Soil Moisture, Runoff, Erosion

long-term comparative studies on vegetated and denuded plots in typical brush areas of California

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The chaparral lands of California—estimated at ten million acres—are covered with brush so dense that herbs and grasses which are suitable for grazing can not survive in competition with it.

Burning—the cheapest and probably the method most commonly used to get rid of the brush—has been opposed on the bases that soils subjected to burning will become less retentive of water; that the infiltration capacity of the soil will be decreased seriously; that water will not be conserved; and that excessive runoff and erosion will result. The results, however, of the experiments described here do not warrant these objections.

Average Annual Runoff in Inches Depth

Plot	Plot years	Covered	Burned
Button Canyon	7	0.11	0.03
Diamond Range No. 1	4	1.19	2.25
Diamond Range No. 2	1	1.00	0.52
Gleason	6	0.12	0.15
Holland No. 1	5	0.11	1.63
Holland No. 2	1	0.40	0.21
Lake No. 1	1	0.09	0.07
Lake No. 2	3	0.07	0.11
Ukiah	4	0.18	0.22
Oregon Oaks No. 1	3	0.04	1.50
Oregon Oaks No. 2	3	0.31	0.01
Madera	4	0.01	0.02
Monterey No. 1	2	0.01	0.04
Monterey No. 2	2	0	0.04
Monterey No. 3	2	0.01	0
Monterey No. 4	2	0.02	0.07
Ono	18	4.58	4.20
	68	Av. 1.36	1.42

The moisture properties of soils—such as the amount of water that can be stored in them and that which can be taken from them by plants—may be considered to be soil-moisture constants. The addition of organic matter in amounts greatly exceeding that likely to occur under natural conditions or even in agricultural practice will not materially affect the amount of water that can be stored in soils. Any surface treatment of brush-covered areas would not be expected to affect the water storage capacity of the soil provided the infiltration of water into the soil is not altered. The question of infiltration, then, is the crucial factor in deciding the question whether to burn or not to burn.

Long-Term Test Plots

A series of plots and small watersheds were established in Shasta, Tehama, Lake, Mendocino, Monterey, Tulare, and Madera counties to obtain measurements of soil-moisture contents, runoff, and amounts of erosion.

The plot sites were selected to give a variety of cover types, soils, and topography, as well as a range in amounts and distribution of rainfall.

Measurements were started in 1936 with a group of plots near Ono in Shasta County and other plots were added in succeeding years. At each location two plots were outlined with side and end boards so that all the water reaching the soil surface and appearing as runoff could be collected at the lower ends and measured. The eroded soil was caught in a tank and was collected and weighed at the end of the season.

The vegetation on one plot of each pair was left undisturbed. The second plot was denuded in the fall. The brush was cut, piled on the plot, and burned, but the surface of the soil was not disturbed any more than necessary to do this work. 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.

Average Annual Erosion in Pounds per Plot

Plot	Plot years	Covered	Burned
Button Canyon	7	5.9	0.8
Diamond Range No. 1	6	1.6	8.2
Diamond Range No. 2	1	3.0	1.0
Gleason No. 3	6	0.1	0.1
Holland No. 1	6	0.4	8.3
Holland No. 2	1	0.8	0.3
Lake No. 1	1	0.2	0.1
Lake No. 2	3	1.0	1.0
Ukiah	4	0.6	0.6
Oregon Oaks No. 1	3	0.1	8.2
Oregon Oaks No. 2	3	6.5	9.6
Madera	4	0.7	2.0
Monterey No. 1	2	0.4	2.8
Monterey No. 2	2	0.7	0.4
Monterey No. 3	2	2.5	2.9
Monterey No. 4	2	1.6	1.4
Ono	18	27.3	25.3
	71	Av. 8.2	9.3

In some plots the brush resprouted and grasses grew. In certain cases the vegetation was almost entirely grass.

Soil samplings were taken with a soil tube. In primary soils sampling was to the full depth of the soil profile; on the old valley-filling material—in some cases—it was only possible to sample 30 inches, while in others, 48-inch samples could be obtained The samples were taken at intervals sufficiently close to give a good soil-moisture history.

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 case, in the burned plots, the entire soil profile of the primary soils,

The foreground shows the conversion of chamise land into grass after burning while the chamise still covers the hills in the background.

and to the depth of the sampling of the secondary soils, was wetted as soon as that in the covered plots. 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 because of the interception of rain by the vegetation, the lag in the time the soil profile was wetted may be accounted for, at least in part, by that 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 in some of the burned and covered plots after going through the first rainy season following the burning were measured 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, were calculated as inches in depth of water from the soil-moisture records.

