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Some Effects of Grazing on Soil and Water in the Eastern Forest

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Abstract

Conservationists continue to decry grazing in the eastern forest, now only one-seventh its 1930 extent, for its presumed ill effects on soil and water. Grazing damages trees and trampling compacts the soil, thereby reducing water infiltration and percolation rates. These hydrologic effects usually are innocuous because only severe trampling reduces infiltration and percolation below usual rates of rainfall intensity. Overland flow is little increased for that reason; it is prerequisite for delivering most soil and other pollutants to streams, so water quality is little affected. Bacterial pollution rises when animals have access to streams, and declines soon after excluding them. The universal soil loss equation, predicated on ubiquitous overland flow, is widely misused to predict erosion from grazed forest land where overland flow seldom occurs. Such misuse overstates soil loss, helping to perpetuate the notion that grazing unacceptably worsens forest soil erosion and stream pollution.

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COVER—the presence of cattle on this severely eroded land suggests that overgrazing caused the erosion. But a complete land use history would show that row crop agriculture started the erosion cycle. The cattle were put in the field only after erosion made row crops unprofitable.

Introduction

Grazing is an annual harvest which, on forested land, converts into animal products the ground vegetation and those parts of the arboreal vegetation within the reach of foraging animals. Grazing unquestionably harms forest vegetation. Loss of small limbs and bark and root injury by trampling reduce both the growth rate of large trees and their resistance to insects, disease, and decay. Preferential browsing among seedlings and small trees ultimately alters forest composition while severe browsing eliminates all tree reproduction. Heavy trampling damages hydrologic properties of the forest floor, reducing its organic cover and compacting the underyling mineral soil. Heavy, prolonged trampling on steep slopes may result in overland flow and accelerated soil erosion.

In their zeal to forestall harm to forest vegetation, conservationists have sometimes overstated the damage to soil and water which overgrazing can cause, but which may not be of consequence in the conventionally grazed eastern forest. For our purposes, the eastern forest is defined as tree-growing land between the Atlantic Coast and the 100th meridian. Our objective was to review the literature on woodland grazing effects on forest soil and water, to interview some of the scientists involved in such studies, and to assess the probable effects of prudent grazing on soil and water in the eastern forest.

Surely, grazing was practiced widely in forested regions of the Old World when herbiverous animals first were domesticated. We can only speculate when mankind learned that overgrazing can damage forest vegetation, soil, and water. Hughes (1975) cited no geological, pedological, or archeological evidence to support his allegation that overgrazing seriously accelerated erosion in Neolithic times; presumably, it did contribute as alleged to the demise of the Greek and Roman Empires. Lowdermilk (1953) identified overgrazing as a severe soil conservation problem of the ancient world.

Figure 1.—Pine-dominated forests of the Southeast have long supported a thriving livestock industry. There, as in much of the hardwood-dominated eastern forest, grazing at recommended intensity and duration causes minimal adverse effect on forest soil and water.

In this country, Hough (1878) warned over a century ago of grazing's ill effects on young forest trees. Ayers and Ashe (1902) deplored the sequence of lumbering, wildfire, cultivation, grazing, and land abandonment perceived as leading to soil ruin in the southern Appalachians. Perhaps ruin was at least partly averted when laws, alluded to by Hursh (1951), helped reduce overgrazing in that region. Reynolds (1911) pointed to overgrazing as the cause of disasterous erosion and floods in the forested mountains of Utah; effects of that magnitude have not been reported in the eastern forest. Citing no quantities or supporting evidence, Munns et al. (1933) reported loss of understory, destruction of litter, and the invariable loss of topsoil on heavily grazed farm woodlands of the Corn Belt. Harper et al. (1957) used similar language nearly a quarter century later, during which years the reprehensibility of all forest grazing seems to have become a firmly entrenched article of faith among conservationists. For example, Spurr and Barnes (1973) stated: "Around the world, grazing by livestock probably has been more important than any other factor in reducing the productivity of uncultivated land."

Sometimes, other probable causes of reduced productivity are ignored or unknown, exaggerating grazing effects as the sole cause. Riordan (1982), for example, characterized Wisconsin's grazed woodlands as "scraggly stands of poor quality timber, pockmarked by barren patches of scarred earth and criss-crossed with trodden pathways that turn all too soon into raw gullies . . . which explode into erosional nightmares." Careless logging, wildfire, exploitive farming, and even drought probably contributed to conditions often ascribed solely to woodland grazing.

