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A COMPARISON OF SOIL-MOISTURE LOSS FROM FORESTED AND CLEARCUT AREAS IN WEST VIRGINIA

Abstract.—Soil-moisture losses from forested and clearcut areas were compared on the Fernow Experimental Forest. As expected, hardwood forest soils lost most moisture while revegetated clearcuttings, clearcuttings, and barren areas lost less, in that order. Soil-moisture losses from forested soils also correlated well with evapotranspiration and streamflow.

Since 1965, forest hydrologists at our Timber and Watershed Laboratory at Parsons, West Virginia, have made several studies of soil moisture. These studies were intended to develop proper techniques for use of the neutron probe for measuring soil moisture; and to learn how forest vegetation depletes soil moisture, and how altering the vegetation changes these depletion rates.

Changes in soil-moisture content over time are expected to provide a basis for correlating estimates of actual and potential evapotranspiration with streamflow. Knowledge of soil-moisture depletion rates for forested and cleared areas would then provide a better understanding of how forest management influences streamflow.

Methods

Three study areas were used. The first consisted of two circular openings (200-foot diameter) and the surrounding uncut forest. The openings were created in 1965, when all trees more than 5-inches d.b.h. were cut. Stumps and vegetation larger than 1 inch d.b.h. were killed with herbicides. Soil-moisture access tubes were installed along a transect through the openings and into the surrounding forest (fig. 1). Since 1966 these openings have revegetated naturally.

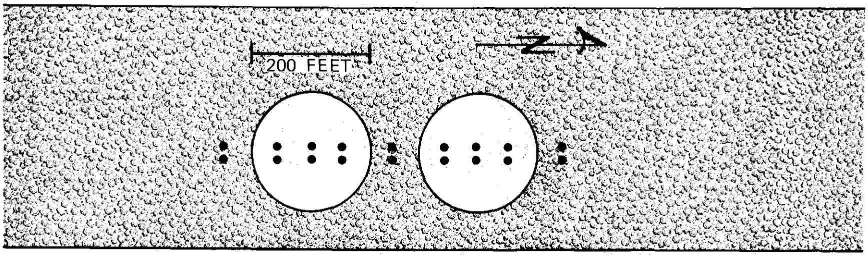


Figure 1.—Diagram of the access tube transect for comparing soil-moisture depletion in clearcut openings and in adjacent forest. The dots indicate positions of access tubes.

The other study areas were located on two experimental watersheds in which 30 acres were clearcut in 1964 and were kept barren with herbicides. In 1966 soil-moisture access tubes were installed above and below the boundary between the forested and barren areas (fig. 2).

Soil-moisture sampling was begun in May 1966 and was continued through the 1967 growing season. Sixteen access tubes were installed in the forest, 12 in the clearcut area, and 10 in the barren areas. Soil moisture was sampled with a Troxler[1] neutron moderation probe having an Amer-

[1] Use of trade names is for information only and does not imply endorsement by the U.S. Department of Agriculture or Forest Service.

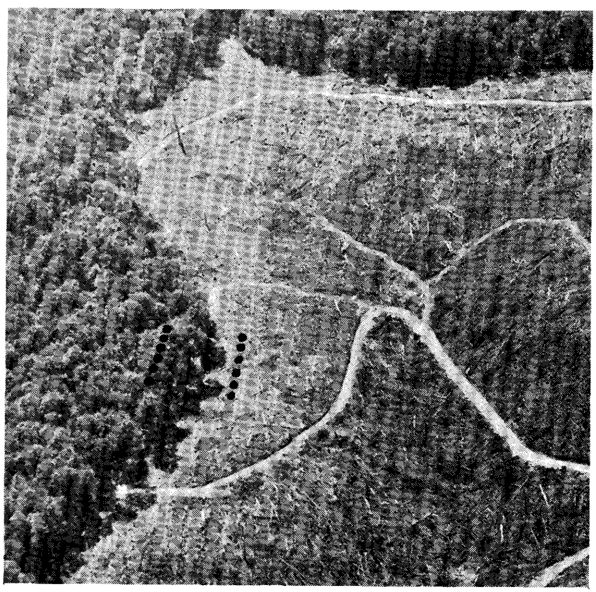


Figure 2.—Aerial view of one of the forest-barren boundaries, showing the approximate locations of soil-moisture access tubes.

