INFLUENCE OF FOREST LITTER ON RUN-OFF, PERCOLATION, AND EROSION

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THE object of the studies described in this paper was to determine:

1. The factors which influence the division of rainfall into surficial run-off and percolated water.
2. The effects of surficial run-off on soil erosion under certain conditions.

The work is a continuation and elaboration of certain studies conducted by the writer in northern China from 1924 to 1926, and forms a part of the program of the California Forest Experiment Station. The results will later be presented in more detail.

DEVIL CANYON PLOTS

Two pairs of surficial run-off plots, with an area of 1,000 square feet per plot, were installed in 1927 in Devil Canyon, San Bernardino National Forest, in southern California to measure the relative effects on the absorption of rain by a mountain soil covered with chaparral and one burned clean. In each case an inset border prevented the incursion of surficial run-off from outside the plot and precluded the escape of surficial run-off from the plot itself except through the aperture which led to measuring devices. Sediment traps between these and the plots made it possible to weigh accurately the eroded material. (Plate 1.)

During the season of 1927-1928, which had few run-off producing storms, the chaparral vegetation with its litter reduced both surficial run-off and erosion. Thus, the total run-off from the chaparral-covered plots was 1.2 cubic feet as against 4.4 cubic feet from the burned plots—a ratio of 1 to 3.7. Erosion from the chaparral plots amounted to 15.7 pounds of material as against 284.4 pounds from the burned plots—a ratio of 1 to 18.1.

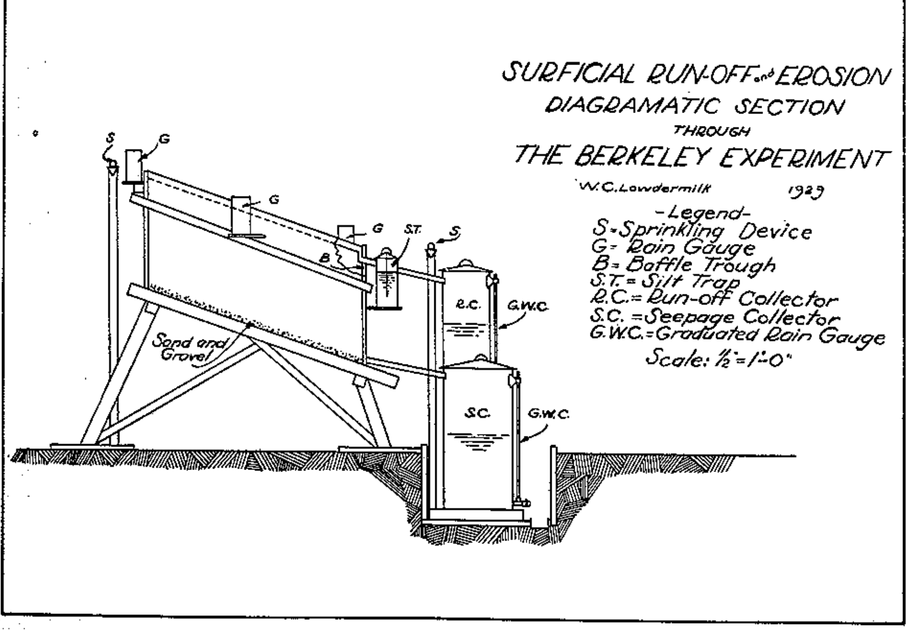
The influence of the chaparral cover and litter on surficial run-off resulting from high intensities of rain is even more striking. Thus, during the 4.34-inch storm of April 2-3, 1928, when the maximum rainfall reached a rate of 0.133 inches per 5 minutes, the 5-minute rate of run-off from the chaparral plots was 0.02 cubic feet as against 1.33 cubic feet from the burned plots—a ratio of 1 to 66.5. These installations served to check the results of the studies in China, which had indicated a hitherto unmeasured rôle of forest litter (5, 6).

BERKELEY EXPERIMENTS

Studies of run-off from plots in place were supplemented by an intensive series of experiments at Berkeley, California, to determine more definitely the relation of litter to surficial run-off. In order to isolate this factor as completely as possible it was considered necessary to eliminate as much as possible sub-surface differences in soils resulting from channels caused by decayed roots and by worm and animal burrows. Because of the greater importance of having the soils used in the experiment uniform than undisturbed, it was decided to take them up in shallow layers and then repack them by layers in their original order and approximately to their original volume.

This procedure was intended to render all conditions as nearly uniform as possible except at the surface of the soils. Differences in run-off or erosion in soil samples otherwise identical could then be attributed solely to the litter.

Figure 1.



The soils were repacked in rectangular tanks of 18-gage galvanized iron encased in reinforced wooden frames. The tanks had horizontal dimensions of 2 x 5 feet and were so built as to provide for a soil depth of 2.5 feet and a surface slope of the soil of 30 per cent. (Plate 2 and Figure 1.) The development of percolation channels between the edge of the tank and the soil was prevented by two sets of narrow flanges, one 4 inches and the second 16 inches from the soil surface. The surficial run-off was caught by a baffle trough at the lower end of the tank, was conducted from here into the sediment trap in which suspended soil particles were separated from the rising current, and thence into the run-off collector tank. The latter was equipped with a glass gage graduated in inches and tenths to permit the direct reading of water heights with a mirror.

Percolated water was collected in a layer of gravel and sand on the bottom of the tank and was conducted thence directly into the percolation tank, which had provision for measurement of water height similar to that of the run-off tank.