Despite widespread knowledge of possible ill effects, woodland grazing is still practiced widely. As of 1982, the USDA Soil Conservation Service (1982) reported that nearly 9 percent of the eastern forest (more than 24 million acres) is grazed, with exclusion of livestock or some other improvement recommended on 68 percent (more than 16 million acres) of the grazed acreage. Much of the grazed forest suggests negligible damage to soil and water (Fig. 1), but other areas show considerable ill effects (Fig. 2). Regardless of damage, grazing probably continues in the eastern forest because its practitioners, many of them conscientious custodians of the land, have learned that such use can be profitable. They probably would fully subscribe to Hawley's (1921) viewpoint that "if overgrazing is avoided, the damage to the average forest and soil is so small as to be safely disregarded." The authors of more recent texts on silviculture (e.g., Smith 1962) and forest soils (e.g., Pritchett 1979) seem to share that same viewpoint, none of them granting the subject more than passing mention.

Anderson et al. (1976) pointed out the enormous diversity of opinion concerning the potential of livestock to damage forest soil and water, and that diversity has indeed caused much controversy. Given its obvious economic implications, woodland grazing—with respect to its variously interpreted effects on vegetation, soil, and water—would seem to present a great opportunity for valuable research. We believe that no significant study of grazing effects on soil and water in the eastern forest has been overlooked in the following search of the literature.

Short-Term Studies of Grazing

Floristic Characteristics

There was wide interest in forest grazing before 1930 but few, if any, reports dealt with the subject quantitatively. Many of the subsequently published accounts of grazing in forests (Campbell 1948; Den Uyl 1948; Hornkohl and Reed 1948; Lutz 1930; Lutz and Chandler 1946; Munns et al. 1933; Stewart 1933) focused on numbers and species of plants consumed by foraging animals and the consequent modification of residual forest vegetation. Colman (1953) generalized the major effects as follows:

> In farm woodlots within the eastern forest types, livestock often use the wooded areas mainly as shelter from the heat. Within the woods, they browse heavily,[1] for there is little grass or herbaceous vegetation. Even light stocking of such land can result in the death of shrubs, young trees, and the lower branches of tall trees.

[1] The terms light, moderate, and heavy grazing appear throughout the literature. These degrees of forage utilization are not closely defined (personal communication, Dr. Gale Wolters, USDA Forest Service, Washington, DC). Moderate grazing sometimes is defined as 50 percent utilization of available forage by the end of the growing season, with light and heavy grazing denoting lesser and greater consumption, respectively. All three terms appear sparingly in this review because it is impossible to apply them consistently. As used here, the term overgrazing denotes loss of virtually all available forage.

Den Uyl et al. (1938) spelled out the floristic effects of browsing in considerable detail. Although they reported conditions in the central hardwoods of the Ohio Valley, their five stages of decadence are in sufficiently general terms to apply to other hardwood-dominated types indigenous to the eastern forest.

- The ungrazed woods. These contain a satisfactory distribution of trees, from seedlings of the current year to mature trees that are to be harvested. Such a woodland is capable of yielding forest products continuously, equal to the amount of annual growth.

- The early stage. All reproduction is killed, lower limbs of the older trees have been browsed back, creating the characteristic pruned appearance (the grazing or browse line) so common to pastured woodlands (Fig. 3).

- Transition stage. The period between the establishment of a browse line and the widespread establishment of pasture grasses. There is no understory or small trees.

- Open park stage. The period when a complete grass cover becomes established and stag-headed trees begin to appear. Removal of cattle will not bring about satisfactory regeneration of trees (Fig. 4).

- The final stage. Differs from open park only in that the tree crown cover is less than 50 percent. Open pasture gradually develops as the trees die off or are cut.

Intensity of grazing in terms of animals per unit area and time is the preferred expression of such land use but it was rarely so reported. Few of the published reports were designed experiments, merely after-the-fact observation in woodland subject to grazing of unknown intensity and duration. Moreover, the literature often suggests that the more spectacular examples often were preferred for detailed description of all effects on forest soil and water.

Figure 2.—Problems with soil and water usually arise when too many grazing animals are confined for too long in too small an area. Overuse by hogs on this lot in Minnesota has destroyed its productivity as forest and has greatly accelerated rates of soil loss. Despite the owner's seeming intention to continue its use as pasture, the U.S. Department of Agriculture criteria define such land as forest because it is more than 10 percent stocked with trees.

