Soils and Water

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Introduction

Controversy in this country about the influence of forests upon the environment dates from the turn of the century. During the early 1900's there was much speculation about the effects of forests on streamflow, soil and climate. Factual information on the subject was quite limited and most arguments were simply opinions. Arguments reached a peak during the period when the Weeks Law was formulated and subsequently passed in 1911. A stated objective and justification of this legislation was protection of the watersheds of navigable streams.

In the last forty years, results from watershed research have helped to clarify the influence of forests on the water and soil resources. Because water is the dominant carrier of materials and because hydrologic processes link the interactions between aquatic and terrestrial processes, the quantity, timing, and quality of water flowing from a landscape serve as sensitive indicators of the long-term success or failure of land management practices. Therefore, my comments will deal primarily with the effects of clearcutting the forest on the quantity, timing, and quality of streamflow. Several detailed summaries have been published on the effects of forest management practices on streamflow modifications (Douglass and Swank, 1972), nutrient losses (Forest Service, USDA, 1971) and flood runoff and sedimentation (Lull and Reinhart, 1972). In the time allotted this morning, I would like to limit my statement to the most salient conclusions of the research findings on these subjects. Furthermore, I would like to restrict my comments mainly to one region of the country--the Appalachian Highlands Physiographic Division in the Eastern United States (Figure 1). Many of the conclusions have been derived from four sites: Coweeta Hydrologic Laboratory; Fernow Experimental Forest and Hubbard Brook Experimental Forest operated by the Forest Service, USDA and Leading Ridge Watersheds operated by the School of Forest Resources, Pennsylvania State University. The one common characteristic of all sites is a mixed deciduous hardwood forest cover, typical of millions of acres of forest land in the Appalachian Highlands.

Clearcutting and Quantity of Streamflow

Cutting forest vegetation induces changes in hydrologic processes, and a major impact is a reduction in evapotranspiration from the landscape. This decrease in water loss to the atmosphere produces a gain in streamflow and/or groundwater on the cutover area. Figure 2 summarizes the results of 23 forest cutting experiments and provides the best information available on the influence of cutting hardwood forests on streamflow in the East (Douglass and Swank, 1972). When a mature hardwood forest is clearcut, an increase in streamflow of approximately 11.5 area inches can be expected the first year after cutting. This is equivalent to slightly more than 300 thousand gallons of extra water produced for each acre clearcut. Experimental evidence suggests that even larger increases in streamflow may occur when coniferous forests are clearcut. The scatter of data occurs because the watersheds differed in slope, aspect,