Table 1.—*Some physical properties of Calvin silt loam soil*

Horizon	Texture	Depth (inches)	Bulk density	Porosity (percent)	Observed Moisture Content (percent by volume)	
					Max.	Min.
A^1	Silt loam	0-2	—	—	—	—
A^3	Silt loam	2-8	1.22	54	32.5	18.0
B	Silt loam	8-16	1.45	45	35.0	24.0
C	Silty clay loam	16-25	1.65	38	32.5	25.0
R	Decomposed shale	25-32	1.90	28	28.0	24.0

ican source. The probe was positioned in the access tubes to sample soil moisture at 6-inch intervals, to depths ranging from 24 to 42 inches. We were not equipped to install access tubes deep into underlying shale and sandstone bedrock.

Some physical characteristics of Calvin silt loam, the predominant soil on all three study areas, are listed in table 1. Bulk density and porosity were calculated from "undisturbed" core samples. Soil-moisture measurements taken below 24 inches (the 21- to 27-inch horizon) are not emphasized in this report because the data indicated relatively small changes in water content below that level. Frequent observations to the depth of 24 inches suggest that the Calvin silt loam profile sampled (0 to 27 inches) contained close to 8 inches of water at full recharge or "field capacity" in early spring.

Results

Soil-moisture changes in clearcut openings were initially grouped by location as north, center, and south. Because there were no consistent differences due to location within openings, only mean values of moisture in clearcut and forest soil were used in this analysis.

Large differences in soil-moisture depletion between forest and clearcut openings occurred in 1966 (table 2). These differences, at least in the upper foot of soil, were erased in 1967 when soil moisture accumulated in clearcut openings was used by invading herbaceous plants, tree sprouts, and seedlings. In 1967 soil moisture in the forest also was depleted to a lower level than in the clearcut areas, but the contrast between the two was not so pronounced as in 1966. Soil-moisture loss per unit time was about the same for the forest during both 1966 and

Table 2.—*Moisture losses from forest and clearcut soils*

Year	Sampling depth (inches)	Moisture loss (percent by volume)		
		Forest[1]	Clearcut[2]	Difference
1966[3]	6	8.1	2.2	5.9**
	12	6.1	1.9	4.2**
	18	5.5	1.3	4.2**
	24	4.7	1.6	3.1**
1967[4]	6	5.4	5.2	0.2
	12	2.7	2.2	.5
	18	1.8	.6	1.2**
	24	1.3	.2	1.1**

[1] Mean of 6 observations.
[2] Mean of 4 observations.
[3] 26 May to 27 June.
[4] 26 May to 9 June; one year of regrowth had occurred.
** Significant at the 0.01 level.

