the ungrazed watersheds has been about 30 percent less than in the grazed watersheds and sediment yield has been about 45 percent less. The greatest change in each of the relationships occurred about 3 years after livestock were excluded from one watershed of each of the pairs. Preliminary studies indicate that within areas of similar physiography, runoff is directly related to the percentage of bare soil present on a watershed.

The statement that a deterioration of rangeland and an increase in erosion and sediment yield took place in the western United States at about the time of settlement by white man has been made by numerous writers. This change has been attributed, in many instances, to the effect of grazing by domestic animals and has been fairly well documented. It would seem logical that if grazing was the cause of deterioration of rangeland, the elimination of grazing would cause an improvement.

Thousands of acres of land in the Colorado Plateaus Physiographic Province are contributing large quantities of sediment and relatively little water to downstream reaches of the Colorado River and its tributaries. This sediment yield and flashy type runoff not only perpetuate the nonproductivity of the rangeland, but damage farmlands, irrigation works, and flood-control projects downstream. The terrain in most of the area is rugged and highly dissected, making any kind of mechanical treatment very difficult and expensive. The control of livestock grazing is one of the most obvious treatments to be applied. The purpose of this study is, therefore, to determine the effect of the elimination of grazing on runoff, sediment yield, and vegetation on salt-desert type rangeland.

[1] Publication authorized by the Director, U.S. Geological Survey. Received July 8, 1969; accepted for publication January 27, 1970.

Description of Area

The study area is located in the Badger Wash basin in western Colorado a few miles east of the Utah-Colorado boundary, about 25 miles west of Grand Junction, Colorado, and is tributary to the Colorado River (Fig. 1). The part of the basin being studied is at an elevation of about 5,000 feet and drains the hilly land between the Book Cliffs and the flat, irrigated section of the Grand Valley.

Although the entire Badger Wash basin is underlain by the Mancos Shale of late Cretaceous age, the lithology differs somewhat in various parts of the basin. The shale in the western and upper parts of the basin contains a number of thin sandstone beds less than 1 foot thick. Because of their greater resistance to erosion, these layers cause an alternation of steep and gentle slopes. The gently sloping areas are on top of sandstone beds. Channels are similarly affected; they are moderately incised on the relatively steep slopes underlain by shale and have wide, shallow cross sections on the sandstone. On the eastern side of the basin, the sandstone beds are absent, and the topography is more uniform, with very steep hillslopes merging with gentle colluvial slopes at their bases. Channels are everywhere incised into the shale.

Soil in the area is poorly developed and generally consists of a shallow, weathered mantle overlying the Mancos Shale. The most extensive soil type in the area is a residual mixture of weathered shale and sandstone chips.

The climate at Badger Wash is arid to semiarid. Average annual precipitation based on 38 years of record at Fruita, Colorado, about 16 miles southeast of the study area, is 8.7 inches. Precipitation from April to October occurs generally from convective type storms. Temperatures during July range from about 55 to 98 F.

Vegetation at Badger Wash is of the salt-desert shrub type, but several subtypes may be distinguished within this type. These subtypes reflect local differences in soil characteristics and available soil moisture. On the lower part of the main drainage, black greasewood (*Sarcobatus vermiculatus*) is dominant. Pure stands of mat saltbush (*Atriplex corrugata*) occur on alkaline flats in the upper reaches of the main-valley alluvium.

Big sagebrush (*Artemisia tridentata*) and rubber rabbitbrush (*Chrysothamnus nauseosus*) grow along the tributaries, mainly on alluvial soils. On the uplands, sandy soils support shadscale (*Atriplex confertifolia*) and a relatively dense understory of galleta (*Hilaria jamesii*). The predominant plant on clay soils is Nuttall saltbush (*Atriplex nuttallii*). On mixed soils, the vegetation is made up of species found on both clay and sandy soils (Lusby and others, 1963).