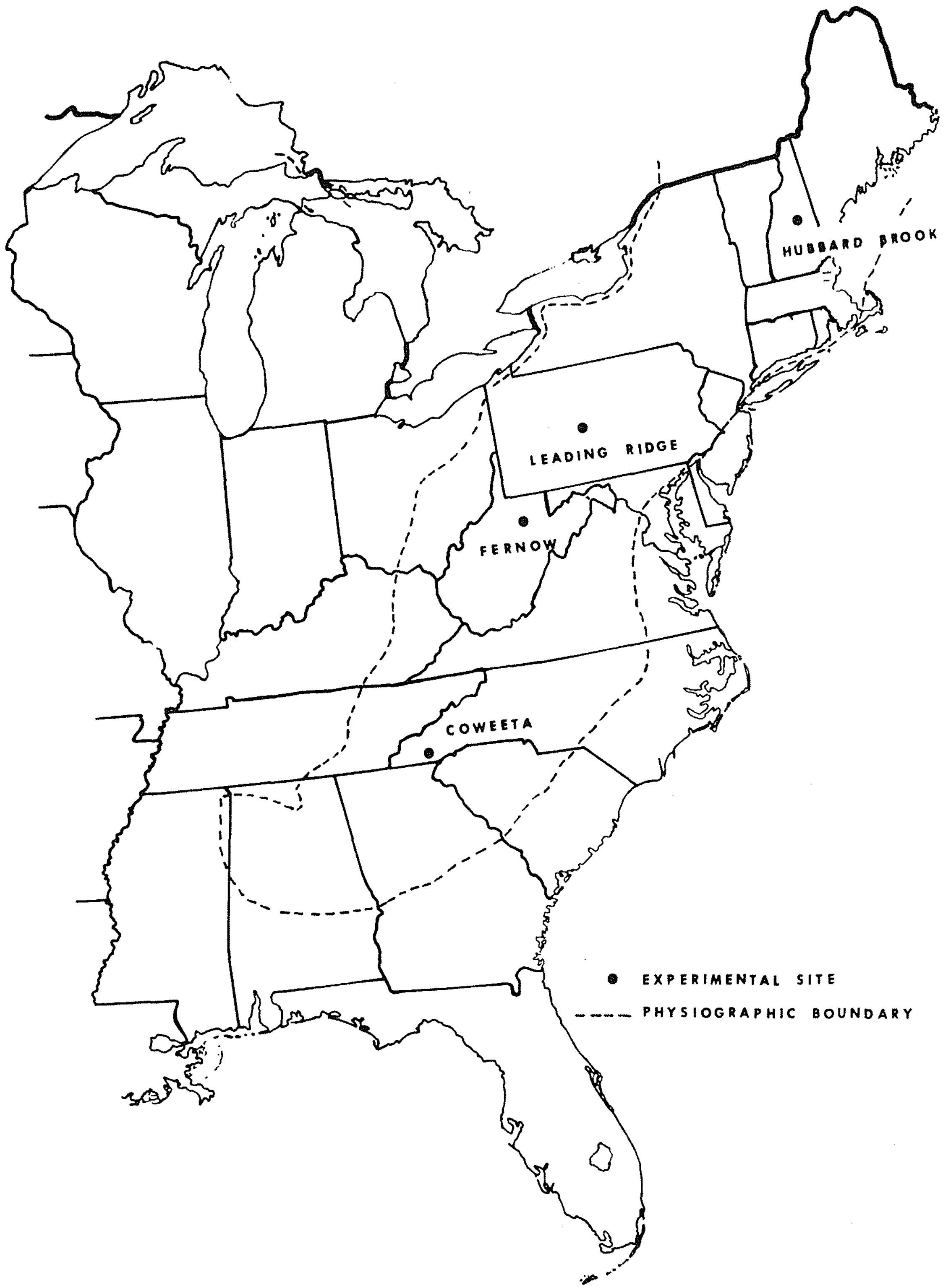

Figure 1. Location of four experimental watershed study sites within the Appalachian Highlands.