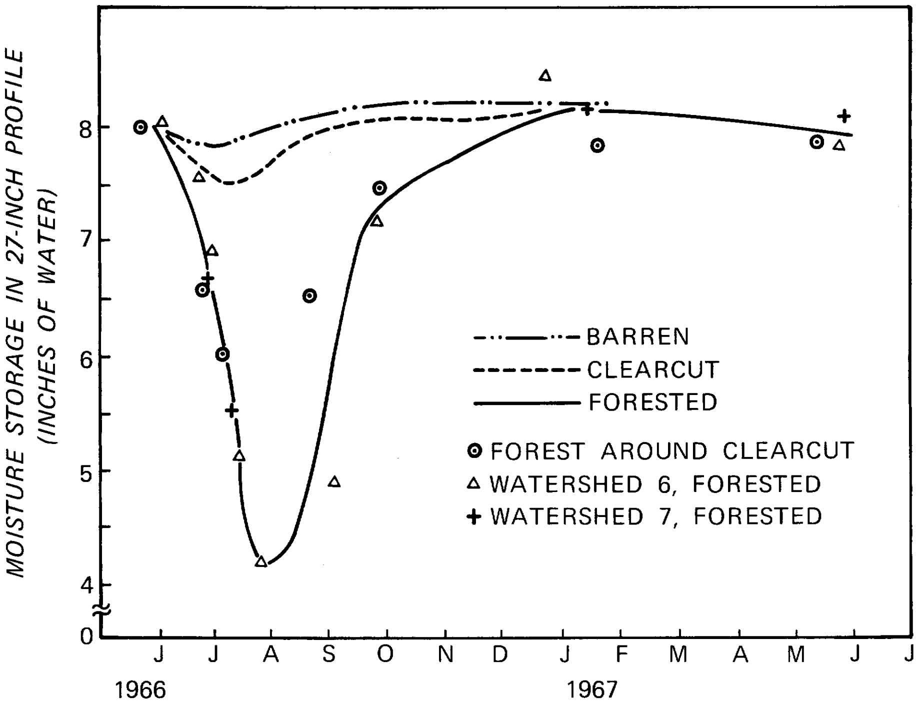
1967. Similarly contrasting moisture losses were observed between forest and barren soils on the other two study areas.

Soil-moisture depletion and recharge data from all sites, May 1966 to April 1967, are incorporated in figure 3. The depletion line for forest (June to mid-July) fits the data extremely well, indicating a similar depletion rate for all locations between May and mid-July. After mid-July, precipitation exceeded evapotranspiration, and soil-moisture recharge began. Not so many soil-moisture samples were taken during the recharge period, and the data are insufficient for plotting a closely defined line. Nevertheless, observed deficits for September and October (1.7 and 0.8 inches) agreed closely with potential soil-moisture deficits (1.5 and 1.0 inches) calculated by Hamon's (*1961*) procedure, using an assumed 8-inch storage capacity. All three forested areas were fully recharged by January and remained so until May. It was apparent, but not statistically tested, that moisture depletion was less in barren soil than in clearcut openings.

Actual evapotranspiration (ET) for one of the forest sites was compared with potential ET during the 1966 and 1967 growing seasons. Potential ET was estimated as 0.7 of average daily pan evaporation (*Kohler et al. 1955*) at Parsons. Actual ET was estimated by using equation 1:

$$\text{Mean daily ET} = \frac{\text{Precipitation} \pm \text{change in soil-moisture storage}}{\text{Length of period in days}} \qquad (1)$$

Figure 3—Composite of all change in soil-moisture storage. Curves were fitted to the data by eye.



When precipitation occurred as small storms, soil-moisture data provided close agreement between potential and actual ET (table 3). During periods with heavier rain, soil-moisture losses to deep seepage and streamflow caused overestimation of actual ET during the rainy periods.

In a humid climate, soil moisture saved by reducing evaporation can increase streamflow (*Wilm and Dunford 1948*). This principle was

Table 3.—*Daily actual and potential evapotranspiration from forest soils, in inches*

Period	Precipitation	Change in storage	Actual ET	Potential ET
5/26 - 6/27/66	3.12	(Loss) 1.47	0.14	0.14
6/27 - 7/7/66	.92	(Loss) .57	.15	.15
7/7 - 8/24/66	7.52	(Gain) .52	.15	.13
5/26 - 6/9/67	1.44	(Loss) .68	.15	.15
6/9 - 9/15/67	14.43	(Gain) 1.36	.16	.11

demonstrated in this study. Evapotranspiration from the forested half of the watershed was estimated by using equation 2:

$$ET = P - RO \pm \Delta s \qquad (2)$$

in which

ET = Evapotranspiration.

P = Precipitation.

RO = Expected streamflow for watershed 6 estimated from the streamflow for the control watershed, using the calibration period relation.

Δs = Change in soil-moisture storage.

Substituting measured values into this equation provided an estimated ET loss of 15.2 inches for the months June to September. Since the watershed was half cut, this has the potential of increasing streamflow by 7.6 inches. Using the estimated streamflow plus one standard deviation in equation 2 still produced an estimated increase of 7.0 inches. Because clearcutting materially decreased but could not prevent all evaporative losses, the actual increase in streamflow was 3.3 inches, less than half the potential.