Soil Physical Properties

There was indeed a shift to examination of grazing effects on the physical properties of forest soils. Most such studies predating 1940 (Auten 1933; Bates and Zeasman 1930; Lutz 1930; Scholz 1938) contained little quantitative information on bulk density, porosity, permeability, or infiltration rates. Quantitative information became increasingly commonplace in the literature after 1940 (Alderfer and Merkle 1941; Blackburn et al. 1980; Chandler 1940; Dils 1953; Duvall and Linnartz 1967; Johnson 1952; Linnartz et al. 1966; Sartz and Tolsted 1974; Steinbrenner 1951; Stoeckler 1959; Wahlenberg et al. 1939). These studies, at least the earlier ones, probably reflect the then current development of techniques essential to accurate quantification of soil physical properties. Lull (1959) discussed the effects of livestock trampling on soil physical properties:

> Soil compaction is a universal process associated with any use of forest or range lands. Its major effect is to drastically reduce the pore space through which water moves into and through the soil, thereby reducing infiltration and percolation, increasing surface runoff, and encouraging erosion.

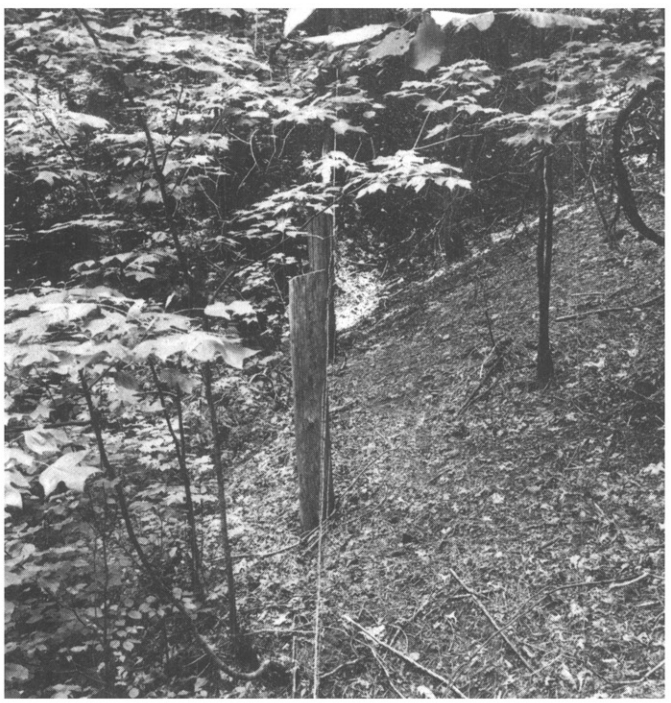

Figure 3.—Only two years of overgrazing virtually eliminated the understory from this cove hardwood stand in North Carolina.