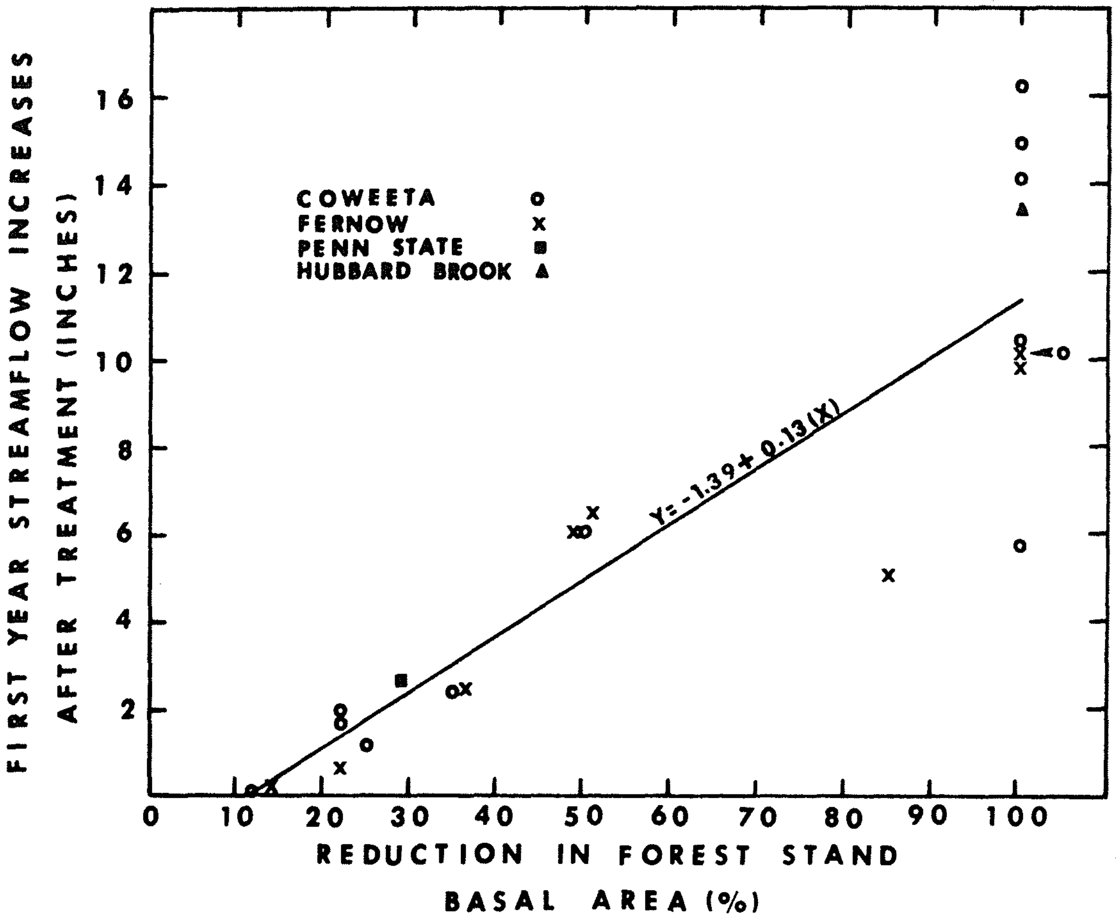

Figure 2. Relationship between the streamflow increase the first year after forest cutting and the percentage reduction in the forest stand.

vegetation density, rainfall and other factors. A large watershed contains a variety of these factors and the relationship depicted provides a good estimate of the average streamflow response to forest cutting.

As the forest on a clearcut area regrows, the evaporating surface area increases and streamflow increases diminish in subsequent years. Equations are available for estimating the total volume of water which accrues from cutting. For example, in a practical forest cutting experiment at the Coweeta Hydrologic Laboratory on part of a 356-acre watershed, a total increase in streamflow of 25 inches was predicted for a seven-year period; an increase of 23 inches was measured (Douglass and Swank, 1972).

Effect on Clearcutting on Streamflow Timing

The seasonal distribution of an increase in annual flow resulting from forest cutting varies somewhat throughout the East. A watershed at Coweeta was clearcut and maintained in a low coppice-herb condition by annual recutting for 7 years. Figure 3 shows the average monthly flow under a hardwood cover and the average monthly increase in flow during the recutting period. About 60 percent of the annual increase in flow came in the period July through November and the remainder appeared during the winter months. In the low flow months of August, September and October, flow was increased by nearly 100 percent. Other experiments at Coweeta confirm this seasonal response to cutting. Further north where soils are shallower, the major portion of streamflow increases appear from June through November. Thus, experimental results consistently show that the increase in flow derived by cutting forests appears mostly in the growing and early dormant seasons when demand for water is greatest and flows are least.

The changes in storm runoff and peak flow rates due to clearcutting are other important characteristics of streamflow timing. When an entire watershed is clearcut, the experimental evidence leaves no doubt that cutting the forest cover, even without disturbing the soil surface, can increase both peak flow rates and volume of water released from upland areas. For example, all vegetation was cut but no forest products were removed and no roads were constructed on a 108-acre watershed at Coweeta. Hewlett and Helvey (1970) found that stormflow volume was increased by 11 percent overall and peak discharge was increased by 7 percent. A more extreme treatment at Hubbard Brook, New Hampshire (where the watershed was maintained free from vegetation after cutting) produced a larger increase in storm peaks but stormflow volume increases were similar to Coweeta results. A commercial clearcut at Fernow, West Virginia was made without stringent controls on road construction and logging methods; both peak discharge and stormflow volumes were increased somewhat (Reinhart and others, 1963). The interpretation of the forests' influence on floods must be considered in respect to size of the area under consideration. In an excellent review of forests and floods in the East, Lull and Reinhart (1972) conclude that although the forest provides a maximum opportunity for controlling runoff from flood-producing rainfalls, the forest cannot prevent floods. They also infer that if only a small proportion of the watershed is clearcut at any one time, increases in peak flow and flood runoff will not be large enough to be important. Other investigators also feel that regulated cutting on upstream forest land will not produce serious flood problems downstream (Douglass and Swank, 1972).

