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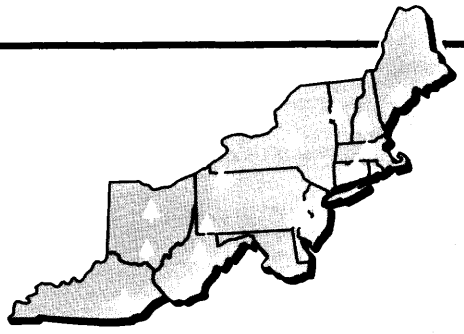

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TIMBER-HARVEST CLEARCUTTING AND NUTRIENTS IN THE NORTHEASTERN UNITED STATES

Abstract. The effect of ecosystem disturbance on nutrients in the system has been receiving widespread attention. An appraisal of research results in the Northeast indicates that timber-harvest clearcutting has not increased nutrient levels sufficiently to reduce water quality below drinking water standards. Losses of nutrients from clearcuttings in New Hampshire over a 2-year period were about 85 pounds per acre for nitrate-N and 80 pounds per acre for Ca. Losses in the central and southern Appalachians were far less. There is both need and opportunity for productive research on many aspects of nutrient flow in forested ecosystems.

For many years, it was believed that the only important effect of timber harvesting on water quality was the sedimentation of streams and reservoirs. This has been quite thoroughly investigated, and the effects of cutting on streamwater temperature have also been the subject of some study.

More recently, the effects of cutting on nutrient discharges in streamflow have attracted widespread attention. In 1965, a 39-acre watershed (Watershed No. 2) on the Hubbard Brook Experimental Forest in New Hampshire was completely deforested in an experiment designed primarily to determine the effect of vegetation elimination on water yield (*Hornbeck et al. 1970*). All trees and other woody vegetation were cut and left in place; herbicides were applied over the next 3 years to prevent regrowth. Along with the major objective, Forest Service researchers and cooperators studied the influence of this experimental treatment on the nutrient cycle (*Pierce et al. 1970*). After treatment, discharge of some nutrients in streamwater was surprisingly high, high enough that some expressed fears about the effects of forest cutting on streamwater quality and site productivity.

RESEARCH ON TIMBER-HARVEST CLEARCUTS

Because of these concerns, the Northeastern Forest Experiment Station initiated studies to determine nutrient losses from actual timber-harvest clearcuts. Several clearcuts on the White Mountain National Forest in New Hampshire were investigated and a timber-harvest clearcut was made on a gaged watershed at the Fernow Experimental Forest in West Virginia.

Two small clearcut watersheds in the Gale River drainage were included in the New Hampshire study. One of these areas had been cut the year before sampling, the other about 2 years before (*Pierce et al. 1972*). Nutrients

discharged in streamflow following cutting were estimated, in pounds per acre, at:

	1st yr.	*2nd yr.*	*2-yr. total*
Nitrate-N	34	51	85
Ca	37	43	80

The effect on other nutrients was relatively small. Amounts of nutrients discharged from the other clearcut areas in the New Hampshire study were of the same general magnitude, though there was considerable variation. For comparative purposes, nutrient discharges from undisturbed watersheds can be considered negligible.

After these clearcuttings in the White Mountains, watershed averages for nitrate-N concentrations in the streamwater ranged from 1.3 to 4.5 parts per million (p.p.m.); the maximum recorded value was 6.4 p.p.m. Measurements made farther downstream illustrated the dilution provided by essentially nutrient-free water from areas not cut. As an example, on one sampling occasion, the nitrate-N concentration in streamwater draining 160 clearcut acres was about 4.3 p.p.m.; at a point downstream for which the total drainage area was 240 acres (160 cut, 80 uncut), the concentration was only about 2.3 p.p.m.

Nutrient discharges were far less following the timber-harvest clearcut studied in West Virginia (*Aubertin and Patric 1972*). In the first year after harvest, nitrate-N discharge was about 2.9 pounds per acre and Ca about 5.6 pounds.[1] Average nitrate-N concentration in streamwater was only 0.2 p.p.m. for the growing season and 0.5 p.p.m. for the dormant season; the maximum recorded was 1.4 p.p.m. Perhaps the per acre values should be increased somewhat to compensate for water lost to deep seepage and not measured at the weir, but such an adjustment would not change the general picture.

