RESEARCH BULLETIN 800 MARCH, 1962

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

ELMER R. KIEHL, *Director*

Comparative Influence of Hardwood Trees, Litter, and Bare Area on Soil-Moisture Regimen

HOWARD W. LULL AND PETER W. FLETCHER

(Publication authorized March 13, 1962)

COLUMBIA, MISSOURI

CONTENTS

Summary 3
Methods 4
Results 4
    Comparative Drying Depths 8
    Comparative Wetting by Depths 13
Discussion 14
Literature Cited 15

This bulletin reports on Missouri Agricultural Experiment Station Number 158—Forest Cover.

This project was financed in part by funds from the Division of Forestry, Missouri Conservation Commission.

SUMMARY

In 1952 a cooperative soil-moisture study was begun at the University Forest, Butler County, Mo., by the School of Forestry, University of Missouri, and the Vicksburg Research Center of the Southern Forest Experiment Station, U. S. Forest Service.

Eight ½-acre plots were established in a 35-year-old mixed oak and hickory stand having a basal area of 60 square feet. Pairs of plots were treated to obtain conditions denoted as *"litter-only," "bare," "trees-and-litter,"* and *"trees-only."* A tier of eight fiberglas units was installed in each plot at soil depths from 1½ to 36 inches. Daily soil-moisture and -temperature readings (except Sunday) were taken.

Throughout two growing seasons the *litter-only* plots were wettest. Profile drying was most rapid on the *trees-only* plots. Summer rainfalls for both years were stored, for the most part, in the top 20 inches. Rates of moisture loss tended to decrease with increasing depth. The rate of drying at the 0-to-20-inch depth was about the same for the *bare* plots as for the *trees-only* and *trees-and-litter* plots. From 20 to 40 inches, the drying rate for the *bare* plots was from one-half to one-fourth that of the tree-covered plots. Drying rate for *litter-only* plots was consistently less than that for the *bare* and tree-covered plots.

The forest soil-moisture regimen is an indicator of the influence that forest cover exerts on water yield. When forest soil is wet, it functions principally as a stable and porous passageway for rainfall on its way to groundwater storage and streamflow. For instance, rain that falls on winter-wet soils moves rapidly through them toward the stream channel, and its effect on streamflow and water yield is immediate. On the other hand, during the growing season, when the forest soil is dried by evapo-transpiration, it stores a great part or often all of the rainfall. Consequently, summer storms can contribute little to streamflow, the amount depending upon the size of the storm and the storage available; this in turn depends upon the time and amount of the last rainfall, and the rate and depth of subsequent drying.

In recent years a number of studies have shown that type, density, and age of forest and associated cover can influence the soil-moisture regimen and thereby influence water yield—though in any one study this has yet to be followed to its ultimate conclusion (Croft, 1950; Rowe and Colman, 1951; Gaiser, 1952; Hoover, Olson, and Greene, 1953; Zahner, 1955, 1958; Fletcher and McDermott, 1957; Lull and Axley, 1958; Koshi, 1959; Metz and Douglass, 1959; Eschner, 1960; Stoeckeler and Curtis, 1960; Della-Bianca and Dils, 1960; and Douglass, 1960).

One aspect of forest soil-moisture regimen that has received little attention is the influence of trees and litter relative to each other. This poses a series of questions: What is the soil-moisture regimen under undisturbed trees and litter? How does it compare with the regimen where litter is burned but trees remain? Or where litter remains after trees are cut? Or where litter is burned and trees are cut?

To investigate this problem, a cooperative soil-moisture study was begun in 1952 at the University Forest, Butler County, Mo., by the School of Forestry, University of Missouri, and the Vicksburg Research Center of the Southern Forest Experiment Station, U.S. Forest Service.

Comparative Influence of Hardwood Trees, Litter, and Bare Area on Soil-Moisture Regimen

HOWARD W. LULL AND PETER W. FLETCHER*

METHODS

Eight ½-acre plots were laid out in a 35-year-old pole-size mixed oak and hickory stand which had a basal area of about 60 square feet, a height of about 50 feet, and an average d.b.h. of dominant trees of about 5 inches. The soil was a Grenada-like silt loam about 40 inches deep with a silty-clay fragipan that in turn rested on a residual chert. The site and soil were fully described by Fletcher and McDermott (1957).

On two of the plots, the trees were cut and removed and the litter was left intact; these are designated *litter-only* plots. On two plots the trees were cut and removed and the litter was burned *(bare).* Two plots were undisturbed *(trees-and-litter)* and on two, the litter was burned *(trees-only).*

On plots where trees were cut, a rank growth of herbaceous species and sprouts appeared. This growth was cut back twice during the 1953 growing season and once in 1954 by chopping and using 2,4,5-T silvicide. On the *trees-only* plots, leaves began to accumulate from the leaf fall of 1953. On the *litter-only* plots, the 2-inch litter accumulation virtually disappeared during the second growing season.

