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COMMITTEE ON RANGE LAND UTILIZATION, UNIVERSITY OF CALIFORNIA

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A Resume of the Results of the Measurements
of Runoff, Erosion, and Soil Moisture from Vegetated and Denuded Plots
in Shasta, Tehama, Lake, and Mendocino Counties, California

prepared by F. J. Veihmeyer*

The names of the plot, the soil, the vegetation, and the slope, in so far as they have been measured, are given in Table 1. It may be mentioned that the Cold Fork plots were probably the steepest of all. While they were not surveyed, the slope probably exceeded 50 per cent. These plots were not used for runoff and erosion measurements, but soil-moisture determinations for a period of 2 years were made.

The Ono plots are equipped with tilt buckets to measure runoff. On all of the others, domestic water meters are used. The measurements on the Ono plots were started in 1936 and they have been burned annually since then. The other plots in Shasta and Tehama counties were burned in 1940 and annually thereafter as long as measurements were continued. The plots in Lake and Mendocino counties were started in the fall of 1944 and 1945.

The denudation was complete in every case. In the initial burning, the brush was cut, piled, and burned. In subsequent years, any resprouting vegetation was cut, and a kerosene torch was applied over the entire surface. This resulted in a more complete removal of the vegetation than is generally possible under broadcast burning. The soil samplings were taken with a soil tube to the full depth of the soil profile in the case of the primary soils; and on the old valley-filling material, in some cases, it was only possible to sample 30 inches, and in others 42-inch samples could be obtained. The soil samples were taken at intervals sufficiently close to give a good soil-moisture history.

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Plots	Average Slope Per Cent	Soil	Vegetation
Button Canyon	10.3	Primary - yellow or reddish clay grading into bedrock (Hugo)	Chamise
Ceanothus Gleason	-	Primary soil, very rocky. Not classified.	Ceanothus
Cold Fork	-	Primary. Brownish clay loam with chocolate-brown clay subsoil (Hugo)	Chamise and Manzanita
Corning	-	Old valley-filling material (Corning)	Manzanita
Diamond Range	30.9	Old valley-filling material (Corning)	Manzanita, oak, pine
Gleason No. 3	24.1	Primary (Gleason)	Manzanita
Holland	18.1	Primary - granitic (Holland)	Manzanita, oak, pine
Inskip	-	Primary - volcanic, not classified	Manzanita with some oak
Lake No. 1	38.7	Primary - volcanic	Scrub oak
Manzanita Gleason	-	Primary (Gleason)	Manzanita
Menzel North	-	Primary (Aiken)	Mostly chamise with some Ceanothus and Manzanita
Menzel South	-	Primary - not classified	Pine, oak, and manzanita
Ono 2	18.2	Primary (Aiken)	Chamise
Ono 3	21.3	" "	"
Ono 4	18.9	" "	"
Oregon Oaks	8.6	" "	Scrub oaks (Oregon Oaks)
Redding	-	Old valley-filling material (Redding)	Mostly manzanita with some pine
Ukiah No. 1	33.1	Primary (Hugo)	Manzanita and oak

rom 50 by 50 Foot Paired Plots in Shasta, Tehama, Lake, and Mendocino Counties with the Rain in Cubic Feet Intercepted by the Vegetation on the Covered Plots

