RAINFALL INTERCEPTION BY HARDWOOD FOREST LITTER IN THE SOUTHERN APPALACHIANS

by

J. D. Helvey

U. S. Forest Service Research Paper SE-8

February 1964

U.S. Department of Agriculture
Forest Seruice
Southeastern Forest Experiment Station
Asheville, North Carolina

Rainfall Interception by Hardwood Forest Litter in the Southern Appalachians

by

J. D. Helvey

The portion of rainfall over forest cover which does not reach mineral soil can be separated into the parts evaporated from the canopy and from the litter. Canopy interception loss is usually estimated by subtracting the sum of throughfall (water falling through tree crowns) and stemflow (water running down stems) from rainfall measured in forest openings (Hamilton and Rowe 1949). Litter interception loss is defined here as the volume of water retained by the L and F layers of the forest floor and later evaporated without reaching mineral soil. Canopy interception has been investigated in many parts of the world, but litter interception has received little attention, and the total amount of water evaporated from litter in hardwood forests has never been accurately determined. This paper presents results from a study of rainfall intercepted by litter in a southern Appalachian hardwood stand.

The maximum field water content of litter and the rate of drying affects the amount of interception loss. Reported maximum field water content of litter varies from 135 percent in mixed hardwoods (Blow 1955) to 215 percent in pine (Metz 1958). After being wetted by rainfall, litter dries to a constant weight unless rainfall interrupts drying. The time required to dry from saturation to a constant weight has' *been* reported as 11 days for pine (Metz 1958) and 13 to 20 days for mixed oaks (Blow 1955; Semago 1960).

The volume of water evaporated varies with litter accumulation, which in turn depends on the balance between litter production and decomposition. Reported litter production in hardwood stands in Eastern United States ranges from 2,400 to 4,400 pounds per acre (Blow 1955; Chandler 1941; Metz 1954; Sims 1932). 1/ At Coweeta, from 2,800 to 3,600 pounds of litter are added to the forest floor each year (Kovner 1955). Litter accumulation varies with species, local climate, elevation, and biological activity (Blow 1955; Jenny *et al*. 1949; Shanks and Olson 1961). The weight of litter accumulation varies not only between stands, but from year to year within the same stand, and during unusual years decomposition may exceed production. Litter accumulations in eastern Tennessee ranged from 4,000 to 24,000 pounds per acre, depending on stand composition and history (Blow 1955). Metz (1954) found that litter accumulated under mixed hardwoods in the South Carolina Piedmont varied from 6,500 to 12,000 pounds per acre just prior to leaf fall. At Coweeta,

1/ Ovendry weights.

litter accumulation, following a controlled burn, reached a peak of 14,000 pounds per acre after 5 years, then decreased to 5,400 pounds per acre during the next 4 years. 2/

Estimated annual litter interception loss, in percent of total rainfall, varies from 2 percent in Tennessee (Blow 1955), and 13 percent in Missouri (Semago 1960), to 34 percent in Wisconsin (Curtis 1960). This wide range is attributable partly to variations in climatic and litter accumulation, but experimental design and methodology may also be important factors. For example, data from litter trays are subject to errors arising from unnatural drainage at the interface between the litter and the material on which it is placed. In the Wisconsin study, litter trays were in the open where all evaporative processes were undoubtedly exaggerated. This may account partly for the high interception losses reported there.

METHODS

A 7-acre watershed at the Coweeta Hydrologic Laboratory near Franklin, North Carolina, was selected for study because accurate data on crown interception loss was available. The cove hardwood stand, type 5'7 (Society of American Foresters 1954), is composed chiefly of a yellow-poplar, hickory, and scarlet oak overstory and a scattered dogwood understory. The area studied ranges in elevation from 3,030 to 3,185 feet and receives about 80 inches of precipitation annually. Rainfall, which accounts for 98 percent of total precipitation, is evenly distributed throughout the year. Precipitation data were obtained from a standard and recording rain gage located in the study area. Rainfall was corrected for canopy interception loss by results of the earlier intensive study of throughfall and stemflow in the same stand (Black 1957). No cutting or other disturbance has been made in the stand since Black's study was completed.