Soil moisture on each plot was measured with fiberglas units installed at eight depths: 1½, 4½, 7½, 10½, 16½, 24, 30, and 36 inches. Readings were taken daily at about 8 a.m. (except most Sundays) from November 1, 1952, to December 31, 1954. The units were field-calibrated and soil-moisture contents were computed for the 0-to-6, 6-to-13½, 13½-to-20, 20-to-27, 27-to-33, and 33-to-40-inch depths according to methods described by Reinhart (1953).

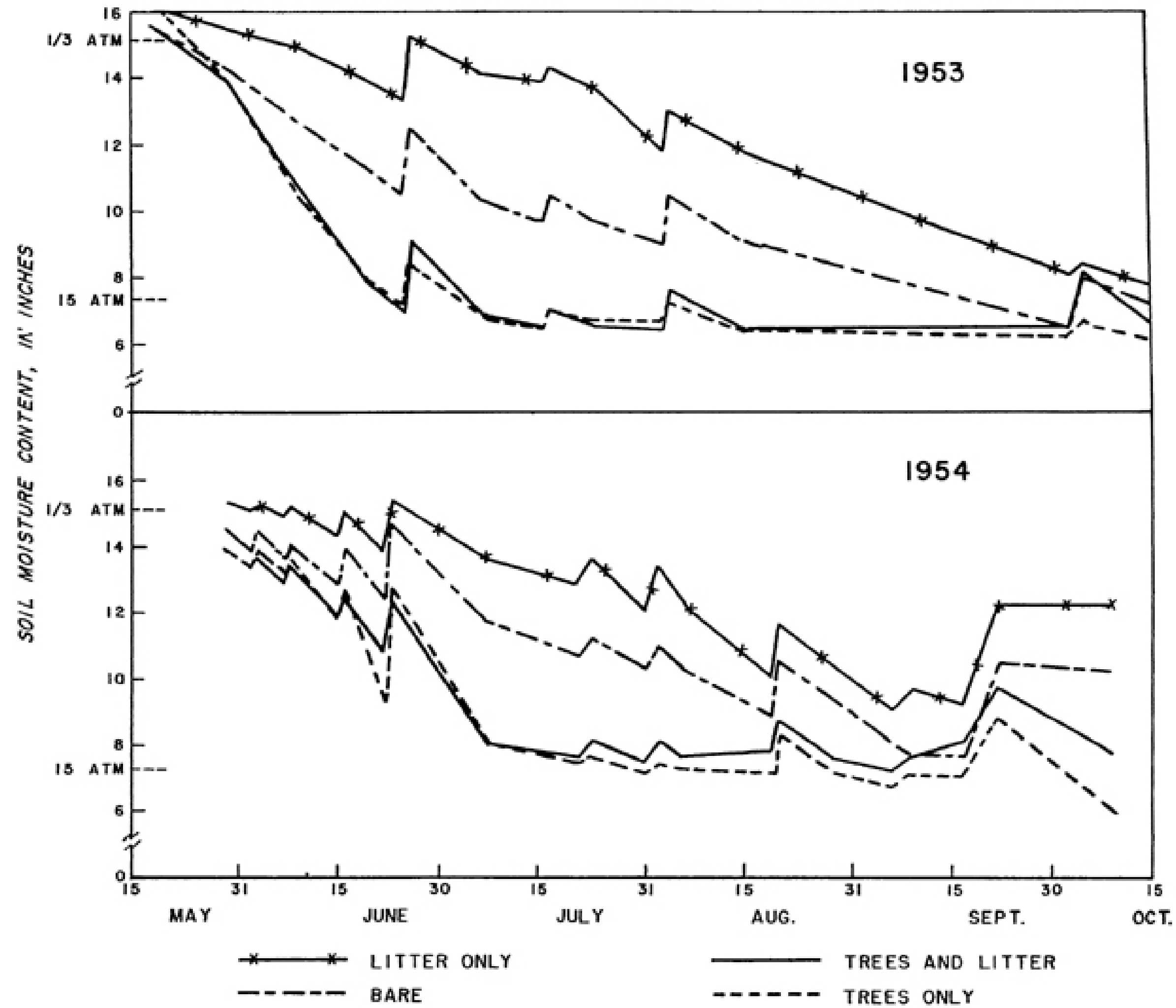
A daily record was kept of rainfall and air temperature. The growing season of 1953—May 15 through October 15—was much dryer than that of 1954. In 1953 there were 10 storms with over 0.10 inch precipitation, and a growing season total of 6.90 inches. In 1954 there were 21 storms and a total of 14.17 inches of rainfall.