	1942 - 43		1943 - 44			1944 - 45			1945 - 46		
- .	Rain inter-cepted on covered plot	Ero-sion	Run-off	Rain inter-cepted on covered plot	Ero-sion	Run-off	Rain inter-cepted on covered plot	Ero-sion	Run-off	Rain inter-cepted on covered plot	Ero-sion
ft.	cu.ft.	lbs.	cu.ft.	cu.ft.	lbs.	cu.ft.	cu.ft.	lbs.	cu.ft.	cu.ft.	lbs.
9	741	2.4	0	--	1.6	0	476	1.0	21	465	1.3
0		1.8	0		0.5	0		0.1	8		0.4
32	769	1.2	-	--	--	-	--	--	--	--	--
58		0.3	-	--	--	-	--	--	--	--	--
--	--	0.9	22	793	0.6	231	871	0.1	642	585	0.4
--		4.4	151		1.0	339		4.5	1118		31.8
17	722	0	0	--	0	42	730	0	76	856	0
19		0	25		0	38		0	47		0
21	1163	0	0	1166	0	19	1028	0.4	30	1219	0
99		8.0	0		7.1	79		1.7	779		7.2
0	960	0	4	1464	0.1	21	1732	0.2	0[2]	--	0.[illegible]
68		4.2	132		5.5	640		15.0	141		5.4
--	--	--	--	--	--	19	1653	0.2	35[3]	--	0
--		--	--		--	11		0.1	61		0.5
--	--	--	--	--	--	24	2185	0.9	26	1985	1.1
--		--	--		--	88		1.2	38		0.2

t in 1943 and destroyed setup. The equipment was not reinstalled.
burned October, 1945, and the other one left unburned.
, 1945.

ange, Holland, and Oregon Oaks plots were burned in September, 1940, but measuring equipment was not by 4 inches wide, with a total exposed surface of 3 square feet, in every case was less than that in the standard rain gauges on the bare plots, the differences being highly significant. The total amount of rain which was intercepted by the vegetation on the covered plots is indicated in tables 2 and 3.

Runoff

The runoff and erosion with the amounts of intercepted rain in cubic feet for all the plots other than those at Ono are given in table 2. The data for the Ono plots are reported in table 3 because they constitute three replications for each year. The soil is similar in each of these plots and have the same kind of vegetation with comparable slopes and rainfall conditions. The intercepted rainfall is converted into cubic feet on the basis of 2500 square feet for each plot. Actually there is more surface than this because of the slope of the plots.

Considering the data in table 2, without regard to the magnitude of the differences in runoff from the covered and burned plots, there are 15 times out of 24 trials when the runoff was greater from the burned than from the covered plots. Such a comparison brings out the differences in actual runoff, but it does not tell the entire story, since less rainfall reached the ground of the covered plots, owing to interception of precipitation by the vegetation. The difference in the catch of rain in the standard rain gauges exposed in the open and that in the trough gauges placed under the vegetation is our best measure of the net interception; but some of the rainfall, momentarily intercepted by the vegetation, reached the ground by running down the stems. No attempt was made to measure the latter amount, but whatever it was, it constituted an additional quantity reaching the ground to that shown by the trough

Table 3

Runoff and Erosion from the Ono Experimental Plots

	1939-40		1940-41		1941-42		1942-43		1943-44			1944-45		
Plots	Run-off	Ero-sion	Run-off	Ero-sion	Run-off	Ero-sion	Run-off	Ero-sion	Run-off	Rain intercepted on covered plot	Ero-sion	Run-off	Rain intercepted on covered plot	Ero-sion
	cu. ft.	lbs.	cu. ft.	lbs.	cu. ft.	lbs.	cu. ft.	lbs.	cu. ft.	cu. ft.	lbs.	cu. ft.	cu. ft.	lbs.
Ono 2														
Covered	1811	208.6	2492	69.7	312	16.2	107	2.8	19	1012	1.7	74	703	2.2
Burned	1228	64.6	1691	20.3	290	9.0	46	1.0	45		1.3	108		3.0
Ono 3														
Covered	3185	63.8	4386	46.5	1423	16.3	303	1.9	98	1202	1.6	411	1074	1.4
Burned	3451	192.6	4748	85.7	684	40.0	561	14.8	158		7.0	414		7.0
Ono 4														
Covered	952	36.9	1317	13.7	251	5.5	10	0.7	13	1279	1.0	16	1758	0.9
Burned	924	1.6	1180	1.4	153	1.2	44	0.2	22		0.5	7		0.7

gauges. An attempt to measure this stem flow was made by P. B. Rowe at North Fork. His conclusion was that it amounted to about 75 per cent of the interception measured, the remaining 25 per cent being lost by evaporation. This figure may not be the correct one to apply to the experiments herein described. But if this figure were to be accepted, it would follow that the precipitation reaching the soil of the covered plots would be less than that reaching the burned plots by the amount of the loss by evaporation from the covered plots; i.e., by 25 per cent of the interception. If this 25 per cent of the interception is added to the runoff from the covered plots, the runoff from the burned plots is found to be greater than from the unburned plots in only 4 out of 24 trials.