The watershed was gridded into 44-foot-square plots and divided into 4 blocks representing 2 elevations and 2 general aspects within each elevation (fig. 1). The forest floor was sampled to provide data on maximum field water content, 3/ moisture depletion rates, and the effect of rainfall on litter moisture. All samples were used to estimate litter accumulation and depletion over a period of 18 months.

To determine maximum field water content, reflective aluminum covers, each 3 feet square, were placed within three randomly selected plots in each block immediately after storms large enough to saturate the litter. After a large rain, water gradually moves from the litter layer into mineral soil. If samples are collected immediately following the rain to establish maximum field water content, the results will be too large, because part of the litter moisture would have drained into the soil under natural conditions. On the other hand, if the samples are not collected until drainage stops, the litter moisture will be reduced by evaporation. By covering the samples, evapora-

---

2/ Unpublished data in Coweeta files.

3/ Defined here as the amount of moisture held in the litter after it has been saturated by natural rainfall, covered to prevent evaporation, and allowed to drain until it has reached an equilibrium moisture content.

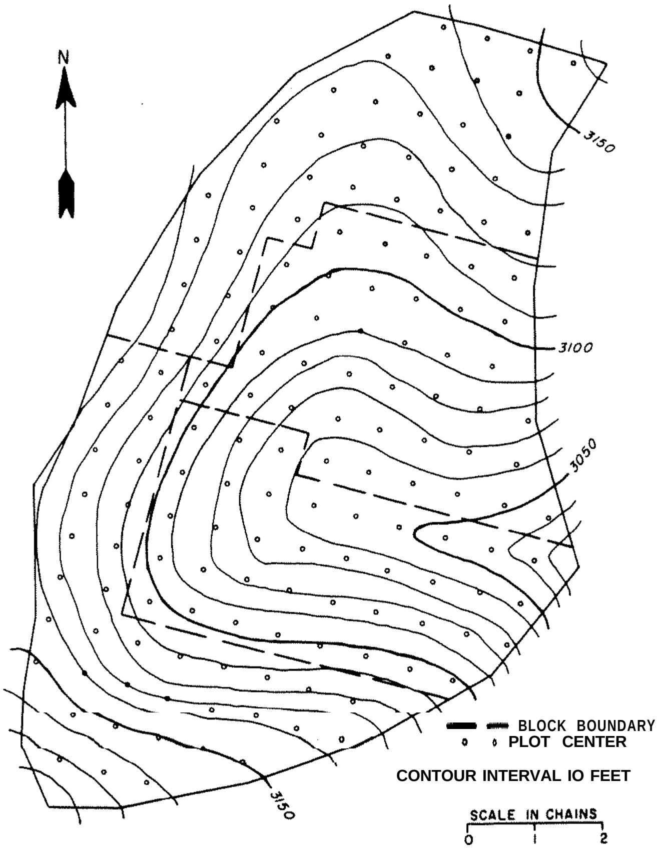


Figure 1. --The experimental watershed showing sampling design.

tion is prevented, excess water drains into the soil, and the measured water content only includes the moisture potentially available for evaporation. After draining 24 hours, a period of time found to be sufficient for excess water to drain, a 2 -foot-square sample was collected from under each cover. The samples were put into plastic bags to prevent water loss before weighing. Branches larger than $\frac{1}{4}$ inch in diameter were not included in the samples because they gain and lose water much slower than leaves (Blow 1955).