RESULTS

Soil-moisture regimens for the two growing seasons are shown in Figure 1; and June, July, and August soil-moisture and rainfall values are given in Table

*Dr. Lull is Chief, Division of Watershed Management Research, Northeastern Forest Experiment Station, U.S. Forest Service, Upper Darby, Pa. Dr. Fletcher is Director, School of Forestry, The Pennsylvania State University, University Park, Pa. and formerly Professor of Forestry, University of Missouri (1952-1959).

Figure 1.—Growing-season soil-moisture contents for the 0-to-40-inch depth.



1. As can be noted, 1953—with much less rainfall than 1954—had two extended drying periods, one in May and June, and one in August and September. The 1954 soil-moisture record was punctuated by more frequent rainfall, and at summer's end the soil had not dried out so completely as it had in 1953.

TABLE 1-JUNE, JULY, AND AUGUST SOIL-MOISTURE CONTENTS AND RAINFALL

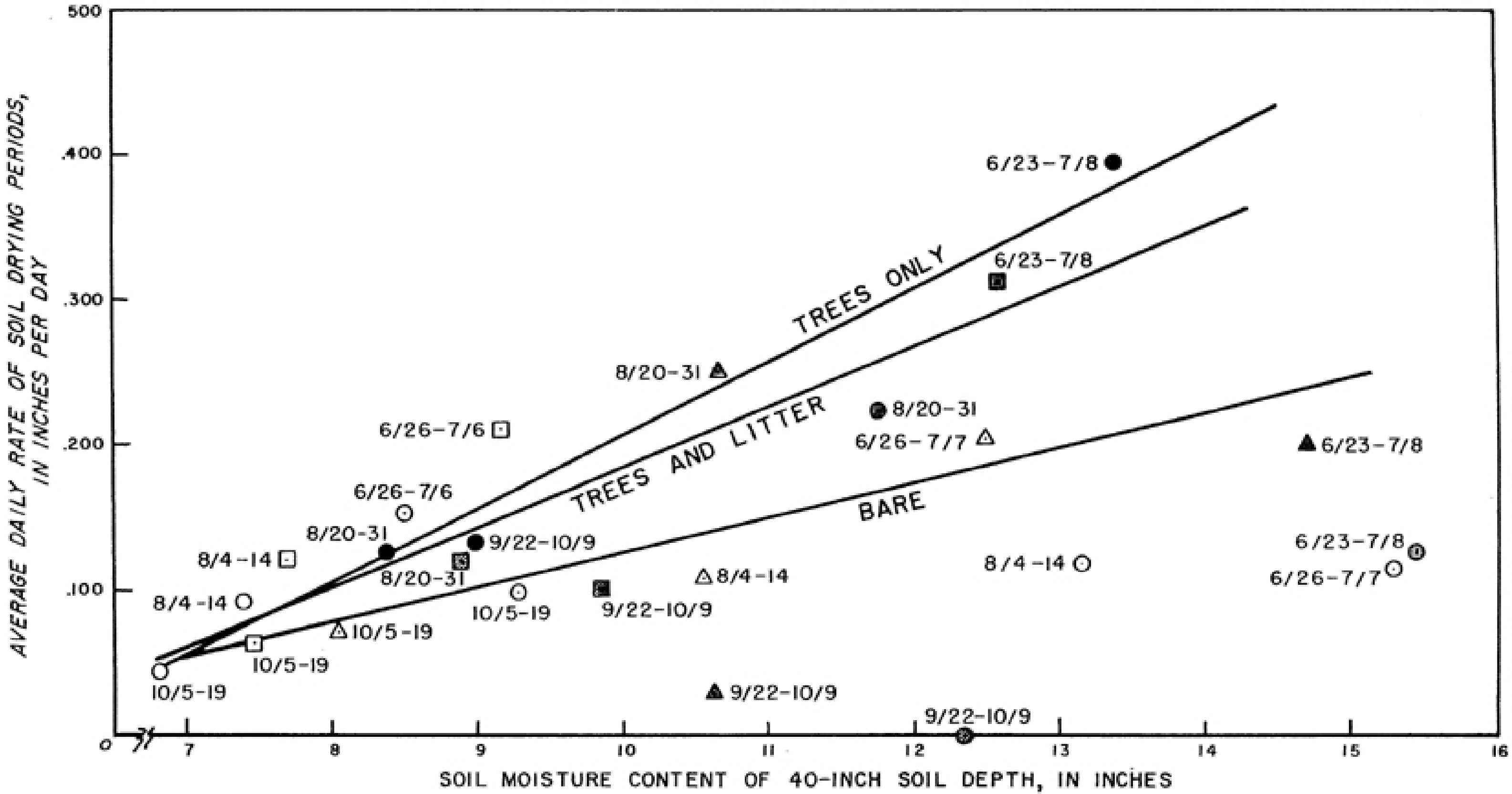
Stand Condition	Year	June	July	August
		Inches	Inches	Inches
Litter-only	1953	14.55	13.99	11.78
	1954	14.76	13.28	11.50
Bare	1953	12.24	10.14	9.19
	1954	13.84	11.24	9.74
Trees-and-litter	1953	9.56	6.82	6.66
	1954	12.33	7.96	7.76
Trees-only	1953	9.54	6.90	6.66
	1954	12.54	7.80	7.41
Rainfall	1953	1.71	0.69	1.22
	1954	4.58	.83	2.53