A beginning in studies on this subject has been made at the Coweeta Hydrologic Laboratory in the southern Appalachians. Researchers there report that "Contrary to findings at Hubbard Brook, the results of experimental treatments at Coweeta have not shown an accelerated loss of ions to the streams" (*Douglass and Swank 1972*).

A recent study by Marks and Bormann (*1972*) showed how forest regrowth tends to minimize nutrient losses from the ecosystem and thus promotes "a return to steady-state cycling characteristic of a mature forest". They sampled stands of pin cherry that followed clearcutting and found, among other things, that the standing crop at age 14 held about 180 pounds per acre of N and 160 pounds of Ca. They estimated that annual uptake of N in the 4- and 6-year-old stands was about 50 percent greater than in the more-or-less mature, undisturbed ecosystem at Hubbard Brook. Perhaps equally important is the shading of the forest floor by new vegetation and the resultant decreases in surface temperature and rate of organic matter decomposition.

DISCUSSION

Site Productivity

Our knowledge about nutrients in the forest ecosystem is still limited. But we are now in a far better position to evaluate the impacts of timber harvesting than we were just after the experimental deforestation of Hubbard Brook Watershed No. 2.

Nutrient losses at the Fernow in West Virginia and at Coweeta farther south in the Appalachians were only a small fraction of those in the White Mountains. Though much remains to be learned, the relatively high New Hampshire losses apparently occurred because of the podzol soils which have large accumulations of organic matter on the surface and mineral horizons that are generally low in available nutrients, and possibly low in ability to retain nutrients.

Exposure of the forest floor — at least on the New Hampshire study areas — resulted in greatly accelerated decomposition of organic matter and the release of stored nutrients. These nutrients are necessary for the rapid establishment and growth of a new stand, and to the extent that the nutrients are so used, the accelerated decomposition

[1] Aubertin, G. M. and J. H. Patric. Water quality after clearcutting a small watershed in West Virginia. Manuscript in preparation.

of the forest floor is desirable. But soluble nutrients are also subject to removal by drainage, and this effect is usually considered undesirable. On the other hand, some nutrient contribution to streams is necessary to maintain aquatic life.

The importance of nutrient loss after clearcutting cannot be evaluated without considering the nutrient capital of the ecosystem and the possible rate of replenishment of losses.

Loss of nitrate-N from the timber-harvest clearcuts studied in New Hampshire was an estimated 85 pounds per acre in two years. Probably an additional but lesser amount would be lost in subsequent years before regrowth reestablished near steady-state conditions. It has been estimated that there is about 4500 pounds per acre of N in the forest floor and upper 18 inches of soil at Hubbard Brook (*Pierce et al. 1972*). If loss after clearcutting is 100 pounds per acre, this would amount to 2.2 percent of the capital. But it must also be recognized that this N capital is in a variety of compounds, some extremely resistant to decomposition.

The Hubbard Brook studies indicate an annual input of nitrate-N in precipitation of about 3.6 pounds per acre; under nearly steady-state conditions, about half of this is discharged in streamflow. But precipitation input and streamflow output do not a nutrient budget make. There are other sources, especially fixation of atmospheric N by organisms, that are poorly understood and even less well measured. And there is some loss of N from the ecosystem to the atmosphere and some loss of nutrients in harvested forest products.

We cannot say with any precision how much Ca is in the nutrient capital of the Hubbard Brook ecosystem. However, according to one estimate there is about 2700 pounds per acre in the organic matter and as available nutrient in the soil (and perhaps 25,000 pounds per acre incorporated in the soil and rock minerals) (*Bormann and Likens 1970*). A loss of 100 pounds per acre would amount to a little less than 4 percent of the organic-available component. Some replenishment may come from the mineral component, but at very slow rates. The precipitation input for Ca is a little less, and the near steady-state discharge in streamflow a little more, than in the case of N.

Some express concern about the impact of repeated clearcutting upon site productivity. Fortunately, decision makers now are not required to decide what to do at the end of the rotation period, 60 to 100 years from now. Decisions then can be based upon conditions at that time and certainly on a fund of knowledge about ecosystems that will be vastly superior to ours. But we must assess now the consequence of the practices applied now. Thus the question raised for stands and soils like these in New Hampshire may be something like this: Can we afford to lose through clearcutting something in the neighborhood of 100 pounds per acre of nitrate N and a similar amount of Ca (perhaps 2 percent of the available capital for N and almost 4 percent for Ca)? And this with the understanding that the rate of replenishment through the next rotation is uncertain, and that some portions of the area will lose more, some less than the average.