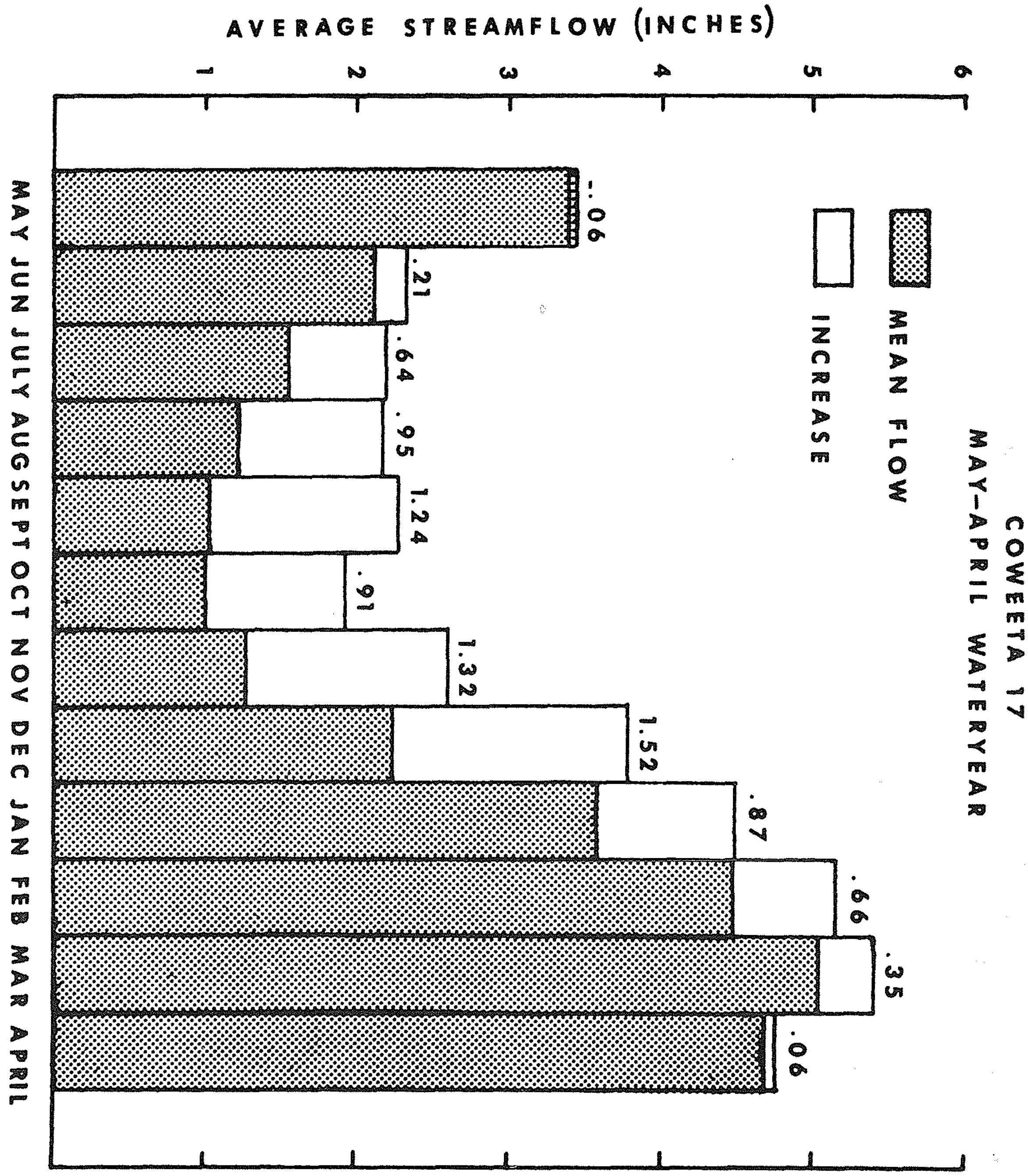

Figure 3. Mean monthly streamflow before treatment and the average increase in flow produced by a Coweeta watershed which was clearcut and cut back annually for seven years.