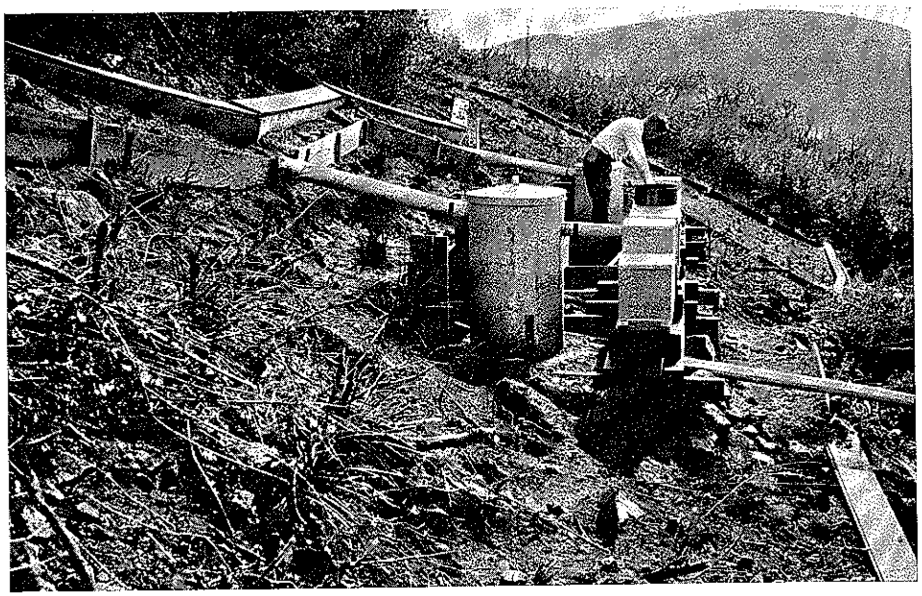


PLATE 1.—A detailed view of the instrumentation to measure rain intensities and rates of surficial run-off from chaparral-covered plots; burned plots are in the background. Baffle troughs at the end of the plots conduct the surficial run-off into pipes through a sediment trap and thence into the tipping bucket instrument which automatically records the rate of run-off. Devil Canyon, San Bernardino National Forest, Calif.

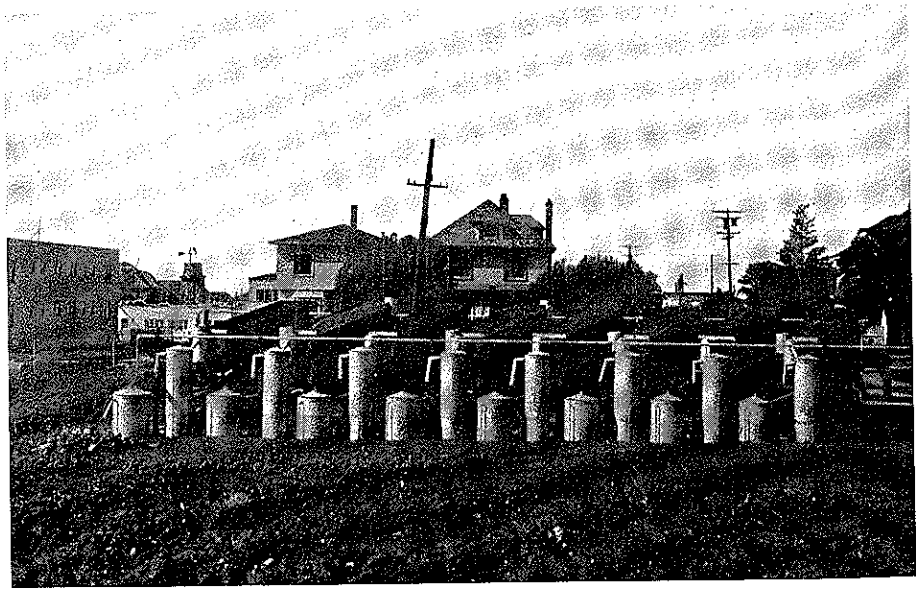


PLATE 2.—A general view of the installation to isolate and measure the influence of forest litter and duff on the surficial run-off from natural and artificial rain and the resultant effects in comparative erosion. Berkeley, Calif.

Provision was made for the rapid removal of percolated water in order to avoid possible interference from a rising water table. This made it possible to study the rôle of forest litter without the complications present on long slopes under natural conditions where a rising water table occasioned by heavy rains may sometimes play a decisive part in the effective infiltration of rain.

Provision was made to supply artificial rain by means of two horizontal 1-inch pipes fitted with special Skinner overhead sprinkling nozzles (No. 2). These nozzles were spaced at 2-foot intervals on each pipe and were so placed as to stagger the jets one foot apart. Provision was made to adjust the angle of the line of jets to varying wind velocities from east and west; adjustment for north and south winds required the sliding of the nozzle pipes either to north or south. Berkeley hydrant water was used under a pressure of approximately 60 pounds per square inch.

This installation made it possible:

1. To simulate rain in various amounts and at various intervals.
2. To measure surficial run-off.
3. To separate and measure material eroded by surficial run-off.
4. To measure percolated water.

Three widely separated soil series were selected for sampling: (1) Aiken, collected near Placerville, California; (2) unmapped Holland, collected 30 miles east of Sonora; and (3) Altamont, collected from the Berkeley Hills. The samples represented typical soil profiles covered with characteristic vegetation and were selected largely because of differences in the rate of percolation of water through them. They were collected and repacked in the experimental tanks by 1 to 4-inch layers in natural order as uniformly as possible. That substantial uniformity was obtained is shown by the results with the two pairs of supposedly identical tanks in the Altamont series which showed satisfactory agreement.

After the soils had been packed in the tanks, forest litter which had covered the respective soils in nature was placed on the surfaces. The soils were then permitted to settle during the rainy period from November, 1927, to March 8, 1928, when the experiment was begun. The natural layers of forest litter averaged approximately 2 inches thick.

The litter on the odd-numbered tanks was burned off clean with a Hauck torch before the application of artificial rain. Except for this, as far as could be foreseen, conditions were uniform within each pair of tanks. Since the experiment was designed to study only the influence of forest litter, apart from other factors, on the division of rain into surficial run-off and percolated water, the results are not directly applicable to percolation rates for a watershed.

The tanks were numbered as follows:

Tank number	Soil	Surface condition
I	Aiken sample from Placerville	Burned
II		Unburned
III	Holland sample from Stanislaus N. F.	Burned
IV		Unburned
V	Altamont sample from Strawberry Canyon, Berkeley Hills	Burned
VI		Unburned
VII		Burned
VIII		Unburned

Artificial rain was applied in series of ten rains of equal duration according to the schedule shown in Table 1. Natural rain also occurred on the dates indicated in this table. A period of one or two days after natural rain was allowed for its seepage fraction to leave the tanks.

