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The Annual Range of Soil Moisture Under High Rainfall in the Southern Appalachians

Knowledge of the seasonal soil moisture limits within the rooting zone of forest vegetation is essential for interpretation of the effects of watershed treatments on water yields. At the Coweeta Hydrologic Laboratory in western North Carolina, where the average annual rainfall amounts to 80 inches per year, the vigor of forest growth testifies to the ready availability of soil moisture. In addition to short-cycle fluctuations of soil moisture representing current rates of evapo-transpiration, drainage, and rainfall, there appear to be rather well-defined annual cycles which reflect the average seasonal water balance in this Southern Appalachian region. In areas where rainfall generally exceeds evapo-transpiration, the annual soil moisture range is characterized by mean springtime maxima and fall minima which reflect recurring limits of soil water stored against drainage and evapo-transpiration. This paper describes the annual trend in soil moisture at Coweeta.

Results given here represent some 14,000 individual soil moisture determinations obtained for various purposes at the Coweeta Hydrologic Laboratory by gravimetric and neutron scattering methods from 1953 through 1959. The soils sampled were sandy loams derived chiefly from mica schists and gneisses fairly uniform in texture and largely free of stone. Sampling was restricted primarily to deep-soiled slopes and ridges located in some 25 scattered plots, which may be taken as a representative—though not strictly random—sample of such areas within the 4,600-acre Coweeta drainage. Sampling was not continuous throughout the seven years at any one site; furthermore, there were periods when no sampling was done. Samples were taken by 6-inch intervals in the surface foot and by 1-foot intervals thereafter to a total depth of 7 feet. Soil moisture determinations were by the usual methods, which in addition to the gravimetric technique using King tubes and undisturbed soil samplers included some determinations with a neutron scattering device. Sampling intervals varied from 7 to 30 days, the growing season from April to October providing the most frequent record.

The curve in Figure 1 represents trends in soil moisture in the average 7-foot profile during the period 1953 through 1959. The plotted points are weighted means of all determinations within a 15-day period. Despite gaps in the record, the trend line appears to approach similar values during various periods of the year. The low value reached in September 1957 reflects exceptionally dry July and August weather by Coweeta standards. Monthly total rainfall, plotted below, shows great variability but little tendency toward any recurring seasonal dry period.

The top curve in Figure 2 represents the average quantity of water in the soil, composited from the entire 7-year period. Again the plotted points are weighted averages of all determinations within a given 15-day period, but irrespective of the year collected. Included is the concurrent 7-year average streamflow in inches per month from the drainage within which the sampling plots were located. The striking similarity between the soil moisture and streamflow curves suggests a close relationship which is seldom apparent from a single year's record of moisture and streamflow. Average maximum streamflow and soil moisture in the top 7 feet occur together about March 31, while average minimum streamflow lags

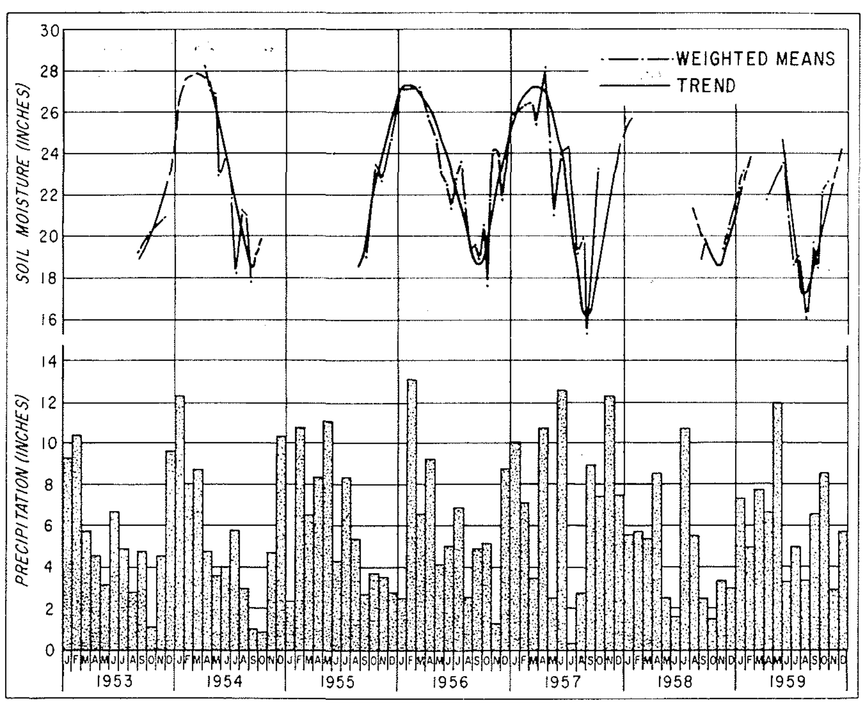

FIG. 1.—Soil moisture trends in a 7-foot profile and average monthly precipitation during the period, 1953 through 1959. Note that soil moisture approaches similar values during spring and fall of each year.

