United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

NE-GTR-115

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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Manuscript received for publication 27 January 1986

Northeastern Forest Experiment Station
370 Reed Road, Broomall, PA 19008
December 1986

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.

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[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.

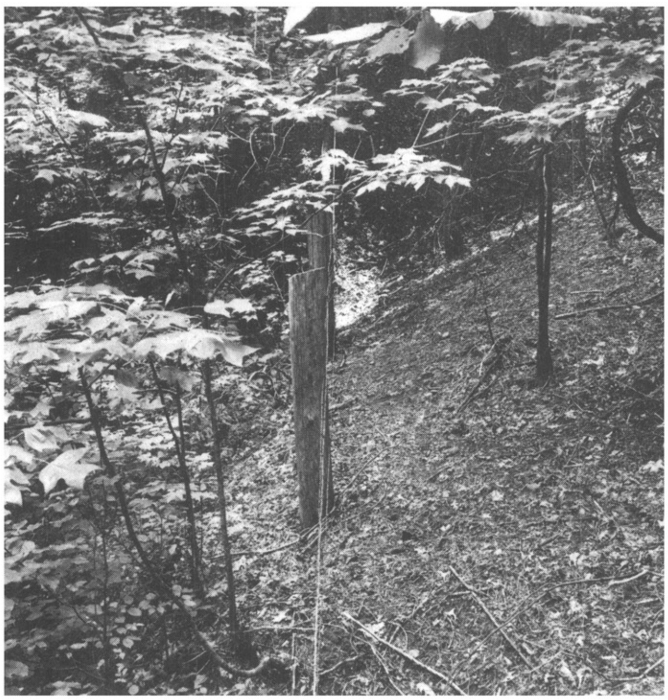

Figure 3.—Only two years of overgrazing virtually eliminated the understory from this cove hardwood stand in North Carolina.

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).

Long-Term Studies of Grazing

At the Coweeta Hydrologic Laboratory, Otto, North Carolina, a grazing experiment spanned 35 years. The study was designed to achieve cumulative effects in 9 or 10 years thought to occur in perhaps 20 to 40 years on the typically grazed farm woodlot (Johnson 1952). To achieve those effects, an average of six "past yearling" cows was pastured on a 145-acre, calibrated, forest watershed from May to September, 1941 to 1953 (Sluder 1958). Most of the palatable forage was consumed during the first year of grazing, necessitating supplemental feeding to forestall starvation of cows thereafter. Cattle roamed the steep upper slopes only during the first few days after they were put into the fenced watershed each spring. Since palatable forage was scant on the upper areas, they spent the remainder of the summer in the topographically concave cove area adjacent to the stream. There, the slopes were not as steep, water was readily available, and perhaps most important, supplemental feed was provided daily. Trampling effects were greatest in the cove (Fig. 7), as evidenced by an intensive study of the soil's hydrologic properties (Table 6).

