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Will Water Demand Dominate Forest Management in the East?

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RECENTLY Secretary of Agriculture Orville Freeman was quoted in a Newark, New Jersey, newspaper to the effect that trees on municipal watersheds may have to be sacrificed specifically to increase water yield. It surprised me that the newspaper statement passed with little comment by either forest managers or laymen in the East. I suppose there are so many proposals nowadays concerning our forests that this one fell on relatively inattentive ears. The defenders of forests and the outdoors are not yet aroused by this strange concept. But it is interesting to speculate whether the people of New York City, who have for many years vigorously opposed any timber cutting within the famous Blue Line that marks off the Adirondack Park, may someday acquiesce to even more drastic forest clearing to increase the city's water supply. Is there an issue brewing here that may eventually change the whole nature of forest practice in the East?

Several developments suggest that it may be. For one thing, much of the forest and wildland areas of the eastern mountain and piedmont regions are not overly productive of timber or game. Mostly hardwood stands, growth is slow and quality of wood and forage is not conducive to high per-acre returns. Silviculture is complex and inexact, often consisting of mere protection or wholesale conversion to conifers. In other words, many square miles of hardwoods are not protected by high intrinsic value of either the stand or the product.

Second, the demand for water, either imagined or real, has reached the point where conversion of sea water has been suggested many times as a feasible solution to municipal shortages. This means that some eastern cities appear willing to buy extra water at the astounding cost of $1.00 per thousand gallons (about $300 per acre-foot).

Third, watershed experiments show that complete cutting of some forest stands in the humid East can increase streamflow up to 16 area inches per year. Although known to forest hydrologists for some years, this fact is only now becoming sufficiently documented to awaken forest managers and the public to its potential use in increasing clean water supplies.

A fourth important development is the improvement of mechanical and chemical control of vegetation to the point that the formerly overwhelming task of forest clearing is brought within almost too-easy reach.

About one-half of the area east of the Mississippi River is classed as forest land. This area yields roughly 500 million acre-feet of water per year through surface streams alone. We "use" at best only 5 percent but the remainder is virtually appropriated to fill ponds and reservoirs and to flush our wastes out to sea. Small watershed experiments cannot yet be extrapolated to such a vast area, but the results we have suggest that complete removal of the eastern forest—heaven forbid, I hasten to add—could produce each year an extra 100 million acre-feet of mostly clean water, equivalent to the annual water supply of half a billion people. All of us view such figures with justified skepticism. On the other hand, if we were to clear *only ten percent* of eastern forest land, an additional 50 million people might be supplied with clean water. We live in an age when planning starts on no better basis than this; consider for example the current emphasis on weather modification and saline water conversion, to say nothing about wild plans to populate the ocean bottoms.

Put these facts together with other recent trends in forest use in eastern uplands and where do they lead us? Perhaps some may feel that I have overlooked recreational use of the forest and the role such use will play in forest management. Despite its dominant role in narrow strips of land in the Great Smokies, the Poconos, the Blue Ridge and elsewhere, recreation still leaves tens of thousands of square miles of forests and wildlands virtually unaffected except by the relatively unspecified interests of trail walkers, naturalists, and preservationists. These groups, though articulate and influential, do not possess overwhelming power in the political process. The majority of voting citizens of New York City, for example, are earnestly dissatisfied with their water supply. How would they vote once it becomes well-known that forests they seldom see or use are competing with them for clean water? I do not pretend to know, but it is time for foresters to give special thought to the possibility that concern for water resources may alter forest practice in the eastern uplands fully as much as it is beginning to in some parts of the West. In fact, the rather startling increases in water yield that have been demonstrated in several eastern experiments, the relative predictability of the amounts, the regularity of increases from year to year, and particularly the low degree of soil and water damage after forest removal, suggests that the demand for clean water may ultimately affect forest management more in the East than in the West.

Have forest researchers been dozing, that these water yield problems appear to have crept up on us recently? Not at all; American foresters have in fact done well to anticipate the role of forestry in water resources, which may not reach emergency proportions for another 20 years. Pointed research on the subject began in 1911 at Wagon Wheel Gap in Colorado and has progressed through a variety of experiments. What has brought water yield to the fore even in the humid East is the hunger of a growing technology for clean water and the high cost of cleaning up dirty water. It was inevitable that attention should focus on forests and wildlands since these

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are the source of most of our clean surface waters and also the best lands for recharge of high-quality groundwater.