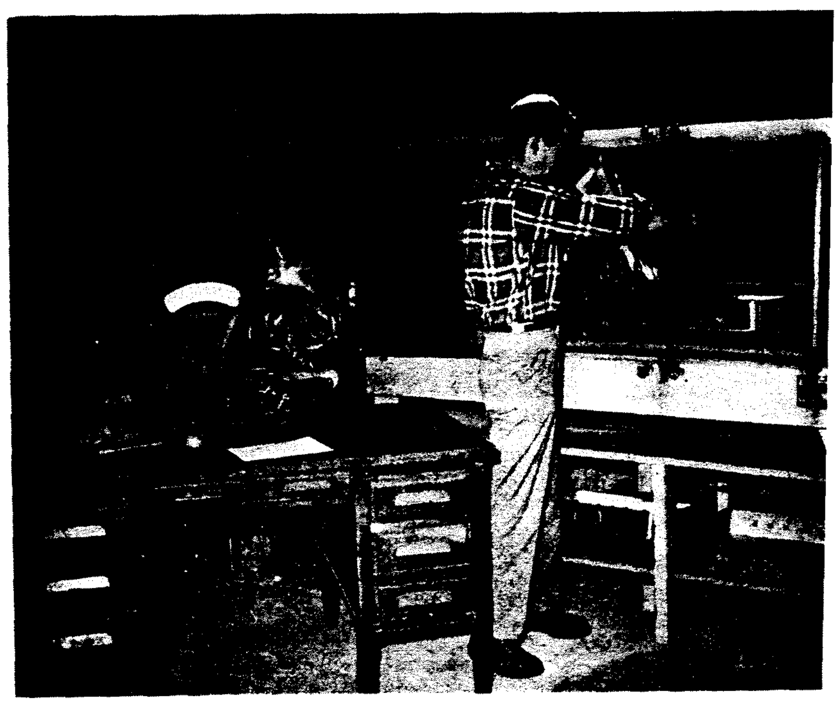
For data on moisture depletion characteristics, three samples were collected from randomly selected plots in each block during several drying cycles. The sampling schedule was not rigid, but samples were usually collected 6 hours, 30 hours, 2 days, 5 days, and 10 days after a rain.

To establish maximum field water content, reflective aluminum covers prevented evaporation while excess water drained into the soil.

Each 2 -foot -square litter sample was collected in a plastic bag to prevent water loss before weighing

To determine the effect of rainfall on litter moisture, three samples in each block were covered after a known amount of rainfall had reached the forest floor. After draining 24 hours, the samples were collected. Litter moisture content before each rain sampled was approximately 40 percent.

After establishing field weight, all samples were dried to a constant weight at 105° C. Moisture content was expressed as percent of ovendry weight.



After measuring field weight, all samples were dried to a constant weight at 105° C.

RESULTS AND DISCUSSION

The amount of water evaporated from litter is controlled basically by the moisture content of litter, wind speed and duration, and heat delivered to the forest floor. Since the heat delivery and the effect of wind are difficult to estimate, an attempt has been made to separate litter interception loss into measurable components. Thus the parameters needed to estimate the amount of rainfall evaporated are (1) the amount of litter on the forest floor, (2) the rate at which moisture increases during rainfall, and (3) the rate litter dries after rainfall stops. Figures 2 through 4, constructed from the data collected, represent these interception parameters.

Ovendry litter weights were quite variable on a given day. The average ovendry weight for all groups of 12 samples collected was 237 grams, and the average standard deviation for all groups was 49 grams. The variation was greater during the winter months when the leaves were blown from place to place. The coefficient of variation averaged 0.20 for all groups of samples collected. Litter weights were not significantly different between the small ranges in elevations or aspects. Therefore, plotted points in figure 2 are means of 12 samples, except that when more than one group of samples was collected within a 7-day period, the groups were averaged and plotted as one observation.

Litter production, estimated as the difference between total amounts on the forest floor before and after leaf fall, was 3,300 and 2,800 pounds per acre for 1961 and 1962, respectively. Litter decomposition was more rapid during 1961, and since rainfall during 1961 totaled 88 inches as opposed to 68 inches during 1962, the difference in decomposition rates and litter production may be related to rainfall differences. Frequent and heavy rainfall keeps forest litter packed down and favors vigorous biological decomposition. For example, Jenny *et al*. (1949) found that decomposition of alfalfa was faster in humid climates.