Clearcutting and Water Quality

There are numerous measures of water quality, depending upon the intended use of the water resource. In this statement, I would like to discuss the relationship between clearcutting and effects on stream temperature, turbidity, and nutrient cycling. Studies have shown that those cutting practices which open up the stream channel to direct solar radiation are the practices which increase stream temperatures. If clearcutting extends to the stream, an increase in water temperature will occur but the magnitude of the increase will depend upon many factors. In the southern Appalachians, where forest trees and all understory vegetation were completely cut, maximum stream temperatures in the summer increased from the normal 66°F. to 73° (Swift and Messer, 1971). This practice was judged to degrade water quality because water temperature exceeded optimum levels for trout habitat. On the other hand, where streambank vegetation was uncut or had regrown, summer maximum temperatures remained unchanged.

Stream siltation and turbidity are not caused by cutting trees, *per se*, but may result from improper road construction and removal of forest products (Lull and Reinhart, 1972; Douglass and Swank, 1972). The effect of poor road location and design on soil erosion and stream turbidity has been demonstrated many times in the past. But proper logging methods and road specifications are currently available; when followed, only small and temporary increases in erosion and turbidity occur.

The effect of clearcutting on nutrient cycling is a more complex subject because both biological and physical factors must be considered. A review of studies conducted the past decade indicates that there is no drastic or irreversible depletion of nutrients caused by timber removal (Forest Service, USDA, 1971). The immediate effect of clearcutting is the removal from the forest of elements in woody material and at the same time return of organic material to the forest floor in the form of slash and residues. Wells (1970) has pointed out that only small quantities of nutrients are removed in timber harvesting in relation to the total amount in the soil and plants. For nitrogen, an element important in plant growth, removal over a 100-year period for a mixed hardwood forest has been estimated to be only about one pound per acre per year. This is considerably less than the annual additions of nitrogen in rainfall.

The organic material returned to the forest floor after clearcutting undergoes biological action. The pathway of nutrients released back to soil is varied, and nutrients may be reabsorbed by plant roots, held on organic and mineral colloids, or leached from the soil to the stream. It is this last pathway which may be detrimental to the site, but most studies have shown that the quantity of nutrients leaching to streams is small compared to the total nutrient reserve in the soil. One exception was at Hubbard Brook in an extreme experiment designed to find the maximum streamflow response from a watershed. All forest vegetation was cut and the area was subsequently treated with herbicides for three successive summers, thereby blocking the uptake of nutrients by vegetation. Large losses in ions were observed and nitrate nitrogen losses were particularly high. However, this was an experimental cutting and not a recommended forest management practice because the watershed was intentionally maintained free from vegetation.

If forest vegetation is permitted to regrow after clearcutting, nutrient losses are kept to a minimum (Marks and Bormann, 1972). The loss of nutrients following forest perturbations has been under study on four watersheds at

Coweeta the past several years (Swank and Elwood, 1971). The watersheds represent four different vegetation covers: (1) Undisturbed mixed hardwoods, (2) grass-to-forest succession, (3) a 7-year-old hardwood coppice forest after clearcutting and without removal of forest products and (4) a 13-year-old white pine plantation. The grass-to-forest succession watershed represents a drastic alteration of the forest ecosystem because the watershed was heavily fertilized, limed and treated with herbicides after conversion from hardwoods. Although there was an accelerated loss of nutrients after treatment, cation concentrations were still low; i.e., 1 ppm or less. Annual cation budgets for the other two young successional forest ecosystems showed smaller losses than the mature hardwood forest.

Additional research is needed to better define and quantify the effect of clearcutting on nutrient cycling because present information is limited with respect to soil conditions, biological factors, and timber types represented.

Summary

Based on experimental evidence in the East, clearcutting has a favorable impact on the water resource by supplementing man's supply of fresh water when consumptive demands are most critical. Heavy forest cuttings will usually increase storm runoff on that portion of the watershed cutover, but since the proportion of a river basin clearcut at any one time is small, the increase in flood runoff will not be large enough to be important. Studies have demonstrated that adequate methods are available to hold water temperature and turbidity increases to a minimum, and usually, it is a question of applying existing knowledge in the management of the watershed. Research indicates that there is no drastic or irreversible depletion of nutrients caused by timber removal but more research is needed to further clarify the impact of clearcutting on nutrient cycling.

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