Significance of Research on Water Yield

Several recent reviews have summarized the findings of catchment experiments in various parts of the world as they relate to water yield increases following both removal and establishment of forest cover. Because of the more rapid response of water yield to forest cutting in contrast to forest planting, cutting experiments, particularly those carried out with an undisturbed forested watershed as a control, have provided the most convincing evidence of greater water yield in the absence of forest cover. Hibbert (1966) summarized 30 forest cutting and poisoning experiments in the United States, Africa, and Japan, as well as nine additional cases in which streamflow increases were studied for some years following afforestation. The controlled experiments all showed significant changes in water yield, averaging about eight inches increase following elimination of fully stocked stands and about the same decrease 20 or 30 years after afforestation. Although there is no space to discuss them here, dozens of soil moisture studies have verified the fact that forest removal or conversion to other vegetal types reduces evaporative draft on soil water and increases the opportunity for these "savings" to be delivered as streamflow.

All but one of the watershed experiments were located in temperate zones of the world, most of them in fairly humid climates. There is little information as yet from tropical rain forest or boreal forest. Maximum annual yield increases following forest cover reduction appears to be associated with high, uniformly distributed rainfall (perhumid climate) at a latitude and altitude fairly free of snow accumulation in winter. The increases obtained after clearcutting by the United States Forest Service at the Coweeta Hydrologic Laboratory in western North Carolina (up to 16 inches per year) are still the largest yet shown. While the size of increases appears to be less in the northeastern states, as might be expected in more northerly latitudes, the amount of water involved is quite substantial (Lull and Satterlund 1964). So far the best documented water yield increases after cutting in areas of considerable snow pack are those carried out by the Forest Service at Fraser and Wagon Wheel Gap, both in Colorado. Since little rain falls there in summer and most of the total water yield occurs from the melting snow pack in spring, it is not surprising that the annual increases also came during spring. The timing of increases in eastern experiments are much less definite because reductions in evapo-transpiration losses by cutting forest under a rainy climate seems to be due about equally to reductions in transpiration and interception losses. It is not clear yet whether the major effect on annual yield increments in snow country is due to reduction in interception loss of snow, or less transpiration after cutting, or whether snow pack depth is increased by more effective trapping and shielding of snow from evaporation (Hoover 1966). Studies by several universities and the Forest Service are underway to clarify the role of forests in snow country but the complex status of snow hydrology prompts me to limit the remainder of this discussion to areas where the snow pack is not the major water supply. Only a small percentage of the East develops anything resembling a true snow pack in which most of the total yield is stored up and discharged in a short time.

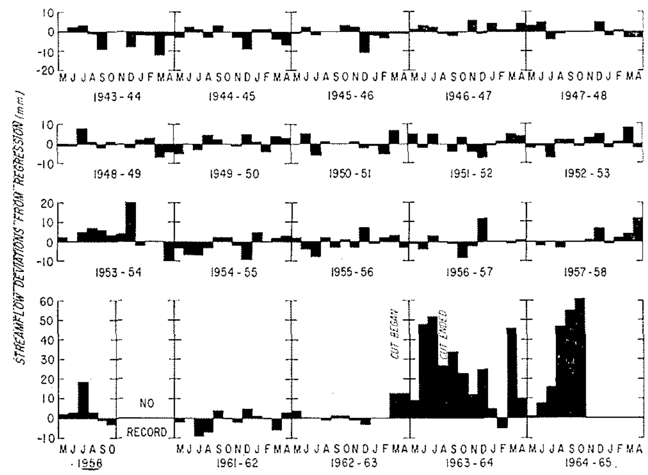

Fig. 1.—This 20-year record of deviation in monthly streamflow between two 100-acre watersheds shows how clearcutting one of them in 1963 affected water yield. The pluses and minuses before March 1963 are normal errors in the ability to predict streamflow on the experimental catchment before cutting. Only a drastic increase in yield could cause the large positive values after March 1963.

Despite complexity of the factors involved, the timing of yield changes are being clarified and predictions of the amounts of water to be secured by forest management are improving. I will use several experiments reported by the Coweeta Hydrologic Laboratory to illustrate the point. Some of the Coweeta results are from the best controlled experiments available, chiefly because extra long watershed calibration periods allow not only accurate estimates of the total increases but some details on when and why the increases occur. Setting aside for the moment any forest management objectives which may have stimulated the type of forest cutting used in these experiments, we will look mainly at what was done to the structure and pattern of the stand, how large the increases were, and when the extra yield appeared in streams.

