Some Relationships of Plant Cover to Run-off, Erosion, and Infiltration on Granitic Soils

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The fact that plant cover influences run-off, erosion, and infiltration has been firmly established by past research. Only under a few special conditions, however, has the degree of this influence been determined quantitatively. The study reported in this article was undertaken to secure a usable measure of this quantitative relationship, and to provide data for watershed management in the mountains of Colorado. With the use of small plots, results have been secured which evaluate plant cover as a watershed factor and at the same time demonstrate that under certain circumstances, soil conditions may overshadow and nullify the effects of vegetation.

PLANT species, types, and densities which regulate run-off and erosion most satisfactorily on a given watershed can be determined only by detailed research over a considerable period of time. Indicative results can be obtained rather quickly, however, by use of small temporary plots to which moisture may be applied artificially. While the results from these plots cannot be considered absolute in terms of large watersheds, they can be used very effectively in quantitatively comparing plant species, types, and densities as watershed factors.

As a preliminary step in a comprehensive watershed management research program on the headwaters of South Platte River in Colorado, the small plot approach was adopted as desirable and necessary to secure immediate quantitative results. Beginning in 1936, therefore, a series of studies using small plots was started. These studies were designed to measure directly the influence of plant type and rainfall intensity on rate of surface run-off and erosion and the effect of individual plant species on the infiltration capacity of the soil. The results obtained, though inconclusive in some respects, are convincing evidence that certain plant species and associations have more effect than others on infiltration, run-off and erosion, and that the effectiveness of any species or type is greatly influenced by soil conditions.

Area Studied

The studies were conducted near Woodland Park, Colorado, at an elevation of about 7,600 feet. Precipitation in this locality averages about 18 inches per year. It occurs largely in the form of rain, with approximately three-fourths of the total moisture falling between April 1 and September 30. Snowfall is occasionally important as a source of spring run-off.

The predominant plant cover is ponderosa pine, with numerous large open parks on both the slopes and along the valley bottoms. The more favorable sites in the valleys have at one time been under cultivation, but at present are abandoned and reverting to a cover of mixed weeds, grass, and browse. The predominant species on the abandoned fields are aster (*Aster* sp.), sunflower (*Helinanthus petiolaris*), and sleepy grass (*Stipa robusta*). The area surrounding the abandoned fields is occupied by native bunchgrass and is designated in this study as the valley bunchgrass type. The predominant species in this type are mountain muhly (*Muhlenbergia montana*), Arizona fescue (*Festuca arizonica*), and fringed sagebrush (*Artemisia frigida*). The vegetation in the mountain bunchgrass type which occupies the parks on the steeper slopes is similar in composition to the valley bunchgrass type, with the same grass and browse species predominating. All studies were confined to these natural park-like areas in the abandoned field, valley bunchgrass, and mountain bunchgrass types.

In order to help minimize the effect of factors other than vegetation, only plots having the same degree of slope were selected within a given type. In both the abandoned field and valley bunchgrass types, slopes of 10 percent were studied since they most nearly represent the average slope condition, while slopes of 40 percent were studied in the mountain bunchgrass type.

The soils of the area are derived chiefly from granite, but remnants of limestone and sandstone formations have contributed some of the finer soil particles. The soils are highly erodible, very porous, and unusually coarse textured. The sand and gravel components (particles over 0.05 mm.) comprise 66 percent of the soil in the abandoned field type, 76 percent in the valley bunchgrass type, and 83 percent in the mountain bunchgrass type.

[1]Maintained by Forest Service, Department of Agriculture, in cooperation with Colorado State College of Agriculture and Mechanic Arts in Fort Collins, Colo.

Methods and Equipment

Surface run-off and erosion.—To determine the influence of plant cover types on surface run-off and erosion, equipment was used which simulated natural rainfall on 1/200-acre plots.[2] Metal baffle plates delineated the boundaries of the plot (6.6 by 33 feet) and at the lower end of each a collector trough conducted surface run-off to a tank where eroded material was deposited. Run-off was measured by a recording tipping-bucket gage. Rainfall was applied by sprinkler pipes on each side of the plot and measured by four standard rain gages and one tipping-bucket recording rain gage. A rainfall rate of two inches per hour was applied to approximately one-half of the plots selected in each type. The remaining plots received a rainfall rate of four inches per hour. On all plots the water was applied for a 30-minute period.