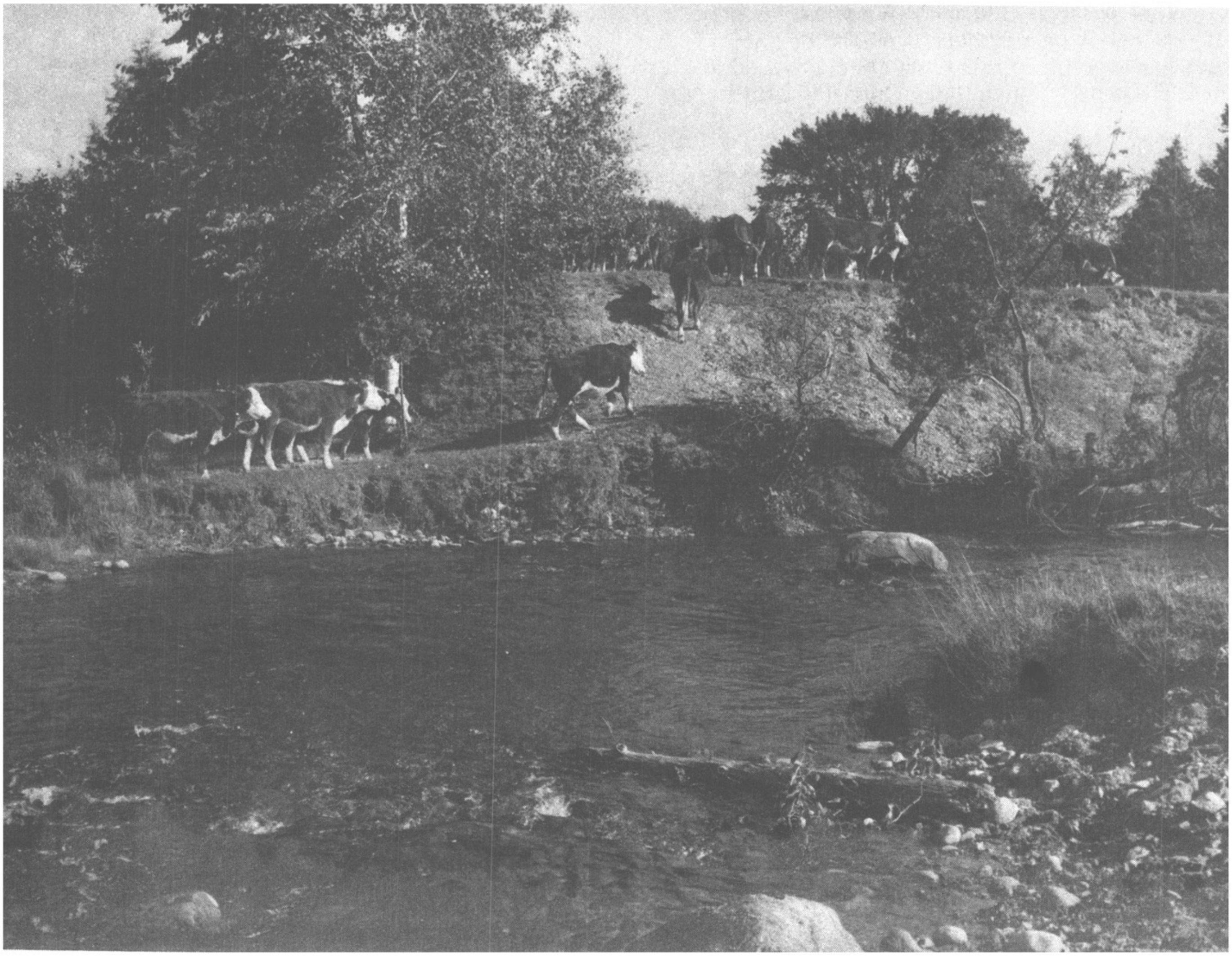

Figure 6.—Cattle with free access to streams can cause pollution by fecal bacteria as well as by increased erosion from streambanks.

Data in Table 6 illustrate how readily differences expressed as percentages can be variously interpreted. The changes do seem alarming, but reconsider them in light of actual numerical values for the soil physical properties described, values developed by Dils (1953) on the watershed immediately adjacent to the forest grazing experiment. Soils of the Tusquitee series dominate at lower elevations on both watersheds. In the undisturbed condition, total porosity of the 0- to 6-inch forest soil was about 55 percent, of which about 30 percent was macropore space (Hursh 1943). The decrease in total porosity signified little more than compression of the macropores by trampling. Permeability of the 0- to 3-inch layer was 171 inches per hour, 64 inches per hour for the 3- to 6-inch layer (Dils 1953). Even a 91-percent loss of permeability at a soil depth of 2 to 4 inches was of little hydrologic consequence because the resulting rate of almost 6 inches per hour still exceeded any but the most intense rate of rainfall.

Similar reasoning applies to the seemingly drastic reduction of infiltration. The senior author has used the ring infiltrometer on several hundred "runs" to demonstrate water intake into soil on grazed and ungrazed forest land at Coweeta. Infiltration rates (the rate at which water enters the soil surface, i.e., passes through the soil-air interface) rarely was less than 150 inches per hour on the ungrazed forest floor, and rarely exceeded 10 inches per hour on grazed cove soils of the experimental watershed. Grazing had decreased infiltration rates on the order of 90 percent, but, again, the reduction was of little hydrologic consequence so long as those rates exceeded the usually experienced intensities of rainfall.

Figure 7.—The cove portion of the Coweeta Watershed about 8 years after grazing began.

Johnson (1952) reported a maximum observed stream turbidity of 107.5 Jackson turbidity units, a not uncommonly high level for stormflow from any forested watershed. Turbidity occasionally exceeds 500 Jackson units, even in streams draining totally undisturbed forest. Stream channel scour producing such turbidity during heavy rain is a part of the normal geological erosion process.