The southern Appalachians, in the area of the laboratory, receive about four to six inches of rain nearly every month, with high flow in late March and low flow in October. Annual total yield under forest is about 40 inches under an average annual precipitation of 72 inches. Several clear felling experiments increased streamflow from the average of 40 up to about 56 inches without damage to storm peaks, water quality, or soils. Until recently the timing of these increases, in contrast to those obtained by forest manipulations in snow country, have been quite a puzzle. Kovner (1956) first observed the peculiar fact that a large percentage of the reduction in evapotranspiration presumably brought about in summer did not appear as streamflow until the following February-to-April period. Further experiments have verified Kovner's finding but such unusual delays have not been reported elsewhere. The porous mantle above bedrock is quite deep at Coweeta, accounting in part for the long delays, but it is in the unsaturated soil that we must look for explanation. Fig. 1 is a graphical analysis of the yield variations on two 100-acre watersheds at Coweeta, both before and after felling of all forest on one of them in 1963. The long calibration period allows detailed study of the effect of monthly rainfall on monthly increases (Fig. 2).

For example, May through July 1963, had above average rainfall and the increase in stream flow reached two inches/month by July. Late summer

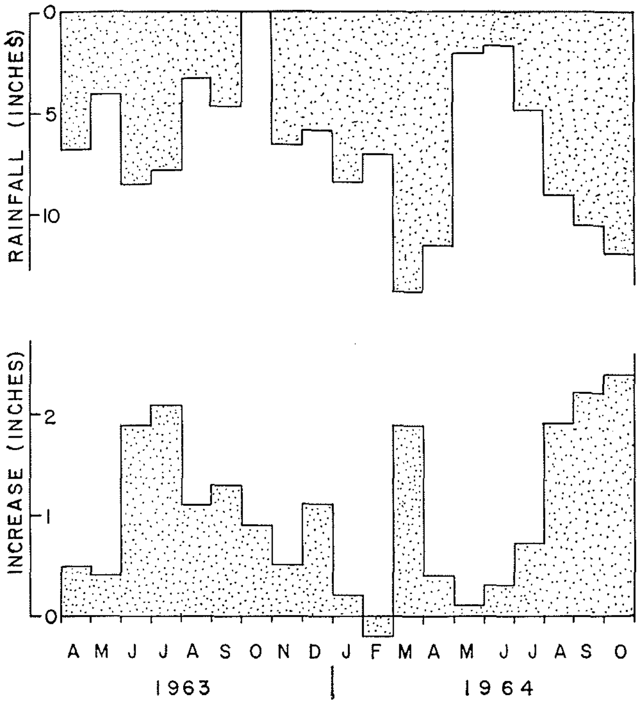

Fig. 2.—The post-treatment data shown in Fig. 1 are replotted here along with current monthly rainfall to show how streamflow increases are controlled by new supplies of rain. During periods of little rain, reductions in evapo-transpiration are locked up in the soil. When the rains are large, more of the accumulated savings are flushed through to streams.

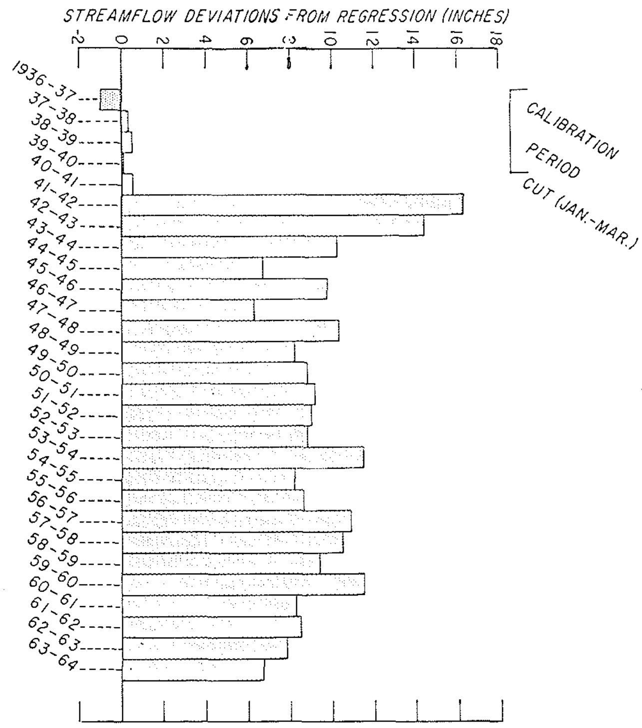

Fig. 3.—A 27-year experiment on a 38-acre watershed shows how annual yield increments due to cutting died away as the forest regrew, but returned to the initial level immediately upon recutting in 1963. The deviations are around regression calculated on the control watershed during the calibration period. After Hibbert *(5)*.