Both natural and artificial rain was measured in nine rain gages located systematically over the installation. These gages were checked for accuracy by calibration. No difficulty was encountered in the measurements of natural rain, which may be assumed to have fallen at uniform depths over all the tanks. Gusty and changeable winds on some days caused irregular depths of artificial rain over the tanks. The wind often changed between reading intervals of two hours and required a new adjustment of the nozzle pipe manifold. It is also possible that the individual jets, which were shot 15 to 20 feet into the air, did not entirely lose their identity, although the application was uniform as far as could be determined by observation.

TABLE I

SCHEDULE OF RUNS OF ARTIFICIAL RAIN ON SURFICIAL RUN-OFF SEEPAGE TANKS, 1928

Series	Duration of each run	No. of runs	Dates of runs	Approx. total rain in inches
A	Irregular (trial runs)	2	March 8–10	7.0
B	1 hour	10	March 14–26 (Rain, March 22–23)	15.0
C	2 hours	10	March 8–April 13 (Rain, Apr. 1–3, 14–18)	26.0
D	4 hours	10	April 20–May 6	44.0
E	8 hours	10	May 7–May 30	78.0
F	½ hour	10	June 5–June 25	7.5
G	1½ hours	10	July 12–Aug. 6	21.0
				198.5
Natural rain				
			March	3.60
			April	1.71
			May	0.37
				5.68

In order to determine the depth of artificial rain, blue print plans of the tank installation were made to exact scale to show the projection surface of each tank and the location of each gage (Figure 2). The rainfall was determined separately for each run by recording the catch of each gage and drawing isohyetal lines through calculated interval points on the triangulation lines between the gage installations. The isohyetal interval was placed at 0.2 inch. The area of each isohyetal zone was planimetered and the total average depth of rain for each tank determined on an area basis. In subsequent experiments it will prove advisable to measure the amounts of artificial rain by rain troughs on each side of the tanks. These will integrate the total fall with greater accuracy and certainly with less calculation than a series of circular rain gages.

COMPARATIVE SURFICIAL RUN-OFF

The surficial run-off following artificial rain is shown in detail in Tables 2-5. In addition, graphs have been prepared for each soil and each series of artificial rain showing the cumulative

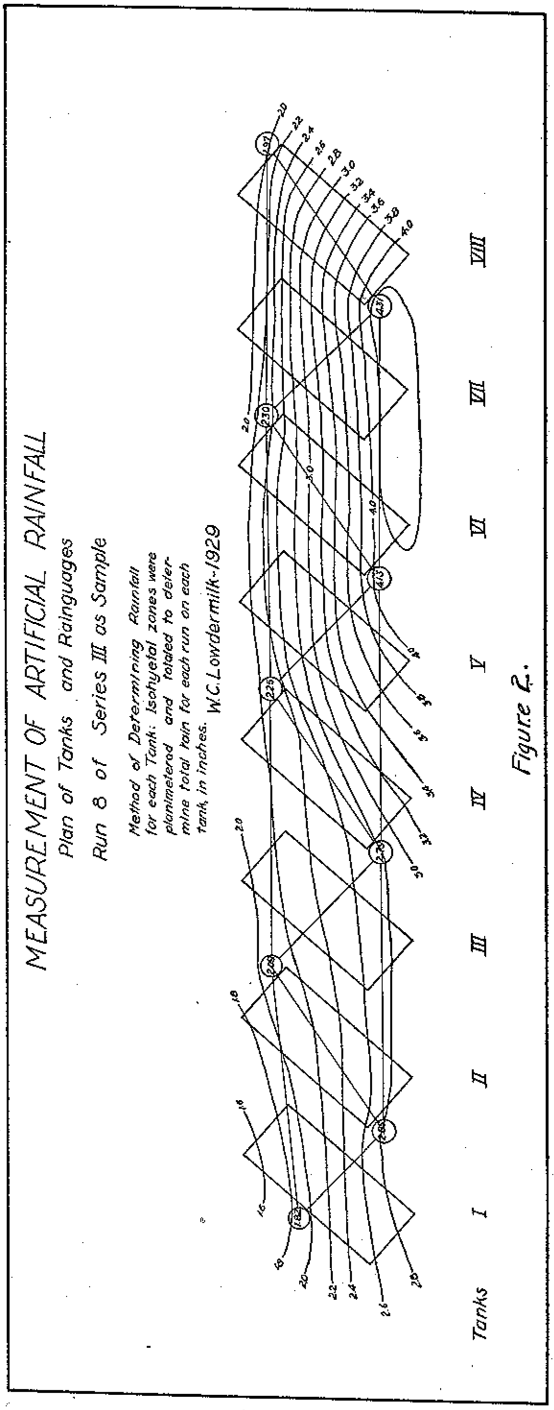


Figure 2.