Throughout both growing seasons the *litter-only* plots were wettest, *bare* plots occupied a position of medium wetness between the *litter-only* and the *trees-and-litter* plots, and there was little difference in moisture content between the *trees-and-litter* plots and the *trees-only* plots. In 1953, for the months of June, July, and August, the *litter-only* plots averaged 5.76 inches wetter and *bare* plots 2.84 inches wetter than the *trees-and-litter* plots. Comparable values for 1954 were 3.83 and 2.26 inches.

Rates of soil-moisture drying for the *trees-only*, *trees-and-litter*, and *bare* plots were related to their soil-moisture content (Fig. 2). For any one soil-moisture value, drying was most rapid on the *trees-only* plots, presumably because of the combined drain of transpiration from trees and evaporation from unprotected soil as well as drainage. The somewhat lower regression for *trees-and-litter* can be attributed to the lower evaporation from the litter-covered soil. The *bare* plots had drying rates roughly 0.5 those of the *trees-and-litter* plots and 0.4 those of the *trees-only* plots. There was no definable relationship between drying rates and soil-moisture content of the *litter-only* plots.

Late-summer drying rates were greater for the *litter-only* and *bare* plots in 1954 than in 1953 (Fig. 1). To compare rates of drying for the same starting levels of moisture content: between August 4 and 19, 1953, the *litter-only* plots lost moisture at the rate of 0.09 inch per day whereas from August 4 to 25, 1954, the rate was 0.20 inch per day. Mean daily temperatures for the two periods

Figure 2.—Soil profile drying rates in relation to soil-moisture content.



1953	1954		CORRELATION (r)	REGRESSIONS
⊙	◉	LITTER ONLY	−.009	
△	▲	BARE	−.545	$\hat{Y} = -.093 + .02116X$
□	▣	TREES AND LITTER	−.859*	$\hat{Y} = -.233 + .04222X$
○	●	TREES ONLY	−.991**	$\hat{Y} = -.304 + .05208X$

* SIGNIFICANT AT 5% LEVEL

** SIGNIFICANT AT 1% LEVEL

were 80 and 83°F., respectively. From the *bare* plots from August 4 to 21, 1953, the loss rate was 0.08 inch per day (mean daily temperature of 79°F.), compared with 0.15 inch per day from August 20 to September 6, 1954 (mean daily temperature of 82°F.). A major factor in the more rapid drying rates of both the *bare* and *litter-only* plots in 1954 was the herbaceous regrowth.

Comparative Drying by Depths

Soil moisture by profile depths is shown in Figure 3. At each depth, the *litter-only* plots were wettest, the *bare* plots occupied a midway position, and there was little difference in rate of drying between *trees-only* plots and *trees-and-litter* plots.

The *trees-only* and *trees-and-litter* plots approached field minimum values at the same time at each depth, but at somewhat progressively later dates at successively lower depths (Table 2). The *bare* plots dried out more gradually, reaching the field minimum at various depths anywhere from 10 to 99 days later than the *trees-and-litter* plots. The *litter-only* plots, slowest to dry, approached the minimum moisture content, in the upper three depths only, from 40 to 102 days later than the *trees-and-litter* plots. In each of the two depths below 27 inches the *litter-only* plots at the end of each growing season contained about ½ to 1 inch more of water than the other stand conditions.