was fairly dry, so further increase was delayed until March 1964, when the accumulating net increments in soil moisture were flushed through to streams by spring rains. Then an early summer dry spell occurred in 1964 and reductions in evaporation were stored in the soil until unusual amounts of late summer rain pushed the savings through deeply weathered soils and downslope into streams. The October increase of about 2.4 inches (20 acre-feet from 100 acres) would almost double the streamflow for that month in an average year, but represents an increase of 25 percent even in this wettest October of record. However, had it been an exceptionally dry fall most of the increase in flow would have been delayed into winter, incidentally doing little to relieve immediate water shortages.

Another often-suspected effect of cutting should be discounted at this point. The 2.4-inch increase in October 1964, the largest monthly change in yield ever reported, represents a steady flow of about two cu ft/sec/mi^2 (csm) throughout October. Although this was a month of record floods in the region, it is unreasonable to suppose that the increase of two csm had much effect either on the recorded 200 csm peak flow or the damage potential of the flood. If we rule out large-scale soil disturbance by cropping, pasturing, or construction operations following forest clearing, it is very hard to see how these small rate increases will aggravate either local or regional floods enough to cause concern.

Cutting or other treatments to reduce evaporation in summer may be in vain if the plan is to turn loose additional water for an anticipated dry season or any other short-term water requirement. Year-around storage must be provided and planning must be long-range if forests are to be managed specifically to increase water yield. Only the treatment of narrow strips along stream channels might release relatively small amounts of water quickly, but probably not enough in the East to relieve a water shortage. In the West, the location of vegetated channels through long stretches of hot dry lands is said to cause enormous riparian loss of moisture, but soils of the East are usually moist and vegetated, providing greater opportunity for all segments of the watershed to evaporate water equally (*2*).

Although results on shallower soils at other locations have not detected long delays in the response of streamflow to evaporation reductions, it remains to be seen whether or not the principle that "it takes water to fetch water" holds in shallower soils as well. Certainly if there is insufficient soil storage available to hold evaporation savings, the opportunity for reducing evaporation should also be less, and even these reductions may later evaporate from the soil before enough rainfall occurs to flush them through to streams. So far, most research in the East indicates that increases in low flows will be large percentagewise, but may dwindle to a trickle just when we most need extra water.

Fig. 3 shows that annual increases do not last indefinitely nor do they disappear quickly. The 38-acre watershed represented was clear felled in 1941 and allowed to regrow naturally until 1963 when it was clear felled as before. The initial annual increase of 16 inches dropped steadily through the years, only to increase immediately upon recutting to 16 inches again (*5*). Here is proof that yield increases are reproducible and fairly independent of annual climate. Fig. 4, representing another experiment at about the same time, shows that annual recuts will not maintain maximum yield but that about two-thirds of the maximum can be sustained. Repeated cutting in this area tends to develop a vigorous green crop of low vegetation which regains part of the evapotranspiration potential of full forest cover. Short of paving the watershed there seems to be a point of diminishing returns in the struggle to sustain the increase obtained the first year after cutting, when the forest floor is very sparsely vegetated. Optimum increases in relation to cost of clearing might be secured by allowing the new forest to grow long enough to crowd out the understory, perhaps five years in this case, and then recut. Other possibilities consistent with timber management objectives begin to suggest themselves, such as cyclic cutting on alternate working compartments, planned to produce wood on the best sites and extra water on others.