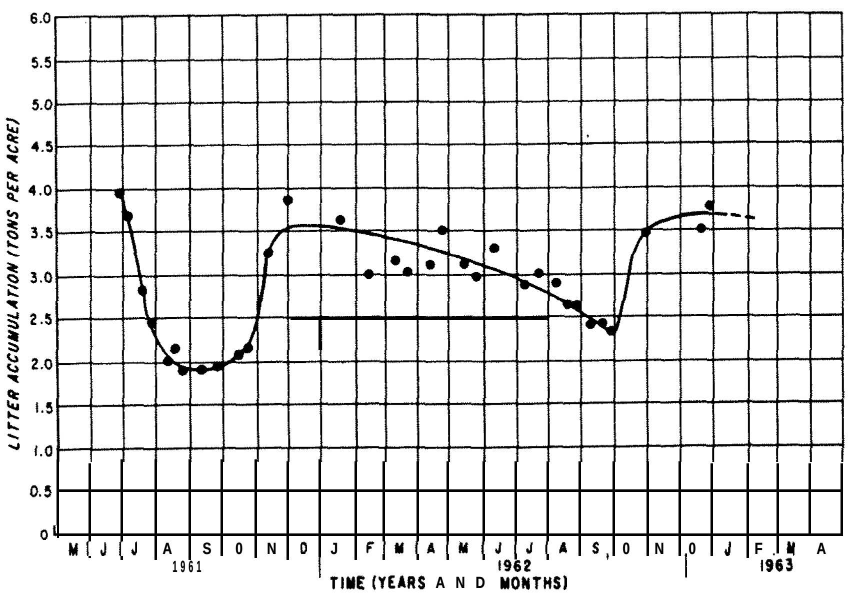


Figure 2. --The trend of ovendry weight of litter per acre in a hardwood forest stand from June 1961 through December 1962.

The maximum field water content of the litter during summer and winter averaged 215 percent by weight. The rate at which the litter dried did not differ significantly between elevation *or* aspect, but there was a marked difference between seasons (fig. 3). The curves were cornposited from several individual drying cycles representing all seasons of the year. Greatest moisture evaporation occurred during the first 3 days of drying, and early drying was much faster during the dormant season. During the growing season, shading, high humidity, and low wind velocity near the forest floor limited evaporation during early drying, but after about 12 rainless days, moisture loss virtually ended, regardless of season or initial moisture content.

Approximately 1 inch of throughfall was necessary to raise the litter moisture content from 40 percent to maximum field water content (fig. 4). Plotted points represent average moisture contents of litter after a known amount of rainfall reached the forest floor.

Moisture evaporation after each storm is small. For example, assuming a litter cover of 3.7 tons per acre (maximum accumulation during 1962), the litter could only hold 0.070 inch of water at maximum field water content. After drying to 40 percent moisture, it still holds 0.013 inch of water. Therefore, after a large storm only 0.057 inch of water is evaporated from the litter.