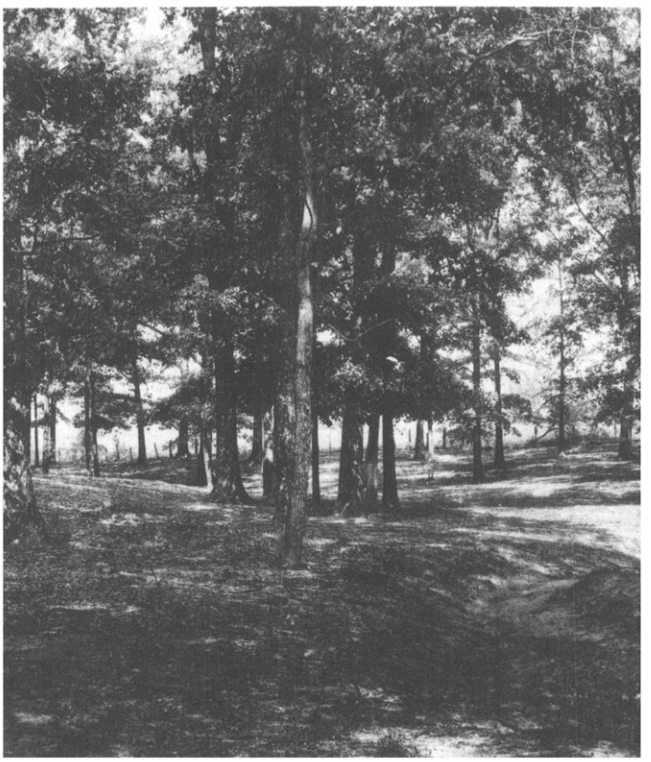

Figure 4.—Is this a poorly managed farm woodlot or a densely shaded pasture? Regardless of present tree cover, we submit that landowner intentions concerning future use of this tract provide the best guideline as to its management needs. If grazing continues, trees will gradually be replaced by grass because there is no tree reproduction and the tract will clearly become a pasture. If maximum wood production is desired, grazing animals must be fenced out immediately to restore forest productivity. In settings such as this, soil and water appear to be minimally at risk; consideration of these resources need not be at issue in shaping the landowner's decision regarding future use of such tracts.

A survey of soils on the Allegheny River watershed (Trimble et al. 1951) provided regional information on grazing effects on selected hydrologic properties of forest soils. Grazing reduced the organic content of the humus layers by 32 percent and increased volume weight of the surface soil by 80 percent. Water transmission (percolation rate) and water removal by gravity (detention storage) were reduced in A1 soil horizons (Table 1), but grazing had no effect on water held against gravity (retention storage). It is doubtful that these hydrologic properties were affected in the A2 horizon.

Table 1.—Effects of grazing on hydrologic properties of forest soils on the Allegheny River watershed

Soil horizon	Percolation rate	Detention storage	Retention storage
	Inches/hr	*——Percent by volume——*	
A1, ungrazed	132.0 ± 28.0[a]	23.4 ± 7.3	41.1 ± 3.1
A1, grazed	30.2 ± 12.0	12.6 ± 2.2	41.4 ± 3.4
A2, ungrazed	17.0 ± 2.8	14.8 ± 1.3	40.4 ± 1.8
A2, grazed	13.1 ± 9.1	13.7 ± 1.1	38.3 ± 1.4

[a]Data are means and standard deviations of all observations.

Data in Table 1 were obtained from typically managed, moderately grazed forest land in New York and Pennsylvania. The hydrologic performance expresed seems especially useful because it was not observed on a tiny experimental plot, no matter how carefully chosen and handled, but on large expanses of wooded land managed by farmers with no connection with the study. The subsequent hydrologic effects resulted when cattle trampled the soil, i.e., compressed the numerous macropores common to the floor of ungrazed forest. These effects were restricted to upper levels of the soil A horizon, but were undetectable in the B and C horizons of grazed forest soil (Trimble et al. 1951). This result contrasts with compaction to at least 16 inches reported by Linnartz et al. (1966) on burned and grazed forest soil in Louisiana, land once forested with longleaf pine but then in the final stage of decadence as characterized by Den Uyl et al. (1938). In other respects, the hydrologic performance described in Table 1 generally agrees with results reported by other observers.

Attempts were made to identify grazing-induced conditions of forest soil (Trimble et al. 1951) for use in classifying soils for flood control surveys. It was thought that these conditions exerted great influence on water supply and soil erosion in river basins. However, most of the expectations for identifying useful criteria were not realized (personal communication, Warren Murphy, USDA Forest Service, retired).

Erosion Rates

Reduction of the understory, accompanied by impaired hydrologic functioning of the mineral soil and forest floor (Fig. 5), posed a long-recognized potential to accelerate erosion on grazed forest land. Although the following statement by Hormay (1948) pertained to California, it was and is widely believed to pertain wherever cattle graze in woodlands:

> In many areas this (thinning the vegetative cover) has caused heavy erosion, accompanied by site deterioration, more rapid, muddy runoff, resulting in loss of water to the ocean, and even destructive floods . . . Tons of soil are being pushed into streams and river channels each year by livestock trampling.

Earliest studies of erosion (e.g., Bates and Zeasman 1930, Meginnis 1935) often featured computations of the percentage of rainfall delivered as overland flow. Table 2, adapted from Borst et al. (1945), did demonstrate greater runoff accompanied by greater soil loss, though a consistent relationship between the two has not been reported to our knowledge. The trifling soil loss from pasture and woods probably reflects nearly complete infiltration watershed-wide, whereas the far larger loss from cultivated land likely resulted from nearly watershed-wide overland flow. More recent studies (e.g., Owens et al. 1983) continue to report the same negligible soil losses from pasture once observed at all of the now disbanded Conservation Experiment Stations.