The question arises, will thinning, understory cutting, and selective harvesting in timbered compartments reduce evapotranspiration? The answer appears to be a definite yes; any felling, removal, or defoliation of vegetation will reduce evaporation rates, augment soil moisture and eventually in most cases add to streamflow or groundwater. In one experiment at Coweeta 50 percent of all standing vegetation was eliminated by killing or cutting alternate 33-foot strips running perpendicular to the main stream channel. The non-commercial nature of the operation had the advantage of yielding an answer in terms of reduction in total volume of the stand without bias introduced by selection of particular stands, species or size classes. It is not really known whether yield increases are best correlated with reductions in total volume, basal area, standing height, surface area, species or location of stands on the catchment, but in the 50-percent clearing all these elements were halved. The first year increase of eight inches was surprisingly (*4*) close to half the increase (16 inches) obtained from a nearby clearcut watershed. This experiment is the best single piece of evidence to date that yield increases are directly and approximately linearly related to the percent of the stand felled or killed. Several nearby experiments, e.g., an understory cut (25 percent of the total watershed basal area), a riparian clearing (25 percent of the total watershed area *and* basal area), and a commercial cut (30 percent of the total watershed basal area removed), all indicate that the percent of the maximum increase to be attained on the watershed was about linear in relation to the percent reduction in total basal area. Similar results are indicated by Reinhart, Eschner and Trimble (1964) based on partial cuts at the Fernow Experimental Forest in West Virginia, although these authors reported cutting data in board feet removed and culled.

The problem of choosing forest areas to manage for maximum water supply is not restricted to choice of riparian versus non-riparian, or deep versus shallow soiled areas, but also may involve the choice of aspect of the watershed. Hewlett and Hibbert (*4*) cautiously drew the conclusion that north and south aspects may affect yield response to cutting rather drastically, with as much as two or three times more water released by cutting similar forest cover on northerly slopes as compared with southerly

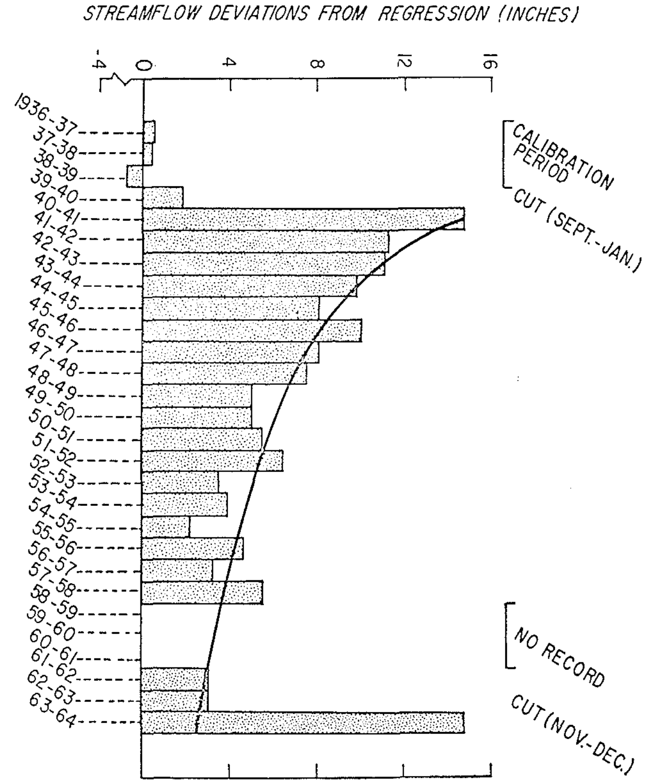

Fig. 4.—Another long-term experiment (the famous Watershed 17) shows how annual yield increments tended to stabilize at about two-thirds the initial increase as regrowth was cut back with bush axes once a year. The downward trend during the last few years is the result of a rapidly growing white pine stand, planted in 1957 as part of another experiment. After Hibbert (*5*).

slopes. This deduction is based on very limited data, but, if verified, the implications for management are clear; greater opportunity to increase water yield on northerly aspects. Another possible choice is whether to concentrate on high or low elevation watersheds. Although some foresters have speculated on the shorter growing seasons at higher elevations and the possible effect on reduced draft on soil moisture, there is very little if any evidence that cutting at higher elevations has less effect on water yield, except insofar as average rainfall, usually related to elevation, controls the available water.

Combining Management Objectives

There is much support and little contrary evidence for these summary conclusions in other types of experimental work in the East. Much remains to be learned about how to predict water yield increases with accuracy and how to apply them within the context of management situations. But the above principles are becoming more widely understood and will perhaps soon stimulate pilot testing on a large scale.