In light of the general understanding that little water is evaporated from depths below 1 to 2 feet, water losses from the *litter-only* and *bare* plots at lower depths were greater than expected. For the 33- to 40-inch depth the total growing-season losses were as follows:

	1953 (inches)	*1954 (inches)*
Litter-only	0.74	0.32
Bare	1.14	.87
Trees and litter	1.38	.94
Trees-only	1.24	.90

Differences between years may be attributable to the somewhat greater initial moisture contents in May 1953 and the longer period of drying that year. Water loss (evaporation and slow drainage) from the *bare* plots was at a much slower rate than from the *trees-and-litter* plots. By the end of the summer, however, the *bare* plot had dried to a moisture content almost as low as the *trees-and-litter* plots. If the loss from the *litter-only* plots may be considered principally as slow drainage, this drainage could be responsible for about one-third to two-thirds of the water loss of the other stand conditions.

Figure 3.—Soil-moisture content by successive soil depths.

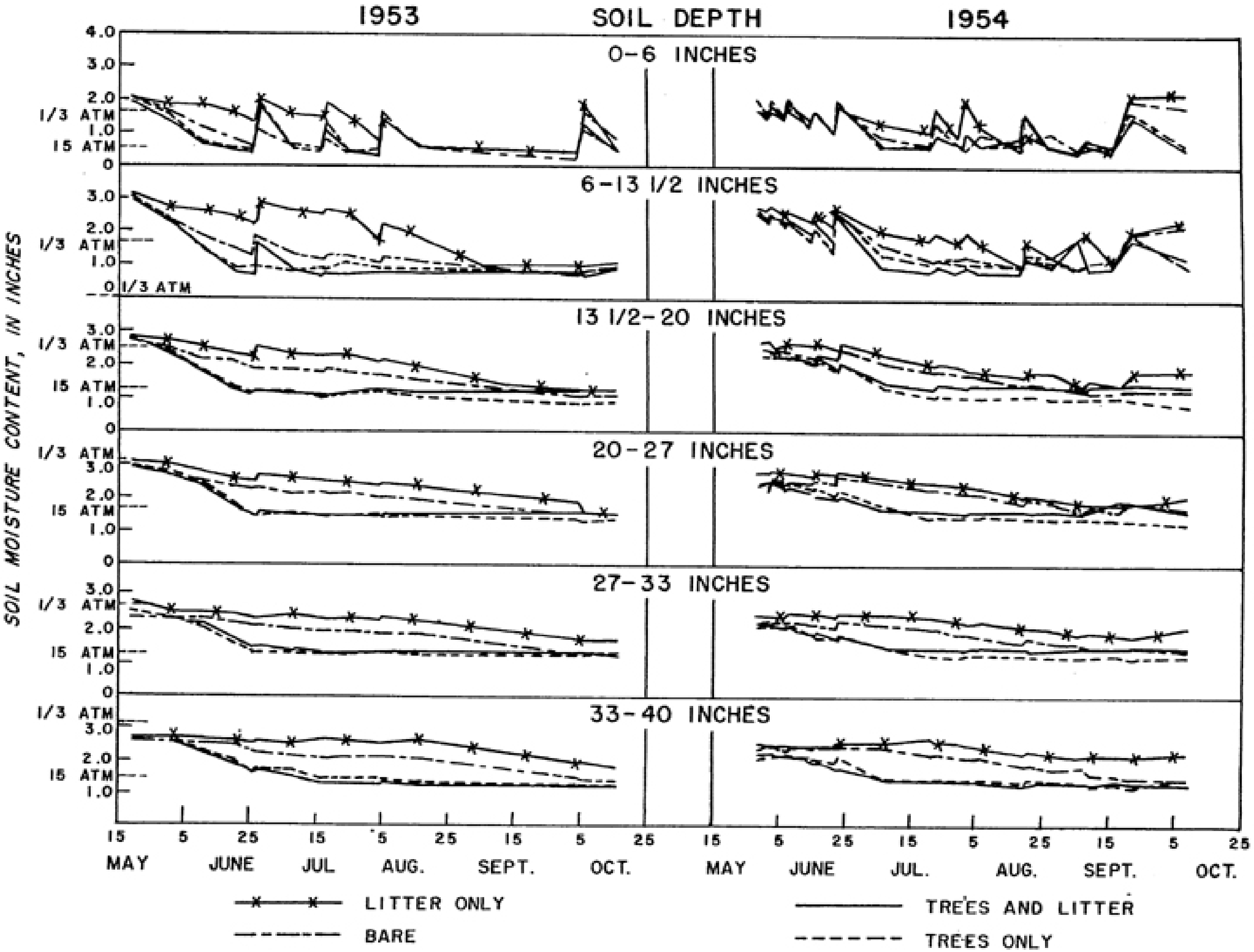


TABLE 2-DATES WHEN EACH SOIL DEPTH REACHED FIELD MINIMUM VALUES AND DATES WHEN THEY WERE RECHARGED BY WINTER RAINFALL

Depth (inches)	Year	Reached field minimum values			Reached winter recharge values			
		Litter-only	Bare	Trees-only and trees and litter	Litter-only	Bare	Trees and litter	Trees-only
0-6	1953	Aug. 24	July 29	June 19	Jan. 16	Dec. 9	Jan. 26	Jan. 11
	1954	Aug. 16	July 19	July 7	Oct. 1	Oct. 1	Oct. 26	Oct. 26
6-13	1953	Sept. 4	Aug. 24	June 24	Dec. 7	Jan. 16	Jan. 20	Jan. 20
	1954	Aug. 19	Aug. 19	July 8	Oct. 26	Oct. 26	Oct. 29	Oct. 26
13-20	1953	Sept. 12	Sept. 15	June 25	Jan. 20	Jan. 20	Jan. 20	Jan. 20
	1954	Aug. 31	Aug. 31	July 16	Oct. 26	Oct. 28	Dec. 6	Dec. 6
20-27	1953	Oct. 5	Oct. 2	June 25	Jan. 20	Jan. 20	Feb. 18	Feb. 18
	1954	*	Sept. 13	July 16	Oct. 26	Nov. 9	Dec. 6	Dec. 6
27-33	1953	*	Oct. 3	July 7	Jan. 20	Jan. 21	Feb. 18	Mar. 9
	1954	*	Sept. 20	July 16	Nov. 22	Dec. 6	Dec. 31	Dec. 31
