Watershed Management Experiments in the Colorado Front Range

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Summer cloudburst storms occur frequently on the eastern flank of the Colorado Range below 9,000 feet elevation. The intensity of these storms is high, often exceeding three inches per hour for 10-minute intervals. Floods from the cloudburst storms cause much damage to lands and improvements in the adjacent plains. A considerable portion of this damage is due to sediment deposited in stream channels and reservoirs, across mountain roads, in homes and towns, in irrigation canals and ditches.

Sediment damage amounts to over $600,000 annually in the South Platte River system above Greeley, Colorado (8). A principal contributor of sediment is the forest and range foothill area where sheet and gully erosion account for 95 per cent of the sediment deposited and the annual rate amounts to 0.25 acre-foot per square mile (Figure 1).

PLOT STUDIES in the Colorado Front Range show that heavy grazing by livestock doubles the amount of surface erosion and increases runoff by about two-thirds when compared to plots moderately grazed. Infiltration studies point to a decrease of 118 per cent in the water absorption rate of mixed granitic and schist soils when very poor forage condition is contrasted to good. These and other studies illustrate the extent to which native vegetation can lessen accelerated erosion and runoff. This decrease can do much toward reducing sediment damages in the Colorado Front Range and adjacent plains.

The Colorado Front Range extends from Canon City, Colorado, into Wyoming, where it merges with the Laramie Range without a perceptible topographic break. The eastern border of the Front Range follows a slightly curved north-south line, passing a short distance west of Colorado Springs, Denver, and Fort Collins. Its topography stands in sharp contrast to the plains to the east. Westward, the Front Range reaches to the crest of the Continental Divide (3).

The low-elevation (6,000-9,000 feet) forests and grasslands of the Colorado Front Range are the mountain sediment-source areas of the South Platte River drainage. The lands are rough and broken, and are dissected by many tributary drainageways. A considerable portion contains soils derived from Pikes Peak granite, reddish in color, and highly susceptible to the forces of erosion. A smaller portion is made up of soils developed from limestones and sandstones, but equally susceptible to erosion because of its steep, hogback topography.

On the Manitou Experimental Forest in Colorado, watershed-management experiments have now been underway about 18 years. This forest, lying just west of the Rampart Range, is eight miles north of Woodland Park, Colorado, and is in the South Platte River drainage. It is located within the foothill zone (6,000-9,000 feet elevation) from which considerable sediment is deposited in mountain streams. The annual water yield appearing as streamflow varies between two and five inches—less than 20 per cent of the annual precipitation. Open forests of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga taxifolia*), and aspen (*Populus tremuloides*), with an understory of Arizona fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), and a variety of shrubs are characteristic of the Experimental Forest and the foothill zone within which it lies (Figure 2), In isolated areas virgin forest predominates, but stands of second growth are the rule.

Watershed-Management Experiments

Most of the precipitation in the foothill zone occurs as rain during the spring and summer months. Frequently the rainfall comes in the form of cloudburst storms of high intensity but of short duration. Watershed-management experiments have dealt primarily with studies of the infiltration of water, surface runoff, and erosion of the soils developed from granitic and other geologic materials. The purpose has been to determine what factors in the ponderosa pine—bunchgrass ranges will provide the optimum conditions for water absorption and for the reduction of surface runoff and erosion from cloudburst storms.

Surface runoff and erosion from six 1/100-acre plots have been measured at the Manitou Experimental Forest for 15 years (2). The plots are distributed in two batteries of three each, lying on a 17 per cent north-facing slope. Each plot is enclosed by sheet-metal baffles and at the foot of each, a series of tanks is used to collect runoff water and eroded material.