Applying these principles, the ideal way to combine wood and water production is to limit most evaporating plant surfaces and volumes to fast growing species producing high-quality wood. Slash and some low vegetation must be left on cleared areas to bind the soil and produce sufficient mulch to insure adequate infiltration. If we may assume that management operations will be planned and supervised, there should be no appreciable damage to soils, water quality, and the stream habitat in the humid East. Because wood soils can take considerable scarification without producing overland flow and accelerated erosion (*8*), we may dismiss the influence of forest cutting on downstream flood damage. On-site damage to roads and the stream habitat for fish can be eliminated by skillful management.

But what of recreation, forage, and wildlife interests? Stripping a watershed of practically all non-wood-producing plants certainly will not please recreationists nor most wildlife managers. The general public would countenance such measures only if persuaded that severe water shortages will be relieved. Therefore additional volumes of evaporating plant material must be allotted to growth of forage and mast, the provision of shelter, and the satisfaction of the esthetic sense of man. Numerous species are available in the East to fill out the forest structure we desire; the selective removal and conversion of plant stands will probably be a substantial part of the

Fig. 5.—Future forest management compartments may look something like this. An experiment in multiple purpose management, this half-square-mile catchment was divided into *three natural compartments to be intensively managed for water, wood, forage, mast, fish,* wildlife and recreation. The contour road system, here looking raw and new, will fade into the landscape after a few years' regrowth. The first year's increase in water yield was about 60 million gallons of clean water, equivalent to the annual water supply of a town of about 800 people.

forester's job if water yield becomes a dominant issue.

What will such a pattern of management look like? We are beginning to get used to the strip and block appearance of high-country forests of the West. Will parts of the East look something like Fig. 5? This 360-acre experiment at Coweeta was planned to see what the sort of management we have been describing might look like as a piece of landscape (*3*). The irregular pattern reveals the effort to suit management to the best use potential of each area. Three blocks are shown; the cove hardwood site along the drainage network was selectively logged and reserved for high timber production but thinned to increase water yield, timber growth and ground forage. The unproductive oak-hickory type on the middle and upper slopes was clearcut to increase water yield and forage. The highest and steepest slopes, through which the Appalachian Trail passes, was left untouched for protection, game cover, and esthetic relief. Some species, such as dogwood and hemlock, were retained here and there because they occupy little space but add much eye-appeal. The carefully engineered road system, here not yet healed by regrowth, will provide access for many purposes, including walking and hunting. A picnic area is established away from the stream at the upper left, affording cool weather and a fine view of the surrounding mountains. The road which serves all parts of the watershed will be permanently available to make future wood harvest less damaging to other watershed values. A formerly wildland area, yielding wood, water and forage at much less than maximum rates, has been turned over to intensive, multiple-purpose management with a fairly low degree of conflict among objectives.

Compatibility among objectives seems to be increasing for several reasons. The capital investment advantages of multiple purpose road systems are becoming better accepted after years of planning access chiefly for timber harvest or other special uses. Water demands are leading to recommendations of forest cutting to increase streamflow. Public attitudes toward outdoor recreation are changing; perhaps most outdoor people will soon overlook the temperary slash and take an interest in well-planned forest operations. Research indicates that frequent cutting benefits wildlife production. Finally, the recent shift from all-aged selection management of hardwoods to even-aged management fits in well with clearcutting to increase water yield and forage. This watershed, incidentally, produced an additional 60 million gallons of water (6 inches) the next year after initial operations.

Will forest management really be this intensive in a few years? Will pressures for water and other uses dictate an acre by acre—almost tree by tree—pattern of management? Are foresters and the public willing to accept the idea that good forest management may mean removal or severe restructuring of the forest? If the pattern here mocked up on a small watershed is unacceptable to managers or the public, what are the alternatives? Will sprays or other non-destructive means be developed to reduce evapotranspiration without removing trees? The questions are becoming sharper but answers are not yet available.

One thing is clear. The forester must anticipate trends in forest use and be ready either to oppose or support them with professional knowledge. We may not have the omnipotence, recently described as a persistent myth (*1*), to select or dictate uses but we have the responsibility to oppose unsound schemes and support wise use regardless of the weight of public opinion. The marshalling of facts about forests and water yield is incomplete by any standard but I believe enough is known to foreshadow the very large role water yield will play in the management of eastern forests, quite aside from the already large role forests play in supplying clean, well-regulated water.[1]

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[1]The author acknowledges the cooperation of the Southeastern Forest Expt. Sta., Forest Serv., U. S. Dept. Agric., in supplying many of the facts and figures used in this paper. The opinions and conclusions, however, are not necessarily those of the Forest Service.