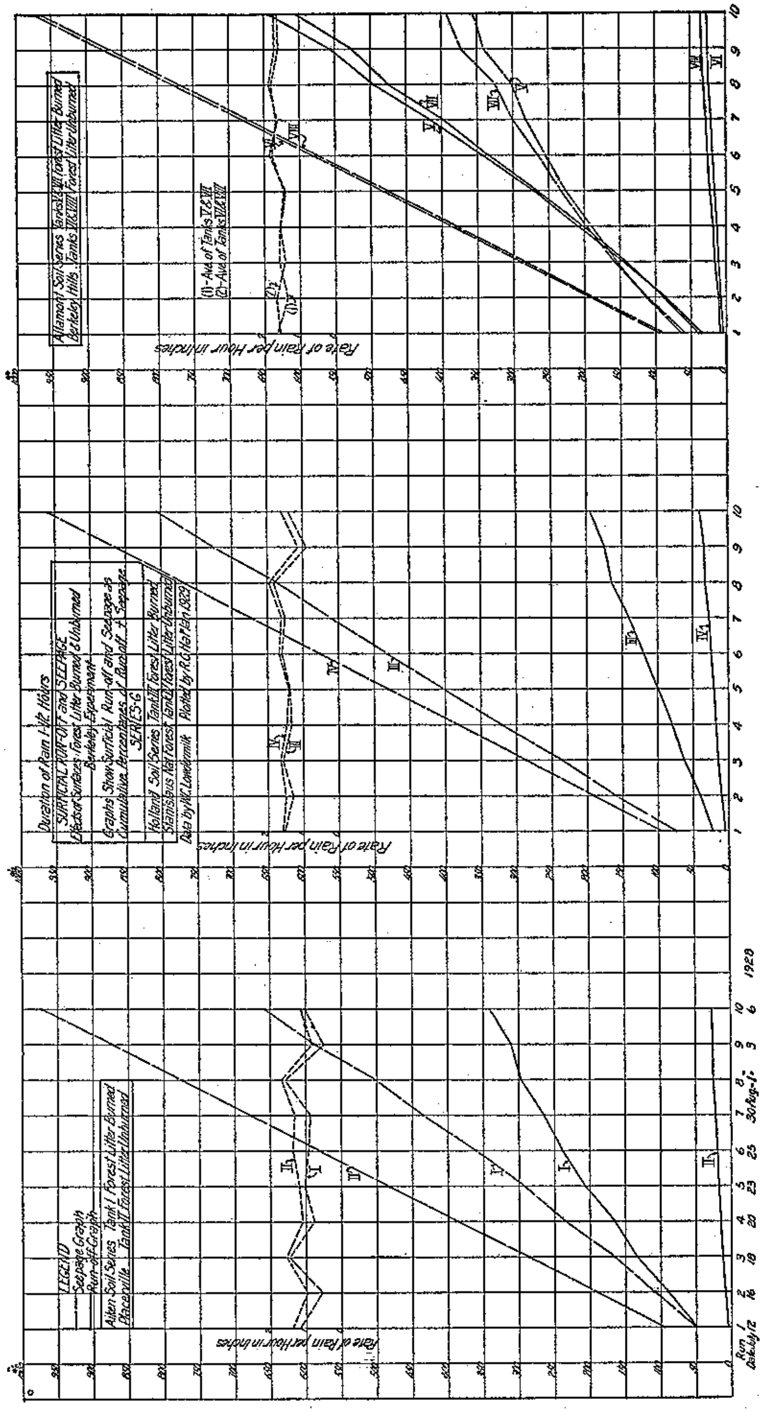


FIG. 3.—Artificial rainfall, cumulative surficial run-off, and cumulative seepage, Series G, Berkeley experiment.

TABLE 2

SUMMARY OF ARTIFICIAL RAIN AND COMPARATIVE SURFICIAL RUN-OFF FOR AIKEN SOIL SERIES, TANKS I AND II

Tanks		Series A[a]	F	B	G	C	D	E
		Depth of Rain and Run-off in Inches						
I	Rain	5.68	6.56	12.05	14.28	15.05	39.87	52.01
	Run-off	.17	2.02	1.73	3.40	4.41	13.13	18.95
II	Rain	5.68	7.13	14.69	18.14	19.18	45.48	67.07
	Run-off	0.07	0.07	0.48	0.49	0.59	1.80	3.09
		Percentages of Run-off						
I		3.0	30.8	14.3	23.8	27.4	32.9	36.2
II		1.2	0.9	3.2	2.7	3.0	3.9	4.6

[a] Natural rain totaled from March 8 through April and May.

TABLE 3

SUMMARY OF ARTIFICIAL RAIN AND COMPARATIVE SURFICIAL RUN-OFF FOR HOLLAND SOIL SERIES, TANKS III AND IV

Tanks		Series A[a]	F	B	G	C	D	E
		Depth of Rain and Run-off in Inches						
III	Rain	5.68	8.19	15.27	20.77	21.13	44.03	75.24
	Run-off	0.11	3.37	9.12	4.05	8.05	12.38	17.75
IV	Rain	5.68	8.36	15.95	22.47	22.59	46.24	80.00
	Run-off	0.08	1.34	3.61	0.94	2.70	6.15	8.53
		Percentages of Run-off						
III	Run-off	1.9	41.1	59.7	19.5	38.0	28.1	23.5
IV	Run-off	1.4	16.0	22.6	4.1	11.9	13.3	10.6

[a] Natural rain totaled from March 8 through April and May.

TABLE 4

SUMMARY OF ARTIFICIAL RAIN AND COMPARATIVE SURFICIAL RUN-OFF FOR ALTAMONT SOIL SERIES, TANKS V AND VI

Tanks		Series A[a]	F	B	G	C	D	E
		Depth of Rain and Run-off in Inches						
V	Rain	5.68	8.12	17.23	23.49	23.01	45.61	83.91
	Run-off	0.95	2.25	7.17	14.44	14.44	19.33	47.70
VI	Rain	5.68	8.43	17.92	24.96	23.44	44.84	88.89
	Run-off	0.06	0.09	0.31	0.63	0.88	2.38	3.12
		Percentages of Run-off						
V	Run-off	16.7	27.7	41.6	61.5	62.7	42.4	56.8
VI	Run-off	1.0	1.0	1.7	2.5	3.7	5.3	3.5

[a] Natural rain totaled from March 8 through April and May.

TABLE 5

SUMMARY OF ARTIFICIAL RAIN AND COMPARATIVE SURFICIAL RUN-OFF FOR ALTAMONT SOIL SERIES, TANKS VII AND VIII (DUPLICATES OF V AND VI)

Tanks		Series A[a]	F	B	G	C	D	E
		Depth of Rain and Run-off in Inches						
VII	Rain	5.68	8.25	17.62	24.55	22.46	42.77	88.68
	Run-off	1.12	2.62	7.67	14.90	14.80	17.42	46.17
VIII	Rain	5.68	7.83	12.82	22.93	14.52	36.68	82.70
	Run-off	0.15	0.11	0.53	0.69	1.07	1.91	3.64
		Percentages of Run-off						
VII	Run-off	19.7	31.7	43.5	60.7	65.8	40.7	52.0
VIII	Run-off	2.6	1.4	4.1	3.0	7.3	5.2	4.4

[a] Natural rain totaled from March 8 through April and May.

surficial run-off and the percolated water as a percentage of their sum together with the average rate of artificial rain per hour. A typical sample of these graphs is shown in Figure 3. Under calm conditions the rate of rainfall was slightly more than 2 inches per hour, with lesser rates during gusty or fairly strong winds. The experiment was not run during heavy winds. The average rate was slightly more than 1 inch per hour.