Vegetation on the plots is primarily grasses—Arizona fescue and mountain muhly—a combination typical of

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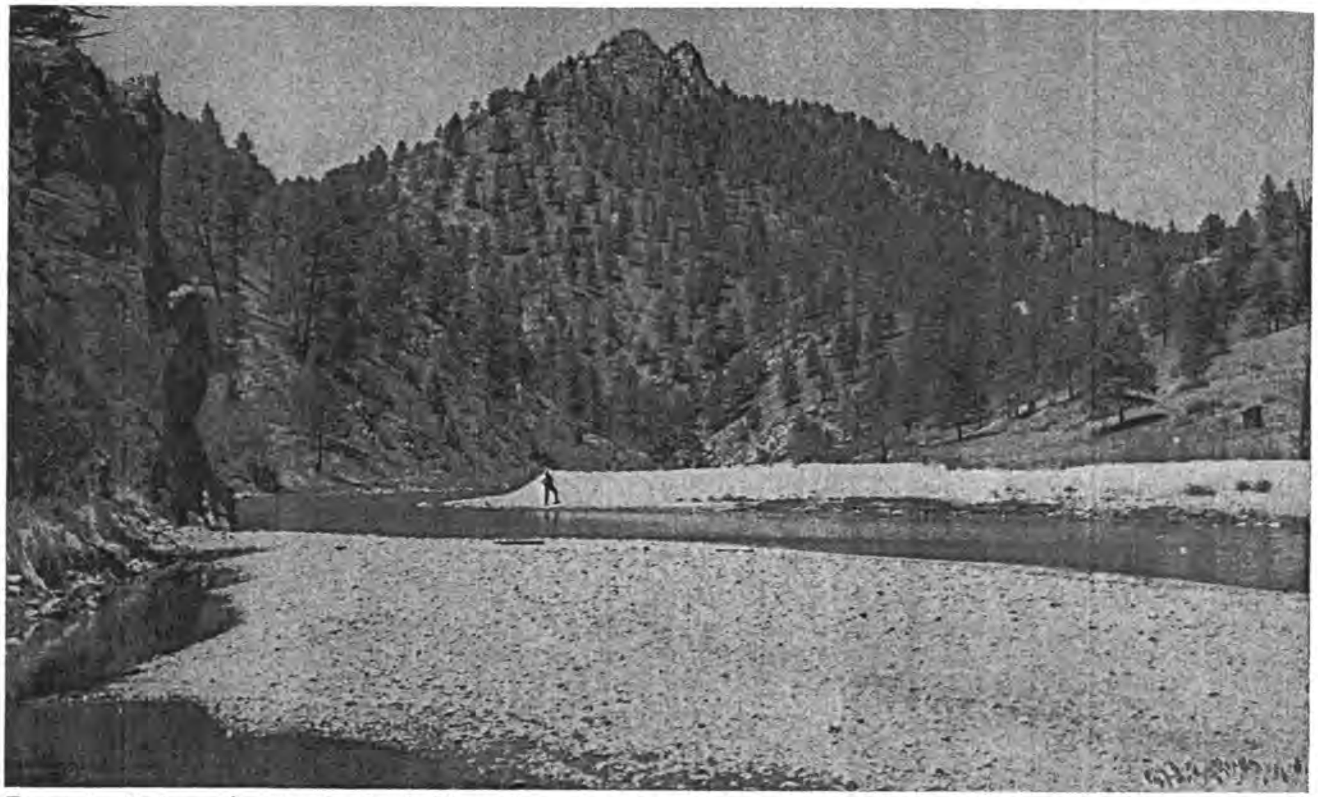

Figure 1.—Sediment bars in the South Platte River channel move downstream at the rate of about 1½ miles per year and are erosion depositions from steep slopes, gullies, and roads. (*Pike National Forest*).

most ponderosa pine-bunchgrass ranges. The relatively impermeable soil originates from a gravelly alluvium, an outwash of Pikes Peak granite.

From 1938 to 1941 the plots were not grazed so that erosion and runoff from undisturbed sites could be assessed. Following this "calibration period" a cattle-grazing treatment was applied. Two plots were heavily grazed by removing 66 per cent of the herbage, and two moderately by removing 33 per cent of the herbage. The remaining two were retained as undisturbed checks. Grazing was regulated by an adjustable electric fence and intensities judged by stubble heights.