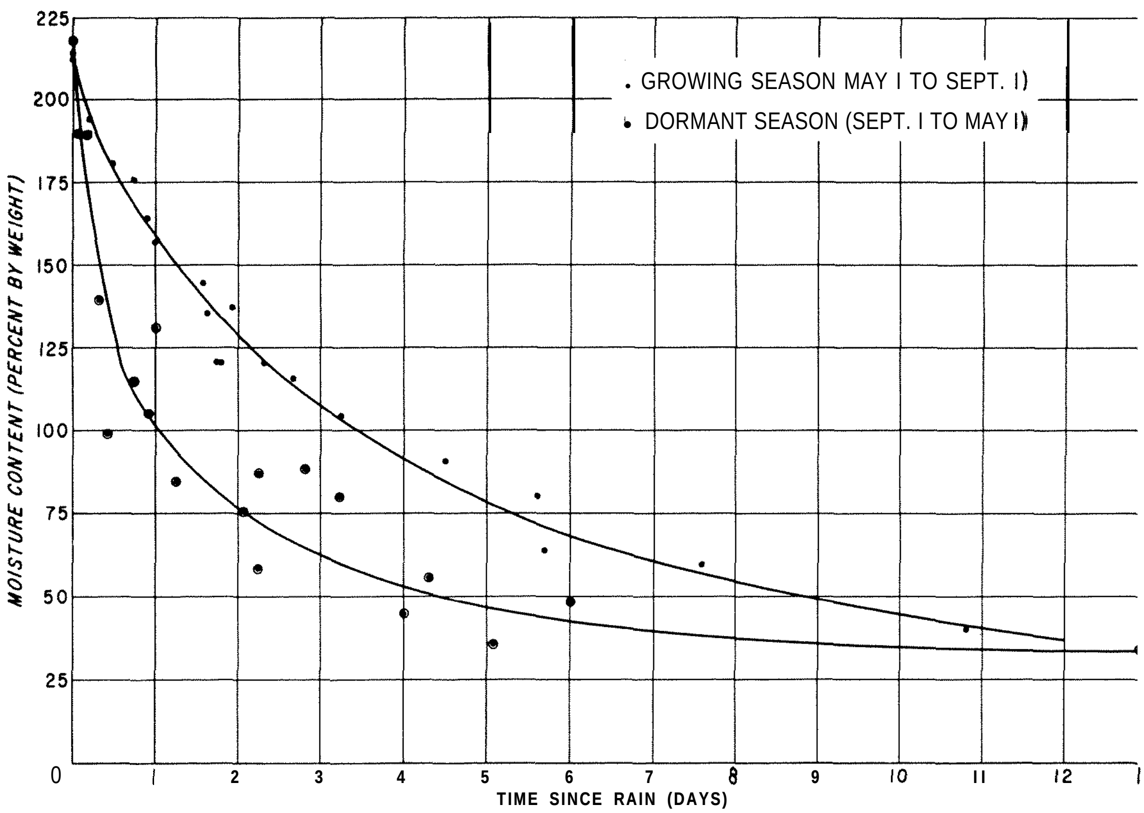


Figure 3. --The relationship between hardwood litter moisture content and time since wetting for the dormant and growing seasons.