Table 2.—Influence of land use on overland flow and soil loss (Borst et al. 1945)

Land use	Overland flow	Soil loss
	Percent	*Tons/ac/yr*
Cultivated	20.6	17.18
Pasture	13.8	0.10
Woods	3.2	0.01

During the past quarter century, hydrologists have increasingly observed that on the permeable, well-vegetated soils characteristic of lands covered with trees and/or grass, infiltration and permeability rates tend to remain high, even during grazing. Most of the rain is absorbed into the soil, then seeps through the soil profile, not across its surface. Under these conditions, overland flow is the exception, not the rule (Kirkby and Chorley 1967). This is probably why reported measurements of erosion from grazed forest land east of the 100th meridian rarely exceed 1.0 t/ac/yr (Table 3).

Soil loss also has been estimated by sampling sediment deposits in reservoirs downstream from variously managed watersheds. We found no reports comparing deposits from grazed and ungrazed forest land east of the 100th meridian. Data from the Black Hills of South Dakota (Table 4), although from beyond our region of concern, show sediment deposits similar in magnitude to erosion rates listed in Table 3. These deposits ranged in age from 32 to 35 years (Black Hills Conservancy Subdistrict 1973). They necessarily integrate sediment produced by formation of reservoir banks as well as all erosion-causing activities contributing flow to the reservoirs; as a result, the erosional effects of forest grazing are exaggerated. Because trapped sediment resulted from many activities and sources, the data show that grazing could have accelerated erosion on these forested watersheds only minutely.

Table 3.—Measurements of soil loss from grazed land in the eastern forest

State	Vegetation	Soil loss	Source
		Tons/ac/yr	
Louisiana	Pines and hardwoods	No evidence of accelerated erosion	Duvall and Linnartz 1967
Mississippi	Oak forest	0.05	Meginnis 1935
	Black locust and osage orange	1.01	Meginnis 1935
Mississippi	Longleaf pine	No evidence of accelerated erosion	Wahlenberg et al. 1939
North Carolina	Clearcut hardwoods	0.80	Dils 1953
Texas	Shrub canopy	0.01	Blackburn et al. 1980
Wisconsin	Open hardwoods	Average 0.14 Maximum 0.79	Hays et al. 1949
Wisconsin	Open hardwoods	Average 0.19 Maximum 0.62	Sartz 1976

Given perennial interest in soil erosion caused by forest grazing, why has it been quantified so infrequently? That question was asked of Richard Sartz (USDA Forest Service, retired), a participant during many years of forest hydrology research in the North-Central United States. His response (personal communication) was that study in sufficient detail soon evidences soil loss too slight to justify the considerable expense of its continued remeasurement. Measured soil losses invariably have been well below the 2 to 5 t/ac/yr regarded as tolerable by the USDA Soil Conservation Service (Wischmeier and Smith 1978).

Figure 5.—Browsing, trampling, and litter displacement to the extent depicted here usually leads to impaired hydrologic functioning of the forest soil. Close to stream channels, this degree of disturbance can cause unacceptable effects on soil and water. Distant from channels, such disturbance may be of little consequence to downstream water quality.

Water Quality

The increased environmental awareness of the late 1960's and early 1970's probably aroused interest in the effects of forest grazing on water quality. At any rate, the earlier literature suggests minimal interest. The general case was stated succinctly by Moore et al. (1979):

> . . . there are significant potentials for adverse water quality impacts from many facets of grazing activities. The most significant of these potential impacts are (sic) related to erosion and sedimentation but in some areas pathogens and salts are significant potential problems.

Having dealt with erosion and sedimentation to the limits of our information sources, further consideration of forest grazing effects on water quality is restricted to those stemming from pollution by salts and pathogens. Thornley and Bos (1985) leave little doubt that such pollution severely reduces quality of water draining from intensively grazed farmland. Pollution on a 90-square-mile watershed containing more than 300 livestock farms caused annual fish kills and bans on swimming in a reservoir supplied by the South Branch of the Thames River, Ontario. Thornley and Bos (1985) reported that streamflow from an ungrazed watershed contained 0.02 mg of phosphorus per liter and 400 coliform bacteria per liter. Streamflow from nearby watersheds which were grazed by cattle contained 0.3 mg of phosphorus per liter and 4,000 coliform bacteria per liter. Thus, grazing increased both key criteria of pollution about 10-fold. Counts of coliform bacteria not exceeding 2,000 per liter of water are considered to be safe for swimming during non-storm flow.