The effect of grazing is most pronounced during the summer rainfall period—June to September, inclusive. Runoff during these months in the pretreatment period was substantially the same for all plots, indicating uniformity before disturbance. Subsequent grazing resulted in a jump from 0.14 area-inch of runoff from the check plots to 0.44 area-inch from the heavily grazed plots. Moderate grazing resulted in an average yield of 0.28 area-inch per season.

Erosion occurred almost exclusively during the months of July and August, a period of high-intensity rainstorms. During calibration the average amount of erosion during the summer period varied from 72 to 98 pounds per acre. After grazing was started no significant change occurred as a result of moderate use, but heavy use virtually doubled the normal amount—an increase to 171 pounds per acre.

Not all rainstorms cause soil erosion from the runoff plots. The average cloudburst storm causing erosion amounts to 0.96 inch of precipitation and a storm of this size is expected to occur once or twice during the summer season.

Heavily grazed plots are poorly protected against the beating action of these intense storms. More soil is dislodged and started downslope because the vegetation is not there to break the force of raindrops and the hail that is often mixed with the rain. Less water can enter the soil because absorption capacity has been lowered by trampling, reduced litter, and the sealing action of the raindrops. The result is that erosion on heavily grazed plots is more than twice the amount of that on moderately grazed and control plots (Figure 3).

The ponderosa pine—bunchgrass ranges are found on a variety of slopes and exposures in the foothill zone. Cloudburst storms capable of causing erosion and runoff occur at such unpredictable intervals that it is difficult to study their effects under the different conditions found in the pine-bunchgrass ranges. As a consequence, many of the watershed-management experiments at the Manitou Experimental Forest and elsewhere in the foothill zone have included the application of rainfall in controlled amounts to small plots which are enclosed by metal frames. These frames, 2.5 square feet in size, can be installed quickly and moved about to study a variety of conditions. Both the rainfall applied, and the amount of surface runoff and erosion occurring, are measured at definite intervals. The difference between the rain applied and the measured runoff provides the infiltration or water-absorption rate of the soil. The amount of erosion measured gives the relative erodibility of the soil surface under different conditions of vegetation cover, slope, and exposure (1).

Initial plot studies of this nature compared surface runoff and erosion under two rainfall intensities on three plant-cover types on two soils (4). Rainfall was applied to plots enclosed by a metal frame 1/200 acre in size for a 30-minute period. Both water applied and runoff were measured at 3-minute intervals; soil material eroded during the 30-minute period was collected, air-dried, and weighed to determine the amount of erosion on each plot. Table 1 summarizes the results of these studies.

Table 1.—Comparison of surface runoff and erosion on three plant-cover types

Cover and soil type	Rain intensity	Surface runoff	Erosion per cubic foot of runoff
	in./hr.	*cu. ft.*	*Grams*
Abandoned field on alluvial soil	2	7.8	233.3
	4	24.1	172.6
Bunchgrass on alluvial soil	2	6.5	64.8
	4	19.4	66.7
Bunchgrass on residual soil	2	2.0	111.3
	4	8.2	105.3

Runoff was greatest on the abandoned field, intermediate on the bunchgrass on alluvial soil, and least on the bunchgrass on residual soil. An increase in rainfall intensity from two to four inches per hour more than tripled the surface runoff for all types. The differences between the cover types were real and were not ascribed to chance.

Erosion was most rapid on the abandoned field, intermediate on the bunchgrass on residual soil, and least on the bunchgrass on alluvial soil. The total volume of eroded material increased with increased rainfall intensity, but the amount of material carried per cubic foot of runoff showed no significant change. The differences between the cover types were not due to chance variations of cover and soil.

It was concluded from these studies that where a good plant cover prevailed on the coarse, porous soils, surface runoff and erosion would be greatly lessened. With this

Figure 2.—Rough, broken lands of the foothill zone are the flood and sediment-source areas of the Colorado Front Range. (*South Boulder Creek*)

information as a background, more extensive studies were undertaken to determine the relative infiltration and erosion rates of different vegetation types growing on soils derived from a variety of geological materials.