There was a close correlation between streamflow and moisture content in the upper 2 feet of soil (fig. 4). When soil moisture was high, streamflow was high and quite responsive to precipitation; when soil moisture was low, the reverse was true. Increasing streamflow lagged behind in-

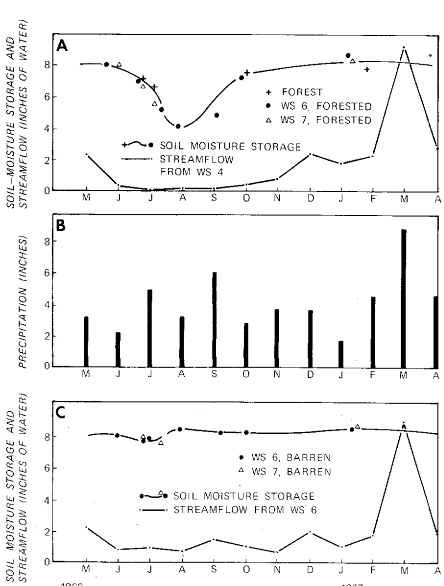


Figure 4.—Soil moisture-streamflow relationships. *A*, soil moisture in forest soil with discharge from a forested watershed. *B*, precipitation. *C*, soil moisture and streamflow from a barren watershed.

creased soil-moisture storage just as decreasing streamflow preceded early summer depletion. During the period of largest soil-moisture deficit (June to July), streamflow was lowest and did not respond to heavy precipitation during late July and August. Streamflow from the barren watershed, which maintained a high soil-moisture content, was much more responsive to precipitation than the forested and drier watershed.

Discussion

Several Fernow studies have suggested that increased streamflow accompanying forest cutting is related to decreased soil-moisture demand (*Reinhart et al. 1963*). My study explored some of the mechanisms involved, relating reduced forest vegetation to measured increases in soil moisture and streamflow. These observations compare well with those reported by Helvy and Hewlett (*1962*) for similar soil-moisture-streamflow observations in the southern Appalachians. Field capacity, seasonal soil-moisture loss, and shapes of the annual soil-moisture depletion-recharge curves are similar. In comparing data from both areas, it is apparent that moisture depletion in the upper 2 feet of soil is similar for both the southern and central Appalachians.

Large differences have been reported in soil depths from which trees draw water—from 18 inches (*Eschner 1960*) to 20 feet (*Patric et al. 1965*). Nevertheless, subsidiary information supports the assumption that most water used by the Appalachian forest is drawn from the upper 2 feet of soil:

- Actual and potential ET were comparable, based on moisture lost from this soil depth. This agreement was expected because the Fernow Forest receives about 30 inches of rain, well distributed over the growing season. Less rainfall probably would result in soil-moisture loss at less-than-potential rates and possibly to greater depths.

- Estimated streamflow increases agreed well with measured increases from treated watersheds. Under barren conditions, evapotranspiration occurred at substantially less than potential rates, and soil water saved from evaporative loss was diverted to streamflow.

- In Calvin soils, 75 to 90 percent of the tree roots are located in the upper 2 feet of soil.[2] These results also agree well with similar studies on agricultural land (*Dreibelbis 1962*).

[2] Personal communication, James N. Kochenderfer, Timber and Watershed Laboratory, Parsons, W. Va.

This preliminary study permits us to rank vegetative cover in order of decreasing soil-moisture use, much as in other studies in eastern hardwoods (*Lull and Axley 1958; Marston 1962; Fletcher and Lull 1963*):

1. Complete forest cover.
2. Revegetating clearcut forest land.
3. Newly clearcut forest land.
4. Barren land.

This ranking is based on gross differences in vegetative cover. Much refinement is needed. Well-documented comparisons of soil-moisture use among variously structured hardwood stands or comparisons between tree species are unavailable. As water becomes an increasingly valuable forest resource in the populous East, the neutron probe offers hope that such refinement may be possible.

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