33-40	1953	*	Oct. 5	Aug. 16	Jan. 22	Feb. 19	Feb. 22	Mar. 9
	1954	*	Sept. 20	July 16	Dec. 9	Dec. 31	Dec. 31	Dec. 31

*Did not dry to minimum value.

Soil-moisture drying curves for each stand condition and profile depth are shown in Figure 4 and the rates of drying for the first 10 days are given in Table 3. The curves were taken from periods without rainfall. The curves for 1953 are based on drying from mid-May to late June. The 1954 curves were derived from the late-June to early July period.

TABLE 3-DRYING RATES BY CONDITION AND DEPTH

Depth (inches)	Year	Litter-only	Bare	Trees and litter	Trees-only
		In./day	In./day	In./day	In./day
0-6	1953	0.010	0.033	0.046	0.046
	1954	.040	.090	.109	.109
6-13 1/2	1953	.037	.039	.047	.055
	1954	.057	.100	.122	.121
13 1/2-20	1953	.017	.045	.026	.048
	1954	.036	.040	.055	.049
20-27	1953	.020	.025	.040	.029
	1954	.017	.016	.040	.043
27-33	1953	.00	.025	.030	.043
	1954	.00	.010	.024	.038
33-40	1953	.00	.00	.039	.039
	1954	.00	.00	.020	.020
Total	1953	0.084	0.167	0.228	0.260
	1954	.150	.256	.370	.380

Rates of soil-moisture loss tended to decrease with increasing profile depth. The rate of drying at the 0-to-20-inch depth was about the same for the *bare* plots as for the *trees-only* and *trees-and-litter* plots. At 20 to 40 inches, however, the drying rate for the *bare* plots was from one-half to one-fourth that of the tree-covered plots. The rate of drying for the *litter-only* plots was consistently less than that for the *bare* and tree-covered plots.

Drying rates for the *litter-only, bare, trees-and-litter,* and *trees-only* plots in 1954 were respectively 1.8, 1.5, 1.6, and 1.5 times the 1953 rates (Table 3). For the *bare* and *litter-only* plots the greater rates were due largely to the regrowth of herbaceous vegetation. They were also due in part to temperature differences for the drying periods. Mean daily temperature from May 18-27, 1953, was 74°F.; for June 23-July 2, 1954, it was 82°F.