On the Ono plots, there are 9 cases out of 18 in which the runoff from the burned plots was greater than from the unburned, and in 2 of the 9 cases the difference in favor of the covered plots was less than 10 cubic feet. While records of intercepted rain by the vegetation on the covered plots are available only for 1943-1945, they indicate that large amounts of water were prevented from reaching the surface of the soil in the covered plots, and if other conditions were equal, it is expected that the runoff from the burned plots would be greater than from the covered ones.

The records for the Ono plots furnish 18 trials under similar conditions of soil, climate, topography, and vegetation and may be considered to be 18 replications, but only 7 times out of the 18 trials was the runoff from the burned plots greater than the covered by amounts exceeding 10 cubic feet. Considering all of the plots, there are 24 times out of 42 trials (Oregon Oaks and Lake No. 1 plots for 1945-46 are not counted) in which the runoff was greater from the burned plots than from the unburned, without regard to the magnitude of the differences and without correction for the amount of intercepted rain on the covered plots. There are only 21 times out of 42 trials when the runoff from the burned plots was greater from the unburned plots by an amount of 10 cubic feet. That differences no greater than 10 cubic feet in runoff are certainly within the experimental error in experiments of this kind is indicated by the records for the Oregon Oaks plots in 1945-46 and Lake No. 1 plots in the same years. The original covered Oregon Oaks plot, on which the vegetation had not been disturbed previously, was burned on October 17, 1945, and the plants which had grown on the plot which had been burned in October, 1944, were left growing on the plot. Yet there was no runoff from the burned plot and 141 cubic feet from the other one for this year. This difference of 141 cubic feet was due probably to the difference in infiltration capacity of the soil in the two plots and not to burning. Likewise the records for the Lake No. 1 plots show that even though both plots were accidentally burned in August of 1945, the difference in runoff was 29 cubic feet for the year 1945-46. It is of interest to note that in only 16 cases out of 42 trials did the runoff from the burned plots exceed that of the covered by more than 50 cubic feet.

Since the runoff from the burned plots in only 21 out of 42 trials exceeded that from the unburned by amounts greater than 10 cubic feet, and without considering the fact that less rain reached the surface of the soil in the unburned plots as compared to the burned, it must be concluded that runoff has not been accelerated by the burning of the brush on the plots used in these experiments.

The soils in the plots used in the experiments have high infiltration capacities. In most cases, the proportion of the rain which was measured as surface runoff from the plots is small. There are only 10 cases out of 88 trials where more than 20 per cent of the rain appeared as runoff. There are 66 cases where the runoff was less than 10 per cent of the rainfall, and 39 times when it was less than 1 per cent.

Measurements of infiltration capacities of soils in these plots by an infiltrometer were made, but are not given in this report because of the unreliability of such means of measurement. The percentage of rain which runs off is an indication of the infiltration capacities and the records show that those of the soil in the burned plots have not been impaired by burning.

Erosion

There were 22 times out of 45 trials when the erosion was greater from the burned than from the covered plots, and in 4 of the 22 times the differences were 1.3 pounds or less, amounts which may be considered, for this type of experimentation, within the experimental error. The case of the Oregon Oaks plots for the year 1945-46 is cited wherein the difference in erosion between the plots, one of which was burned in October, 1945, and the other in October, 1944, was 4.5 pounds. Subtracting the four cases with the small differences from the 22 times in which the erosion was greater from the burned than from the unburned plots, leaves 18 times out of 45 trials for greater erosion from the burned plots -- a number which is not considered to be significant, and justifies the statement that erosion has not been accelerated by burning the brush on these plots.