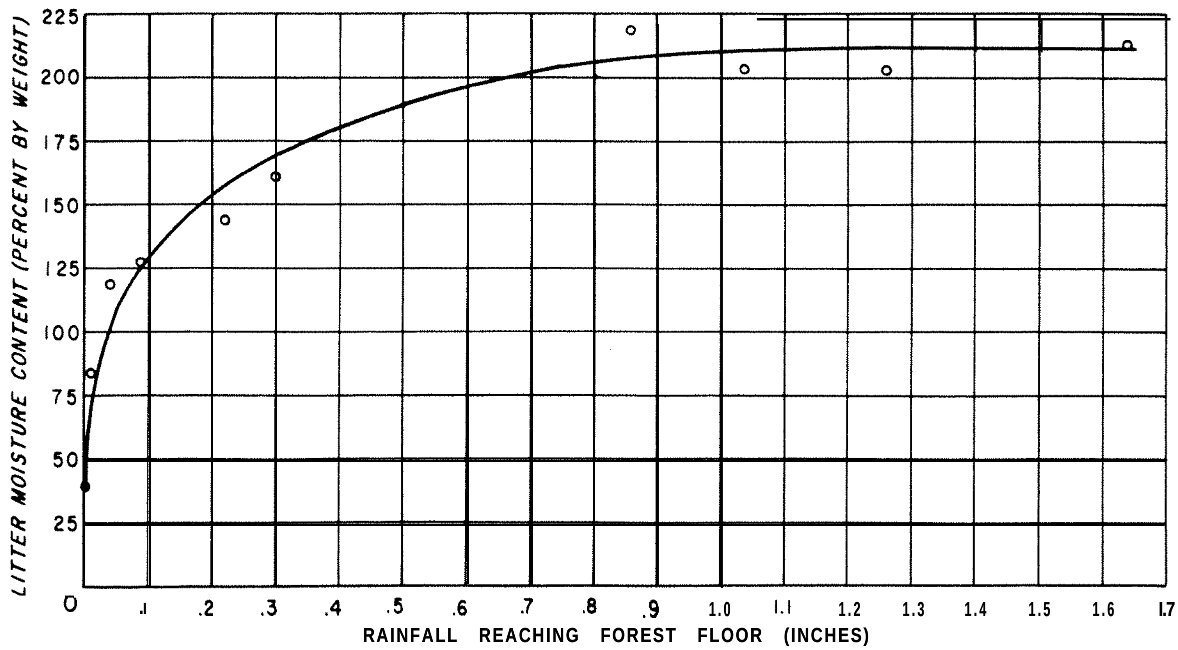


Figure 4. --Moisture buildup in litter plotted against rainfall reaching the forest floor.

To arrive at a preliminary estimate of average annual litter interception loss, monthly rainfall was averaged over a 15-year period, and then applied to the litter accumulations during 1962 and the measured moisture relations of litter. Some assumptions had to be made in order to arrive at this estimate. It was assumed that (1) storms were evenly distributed through the month, (2) the litter moisture content just before each storm was 40 percent of ovendry weight, and (3) the litter accumulation during 1962 was average at Coweeta. The estimated average litter interception loss (3.6 inches)tends to be too large, because computed drying times are almost ideal for maximum evaporation, average rainfall cancels out large and small storms that add little to interception loss, and the moisture content of litter is not always at 40 percent before each rain. This estimate, although not exact, serves to fix an upper limit for average annual litter interception loss at Coweeta. During a la-month period, it could conceivably equal or even exceed the 3.6-inch estimate if there were numerous small storms, each followed by 3 or 4 days of fair weather.

It was possible to compute litter interception loss more accurately for 1962. Rainfall measured in the open was corrected for canopy interception loss and storms were separated to the nearest hour. Moisture contents at the beginning and end of each drying cycle were determined from figures 3 and 4. For each drying period, the difference between starting and ending moisture contents was multiplied by the current litter accumulation (fig. 2) to give water evaporated in pounds per acre. Evaporation during all drying periods during the year was totaled and converted to area inches of water.

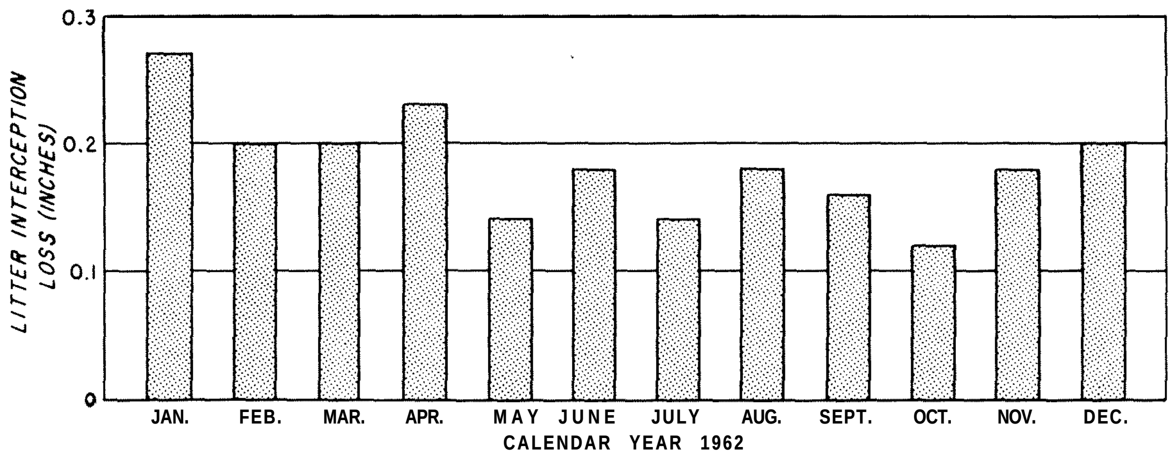


Figure 5. --Litter interception loss by months. Note that monthly interception loss is greatest during the winter months.