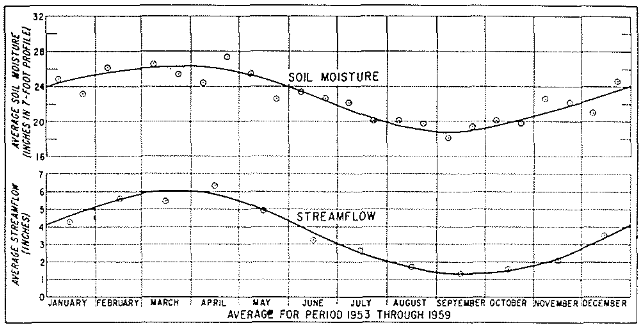

FIG. 2.—Soil moisture compared to total monthly streamflow averaged from the period of record 1953 through 1959. Such close relationship between soil moisture and streamflow is rarely evident from a single year's record.

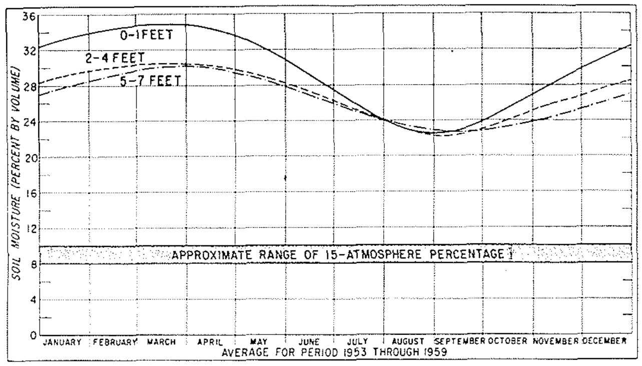

FIG. 3.—Soil moisture trends in three layers of a 7-foot profile as related to wilting (15-atmosphere percentage). Note that moisture content appears to approach the annual minimum first in the upper (0-1 foot) horizon and last in the deepest (5-7 foot) horizon.

minimum soil moisture by roughly two weeks in September.

Figure 3 is plotted from the same data except that moisture is expressed in percent by volume averaged separately for the 0-1, 2-4, and 5-7 foot horizons. Differences exist in texture and degree of weathering of these horizons, thus limiting the interpretation of the curves. However, it is apparent that the 0-1 foot layer both stores and loses more water on a percent-by-volume basis than the remainder of the profile. Close agreement between the 2-4 and the 5-7 foot layers indicates rather uniform losses by drainage and evapotranspiration from the remainder of the profile. Variation in the data prevents determination of any sequence in maximum storage levels among the several layers, but there is evidence from Figure 3 that the period of minimum storage is reached first by the upper (0-1 foot) horizon and last by the deepest (5-7 foot) horizon. Correspondingly earlier recharge of the upper horizons is evident during October to February. Storage limits in the deepest layer (5-7 feet) appear to occur closely in phase with the corresponding limits of streamflow, shown in Figure 2.

These data, insofar as they represent average moisture conditions for seven years of record, provide evidence that vegetation on deep soils at Coweeta, and probably on similar soils elsewhere in the high rainfall belt of the Southern Appalachians, seldom if ever suffers from true drought. Average values of the 15-atmosphere percentage, generally thought to approximate the lower limit of moisture available to plants, have accumulated from various soil studies at Coweeta, indicating a range from about 8 to 10 percent by volume in these soils. Accepting this range as an approximation for comparison, it can be seen from Figure 3 that during the average evapo-transpiration season the lower limit of available moisture in the top 7 feet of soil is not approached. Even in the top 1 foot, where many of the absorbing roots are located, moisture remains available, with possible rare exceptions, throughout the growing season.

It may be reasoned that fluctuation in soil moisture from season to season under humid climates reflects both evapo-transpiration and drainage, but that these may occur in a ratio to each other which will be difficult to determine from soil moisture records alone. The spring build-up in soil moisture parallels increases in streamflow, and minimum soil moisture storage in September is accompanied or shortly followed by minimum stream discharges. There is apparently little if any lag between recharge of the 5-7 foot horizon on slopes and ridges and the beginning of increased streamflow in late September.

Experiments with small watersheds at Coweeta have demonstrated varying amounts of increased streamflow following reduction in vegetative cover (*2*, *3*, *4*, *5*). The condition of readily available soil moisture under which the experimental vegetation grew must be taken into account in efforts to extend these results to other areas of the world. For example, Dunford and Fletcher (*1*) in a small experiment at Coweeta explored the idea that streamside trees and shrubs are unusually heavy water users because their roots penetrate the water table; but they found that streamflow increase was no larger than might be expected from an equal area of cutting elsewhere on the experimental watershed. Thus the riparian effect, so important along channels in arid lands appears to be lacking under Coweeta's perhumid climate. It may be expected that the riparian effect will be largely masked in areas where soil moisture on all sites remains readily available throughout the year.

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