Soil-Moisture Records

A comparison of the soil-moisture records for the burned and covered plots in each pair shows that there is no case in which burning has apparently affected the infiltration capacity of the soil adversely. In every trial, the entire soil profile of the primary soils, and to the depth of sampling of the secondary soils, in the burned plots, was wetted as soon as that in the covered plots. In fact, in all but a few cases, the soil in the burned plots was raised to its field capacity before that in the adjacent covered ones. This shows that the infiltration capacity of the soil in the burned plots was greater than or at least equal to that of the covered plots. Since less water reached the surface of the soil on the covered plots, the lag in the time the soil profile was wetted may be accounted for, at least in part, because of the interception. The soil in all of the plots became fully wet in the early part of the season after sufficient rains had fallen to raise the soil to its field capacity.

The differences in soil-moisture contents for the full depth of soil between the burned and covered plots in the fall of 1941 for the pairs of plots, of which one had been burned in September, 1940, are given in table 4. They are given in inches and as per cent of the total soil-moisture capacities. The amounts which can be stored in the soil each season, measured by the difference between the field capacities and the minimum moisture contents reached in the unburned plots at the end of the growing season, are shown in the table, and are calculated as inches in depth of water from the soil-moisture records. It is clear that the storage capacities of these brush-land soils are limited.

In every case, the residual moisture content of the full depth of soil in the fall and before the beginning of the rainy season was greater in the burned than in the unburned plots. In one case, Button Canyon, there was only 0.08 inch in favor of the burned plot while in others the difference was much greater. In seven cases out of 12, the moisture in the top six inches of soil was greater in the unburned than in the burned plot, and in the 6- to 12-inch depth, this was true for 4 out of the 12 cases. In only one case, Button Canyon, in the 18- to 24-inch depth, was the difference in favor of the unburned plots in depths below 12 inches. In general, the differences in the surface layers were small, whether the plots were burned or not. The differences in soil moisture are a reflection of the kind of vegetation which grew subsequent to burning. In cases where the brush sprouted and grew rapidly, there were slight differences. For example, this was true for the Button Canyon, Menzel North, and Oregon Oaks

Table 4

Differences in Minimum Soil-Moisture Contents

Between Burned and Unburned Plots in the Fall of 1941

and Total Soil-Moisture Capacities

Plot	Difference in inches	Per cent of total capacity	Total capacity, inches
Button Canyon	0.08	1.2	6.4
Cold Fork	2.06	36.1	5.7
Holland	2.66	35.0	7.6
Menzel North	0.55	5.7	9.7
Manzanita Gleason	0.90	12.3	7.3
Oregon Oaks	0.52	7.0	7.4
Ceanothus Gleason	1.13	16.9	6.7
Corning	1.80	32.7	5.5
Diamond Range	0.68	10.1	6.7
Inskip	0.71	7.1	10.0
Menzel South	1.62	22.8	7.1
Redding	0.64	10.7	6.0

plots. On the other hand, on those plots where mostly annual grasses grew, the differences were quite large, as on the Cold Fork, Holland, Ceanothus Gleason, Corning, and Menzel South plots. The intermediate group, Manzanita Gleason, Diamond Range, Inskip, and Redding, had some revegetation by brush and some grasses.

These results indicate that the losses of moisture were determined by the depth of rooting of the plants and their persistence throughout the growing season. Although some of the annual grasses may have been deep-rooted enough to penetrate the full depth of soil, their early maturity and death would eliminate the draft on the soil-moisture supply during the forepart of the season, so that some readily available water was left in the lower depth of soil.