Computed litter interception loss during 1962 was 2.2 inches of water. It is noteworthy that the monthly evaporation (fig. 5) was usually greatest during the dormant season when evaporative processes are generally thought to be minimum. The leafless condition of hardwood trees in winter, offering little interference to solar radiation and wind movement, combined with maximum litter accumulations, probably accounts for this difference. Estimated annual canopy interception loss was 10.2 inches, and thus water reaching mineral soil was 55.8 inches, or 82 percent of total rainfall measured in a forest opening. Litter interception loss during 1962 was probably below average at Coweeta, because both rainfall and number of storms was below the 30-year average.

Since estimated litter interception loss from rainfall records (3.6 inches) appears above average, and that observed during 1962 (2.2 inches) appears below average, the annual litter interception loss at Coweeta should approximate 3 inches, ranging from 2 to 4 inches. Thus, about 3 percent of the annual rainfall in the humid southern Appalachians is evaporated from litter, a result only slightly higher than Blow's (1955) estimate of 2 percent for upland hardwoods in eastern Tennessee.

There is a need for more information on the amount of rainfall evaporated from the forest floor. Several estimates which have appeared in the meager literature on this subject appear too high, but there is no doubt that forest litter prevents some rainfall from adding effectively to soil moisture recharge and streamflow.

LITERATURE CITED

BLACK, PETER E.
1957. Interception of rainfall by a hardwood canopy. Master's Thesis, Univ. Mich.

BLOW, FRANK E.
1955. Quantity and hydrologic characteristics of litter upon upland oak forests in eastern Tennessee. Jour. Forestry 53: 190-195.

CHANDLER, ROBERT F., Jr.
1941. The amount and nutrient content of freshly fallen leaf litter in the hardwood forests of central New York. Jour. Amer. Soc. Agron. 33: 859-871.

CURTIS, W. R.
1960. Moisture storage by leaf litter. U. S. Forest Serv. Lake States Forest Expt. Sta. Tech. Note 577, 2 pp.

HAMILTON, E. L., and ROWE, P. B.
1949. Rainfall interception by Chaparral in California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta., 43 pp.

JENNY, BANS., GESSEL, S. P., and BINGHAM, F. T.
1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Sci. 68: 419-432.

KOVNER, JACOB L.
1955. Changes in streamflow and vegetation characteristics of a southern Appalachian mountain watershed brought about by forest cutting and subsequent natural regrowth. Doctoral Thesis, *State* Col. *N. Y.*

METZ, LOUIS J.
1954. Forest floor in the Piedmont region of South Carolina. Soil Sei. Soc. Amer. Proc. 18 (3): 335-338.

____
1958. Moisture held in pine litter. Jour. Forestry 56: 36.

SEMAGO, W. T.
1960. Interception of precipitation by hardwood litter. Master's Thesis, Univ. Mo.

SHANKS, R. E., and OLSON, J. S.
1961. First year breakdown of leaf litter in southern Appalachian forests. Science 134 *(3473):* 194-195.

SIMS, I. H.
1932. Litter decomposition and accumulation in the pine oak type of the southern Appalachians. Jour. Forestry 30: 90-91.

SOCIETY OF AMERICAN FORESTERS
1954. Forest cover types of North America (exclusive of Mexico). Corn. on Forest Types Rpt., 67 pp., illus. Wash., D. C.