The natural presence of fecal coliform confounds bacterial sampling even in wildland streams. In reviewing the literature, Bohn and Buckhouse (1985) found that coliform populations fluctuated wildly in response to stage of streamflow, water temperature, season of the year, and wildlife populations. McSwain and Swank (1977) even found coliform counts inversely related to the diurnal fluctuations of streamflow on an ungrazed watershed in North Carolina, where maximum and minimum counts corresponded with daily low and high flows, respectively. Concentrations of coliform bacteria and phosphorus were similar in the streams draining ungrazed forest watersheds in Canada and North Carolina.

Table 4.—Sedimentation in lakes supplied from grazed watersheds in the Black Hills (Black Hills Conservancy Subdistrict 1973)

Lake	Land use on watershed	Average sedimentation rate[a]
		Tons/ac/yr
Mitchell	Grazed timberland	0.01
Major	Mostly timber, hay and grazing near creek	0.01
Newton Fork	Same as Major	0.01
Roubaix	Same as Major	0.05
Sheridan	Mostly timber, some hay, grazing and cropland	0.14
Reausaw	Same as Major	0.29
Stockade	60% timber, balance in hay and grazing	0.70
Bismark	50% timber, balance in hay and grazing	0.78
New Underwood	Grazed grassland	0.45
Mirror	Grazed grassland	1.06

[a]Computations of soil loss (i.e., average sedimentation rate) are based on an assumed density of 70 pounds per cubic foot of lake deposit.

Kunkle (1970) determined the background populations of enteric organisms in the stream draining a 2,000-acre forested watershed in Vermont. He presumed an average of 10 cattle on that watershed. Upland contribution of bacteria was minor, with water consistently of excellent quality. During one year of record, concentrations of fecal coliform bacteria did not exceed 80 counts per 100 ml of stream water and remained below 20 for about half the year. There was no difference in delivery rates of phosphorus between the grazed forested catchment and nearby grass-covered catchments containing more cattle.

Cattle with complete access to a stream (Fig. 6) are an obvious source of fecal contamination. No report was found concerning this effect in eastern streams but Johnson et al. (1978) reported counts of fecal coliform and streptococci elevated by this means in a Colorado stream; the effect dropped to statistical nonsignificance 9 days after the cattle were removed.

We found no specific reports of nutrient outflow from grazed versus ungrazed forest. Data on several rural land uses (Table 5) suggest that grazing effects on nutrient outfow increase the chemical loading of streams only minimally.

Kunkle (1970) emphasized that permeable soils on vegetated watersheds maintain a high capacity for utilizing animal wastes while not contaminating streams, where those wastes are not deposited near channels. A study in Oklahoma found little need even for that proviso; there, direct overland movement of dung into stream channels was minimal because standing vegetation and litter retarded and filtered its movement to streams (Powell et al. 1983). There was little difference in nutrient content of streams draining a forested watershed and a lightly fertilized pasture in Ohio (Owens et al. 1983). Pinkowski et al. (1985) reported that oak-hickory forests effectively filtered runoff from feedlots in southern Illinois. In most studies of water quality, there is little evidence that overland flow is the ubiquitous transport mechanism so frequently cited. Indeed, such studies point to minimal downslope movement of most potential stream contaminants on grazed forest land (Hewlett and Troendle 1975).

It can be argued that the addition of dissolved salts sometimes is desirable because it increases the productivity of infertile streams. Smart et al. (1985) found streams draining pastures in the Ozarks more productive than streams draining forests; it is unclear whether the greater productivity is due to the presence of cattle, pasture fertilization, or some other source of "pollution."

Table 5.—Nitrate and phosphorus concentrations in streams draining watersheds subject to various uses

Watershed designation	Land use	Human population on watershed	NO_3-N	P
			----*mg/l*----	
Helton[a]	94% forested 6% residential	200[b]	0.10	0.02
McGill[a]	75% forested	40	0.23	0.04
Forested[c]	100% pine and hardwoods	0	0.34	0.015
Farmland[c]	50% pasture 50% crops and hay	0	1.28	0.022

[a]From Kentucky (Thomas and Crutchfield 1974).
[b]This level of human population on presumably forested land probably is a misprint.
[c]From Ohio (Taylor et al. 1971).