The close agreement between the permanent wilting percentages determined with sunflowers as a laboratory procedure and the minimum moisture contents of the lower depths shows that all of the readily available water was taken from the soil in the unburned plots. The reduction of the soil-moisture content below the permanent wilting percentage in the surface 6 inches, and, in some cases, in the 6- to 12-inch depth, indicates that evaporation directly from the surface of the soil was effective in removing some water from the zero- to 6-inch depth and, in some of the plots, from part of the 6- to 12-inch depth. But it seems clear that transpiration was the principal cause for the loss of moisture below the surface layer.

In April, 1944, at four of the locations, Button Canyon, Diamond Range, Holland, and Menzel North, small plots were sterilized with sodium borate to prevent the growth of vegetation. These plots were about 15 feet square and were adjacent to the burned plots at each location. Enough of the sterilant was added to prevent all growth and the plots were sampled for two years. The results show that the losses of moisture were confined largely to the surface foot of soil. The difference between the soil-moisture contents in the sterilized plots below the first foot and that in the covered plots was striking -- the curves for the sterilized plots are almost horizontal.

Summary

The soil-moisture records for the various plots are referred to for details. It is pointed out that these are the first records of soil moisture taken in sufficient number and frequently enough to give a true picture of the moisture regimen of covered and burned areas. The fact that, in most cases, the moisture content in the full depth of the soil in the burned plots was filled to its field capacity earlier in the season than in the covered ones indicates that the infiltration capacity of the soil was not interfered with by burning. In fact, the records, if anything, show that they were increased. It must be remembered, however, that less water reached the surface of the covered plots than in the burned ones, because of the interception of rain by the vegetation.

The average annual runoff figures, converted to inches depth, are:

	Covered	Burned
Button Canyon	0.13	0.04
Corning	5.02	6.67
Diamond Range	1.43	2.57
Gleason No. 3	0.16	0.16
Holland	0.08	1.87
Ukiah	0.12	0.30
Ono No. 2	3.85	2.73
Ono No. 3	7.85	8.01
Ono No. 4	2.05	1.86
Average	2.30	2.69

Four of the covered plots listed show very small average annual runoff, i.e., less than one inch; from the others the runoff from the covered plots varied from 1.43 to 7.85 inches. In the case of the annually burned plots, three show runoff of less than one inch; for the others it varies from 1.87 inches to 8.02 inches. Disregarding the magnitudes of the runoff, it was higher in the burned plots in five cases and in the covered plots in four. However, the differences in some cases were very small; for the averages, the difference was only 0.39 inch, which can be considered negligible.

The average annual erosion, in pounds, for all of the years of record, for each pair of plots, is as follows:

	Covered	Burned
Button Canyon	7.5	1.0
Corning	5.2	8.5
Diamond Range	1.8	14.3
Gleason No. 3	0.0	0.0
Holland	0.4	9.2
Ukiah No. 1	1.0	0.7
Ono No. 2	50.2	16.5
Ono No. 3	21.9	57.9
Ono No. 4	9.8	0.9
Average	10.9	12.1

In four cases the erosion was greater from the covered plots, in four cases it was the greater from the burned plots, and in one case it was zero from both plots. In most instances the erosion was negligible, as was the average difference.

The records of the runoff, the rainfall, and the percentage of the rainfall which appeared as runoff, indicate that the infiltration capacity of the soil in the burned plots has not been adversely affected by burning.

The extraction of moisture from the soil seems to depend upon the ability of the species of plants which grow after burning to extend their roots throughout the full depth of soil and upon the persistency of the plants throughout the growing season. In every case in the unburned plots, the moisture content of all of the soil was reduced to the permanent wilting percentage. On the other hand, on those plots where the brush did not sprout and where the grasses grew for a short time early in the season, the soil moisture, except in the surface layer, was not reduced to the permanent wilting percentage. Under such condition, burning will result in the saving of water and, at the same time, in the production of forage.

The records indicate that runoff and erosion were not accelerated on the burned plots in the areas where these experiments were conducted, and burning should not be condemned, at least for these localities.

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