The cumulative graphs were used because they constitute one of the most sensitive methods for indicating a trend of a series of phenomena. The more uniform the trend the more nearly the graph approaches a straight line. Its angle with the base line may be taken as an index of the trend.

In the present experiments the surficial run-off from the burned surface was greater in every instance than from the litter-covered surface. The differences in the Holland soil, a fine sandy loam, were on the order of 3:1; in the Aiken soil, a sandy clay loam, on the order of 9:1; and in the Altamont soil, a clay loam, on the order of 16.5:1. The litter was thus more effective on the fine-texured soils than on the coarser-textured soils.

Contrary to expectation the coarser-textured Holland soil in a bare condition was not the most absorbent of rain. With this the average percentage of surficial run-off was 35, while with the Aiken soil it was 27, and with the Altamont 49. Under the forest litter, however, the absorptive capacities of the soils changed remarkably. Surficial run-off from both the Aiken and Altamont soils approximated 3 per cent, as against 13 per cent with the Holland soil—a ratio of 1:4. The forest litter, therefore, played a much larger rôle in the absorption of rain on the fine-textured soils. This order of influence coincides with the influence on erosion by the surficial run-off.

The original experimental runs were completed in August, 1928. The installation was maintained throughout the following year with no additional treatment except to prevent the development of vegetation, and repeat runs were made in July and August of 1929 to discover if further settling or other influences might change the relationships discovered in the first series of experimental runs. Table 6 shows a comparison between runs of the original series of similar duration and intensities with the

repeat runs. Series A, including the intermittent natural rains, is not included in these comparisons.

The results of the repeat runs confirm the findings of the original experiment. After a year's time the litter appears to be more effective in favoring penetration of rain into the soil. The only explanation which has been found is the activity of earthworms, whose castings are evident in the litter-covered tanks. The development of macro-structural features in a soil profile which were noted in the sampling can reasonably be assumed to increase its capacity for penetration over artificially packed soils, a condition represented by the tanks during the first experimental runs.

The most significant feature of the experiments is that the forest litter continued to function for all durations of rain in approximately the same order. Run-off graphs for the burned and litter-covered tanks in the same soil series maintain uniform angle relationships except when the rainfall differs widely for the two tanks. Indeed, the percentage of surficial run-off from the Altamont and Holland soils was lower in the 8-hour application than in the 4 or 2-hour applications. It is difficult to explain this reversal of expectation, which only accentuates the finding that the litter when saturated continued to maintain a high percolation capacity in the soil.

TABLE 6

SURFICIAL RUN-OFF IN REPEAT RUNS AND FIRST EXPERIMENTAL RUNS, IN PERCENTAGE OF SURFICIAL RUN-OFF PLUS SEEPAGE

Soil series	Aiken		Holland		Altamont			
Tanks	I	II	III	IV	V	VI	VII	VIII
First Runs	30.7	3.5	31.2	13.0	48.6	3.6	47.1	4.7
Repeats	38.7	0.7	40.8	21.9	66.7	1.3	58.5	1.4

COMPARATIVE EROSION

Eroded material caught in the sediment traps is shown in Table 7. Surficial run-off from burned surfaces was muddy while that from litter-covered surfaces was clear. Such material from the latter as was collected in the sediment traps was chiefly organic particles of the litter as determined by ignition tests.

The differences between the burned and litter-covered soils in amounts of eroded material are far greater than the differences in run-off. Erosion thus proved to be a more sensitive index in the change of surface condition than surficial run-off. The rate of erosion, however, did not increase uniformly with the increase in total surficial run-off. This effect was most noticeable on the Aiken soil, where a conspicuous "erosion pavement" developed.

Differences in eroded material from the different soils are notable. The fine-textured soils yielded the greatest amount of sediment. For example, the sediment in Series C from the bare Altamont soil was 11 to 16 times that from the Aiken, and 4 to 6 times that from the Holland.

RÔLE OF FOREST LITTER

In these experiments the forest litter, independent of the forest, served to maintain the soils under them in a state of far greater absorptive capacity than the same soils which had been burned bare of forest litter. This action, which has not hitherto been measured, continued far beyond the complete saturation of the litter.

Forest litter has generally been credited chiefly with a capacity to absorb water up to the saturation point, and various authors have expressed the view that when this point is reached the surficial run-off from forest soil will be at the same, or almost the same, rate as from a bare surface (1, 2, 8, 9). This view overlooks the macro-structural characters of the soil which may be related to the presence of a mantle of vegetation during the course of soil development. Likewise, emphasis has been placed upon the forest rather than upon the soil mantle, which in the final analysis is the primary absorbent of rainfall. Vegetation, its litter, and the soil fauna which it supports have determined under given climatic conditions through long periods of time the characters which a soil profile possesses.