In 1953, representatives of the U.S. Geological Survey, U.S. Forest Service, Bureau of Land Management, and Bureau of Reclamation, under the auspices of the Pacific Southwest Inter-Agency Committee, selected four pairs of watersheds on public lands within the Badger Wash drainage basin for intensive study. These watersheds range in size from 12 to 105 acres. Each pair was selected to be as nearly similar as possible with respect to size, soil, aspect, geology, topography, and vegetation. One of each pair of watersheds was chosen at random to be fenced to exclude livestock. The other was to be grazed by both cattle and sheep during the winter and spring, as is normal for the area. A reservoir in which runoff and sediment could be measured was constructed at the lower end of each watershed. Precipitation

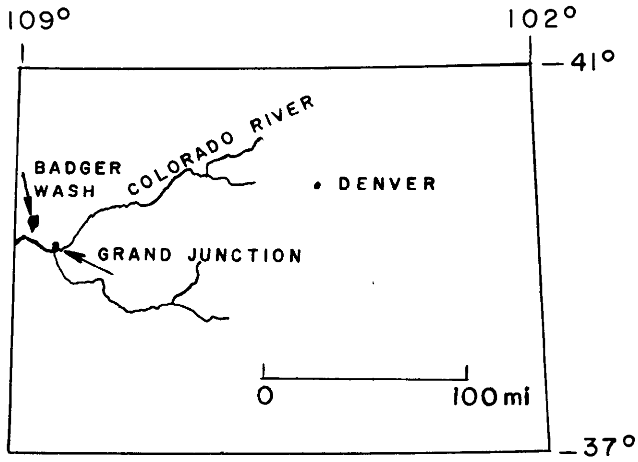

FIG. 1. Index map of Colorado showing location of Badger Wash.

recorders were established in each pair of watersheds to measure areal distribution of rainfall. Precipitation amounts were computed using the Thiessen Polygon method (Thiessen, 1911). Gully cross sections and sidehill transects were established which could be surveyed to determine the relative magnitude of channel and hillslope erosion. Twenty-four vegetation transects were established in each watershed for use in determining cover, trends, and use. Records of cover were obtained along the transects using a loop method similar to that described by Parker (1951). Each transect also served as the side of a 2-foot wide belt transect on which forage utilization estimates were made.

During the early years of the study, a trend toward more sediment yield and runoff from grazed areas than in ungrazed areas was noted. The change was attributed in a previous report (Lusby, 1965) to the trampling effect of livestock on soil that was loosened by frost heave. This report more completely defines the changes in runoff and sediment yield.

Results

The evaluation of the effects of grazing on the hydrology of the study watersheds is dependent on trend comparisons of paired watersheds, because there was no calibration period at the beginning of the study. The characteristics that determine runoff and erosion, including size, slope, aspect, vegetation, and soils, are similar for paired watersheds. The trends in four pairs of watersheds should be indicative of the actual events taking place.

Precipitation

Rainfall during the study period 1956–66 was generally below the long term average. Average annual precipitation at Fruita was 8.24 inches during the period, which compares with the long term average of 8.75 inches.

Of primary importance in this study is the equality of precipitation over each pair of watersheds. Considerable variation of precipitation among the pairs of watersheds has been observed,

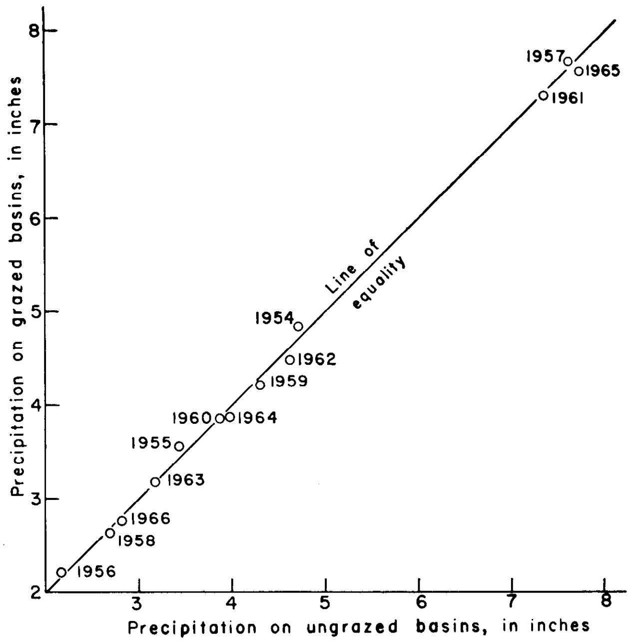

FIG. 2. Comparison of seasonal rainfall on grazed and ungrazed basins at Badger Wash.

but differences between watersheds of each pair have been rather slight. The yearly difference in summer rainfall between grazed and ungrazed watersheds averaged 3 percent, but the total summer rainfall for 13 years on each pair of watersheds did not differ by more than 1.8 percent. No definite pattern of rainfall was observed over the basins.