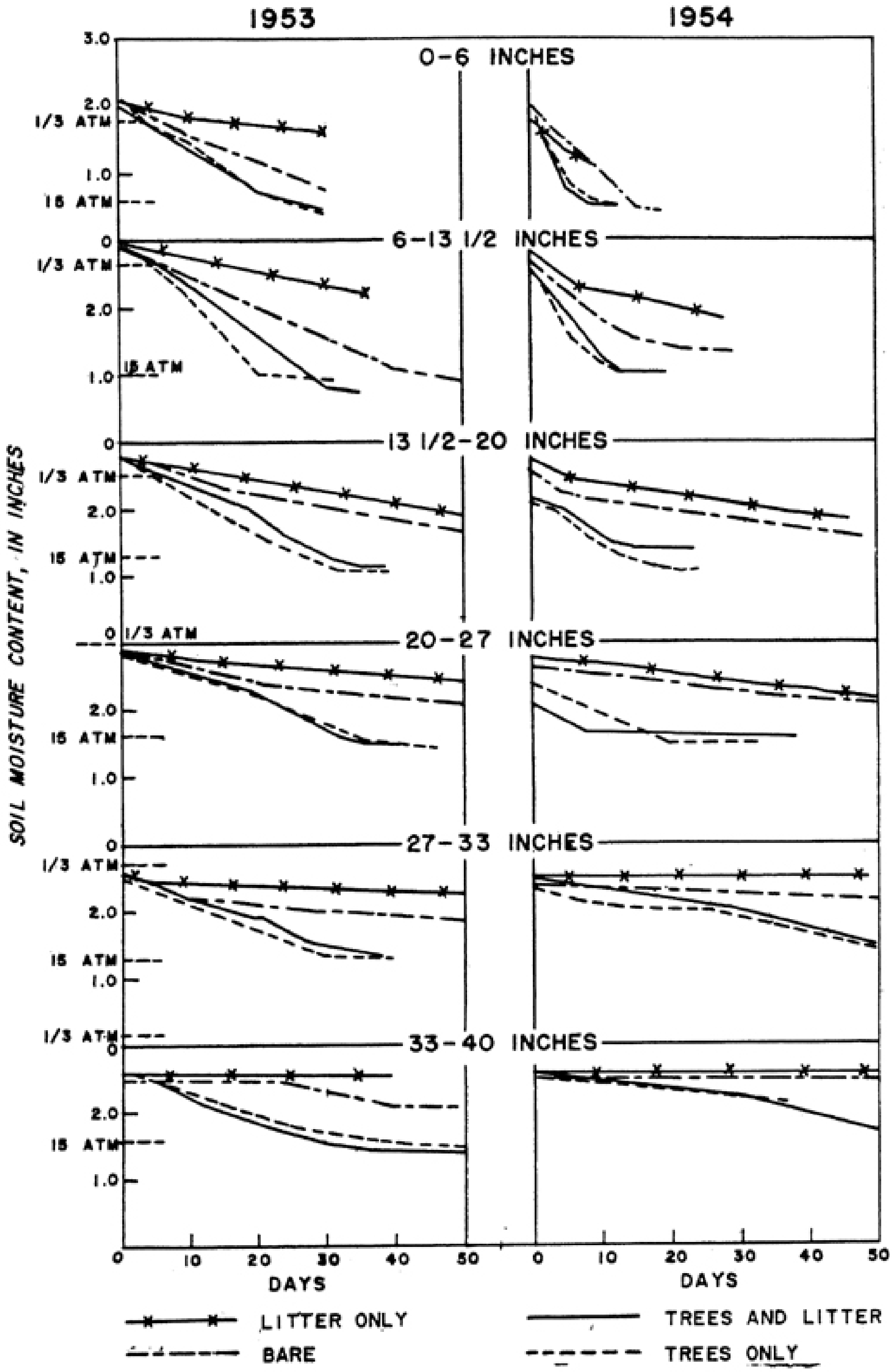


Figure 4.—Soil moisture depletion by stand condition and soil depth.

Total rates of drying—particularly for the tree-covered plots in 1954—are high in relation to those reported by other investigators. Zahner (1955, 1958) reported June losses of about 0.25 inch per day from the upper 48 inches of soil in pine and hardwood stands in southern Arkansas. Koshi (1959) found a maximum rate of 0.20 inch per day from a 2-foot depth in oak stands in Texas. Evapo-transpiration data from Coshocton, Ohio (Harrold and Dreibelbis, 1951) show average daily rates of 0.15 to 0.20 inch per day during the summer months.

High drying rates (Table 3) are associated with moisture contents greater than field capacity (Fig. 4); drainage is involved as well as evapo-transpiration. Equally high or higher rates have been reported by others: for instance, Broadfoot (1958) found a forest water use of 0.35 to 0.50 inch per day in July and August in a hardwood river bottom in Mississippi in which water previously had been impounded to a depth of 2 feet. Gaiser's data (1952) on drying of the 0-to-40-inch soil depth in hardwood stands in Ohio for 7-day periods show rates in excess of 0.50 inch per day.

Comparative wetting by depths

Summer rainfalls for both years were stored in the upper three depths, little if any of it penetrating below 20 inches.

In the *trees-only* and *trees-and-litter* plots, fall recharge in 1953 (the dryer of the two years) was not completed until early March 1954 (Table 2). After the 1954 growing season, fall recharge was virtually complete by December 31, due to a combination of less storage to fill and greater rainfall.

Litter-only plots, after the 1953 growing season, were recharged by January 22, about 6 weeks before the tree-covered plots. After the 1954 growing season they were recharged 3 weeks before the tree-covered plots. *Bare* plots, on the other hand, were recharged about the same time as the tree-covered plots.