An estimate of plant cover density was made on each plot by the "point-observation" method,[3] and a soil sample was taken on each side of the plot for subsequent mechanical analysis. These samples consisted of the surface inch of soil taken from three holes within a radius of five feet to form one composite sample. Material eroded during each test was collected, air dried, and weighed to determine the amount of erosion on each plot.

In the analysis of surface run-off and erosion the data were grouped by rainfall intensities and plant cover types. The average run-off in cubic feet and the average erosion in grams per cubic foot of run-off were determined for each type and intensity of rainfall. Both surface run-off and erosion were then analyzed by the variance method[4] using two rainfall intensities and three plant cover types. An analysis of the soil was made to determine the percent of sand and gravel, silt and clay, and colloids.

Infiltration.—The influence of individual plant species on the infiltration of water into the soil was studied on plots located by a system of 50-foot rectangular coordinates in each of the three plant types. A square-foot plot containing the individual species to be studied was selected within a radius of 10 feet from each coordinate intersection. The density of the plant species on each plot was estimated by the "point-observation" method. Within a given plant type, plots occupied by bare soil were selected in a similar manner for comparison with vegetated plots.

The equipment used for studying infiltration consisted of a metal plot frame one foot square, fitted with a feeder pipe along the inside of the upper wall and with a collector trough forming the opposite wall. From a reservoir attached to the feeder pipe, water was applied to each plot for 30 minutes in quantities sufficient to produce run-off. Both water applied and run-off were measured at 3-minute intervals, the difference between the two representing infiltration.

The infiltration for each 3-minute period was totaled for all plots characterized by a given plant species and the average infiltration rate calculated for each period and condition. The infiltration rates for the ten 3-minute periods were plotted and a free-hand curve fitted to the plotted points. In nearly all cases the curve flattened off after about 21 minutes, showing that in the last 9 minutes the infiltration rate remained about uniform. Infiltration in inches per hour for the last 3-minute period was used in the analysis to represent the constant minimum infiltration capacity.

The infiltration data were tested statistically to determine the significance of differences between the following conditions: individual plant species versus bare soil within cover types, bare soil between years, and individual plant species between years. In addition, a simple correlation analysis was made to ascertain the relation of plant density to the infiltration capacity of soil.

Results and Discussion

Run-off.—The volume of surface run-off differed considerably between the two rainfall intensities and the three plant cover types (Table 1). Run-off was greatest on the abandoned field type, intermediate on the valley bunchgrass, and least on the mountain bunchgrass type (Fig. 1). An increase in rainfall intensity from two to four inches per hour more than tripled the surface run-off for all three types. The variance analysis showed these differences to be highly significant in all cases.

The fact that surface run-off from the mountain bunchgrass plots on a 40 percent slope was less than from the other two types on 10 percent

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[2] Pearse, C. Kenneth. Specifications for the construction and operation of a portable apparatus for measuring surficial run-off and erosion. Intermountain Forest and Range Experiment Station, Mimeo. March, 1936.

[3] Stewart, George and S. S. Hutchins. The point-observation plot method of vegetation survey. Jour. Amer. Soc. Agron. 28. 1936.

[4] Snedecor, G. W. Statistical methods. Collegiate Press, Inc. Ames, Iowa. 1938.

slopes can be explained by characteristics of the soil. The plots on the steeper slopes had significantly more sand and gravel and less silt, clay, and colloids than the plots on the gentler slopes (Table 1). Since the coarser particles in this soil should tend to increase infiltration, the logical assumption is that soil conditions obscured the effects of slope. This assumption is strengthened by a porosity study which revealed that on the steeper slopes the non-capillary pore space was 7.55 percent compared to only 1.35 on the gentler slopes in valley bunchgrass.

Plant density influenced run-off in this study only where abandoned fields and valley bunchgrass plots were compared. When the mountain bunchgrass plots were introduced it was again apparent that conditions of the soil overshadowed not only the effects of slope but also the effects of plant density. The relation of plant densities to run-off within types was the subject of a separate analysis which failed to reveal any correlation. Apparently the range of density which was possible to include in this study was not sufficiently pronounced to overcome the natural soil variations between plots in the same type.

Erosion.—Erosion was found to be most rapid on the abandoned fields, intermediate on the mountain bunchgrass, and least on the valley bunchgrass type. Variance analysis showed these differences in erosion rates between types to be highly significant. The total volume of eroded material naturally increased with increased intensity of rainfall, but the amount of eroded material carried per cubic foot of run-off showed no significant change.