Figure 2 shows the average seasonal precipitation for grazed versus ungrazed watersheds and indicates that precipitation amounts have been quite similar for paired watersheds.

Runoff

Runoff at Badger Wash occurs almost wholly in response to summer rains. Very infrequently, rainstorms may occur during the winter that produce some runoff. Snow generally does not accumulate enough to cause runoff in the spring.

For the purpose of this paper, the comparison of average runoff from the four grazed basins with that from the four ungrazed basins is used to define the effect of basin use. Figure 3 (upper) shows a mass diagram, by years, of such a comparison. No runoff occurred in 1956, 1958, and 1966. The average slope of the line after 1956 is about 1.3, indicating that the grazed watershed was producing 30% more runoff than the ungrazed watershed. This change apparently started almost immediately after livestock were excluded in the winter of 1953, but the greatest difference did not occur until about 3 years later. The individual pairs of watersheds all show the same pattern as the average except for one pair that is complicated by the presence of an

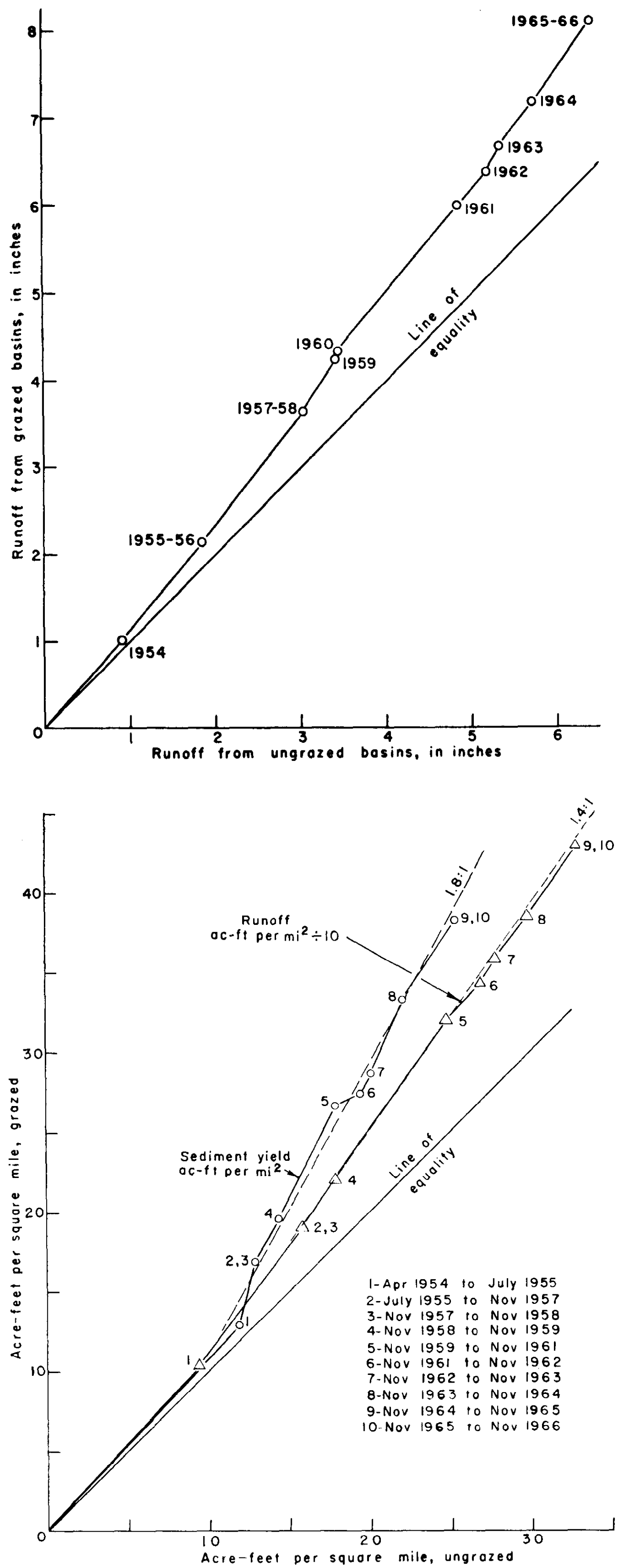

FIG. 3. Mass diagrams. Upper, runoff in grazed and ungrazed basins at Badger Wash, by years; Lower, sediment yield and runoff at Badger Wash, by periods.