Infiltration, or water-absorption and erosion studies, follow the procedures described in a bulletin by Dortignac (1) and by Wilm (9) (Figure 4). The water-absorption rates, expressed in inches per hour, are the average rates for the last 20 minutes of a 50-minute infiltration run. Generally, plots are prewetted and the soils allowed to drain for 12 to 24 hours before the run is made. Erosion rates are determined by collecting the total amount of soil materials moving off the plots, oven-drying this amount, and expressing the result in pounds per acre per inch of surface runoff.

It is quite common in the foothill portion of the Colorado Front Range for water to run off the land surface in a flashy type of flow, bringing with it heavy loads of sediment and leaving depleted eroded sites. Two factors cause this. One is the high intensities often reached in rainstorms and the other is the inadequacy of vegetative cover. Man's use of the land, of course, greatly modifies and often deteriorates the protective influence of the vegetation. Aside from these modifications, wide variations exist in natural protective qualities. This has been borne out by infiltration and erosion studies made on three vegetation types growing on soils derived from granite.

A summary of the results of this study follows:

Vegetation type	Range in slope	Average infiltration rate	Average erosion rate[1]
	Percent	*Inches/hour*	
Aspen	9-41	4.30	16
Ponderosa pine	9-39	3.14	557
Mountain brush	24-56	3.22	2,356

[1]Expressed as pounds per acre per inch of surface runoff.

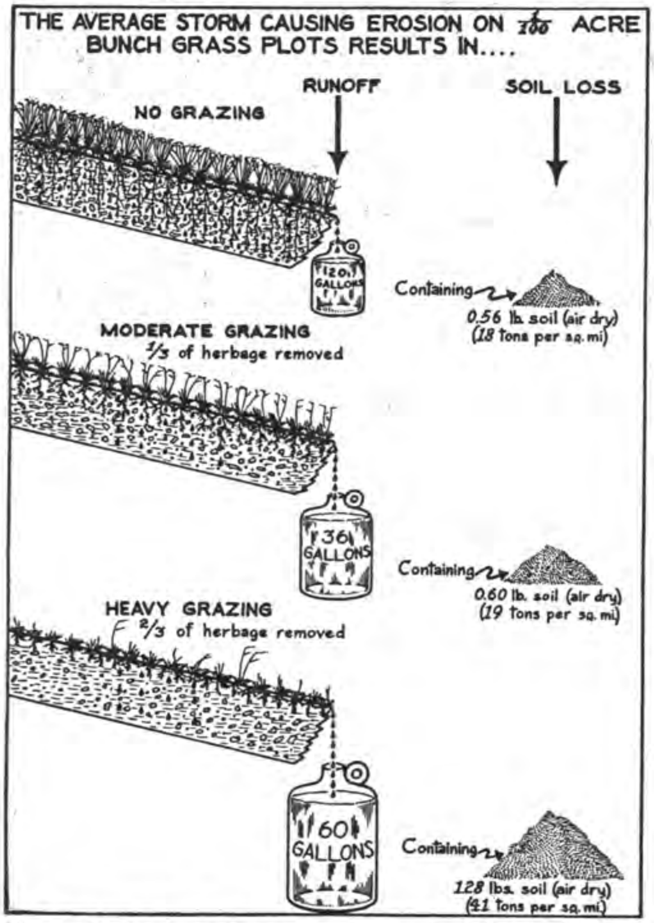

Figure 3—Intense rainstorms cause more soil loss and runoff on heavily grazed plots. (*Manitou Experimental Forest*)

The aspen type, by virtue of its high infiltration rate and low erosion rate, provides superior watershed protection. The ponderosa pine type, although having a moderately high infiltration rate, has also an accelerated erosion rate which is not as serious as that found on the mountain-brush type. Infiltration rates of the mountain-brush type are moderately high, but the runoff which does occur moves large quantities of soil. Unlike the other two types, the ground surface is not well protected by plants or litter, often consisting only of a bare gravel pavement from one to two inches thick. It is capable of absorbing water rapidly due to its gravelly nature, but is highly erodible even when small surface flows of water occur. These studies show that, among the three types studied, mountain brush provides the poorest watershed protection, ponderosa pine is intermediate, and aspen is the best.

