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 forbidden, 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
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 almost entirely to reductions in transpiration and interception losses. It is not clear yet whether the major effect on annual yield increases 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.

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 streamflow.

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 50 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, has been quite a puzzle. Kovner (1936) 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-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 Cowee- ta, 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
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/acre (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.

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 evaporate 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 proportionately, but may dwindle to a trickle just when we 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 its 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 them-
DIVISION OF WATERSHED MANAGEMENT

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experiments, e.g., an understory cut (25
authors reported cutting data in board
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 near-
leafless watershed. This ex-
periment is the best single piece of
evidence to date that yield increases are directly and approximately line-
early 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 per-
cent 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 au-
thors reported cutting data in board
feet removed and culled.
The problem of choosing forest ar-
eas 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 drastic-
cally, with as much as two or three
times more water released by cutting
similar forest cover on northerly
slopes as compared with southerly
slopes. This deduction is based on very
limited data, but, if verified, the impli-
cations for management are clear:
greater opportunity to increase water
yield on northerly areas. Another
possible choice is whether to concen-
trate on high or low elevation waters-
sheds. Although some foresters have
speculated on the shorter growing sea-
sons at higher elevations and the pos-
sible effect on reduced drift on soil
moisture, there is very little if any
evidence that cutting at higher eleva-
tions 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 experi-
mental work in the East. Much re-
 mains to be learned about how to pre-
dict water yield increases with ac-
currancy and how to apply them within
the context of management situations.
But the above principles are becoming
more widely understood and will per-
haps soon stimulate pilot testing on a
large scale.

Applying these principles, the ideal
way to combine wood and water pro-
duction is to limit most evaporating
plant surfaces and volumes to fast
growing species producing high-
quality wood. Slash and some low ve-
getation 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 super-
vised, there should be no appreciable
damage to soils, water quality, and the
stream habitat in the humid East. Be-
cause wood soils can take considerable
scarification without producing over-
land 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 elimi-
nated by skillful management.

But what of recreation, forage, and
wildlife interests? Stripping a waters-
hed 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
to the East to fill out the forest struc-
ture we desire; the selective removal
and conversion of plant stands will
probably be a substantial part of the

![STREAMFLOW DEVIATIONS FROM REGRESSION (INCHES)](image_url)
appeal. The carefully engineered road
Appalachian Trail passes, was left un-
occupy little space but add much eye-
and esthetic relief. Some species, such
touched for protection, game cover,
water yield and forage. The highest
upper slopes was cleareut to increase
increase water yield, timber growth
and steepest slopes, through which the
high timber production but thinned to
oak-hickory type on the middle and
and ground forage. The unproductive
selectively logged and reserved for
blocks are shown; the cove hardwood
use potential of each area. Three
might look- like as a piece of landscape
forester's job if water yield becomes a
dominant issue.
What will such a pattern of manage-
ment look like? We are beginning to
get used to the strip and block appear-
ance of high-country forests of the
West. Will parts of the East look
something like Fig. 5? This 360-
are experiment at Coweeta was
planned to see what the sort of man-
agement we have been describing
will look like as a piece of landscape
The irregular pattern reveals the
effort to suit management to the best
planned to see what the sort of man-
agement 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 cleared to increase
water yield and forage. The highest
and steepest slopes, through which the
Appalachian Trail passes, was left un-
touched for protection, game cover,
and esthetic relief. Some species, such
as dogwood and hemlock, were re-
tained here and there because they
occupy little space but add much eye-
appeal. The carefully engineered road
system, here not yet healed by re-
growth, will provide access for many
purposes, including walking and hunt-
ing. 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 avail-
able 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 rea-
sons. The capital investment ad-
vantages 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 recom-
mandations of forest cutting to in-
crease streamflow. Public attitudes
toward outdoor recreation are chang-
ing; perhaps most outdoor people will
soon overlook the temporary slash and
take an interest in well-planned forest
operations. Research indicates that
frequent cutting benefits wildlife pro-
duction. Finally, the recent shift from
all-aged selection management of hard-
woods to even-aged management fits in
well with clearcutting to increase
water yield and forage. This water-
shed, incidentally, produced an ad-
tional 60 million gallons of water (6
inches) the next year after initial op-
erations.
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 ac-
cept the idea that good forest manage-
ment may mean removal or severe re-
structuring of the forest? If the pat-
tern here mocked up on a small water-
shed is unacceptable to managers or
the public, what are the alternatives?
Will sprays or other non-destructive
means be developed to reduce evapo-
transpiration 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 sup-
port them with professional knowl-
edge. We may not have the omni-
potence, recently described as a persis-
tent myth (1), to select or dictate uses
but we have the responsibility to op-
pose 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 be-
lieve 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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