When grazing was discontinued in 1953, the cove portion of Coweeta's grazed watershed probably was near the transition stage as characterized by Den Uyl et al. (1938). By 1960, all evidence of grazing had disappeared from the slopes and ridges. Johnson's (1952) prediction that ". . .this watershed is becoming a local flood source area" did not come to pass. There was little, if any, evidence of grazing effects on the amount and timing of stormflow during the 1960's when both authors were stationed at Coweeta. We observed no rill or gully erosion to indicate overland flow, even in cove areas where trampling was most severe. The only lasting effect was the browse line and dearth of understory (Fig. 7).

Boring et al. (1981) evaluated the results of forest grazing as "short-term effects limited primarily to soil compaction and overgrazing in the cove area adjacent to the stream. Little lasting impact from the study has been apparent." James Douglass (USDA Forest Service, retired), long-time project leader at Coweeta, confirmed that evaluation (personal communication). We note that results of the Coweeta experiment mesh neatly with the pattern evident among the shorter term studies. In light of these on-site impressions, we were surprised to read that "Abusive livestock grazing caused devastating effects on a hardwood watershed at the Coweeta Hydrologic Laboratory" (Blackburn et al. 1982). We witnessed no devastation and believe that Boring et al. (1981) are close to an accurate assessment of the actual effects of forest grazing.

Long-term grazing effects were studied at the Forest Watershed Laboratory at LaCrosse, Wisconsin. Pioneering research by Bates and Zeasman (1930) had focused the attention of conservationists on the "Driftless Area," that southwestern quarter of Wisconsin which remained ice-free throughout the last epoch of continental glaciation. During their research, most of the Driftless Area was recovering from exploitive logging and wildfire of 30 years earlier. In addition, several years of drier than usual weather had reduced the vigor of plant growth (personal communication, Dr. Dean Knighton, USDA Forest Service, Washington, DC). More to the point, woodland grazing had been practiced almost universally (Sartz 1975). So prevalent were soil loss (Fig. 8) and gullying that in 1931, the Upper Mississippi Valley Erosion Experiment Station was established near LaCrosse to address these land-use problems. As part of a far larger research program, three small watersheds were placed under close observation in 1933; runoff and soil losses were observed until 1941. Hays et al. (1949) provided the most complete published summary of results. Annual overland flow (expressed as percentage of rainfall) was 1.16 for grazed woodland, 0.35 for open pasture land, and near zero for undisturbed forest. Average annual soil losses were 0.14, 0.05, and near zero t/ac/yr for grazed woodland, open pasture, and undisturbed forest, respectively. Maximum soil loss during 8 years of observation on this grazed woodland watershed was 0.79 t/ac/yr.

Table 6.—Differences in physical properties of forest soil caused by trampling by cattle[a]

Forest type	Total porosity		Permeability		Infiltration at soil-air interface
	0 to 2 inches	2 to 4 inches	0 to 2 inches	2 to 4 inches	
	———Percent less than ungrazed forest———				
Hardwoods in cove	42	56	70	91	91
Oak-hickory on slopes	15	12	32	32	67
Pine-oak on ridges	6	4	13	0	0

[a]Adapted from Johnson 1952.

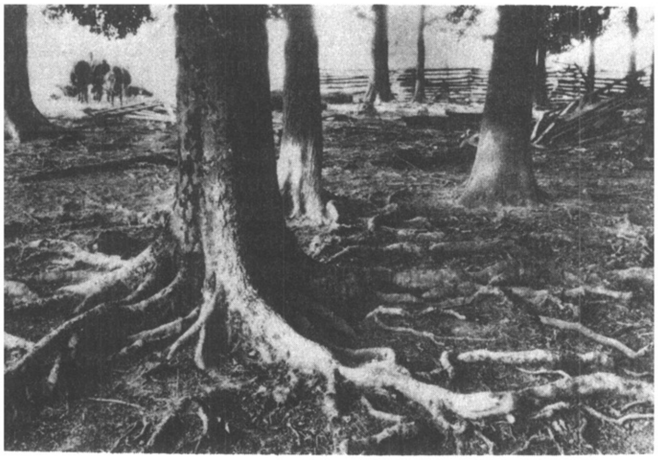

Figure 8.—Concentrated grazing over many years caused sufficient erosion to expose tree roots in this Indiana woodlot.

Munns et al. (1938) reported soil loss of 1,600 pounds per acre from grazed woodland in Wisconsin during a single storm. These authors cited no source for this information and, curiously, no reference to so large a soil loss appeared in the subsequent literature on forest grazing. Inquiry to Richard Sartz (USDA Forest Service, retired) established that this soil loss resulted from overtopping of a cropland diversion terrace upslope from the wooded pasture at LaCrosse. A 1940 photograph in the Forest Service's Washington collection clearly shows the juxtapositioning of research installations referred to by Sartz.