TABLE 7

MATERIAL ERODED FROM TANK SURFACES BY SERIES OF APPLICATIONS OF ARTIFICIAL RAIN, AND WEIGHT RATIO OF SILT TO SURFICIAL RUN-OFF WATER. (ARRANGED ACCORDING TO CHRONOLOGICAL ORDER OF RUNS)

Item	Tanks							
	I	II	III	IV	V	VI	VII	VIII
	Series B. 10 Runs of 1 Hour Each							
Weight, grams	40.60	0.40	646.75	1.70	516.80	0.300	670.65	0.90
Ratio, %	0.10	0.035	0.30	0.02	0.31	0.041	0.37	0.07
	Series C. 10 Runs of 2 Hours Each							
Weight, grams	89.65	0.35	235.60	0.59	1003.50	0.43	1472.93	3.61
Ratio, %	0.86	0.025	0.12	0.009	0.260	0.002	0.42	0.014
	Series D. 10 Runs of 4 Hours Each							
Weight, grams	35.40	0.45	19.02	2.48	437.35	0.500	370.81	1.0
Ratio, %	0.001	0.0001	0.006	0.001	0.1	0.001	0.09	0.002
	Series E. 10 Runs of 8 Hours Each							
Weight, grams	48.65	0.50	235.60	1.07	2253.7	0.30	1910.6	0.95
Ratio, %	0.01	0.0007	0.05	0.0005	0.200	0.0004	0.18	0.001
	Series F. 10 Runs of One-Half Hour Each							
Weight, grams	18.60	0.05	234.02	2.00	275.80	0.60	295.10	0.42
Ratio, %	0.040	0.003	0.30	0.086	0.520	0.030	0.46	0.016
	Series G. 10 Runs of 1½ Hours Each							
Weight, grams	38.15	2.00	28.10	0.950	1317.70	0.400	1241.20	0.47
Ratio, %	0.047	0.017	0.030	0.004	0.383	0.0027	0.353	0.0028

The capacity of forest litter to hold large quantities of rain has been most emphasized by former workers, and additional functions such as mechanical hindrance to surface flow have been recognized but not measured (3, 4, 5, 10, 11, 12). Accordingly, the litter samples in the present experiment were studied with reference to these factors.

In determining the moisture-holding capacity tubes 4 inches in diameter and 36 inches long with fine screen bottoms were filled with litter, set in water for different lengths of time, and allowed to drain after each wetting. The water retained by the litter sample against gravity was determined three times successively with the results shown in Tables 8 and 9.

The litter was collected in two layers easily determinable in the field, namely the top and second layers. The top layer comprised all litter which showed no evidences of decay and represented the current fall of leaves. The second layer or duff comprised all partially decomposed material above the mineral soil surface. Both layers are designated in soil terminology as "A_0" of the profile. The top layers had at the end of the third determination water-holding capacities of from 200 to approximately 300 per cent of their laboratory dry weight, and the second layers of from 85 to approximately 250 per cent of their dry weight. On this basis where the top layer is 1/9 and the second layer 8/9 of the total litter, its average water-holding capacity is 180 per cent of its air-dry weight. The depth of rain water absorbed by the pine-fir forest litter was approximately 0.26 inches. The smaller samples of litter from the chaparral type of the Berkeley Hills when evenly distributed to a depth of 2.0 inches was estimated to absorb 0.6 inch.

TABLE 8

QUANTITY OF FOREST LITTER [a]

Locality	Forest type	Air-dry litter weight per 0.001 acre			Metric tons per acre
		Undecomposed layer Kgs.	Decomposing layer Kgs.	Total Kgs.	
Near Placerville, Aiken Series	Pine-fir-cedar	3.909	23.888	27.797	27.8
Stanislaus National Forest, near Strawberry	Pine-fir	1.902	25.677	27.579	27.6
Berkeley Hills	Oak-chaparral	(estimated on basis of square foot samples)			25.0

[a] The undecomposed layer represents the year's fall of litter. The decomposing layer represents a number of years' fall, depending on its rate of decomposition, which has not been determined.

TABLE 9

WATER-HOLDING CAPACITY OF FOREST LITTER SAMPLES, 1928, IN GRAMS AND PER CENT OF DRY WEIGHT

Sample number	Forest type	Layer	Air dry weight	Water retained after successive saturations					
				March 3		March 7		March 24	
				Grams	Per cent	Grams	Per cent	Grams	Per cent
1	Pine-fir	Top	689	947	137.4	1642	238.3	1439	208.8
2	Pine-fir	Top	579	827	143.0	1416	244.5	1178	203.4
3	Pine-fir	Second	2916	1930	66.2	2515	86.2	2454	84.1
4	Pine-fir	Second	2515	4469	177.7	5096	202.6	5015	199.4
5	Pine-fir-cedar	Top	543	1164	214.3	1832	337.3	1591	293.0
6	Pine-fir-cedar	Top	580	1268	218.6	1966	338.9	1724	297.2
7	Pine-fir-cedar	Second	1488	2941	197.6	3749	252.0	3676	247.0
8	Pine-fir-cedar	Second	1533	3133	204.3	3826	250.0	3725	243.6

The experimental runs with the large tanks of soil followed each other so closely that the litter was dry only at the surface at the beginning of succeeding applications. Since the trend of absorption maintains practically straight line relationships with run-off the absorption of the litter to saturation point could have played only a very small part in the differences in run-off from the contrasted surfaces.

Mechanical hindrance to flow by the litter doubtless is important. By delaying the surface flow and producing small hydrostatic heads this tends to increase percolation, particularly for small quantities of rain. Analysis of the data in the present experiments, however, indicates that mechanical hindrance to surface flow is not the most important factor in promoting percolation. Thus the percentage of surficial run-off from Tank II in Series B to E increased from 3.2 to 4.6 per cent of the rainfall, or about 44 per cent, while in Tank I the increase was from 14.3 to 36.2 per cent, or more than 253 per cent. In Tank IV there was an actual decrease in the run-off in percentage of rainfall from 22.6 in Series B to 10.6 per cent in Series E.

The evidence is not sufficient to indicate a direct relationship between surficial run-off and the colloidal clay surface of the soil. The percentage of the run-off from bare soils, however, exhibited the same trend as the colloidal clay fraction. This trend is reversed in the case of soil samples covered with forest litter. The finer the soil texture the more the forest litter may be expected to function in reducing the percentage of surficial run-off in cases where the percolation capacity of the soil is not exceeded. It is probable that with an increase of textural sizes, a point may be reached where forest litter will have no influence.