The highest rates of erosion on the abandoned field type were probably due to two reasons: first, the nature of the soil, which is composed of a larger quantity of easily erodible fine particles such as silt and clay; second, the density of the plant cover which was somewhat less than in the other two types (Fig. 1).

The mountain bunchgrass type, which produced the least surface run-off, was intermediate in the rate of erosion per cubic foot of surface run-off. Although the soil in this type is very coarse and highly porous, the relatively greater erosion when compared with the valley bunchgrass type may be accounted for by higher velocities of overland flow caused by the steepness of the slope. The density of plant cover occupies an intermediate position when compared with the other two types, and probably exerts an intermediate effect on erosion in comparison with the plant cover in the other two types.

Of the three types, valley bunchgrass had the lowest erosion rate per cubic foot of run-off. Although the soil is finer than that of the mountain bunchgrass type, it did not erode as rapidly; probably due to the reduced velocity of run-off on the gentler slopes, and possibly by the slightly higher plant density. In comparison with the abandoned field type, the valley bunchgrass type has a coarser soil and greater plant density; both of these factors apparently account for the lower rate of erosion in the valley bunchgrass type.

Infiltration.—The infiltration rates of soils supporting 14 dominant plant species and their comparison with similar and adjacent bare soils are presented in Table 2. Of the ten plant species studied in the abandoned field type, only the soil supporting Pentstemon (*Pentstemon unilateralis*) showed a significantly higher infiltration capacity than bare soil. In contrast, soil supporting prostrate knotweed (*Polygonum aviculare*) showed significantly lower absorption rates than comparable bare areas. The effect of the remaining eight species was not significant in either direction.

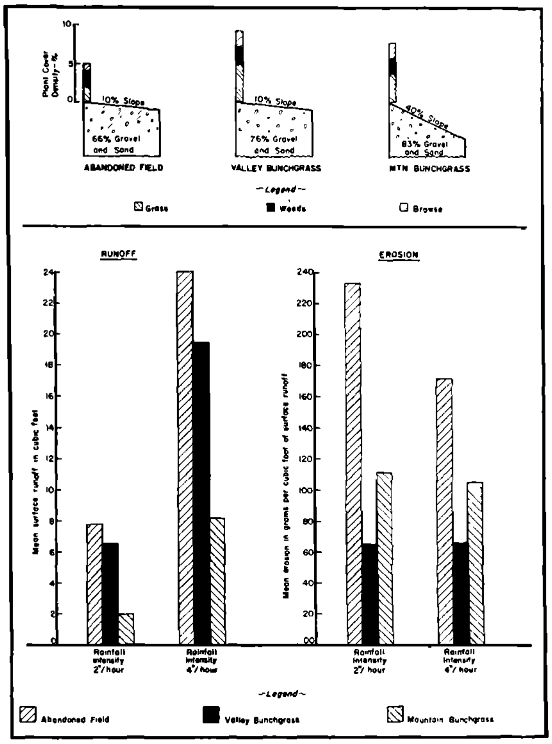

Fig. 1.—Run-off and erosion statistics for three plant types.

TABLE 1.—COMPARISON OF SURFACE RUN-OFF AND EROSION WITH DIFFERENT RAINFALL INTENSITIES AND SOIL FACTORS ON THREE PLANT COVER TYPES

Cover type	Rain intensity	Number of plots	Surface run-off	Erosion per cu. ft. of run-off	Soil components: Sand and gravel	Silt and clay	Colloids	Plant density
	In. per hr.	*No.*	*Cu. ft.*	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*
Abandoned field	2	20	7.8	233.3	66	34	17	4.8
	4	16	24.1	172.6				
Valley bunchgrass	2	24	6.5	64.8	76	24	10	9.2
	4	25	19.4	66.7				
Mountain bunchgrass	2	24	2.0	111.3	83	17	7	7.7
	4	23	8.2	105.2				