Experimental Plots and Watersheds Used in Determining Soil Moisture, Runoff, and Erosion

Plots	Ave. slope %	County	Soil	Vegetation
Button Canyon	10.3	Tehama	Primary. Yellow or reddish clay grading into bedrock (Hugo)	Chamise
Ceanothus Gleason	...	Tehama	Primary soil, very rocky. Not classified.	Ceanothus
Cold Fork	...	Tehama	Primary. Brownish clay loam with chocolate-brown clay subsoil (Hugo)	Chamise and manzanita
Corning	...	Shasta	Old valley-fill material (Corning)	Manzanita
Diamond Range	30.9	Tehama	Old valley-fill material (Corning)	Manzanita, oak, pine
Gleason No. 3	24.1	Shasta	Primary (Gleason)	Manzanita
Holland	18.1	Shasta	Primary. Granitic (Holland)	Manzanita, oak, pine
Inskip	...	Shasta	Primary. Volcanic, not classified	Manzanita, with some oak
Lake No. 1	38.7	Lake	Primary. Volcanic	Scrub oak
Manzanita Gleason	...	Shasta	Primary (Gleason)	Manzanita
Menzel North	...	Shasta	Primary (Aiken)	Mostly chamise with some Ceanothus and manzanita
Menzel South	...	Shasta	Primary. Not classified	Pine, oak, manzonita
Ono 2	18.2	Shasta	Primary (Aiken)	Chamise
Ono 3	21.3	Shasta	Primary (Aiken)	Chamise
Ono 4	18.9	Shasta	Primary (Aiken)	Chamise
Oregon Oaks	8.6	Shasta	Primary (Aiken)	Scrub oak (Oregon oak)
Redding	...	Shasta	Old valley-fill material (Redding)	Mostly manzanita with some pine
Ukiah No.1	33.1	Mendocino	Primary (Hugo)	Manzanita and oak
Monterey No. 1	22.3	Monterey	Old valley-fill material (Lockwood)	Chamise
Monterey No. 2	34.0	Monterey	Old valley-fill material (Lockwood)	Wild cherry
Monterey No. 3	61.6	Monterey	Old valley-fill material (Lockwood)	Red berry, oak
Monterey No. 4	38.7	Monterey	Old valley-fill material (Lockwood)	Oak, chamise
Madera No. 1	18.3	Madera	Primary (Holland)	Oak, ceanothus
Madera No. 2	15.9	Madera	Primary (Holland)	Oak, ceanothus

Residual Moisture Content

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. For instance, the denuded Button Canyon plot after being burned each fall for nine years had more than three inches of residual moisture remaining in the soil at the end of the growing season than in the adjacent covered plot. This represents a savings since the amount of water required to refill the soil reservoir by the rains will be much less than in the covered plots.

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. This was true for the Button Canyon, Menzel North, and Oregon Oaks 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. The differences in soil-moisture contents reported in the table, which represent savings in water by denudation, are only for the first year. As the brush species were removed by repeated burning the differences become much larger.

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 six 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 0- to 6-inch depth and, in some of the plots, from part of the 6- to 12-inch depth. It seems clear that transpiration was the principal cause for

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Illustrating the manner in which soil eroded from a denuded plot was caught and collected in a tank to be weighed at the end of the season.

SOIL

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the loss of moisture below the surface layer.

At four of the locations small plots were sterilized with sodium borate to prevent the growth of vegetation and soil samples were taken over a five-year period. The results show that the losses of moisture were confined largely to the surface foot of soil. The difference between the soil-moisture content on the sterilized plots and that on the covered ones was striking. The moisture-content curves for the sterilized plots are almost horizontal for the five-year period whereas in the covered ones all of the available moisture was exhausted by midsummer.

Runoff

A plot year consists of one pair of plots for one year. For instance, in the Button Canyon plots there is one pair of plots for seven years; while for the Madera plots there are two pairs for two years. The compilation is for a total of 68 plot years.

The average runoff for all the plots is only about 7% of the rainfall, indicating high rates of infiltration. It has been said that chamise vegetation occupies sites where the soils have been damaged by burning implying that their infiltration capacities have been affected adversely. Since chamise occupies so much of the brush lands of the state, particular attention has been paid to it, and a number of chamise plots have been included in the experiments.