An unpublished study by Scholz[2] covered 46,000 acres of severely eroded lands near LaCrosse. Not one instance of erosion through forest was found, except where it resulted from cropfield drainage upslope (Fig. 9). Thirty years later, Curtis (1967) reported findings similar to Scholz's. During all of those years, the many gullies on forested land in southwestern Wisconsin had led many to believe that uncontrolled grazing had been a major cause of their development (Sartz 1978). This first phase of soil-plant-water research at LaCrosse terminated with the outbreak of World War II in 1941.

[2] Scholz, Harold F. 1935–1936. Farm woods erosion study. (In Part II of Erosion: its relationship to woodlot management and the use of critical slopes for pastures and tilled crops).

Studies of forest grazing resumed in 1958 with the establishment of the Coulee Experimental Forest at another site near LaCrosse. There, studies similar to earlier ones were undertaken on a larger scale (Sartz 1978). A 15-acre catchment on a 35-percent slope had been grazed for about a century but never plowed. It had a park-like cover, probably the final stage of forest decadence described by Den Uyl et al. (1938). It was traversed by a tractor road, a frequent source of overland flow and eroded soil. Because of its poor tree cover, large amount of exposed mineral soil, and obvious indications of overland flow, Sartz (1970) rated this an extreme example of overgrazed forest.

Several years (1962–69) of hydrologic observation have been reported for the grazed catchment on the Coulee Experimental Forest. There was no measurable stormflow during storms less than 0.4 inch; during five major storms, peak discharge averaged about 0.12 inch per hour and stormflow about 0.04 inch (Sartz 1970). Maximum observed concentration of sediment was 55,900 ppm, a value almost certainly augmented by soil eroded from the tractor road (Sartz 1970). Sediment yield ranged from zero to 0.62 t/ac/yr, averaging 0.19 t/ac/yr (Sartz 1976), amounts very similar to those reported a quarter century earlier by Hays et al. (1949). To our knowledge, these are the only replications over time of forest grazing-soil erosion studies. Sartz (1976) concluded that forest slopes of the Driftless Area do not contribute significant amounts of floodwater or sediment to receiving streams.

Figure 9.—Eroded material from the cornfield upslope was deposited downslope in this Illinois woodlot.

Livestock were excluded from one-half of this grazed watershed in 1970. A heavy mat of grasses developed on the ungrazed portion but no overland flow was produced from either half during 1970–71. During the next 2 years, the ungrazed-grazed ratio for mean total stormflow dropped from 1.77 to 0.10 and from 0.82 to 0.03 for mean peak flow (Sartz and Tolsted 1974). Bulk density of the soil was slightly lower 5 months after grazing stopped. Rapid recovery of grass led the authors to speculate that improved infiltration could have reduced stormflow even during the first year after livestock exclusion. This second phase of hydrologic observation at LaCrosse was terminated with closing of the Forest Watershed Laboratory (Sartz 1978).

Aerial photographs of the Coulee Experimental Forest and vicinity (loaned to the senior author by Dr. Dean Knighton, USDA Forest Service, Washington, DC) depict substantial differences in the landscape between flights of 1938 and 1967. The earlier photographs clearly show active gullying on most of the farmed land while the woodlands seemed to contain few and relatively small trees. Even though gully scars were visible in the 1967 flight, there was far less appearance of active erosion and the forest cover was more complete. Dr. Knighton, a former participant in the research at LaCrosse, felt that recovery from drought conditions of the early 1930's coupled with generally improved farm management practices had substantially reduced the potential for accelerated erosion across much of the Driftless Area. In a sense, then, results from the most recent of the LaCrosse studies may be considered artifacts, relic samples of conditions on grazed forest land as they probably existed over a half century ago.

Recovery from Grazing

Years of observation at Coweeta and LaCrosse suggest that removal of grazing animals is followed by prompt return to pregrazing hydrologic conditions, a recovery rate on the order of several months to a few years. Watershed scientists have observed for decades that removal of disturbance (logging, fire, recreational overuse, and grazing) is followed promptly by recovery to predisturbance hydrologic conditions. Walter Lyford (former soil scientist at Harvard University) mused about this recovery capability, which he termed "the forgiveness of nature." Years of close observation throughout the Eastern United States had convinced Lyford of the forest soil's near universal capability to regain productivity and hydrologic functioning soon after any land mismanagement was terminated. We agree that there is considerable evidence to support rapid recovery.