DISCUSSION

What has been learned about the relative influence of hardwood trees and litter on the soil-moisture regimen? For the time and conditions of this study perhaps these things:

1. During June, July, and August of a very dry summer, an area bare of trees and litter will contain, in the upper 40 inches of soil, about 3 inches more water than a forested area; an area without trees but litter-covered will average about 6 inches more water. During a moderately dry summer these values were reduced to about 2 and 4 inches.

2. Rates of soil-moisture drying for the tree-covered and bare plots were positively related to their profile moisture contents. In this relationship, bare areas had drying rates about 0.5 those of the forested area, and removing only the litter speeded drying to about 1.2 times the *trees-and-litter* rates.

3. Rates of drying tended to decrease with depth, and field minimum moisture contents were approached at successive depths at successively later dates.

4. When the moisture content is around field capacity:

(a) Removing litter alone may increase summer rates of soil drying 5 to 10 percent.

(b) Removing trees alone will reduce rates about two-thirds.

(c) Removing trees and litter will reduce rates about one-third.

Watershed-management implications in these findings are fairly obvious. A surface fire that destroys the litter will tend to increase slightly the rate of soil drying, thereby increasing the opportunity for storage of summer rainfalls. This effect would be insignificant because there is commonly more than enough storage available. Litter-burning effects on infiltration and surface runoff may be of much greater import.

Clearcutting but leaving a litter cover will sharply reduce soil drying and conversely increase water yield. However, litter accumulation will no more persist under the clearcut conditions than will the clearcut condition itself. Simultaneous deterioration of litter and growth of herbs and sprouts will soon increase soil-drying rates.

Bare areas are akin to litter-covered areas in that this condition is relatively temporary, depending on the rapidity with which vegetation invades.

LITERATURE CITED

Broadfoot, Walter M. 1958. A method of measuring water use by forests on slowly permeable soils. Jour. Forestry 56: 351.

Croft, A. R. 1950. A water cost of runoff control. Jour. Soil Water Conserv. 5: 13-15.

Della-Bianca, Lino, and Robert E. Dils. 1960. Some effects of stand density in a red pine plantation on soil moisture, soil temperature, and radial growth. Jour. Forestry 58: 373-377.

Douglass, James E. 1960. Soil moisture distribution between trees in a thinned loblolly pine plantation. Jour. Forestry 58: 221-222.

Eschner, Arthur R. 1960. Effect of scrub oak and associated ground cover on soil moisture. U.S. Forest Serv., Northeast. Forest Expt. Sta. Paper 133, 16 pp., illus.

Fletcher, P. W., and R. E. McDermott. 1957. Moisture depletion by forest cover on a seasonally saturated Ozark ridge soil. Soil Sci. Soc. Amer. Proc. 21: 547-550.

Gaiser, R. N. 1952. Readily available water in forest soils. Soil Sci. Soc. Amer. Proc. 16: 334-338.

Harrold, L. L., and F. R. Dreibelbis. 1951. Agricultural hydrology as evaluated by monolith lysimeters. U.S. Dept. Agr. Tech. Bul. 1050, 149 pp., illus.

Hoover, Marvin D., D. F. Olson, Jr., and G. E. Greene. 1953. Soil moisture under a young loblolly plantation. Soil Sci. Soc. Amer. Proc. 17: 147-150.

Koshi, Paul T. 1959. Soil-moisture trends under varying densities of oak overstory. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 167, 12 pp., illus.

Lull, Howard W., and John H. Axley. 1958. Forest soil-moisture relations in the coastal plain sands of southern New Jersey. Forest Sci. 4: 2-19.

Metz, Louis J., and James E. Douglass. 1959. Soil moisture depletion under several Piedmont cover types. U.S. Dept. Agr. Tech. Bul. 1207, 23 pp., illus.

Reinhart, K. G. 1953. Installation and field calibration of fiberglas soil-moisture units. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 128, pp. 40-48.

Rowe, P. B., and E. A. Colman. 1951. Disposition of rainfall in two mountain areas in California. U.S. Dept. Agr. Tech. Bul. 1048, 84 pp., illus.

Stoeckeler, J. H., and Willie R. Curtis. 1960. Soil moisture regime in southwestern Wisconsin as affected by aspect and forest type. Jour. Forestry 58: 892-896.

Zahner, Robert. 1955. Soil water depletion by pine and hardwood stands during a dry season. Forest Sci. 1: 258-264.

Zahner, Robert. 1958. Hardwood understory depletes soil water in pine stands. Forest Sci. 4: 178-184.