The runoff from the burned Button Canyon plot which is in a chamise area averaged only 0.17% of the rainfall. The chamise plots in Monterey County had only 0.4% of the rainfall in runoff, and the Ono chamise plots had a runoff of 14% of the rainfall.

There are 35 plot years where the runoff was greater from the burned areas than from the unburned, and 33 years when the unburned had the greater runoff. In most cases the differences between runoff under burned and unburned conditions are small.

The difference may seem large in a few cases—for example, the Oregon Oaks plots. For three years the average runoff from the covered plots was 0.04 inch as compared to 1.50 for the burned, a difference of about 37 times. Upon reversing the treatment for the next three years when the plot which previously had been vegetated was burned each year, the newly burned plot had only 0.01 inch runoff against 0.31 from the unburned—a difference of 31 times.

Another example is the Diamond Range plots. Here, when the runoff for four years averaged 1.19 inches for the unburned and 2.25 from the burned, there was a difference of about 1.9 times, but upon reversal the runoff from the unburned exceeded that from the burned by 1.92 times.

It is apparent that the differences in runoff are not significant but arise from variations in soil between the adjacent plots. There is also another factor which must be considered—the surprisingly large amount of water intercepted by the vegetation on the unburned plots—which means that much larger quantities of water were received by the soil on the burned areas than the unburned.

The interception was measured by the difference in catch of rain in the standard rain gauges exposed in the open on the burned plots and that in trough gauges placed under the vegetation in the covered plots. The average yearly amount of rain intercepted for the 68 plot years is 4.05 inches. The mean rainfall for all of the plots was 20.09 inches so that the interception was 20.11% on the average. Some of this water was evaporated from the leaves and some reached the ground by running down the stems of the plants, but the amounts are not known.

Erosion

The amount of erosion is small. The yearly average for the 71 plot years is 8.2 pounds for the unburned and 9.3 pounds for the burned plots. Converted to depth and using an average value for soil density these figures are 0.00049 for the unburned and 0.00056 for the burned. One pound of eroded material is about 0.00006 inch in depth.

There are 32 plot years where the erosion is greater from the unburned areas and 26 plot years where it is greatest from the burned areas. In 13 plot years there are equal amounts from the unburned and burned plots. The largest difference is for the Holland plots with an average annual erosion of 0.4 pounds for the unburned and 8.3 for the burned, or 21 times more erosion from the burned, but the actual difference is very small. In inches depth it amounts to only 0.0004 inch and upon reversal of the treatments the unburned had 0.8 and the burned 0.3 pound eroded.

The moisture properties of the soil in these experiments have not been adversely altered by burning. Runoff and erosion have not been accelerated in the areas where these experiments were conducted, and consequently burning should not be condemned at least for these localities.

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SUGAR BEET

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The yield in net tons per acre from all tests showed that a significant difference at 19 to one odds was obtained on all four-inch spacing over all others and that the yield of the 16-inch spacings was significantly poorer than all others. The spacing groups from six to 12 inches were not significantly different.

The table in columns one and two on page 6 shows the average yields of the various spacings attempted in these field studies.

The yield table shows that the attempted four-inch spacing regardless of the population is significantly better than all others and the 16-inch spacings are significantly poorer than all others. Also it is shown that there is no significant difference between any of the other spacings.

These differences are based on groupings and not on actual populations; of course, the closer spacings give the higher population. The four-inch spacings ranged from 47,000 plants per acre down to 21,000 plants per acre. These were the extremes. The average number of plants in all four-inch spacings were 34,968 plants per acre.

An analysis of this shows a significant difference at the 5% level between populations of 34,000 or more beets per acre—which were obtained in the four-inch spacings—over all other spacings. It was thought that possibly the inclusion of the 42-inch double row planting and one 34-inch single row planting which had high populations and a low yield might have a noticeable effect on these results. A second analysis was run excluding these two ranches and the average population of the four-inch spacing was reduced to 31,158 plants per acre. This made the significance of the four-inch spacing more pronounced than in the first analysis at the 5% level. This, of course, does not show that any given population is better than any other, but does point out that where the higher populations were obtained better yields resulted.

A closer study of the individual replications indicates a more uniform yield at the higher or population levels of 29–34,000 beets per acre. The other spacing groups gave some high yields but there are both high and low yields in these groups whereas in the higher populations, the yields are all in the same range.

It is believed under the conditions in Imperial Valley that if populations of around 33,000 beets per acre can be maintained more nearly maximum yields would be attained. This can be done by calculating on the basis of row width what plant spacing will give this population.

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