In order to test experimentally the effect of muddy water on the rate of percolation into bare soil under controlled conditions, four tubes 8 inches in diameter, numbered 10, 11, 12, and 13, were uniformly packed with Holland soil. (Figure 4.) By careful manipulation water was first applied at the drainage outlets and made to rise slowly through each soil column until the soil surface was covered with clear water. A sieve with 100 meshes to the inch was fitted into the top of the tube and the water level raised above the sieve, which was used to prevent the formation of currents over the soil as additional water was applied to the surface. These currents would pick up fine particles of soil in suspension and sort them in settling.

Once the soils had been saturated and covered with water they were kept so by a supply from the top. Automatic floats were installed to keep the head of clear water at a constant level. The percolated water was then caught in the bottom and measured, generally at one-hour intervals.

Clear water was run through the four tubes for parts of seven days to establish the percolating characteristic of each. Muddy water was then prepared by stirring samples of the same soil into water. In accordance with the well-known Stokes Law for the rate of fall of soil particles in a liquid, water was siphoned from the mixture so as to contain soil particles in diameters of .05 mm. and less. Only silt and clay fractions were contained in the muddy water, which was agitated by a paddle driven by an electric motor to prevent settling. Determinations for sediment showed 1.7 to 1.9 per cent by weight.

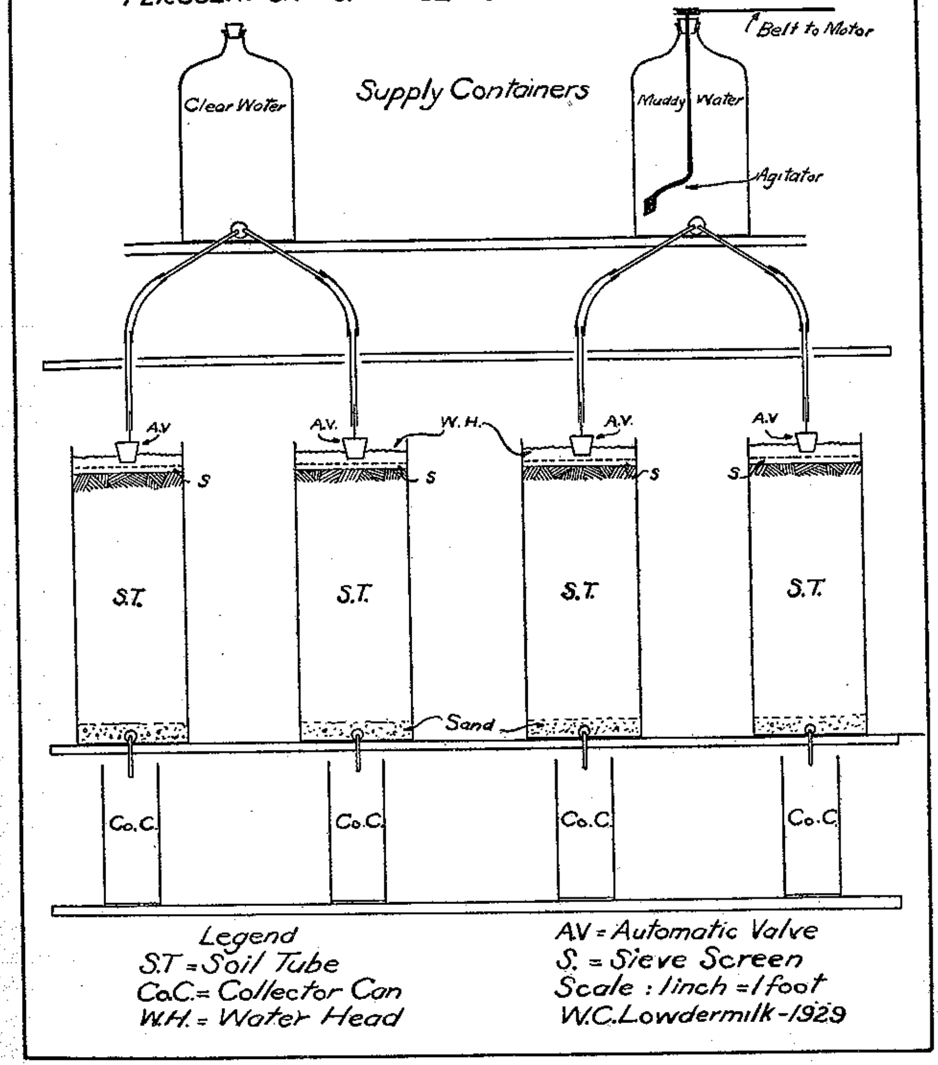
As soon as the muddy water was applied to tubes 10 and 11, the rate of percolation diminished until within 6 hours it had fallen to less than 1/10 of the rate for clear water. The percolated water remained clear. (Figure 5.)