A similar study was carried out in three intermixed vegetation types on soils developed from granitic alluvial materials. These soils differ from those of the previous study in that they are of finer texture and exhibit definite profile characteristics (7). The infiltration plots were not prewetted before the infiltration runs were made, rather a complete "dry" run was conducted first, followed by a "wet" run on the same plot 15 to 24 hours later. The dry run deals with conditions similar to those encountered when a rainstorm occurs on a dry soil, while a wet run deals with conditions found in a wet soil. Such studies are of significance since it has been observed that the greatest amount of surface runoff occurs from rainstorms which follow each other by a period of 24 to 36 hours (8). In this case the water-storage capacity of the soil has been reduced by the amount of water absorbed during the first storm, thus limiting the amount that can be absorbed from the ones that follow.

The results of this study are summarized below:

Vegetation type	Average slope	Average infiltration rate		Average erosion rate[1]	
		Dry Run	Wet Run	Dry Run	Wet Run
	Percent	*in./hr.*			
Ponderosa pine—litter	16	2.22	2.07	209	161
Ponderosa pine—grass	9	2.13	1.96	160	139
Grassland	8	2.00	1.59	249	222

[1]Expressed as pounds per acre per inch of surface runoff.

The infiltration rates are greater during the dry runs

Figure 4.—Rocky Mountain infiltrometer used to apply rain to small plots to obtain rates of water absorption, runoff, and erosion under different conditions of vegetation, soil, and use. (*Manitou Experimental Forest*)

Figure 5.—These infiltrometer plots show that different "plant-soil complexes" have different surface erosion and runoff characteristics as exhibited by the protection they provide the soil surface. (*Manitou Experimental Forest*). Left to right Ponderosa pine—litter on granitic alluvial soils, Ponderosa pine—grass on granitic alluvial soils, and Grassland on granitic alluvial soils.

than during the wet runs, indicating a greater capacity of the soils to absorb water under dry conditions. The greatest difference occurs in the grassland which does not have a heavy pine needle litter cover to facilitate the absorption of water.

The difference between the erosion rates for the dry and wet runs does not necessarily mean that more erosion occurs during dry soil conditions. True, the rate is higher but the amount of runoff is less because of the higher infiltration rates. More total surface erosion will occur under wet soil conditions than under dry, since there is more surface runoff to move the soil materials. The higher erosion rate observed during the dry runs appears to be due to the looseness of the surface soil particles and to their initial resistance to wetting. Once wetted, the surface soil particles appear more firmly fixed and are less subject to transportation by water.

Not only do the major inherent characteristics of vegetation types influence infiltration and erosion rates, but also the condition of the vegetation found within a type exerts an effect. For example, infiltrometer studies in a grassland growing on soils derived from a mixture of granite and schist show distinct differences in infiltration and erosion rates under different conditions of forage production (6). The infiltration rate of the plots in good forage condition was 118 per cent greater than on plots in very poor, 80 per cent greater than plots in poor condition and 35 per cent greater than plots in fair condition. Likewise, the erosion rate on the plots in good condition was about one-fourth that from the plots in very poor condition, and about half that from plots in fair condition.

The results of this study in a grassland on soils derived from a mixture of granite and schist are tabulated below.

Forage condition class	Average infiltration rate	Average erosion rate[1]
	in./hr.	
Good	2.22	166
Fair	1.64	269
Poor	1.23	699
Very poor	1.02	528

[1]Expressed as pounds per acre per inch of surface runoff.

It is apparent from this study that a good grass cover from the standpoint of forage production also gives the best watershed protection.

Soil characteristics occasionally overshadow the influence of forage condition on infiltration and erosion rates. For example, infiltration studies of a grassland growing on soils derived from biotite schist gave the following results (6):

Forage condition class	Average infiltration rate	Average erosion rate[1]
	in./hr.	
Excellent	0.88	93
Good	1.30	152
Fair	1.77	1,531
Poor	2.06	1,327

[1]Expressed as pounds per acre per inch of surface runoff.