A timber harvest by strip cutting, a method favored by many silviculturists for use in northern hardwoods, is now being studied on a gaged watershed at Hubbard Brook. Trees are being cut in a series of three successive strips at 2-year intervals in this modification of clearcutting, and nutrient outflows are being measured. When results are available, they should show the extent to which the trees left on the site slow decomposition by shading the forest floor and utilize nutrients made available by the cutting.

For soils like those at the Fernow and Coweeta — and in a general way this *may* turn out to include most non-podzols in the East — losses of nutrients appear to be negligible.

One way to meet the problem presented by the different results at different locations is to monitor streamflow from areas harvested in the near future, to get a better idea of the situation in each locality. The consistency of nutrient concentrations that has been demonstrated at any sampling site from week to week should make such monitoring relatively easy. Probably as few as three samples col-

lected during the year after cutting and analyzed for N and Ca would have demonstrated the big difference in reaction to cutting of the Gale River and Fernow watersheds.

My discussion so far, and much that has appeared recently in the literature, has dealt only with the cutting of trees. A review of both older and more recent literature still impresses me with the fact that in timber harvest the soil disturbance associated with logging has a greater impact on the site than tree cutting by itself. Thus when harvesting timber — whether by clearcutting or some other method — care in logging is of great importance. Much has been written about how to log with a minimum impact on soil and water and I won't go into it here.

Water Quality

None of the measurements of streamwater from timber-harvest clearcut areas indicated nutrient concentrations higher than public health standards for drinking water. Barring almost simultaneous clearcutting of all the area in major drainages, that problem will not even be approached. Not even the strongest advocates of clearcutting are advocating that kind of application.

Minor localized and probably transient eutrophication of small streams may follow clearcutting (*Pierce et al. 1972*). Because this effect is temporary, it does not appear to pose any serious problem.

RESEARCH NEEDED

We can now paint with a broad brush the impact of timber harvest on nutrients. But more knowledge is needed on many aspects to round out the picture.

We need continued study to determine effects over a longer period of years. And we need to find out what soil and other factors contributed to the great differences in nutrient discharge obtained at different locations.

We need quantitative information on nutrient input from sources other than precipitation, especially the fixation of atmospheric N. And at what rates do the N and Ca in the organic matter and in the soil become available to plants under both steady-state and disturbed conditions?

We can now readily measure the discharge of nutrients in streamflow and thus determine the average loss over the watershed. But it is safe to assume that different parts of the watershed are affected differently, and we must learn more about this as a guide to more intensive management.

A far-reaching appraisal of the general well-being of a variety of stands on sites subjected to various severe disturbances should improve our ability to make value judgments. Included might be European stands regularly clearcut over a period of several hundred years, stands established on abandoned depleted farmland, stands of near-rotation age on surface-mined sites, and stands on sites logged and burned in years past. The capacity of forest cover to survive and often prosper under difficult conditions should be documented.

Application of fertilizer to compensate for nutrient losses is a possible option in future management. We need to investigate the feasibility of this practice, including considering side effects on the ecosystem.

We need to learn more about how much nutrient increase it takes to cause eutrophication of specific water bodies, and the damage and benefits resulting from this eutrophication.

And perhaps most important, we must learn how to put it all together to better understand, manage, and protect the ecosystem.

SUMMARY AND CONCLUSIONS

Recent research on the impact of timber-harvest clearcutting on soil nutrients may be summarized thus:

In 2 years following clearcutting in New Hampshire, about 85 pounds per acre of nitrate-N and 80 pounds of Ca were discharged in streamflow. Losses after cutting may amount to about 2 percent of the N capital available in the ecosystem and 4 percent of the Ca. These are only approximations and are average figures; losses in particular situations, such as in very shallow soil, may be greater relative to nutrient capital on the site.

Nutrient losses following clearcutting in the central and southern Appalachians appear to be negligible. The differences between the

New Hampshire and other results seems to be associated with the nature of podzol soils.

Timber-harvest clearcutting did not result in reducing water quality below drinking water standards in any of the studies made. Slight, local, and temporary eutrophication of streamflow was noted in the New Hampshire studies.

There are many opportunities for productive research on various aspects of nutrient flow in forest ecosystems.

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