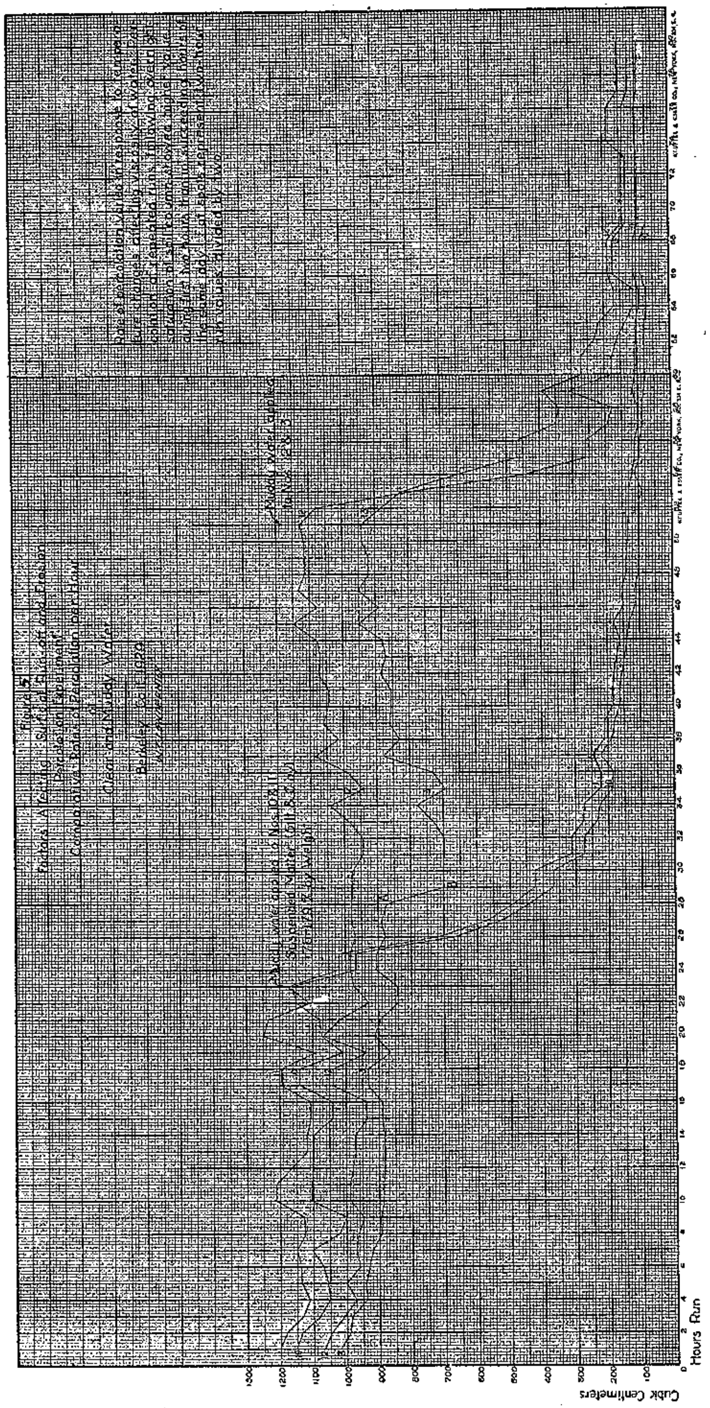
Clear water was run through tubes 12 and 13 for another week. An accident with tube 13 caused a stir of the surface soil into suspension with an immedi-

Figure 4

SURFICIAL RUN-OFF EROSION STUDIES

PERCOLATION OF CLEAR AND MUDDY WATER





ate response in reduced percolation. See A-B, Figure 5. Muddy water was finally applied to tubes 12 and 13 and clear water again to tubes 10 and 11. Immediately the rate of percolation diminished in tubes 12 and 13 in essentially the same way as it had previously done in tubes 10 and 11. Furthermore, the rate of percolation in tubes 10 and 11 did not change with the application of clear water following the application of muddy water. Evidently the fine-textured layer which had formed at the surface continued to determine the rate of percolation for the entire soil column.

This experiment demonstrated decisively that muddy water percolates through a sandy loam soil at only a fraction of the rate of clear water. Suspended particles were filtered out at the soil surface where they formed layers of fine-textured material which determined the rate of percolation quite independent of the percolation capacity of the soil column. The reduced rate of percolation is of sufficient magnitude to account for major differences in absorption such as were observed in the present experiments.

The formation of a fine-textured layer at the surface of a bare soil as a result of filtering suspended particles from percolating muddy water is, therefore, concluded to be the decisive condition which increases the surficial run-off from bare surfaces. This fact indicates that the most important function of forest litter is to maintain the natural characteristics of a soil profile by keeping the rain water clear—a function which has been generally overlooked, or if considered at all only with an inadequate conception of its significance. It seems clear that with an undisturbed mantle of vegetation the percolation capacity of the soil remains at a maximum even in extremely heavy and prolonged rains. The removal of percolated water from the soil is a matter of streamflow in waterways which is beyond the scope of this paper.

NORMAL AND ACCELERATED EROSION

It is clear that the normal rate of erosion, including the responses to unusual meteorological phenomena, is inseparably related to the natural mantle of vegetation as it existed prior to disturbance from outside factors, such as man and his agencies. When, however, the mantle of vegetation is destroyed so as to expose the soil to the full force of processes of surface removal, against which it was formerly protected, we find erosion of a different order. This has been termed "accelerated erosion," in contrast to the norm established in response to the interplay of geologic factors, including climate and time.

Accelerated erosion reduces the depth of the soil profile on sloping lands and thereby reduces the capacity of the soil to absorb rain water. Further consideration of this phase of the subject belongs with an examination of the accumulation of water in stream channels.

The index of accelerated erosion is increased silt or suspended soil carried in the streams of run-off water. A marked increase in the sediment load of streams can usually be attributed to a more rapid erosion of the soil mantle of a drainage basin rather than to augmented corrasion and abrasion by streams. A sediment record of rivers is as important in a hydrographic record as the volume of streamflow, and is a more sensitive index of the state of the watershed than measured streamflow which is dependent on a number of interacting factors.

Accelerated erosion, therefore, alters the processes of soil weathering. The A horizon is the first to go, and the sealing action resulting from the filtering-out at the surface of suspended particles tends to accelerate the surficial run-off with augmented capacities for erosion and transport. An unlooked-for element in the run-off erosion factor in the present experiment, particularly in the Aiken soil samples, was the development of "erosion pavement." Its formation is not unlike that of desert pavement, wherein the agency removing fine soil particles is unable to move larger particles. As the depth of removal of fine particles increases the larger fragments collect on the surface until a pavement of cobble is formed. This erosion pavement serves to check further removal of fine particles until the formation of gullies which undermine the pavement and hasten the process of soil removal.

Conclusions

1. Forest litter in these experiments greatly reduced surficial run-off, particularly in the finer textured soils; and this influence continued long after the litter was completely saturated.

2. Destruction of the litter and the consequent exposure of the soil greatly increased the amount of eroded material and reduced the absorption rate of the soil.

3. Suspended particles in run-off water from bare soils were filtered out at the surface and sealed the pores and seepage openings into the soil sufficiently to account primarily for the marked differences in rate of absorption between bare and litter-covered soils.

4. The capacity of forest litter to absorb rainfall is insignificant in comparison with its ability to maintain the maximum percolating capacity of soil profiles.

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