TABLE 2.—INFILTRATION RATES FOR VARIOUS PLANT SPECIES AND THEIR COMPARISON WITH BARE SOIL

Condition	Year	Plots	Infiltration capacity	Standard error[1]	Plant[2] species vs. bare soil	"t"[3]
		No.	*In./hr.*	*In./hr.*	*In./hr.*	
Abandoned fields						
Hordeum jubatum	1937	18	1.66	0.18	—0.15	0.575
Agropyron pauciflorum	1937	18	1.45	0.22	—0.36	1.270
Stipa robusta	1937	18	1.61	0.13	—0.20	0.910
Artemisia canadensis	1937	18	2.00	0.18	+0.19	0.740
Artemisia frigida	1937	18	1.93	0.30	+0.12	0.364
Bare soil	1937	18	1.81	0.18	....	....
Polygonum aviculare	1938	30	2.03	0.13	—0.64	2.331[4]
Pentstemon unilateralis	1938	30	4.32	0.31	+1.65	4.167[5]
Helianthus petiolaris	1938	30	2.36	0.21	—0.31	0.950
Cirsium undulatum	1938	30	2.51	0.25	—0.16	0.458
Astragalus sp.	1938	30	2.42	0.27	—0.25	0.671
Bare soil	1938	30	2.67	0.24	....	....
Valley bunchgrass						
Muhlenbergia montana	1937	36	2.36	0.12	+0.56	2.906[5]
Festuca arizonica	1937	31	1.88	0.15	+0.08	0.124
Bare soil	1937	31	1.80	0.15	....	....
Grama (sub-type)						
Bouteloua gracilis	1937	30	1.81	0.12	—0.46	2.618[4]
Bare soil	1937	30	2.27	0.13	....	....
Mountain bunchgrass						
Arctostaphylos uva-ursi	1938	17	9.67	1.01	....	....
Festuca arizonica	1938	30	6.00	0.70	....	....
Muhlenbergia montana	1938	31	3.16	0.28	....	....

[1]Standard error of the mean infiltration rate.
[2]This comparison is expressed as the difference between infiltration capacities of soil occupied by the plant species and bare soil.
[3]Differences were tested for their significance by Student's "t" test.
[4]Significant.
[5]Highly significant.

In the valley bunchgrass type, mountain muhly caused a significant increase in the infiltration capacity of the soil, while Arizona fescue showed no appreciable influence. Blue grama significantly decreased absorption rates. Apparently plant cover such as blue grama sod when present on soils with naturally high infiltration rates tends to create conditions which decrease the rate at which water is able to enter the soil.

Infiltration data for the soil in the mountain bunchgrass type show very high absorption rates, supporting results from studies of surface run-off by larger plots. Soil supporting Manzanita (*Arctostaphylos uva-ursi*) had the highest rate of infiltration of any species tested; more than twice as great as the highest rate in the abandoned field type. It is very probable that the higher infiltration rates in this type are not due to the effect of the plant cover, but principally to the greater porosity of the soil. No studies were made of the infiltration capacity of bare soil in this type.

Data from all the plots were combined in a correlation analysis which indicated that, under the conditions of this study, there was no significant relationship between plant density and the infiltration capacity of the soil. The lack of relationship may be due to the small range of plant densities encountered within the types, together with the extremely coarse, porous soil which tends to minimize the effect of plant cover on infiltration.

Summary

Beginning in 1936 a study was made of surface run-off and erosion as affected by rainfall intensity and plant types, and of the effect of individual plant species on the infiltration capacity of the soil.

The study was made on the watershed of the South Platte River in central Colorado. Artificial rainfall was applied to plots, 1/200 of an acre in size, to study surface run-off and erosion. Smaller plots were used to determine the effect of individual plant species on the infiltration capacity of the soil.

For the three plant cover types studied it was found that:

1. The abandoned field type produced the most run-off, the valley bunchgrass an intermediate amount, and the mountain bunchgrass the least. This was true of rainfall intensities of both two inches and four inches per hour.
2. Within each of the three types studied, plant density seemed to have no definite effect on surface run-off or infiltration. This was probably due to the extreme coarseness of the soil, which in effect far overshadowed the influence of plant cover.
3. The volume of erosion per cubic foot of run-off was greatest on the abandoned field, intermediate on the mountain bunchgrass and least on the valley bunchgrass type. When the rainfall intensity was raised from two to four inches per hour the run-off increased, thereby increasing the total amount of erosion although the eroded material carried per cubic foot of run-off did not significantly increase. Porous soil, gentle slopes, and a high plant cover density all combine to decrease erosion such as in the valley bunchgrass type where the least erosion occurred and where the soil is coarse, slopes are gentle, and density of the plant cover was the highest of the three types studied.
4. Of the 14 plant species compared to bare soil, two species increased the infiltration capacity of the soil, two species decreased it, and ten species had no significant effect.

Pennsylvania Game Commission Big Landowner

The Pennsylvania Game Commission announced on July 16 that it now owns 664,171 acres of land, and has under contract for purchase 45,000 acres more. Both state game funds and federal aid funds are being used for these purchases.