It is obvious that the excellent and good forage conditions excell in the control of erosion, even though they have lower infiltration rates than the fair and poor conditions. Upon analysis of the factors governing the infiltration rates of these soils, it was found that the amount of clay in the subsoil (three to seven inches) accounted for 70 per cent of the variation between the plots. The plots in both the excellent and good forage condition contained more clay in the subsoil than the plots in fair and poor forage condition.

In general, infiltration studies provide the relative infiltration and erosion rates between different vegetation types and between different conditions within the types. They also correlate these rates with soils developed from different geologic materials. The extent of individual "plant-soil complexes" within a particular drainage basin determines the characteristics of the basin with regard to surface erosion and runoff. For example, a drainage basin covered with a grassland growing on soils derived from biotite schist will have different surface erosion and runoff characteristics than a similar basin which is covered with a grassland growing on soils derived from granite. Infiltration studies provide information on the surface erosion and runoff characteristics of the different "plant-soil complexes" and are helpful in determining the reaction of different drainage basins to cloudburst storms of varying amounts and intensities (Figure 5).

The Value of Watershed Management

The infiltration studies in the foothill zone, together with other studies at the Manitou Experimental Forest (5), all show the need for careful use of the forage and forest resources. Excessive removal of the native vegetation exposes the highly erodible granitic and schist soils, and when coupled with intense cloudburst storms, results in damaging floods and destructive sedimentation.

The point at which vegetation can lessen floods and at the same time hold the soil in place is the critical point in watershed management. It becomes more critical when a certain portion of the vegetation is used for economic reasons. The determination of the degree to which vegetation can be used and still be effective in curtailing damaging floods is the objective of watershed-management research. It is the key to the wise use of the foothills of the Colorado Front Range.

Watershed management is closely associated with other uses of the foothill zone, particularly grazing by livestock and the harvesting of timber. For example, based on current market values, the annual return to ranch income is 45 cents per acre more for moderate grazing use than from heavy grazing use as practiced in the experimental pastures at the Manitou Experimental Forest (10). The maintenance of the productivity of the moderately grazed pastures depends upon the maximum absorption of water and the minimum of surface erosion. Here watershed management makes its contribution to range production at the same time that the watershed itself is improved.

LITERATURE CITED

1. E. J. Dortignac. *Design and operation of Rocky Mountain infiltrometer.* Station Paper No. 5. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 1951.
2. E. G. Dunford. *Relation of grazing to runoff and erosion on bunchgrass ranges.* Research Note No. 7. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 1949.
3. N. M. Fenneman. *Physiography of western United States.* First edition. McGraw-Hill Book Company. 1931.
4. W. M. Johnson and C. H. Niederhof. *Some relationships of plant cover to runoff, erosion, and infiltration on granitic soils.* Jour. Forestry 39: 854-858. 1941.
5. L. D. Love and W. M. Johnson. *The Manitou Experimental Forest—its work and aims.* Station Paper No. 7. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 1952.
6. E. H. Reid and L. D. Love. *Range-watershed conditions and recommendations for management, Elk Ridge and Lower Elk Ridge cattle allotments, Roosevelt National Forest, Colorado.* Forest Service, U. S. Dept. of Agriculture. Mimeographed. 1951.
7. J. L. Retzer. *Soils and physical conditions of the Manitou Experimental Forest.* Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Mimeographed. 1949.
8. Supplemental Report, Missouri River Basin Agricultural Program. House Document No. 530, 82nd Congress, 2nd Session. Government Printing Office, Washington, D. C. 1952.
9. H. G. Wilm. *The application and measurement of artificial rainfall on types FA and F infiltrometers.* Trans. Amer. Geophys. Union Part II, 480-486. 1943.
10. 1952 Annual Report—Does Research Pay? Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Processed. 1953.

First, and most essential, we must know the physical realities which we face. Too long we have reckoned our resources in terms of illusion. Money, even gold, is but a metrical device. It is not the substance of wealth. Our capital is the accumulation of material and energy with which we can work. Soil, water, minerals, vegetation, and animal life—these are the basis of our existence and the measure of our future.

—PAUL B. SEARS