upstream reservoir sediment deposit. The slope of the mass line for three pairs of watersheds ranges from 1.40 to 1.45 during the latter part of the study period.

A plot of runoff in a grazed basin versus that in an ungrazed basin, by storms, indicates a different relation before and after the break in the mass plot indicated in Fig. 3 (upper). During 1954–55 the points are characterized by the regression equation $Y = 0.0059 + 1.09X$, with a correlation coefficient of 0.99. During 1956–66, the points are characterized by a regression equation of $Y = 0.0386 + 1.13X$, with a correlation coefficient of 0.98.

Sediment Yield

Sediment yield was measured by surveying the catchment reservoirs at the end of 10 periods during the study. The results of these measurements, along with runoff for the same periods, are shown graphically in Fig. 3 (lower). After the first period, April 1954 to July 1955, the mass curve departed from the line of equality and assumed a slope of about 1.8 to 1. At the same time the runoff line assumed a slope of about 1.4 to 1. The measurements of sediment do not assume so smooth a curve as that for runoff because of the compaction of sediment during dry periods. During periods of large runoff and sediment yield, the reservoirs usually contain water at survey time and measurements are of sediment that is not compacted. During dry periods, the reservoirs are usually dry most of the time, allowing the sediment to shrink and become compacted. The trend of the sediment yield lines is indicative of compacted sediment. Volume weight of deposited sediment has been measured at from 80 to 100 lb/ft^3 or about 2,000 tons/acre-foot.

Watershed Cover

Measurements of watershed cover made by U.S. Forest Service personnel indicate that at the beginning of the study no significant difference existed between plant cover on watershed pairs, although the ungrazed watersheds contained an average of 5% more bare soil than those that are grazed (Lusby and others, 1963). Periodic measurements of watershed cover indicate no large or sudden changes, but measurements made in the fall of 1953 and the fall of 1963 show some definite changes for the entire period. These changes are shown in Fig. 4.

Although some of the changes shown are not of large magnitude, they appear to be important as far as percentage is concerned. From the bar graphs shown, it appears that the ungrazed watersheds remained in about the same condition as at the start of the study and most changes took place in the grazed basins. The marked increase in bare

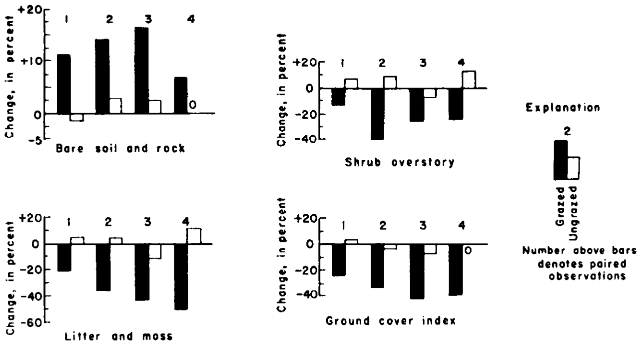

FIG. 4. Changes in watershed cover from fall 1953 to fall 1963. Change is expressed in percent of value measured in 1953.

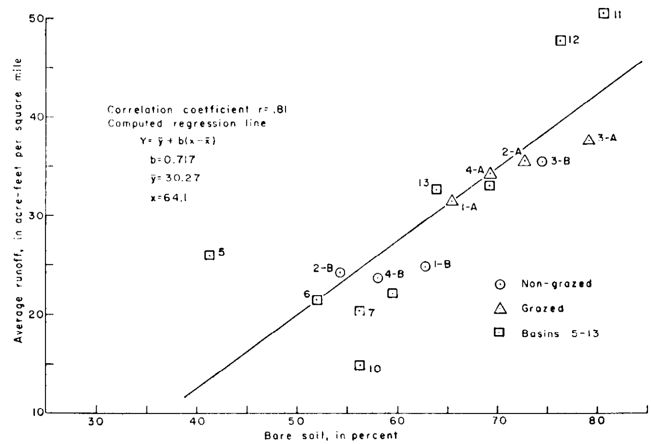

FIG. 5. Percentage of soil which is bare versus average runoff for 14 years in basins at Badger Wash (Loop method, 1967–68).

soil and rock on all grazed watersheds, accompanied by a decrease in shrub overstory, litter and moss, and ground cover index, indicate that the grazed watersheds were in worse condition hydrologically at the end of the study period than at the beginning. This may have been caused by several dry years or increased grazing pressure because of the availability of water in the area or by both.

Source of Sediment

At the beginning of the study, permanent cross sections were established on gullies in the paired watersheds and transects were established on the hillsides to determine the source of sediment being produced. The average change in elevation of the ground surface on cross sections and transects is used to determine these relations. Sections in all watersheds show erosion in the gullies.

The gullies in grazed watersheds have about twice as much erosion as those in ungrazed watersheds. The greatest amount of gully erosion apparently took place in one of the grazed, more sandy areas in which the channels are established in alluvium. The most erosion on hillside transects took place in one of the grazed, mixed soil type watersheds that contains the steepest topography in the Badger Wash area.

Although no definite statement can be made concerning the actual volume of material removed by each type of erosion, the relative extent of each type may be obtained by comparing measurements of gully erosion and hillside erosion. Sheet erosion appears to be more dominant in three watersheds that contain the steepest topography. In two of the ungrazed watersheds, the ground surface was actually higher in 1966 than in 1954, probably because of expansion of the soil from frost heave.

Runoff in Relation to Watershed Characteristics

Recent investigations by F. A. Branson and J. R. Owen of the U.S. Geological Survey indicate that a useful correlation may exist between the percent of bare soil and runoff. Figure 5 shows this relation for 17 watersheds on which measurements are available at Badger Wash. The points have a significant correlation coefficient of 0.81 about the computed regression line. Although the fit about the regression line is not extremely close, the trend is indicative of a relation between bare soil and average annual runoff. Investigations in other areas indicate that the same sort of relation may exist, but at a different level. What may actually exist is a series of curves dependent on the particular physiographic and climatologic characteristics of the region. If these curves can be defined by future work, they may be useful in predicting runoff from ungaged areas.

Summary

After the initial 2 years of study, ungrazed watersheds at Badger Wash have averaged 30% less runoff than grazed watersheds, during periods of similar rainfall. At the same time, ungrazed watersheds have averaged 45% less sediment than grazed watersheds.

The difference in runoff and sediment yield took place soon after livestock were excluded and was not accompanied by a corresponding difference in watershed cover, although at the end of 11 years, significant differences were noted in bare soil and rock, litter and moss, shrub overstory, and ground cover index. The reason for the hydrologic changes has been described in a previous report as being caused by the trampling effect of livestock on soil that was loosened by frost heave (Lusby, 1965).

A definite relation between bare soil and runoff at Badger Wash was established. Investigations in other areas show that a series of curves for different regions may exist. If further investigation is able to define these curves more fully, the relation might be a worthwhile predictive tool.

Literature Cited

LUSBY, G. C., G. T. TURNER, J. R. THOMPSON, AND V. H. REID. 1963. Hydrologic and biotic characteristics of grazed and ungrazed watersheds of the Badger Wash basin in western Colorado, 1953–58. U.S. Geol. Survey Water-Supply Paper 1532-B:1–73.

LUSBY, G. C. 1965. Causes of variation in runoff and sediment yield from small drainage basins in western Colorado. U.S. Dep. Agr. Misc. Pub. 970, paper 14:9–498.

PARKER, K. W. 1951. A method for measuring trend in range condition on national forest ranges. U.S. Dep. Agr., Forest Service, 26 p.

THIESSEN, A. H. 1911. Precipitation for large areas. Monthly Weather Review, v. 39:1082–1084.