Lull (1959) felt that persistence of compaction effects was largely conjectural. Diller (1935) provided some information concerning the timing of improved hydrologic performance after removal of cattle from an oak-hickory forest. The average bulk density of the upper 3-inch layer of soil in woodland protected from grazing for more than 10 years was 15 percent less than soils from which cattle only recently had been removed. After 16 years of protection, the surface soil of formerly grazed woodland absorbed water almost 7-1/2 times faster than surface soils on currently grazed woodlands. Diller (1937) also suggested that slight decreases in the July-August soil moisture tended to kill tree reproduction on formerly grazed forest land. This finding conflicts with the results of more recent studies, and the use of modern techniques to quantify soil moisture could cast doubt on this suggestion.

Somewhat related observations from the Missouri Ozarks suggest long-term recovery. Hornkohl and Reed (1948) reported that overgrazing and burning had compacted the forest soil, weakened the deep-rooted perennial cover, and replaced it with annuals which covered the soil only during the growing season. Presumably, those fire and overgrazing effects had contributed to deterioration of watershed values. Long afterward, Kimmel and Probasco (1980) reported general recovery of the Ozark glade vegetation (Fig. 10) following decreased fire and grazing. Gates et al. (1982) observed minor overland flow in the same general vicinity, with a large percentage of streamflow discharged as interflow, suggesting full hydrologic recovery from overgrazing and other land mismanagement.

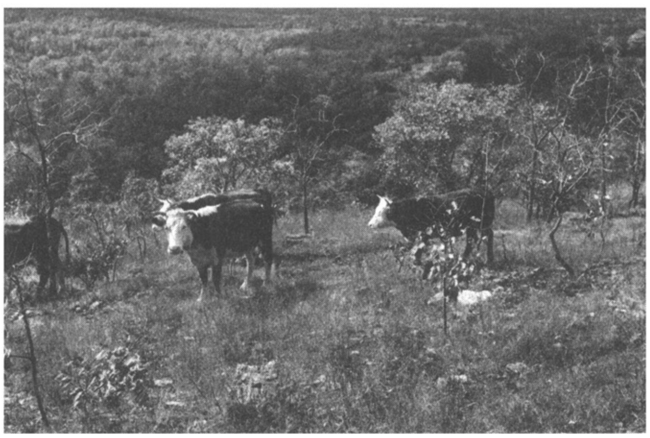

Figure 10.—Cattle grazing in typical glade-type topography on the Mark Twain National Forest near Long Run, Missouri.

There is a dearth of solid scientific evidence on the persistence of grazing effects, but one fact should not be overlooked. Some of the vast presettlement buffalo herds had grazed much of the midcontinent for thousands of years, ranging at least as far east as the mountains of West Virginia. We can never know how their presence affected soil and water in those pristine forests but it seems certain that no ill effects from their presence were apparent at the time of settlement or since.

Discussion

This review has shown that grazing is widely perceived as inimical to soil and water in the eastern forest despite decades of research which demonstrated repeatedly that the ill effects are slight. Why then, does the concern persist? Perhaps the major reason is the century-long denunciation of grazing by well-intended conservationists. Another reason may be the inability of scientists to disseminate research results effectively; study findings tend to remain within the research community, too often unknown to the technicians and laymen most likely to benefit from them. But other factors, old and new, serve to perpetuate this common misconception.

Surely, the truism that thrifty trees best protect the forest soil and water predates both the professions of forestry and range management. Hence, it follows that any land use that endangers trees will be interpreted as harmful to the soil and water they safeguard. Perhaps that rationale explains the concern about forest grazing so often voiced in the earlier literature. For example, the voluminous "National Plan for American Forestry" (Munns et al. 1933) evaluated the effects of forest grazing in nonquantitative terms for each section of the country. But the concern persists despite much research to show that it usually is unfounded. Lee's (1980) text on forest hydrology described the conventional concerns with overgrazing but offered no constructive alternative, that prudent grazing can have its place in the responsible management of forested land. This negative attitude colors much of the thinking of the conservation-minded public.

Robert E. Horton, a pioneer of hydrologic science, championed the concept of limited infiltration, postulating that large fractions of the rain fail to enter the soil, flow overland, and carry to streams whatever soil particles and pollutants are movable (Horton 1933). Soil erosion was presumed to be a function of this pervasive, watershed-wide, overland flow. In light of Horton's ideas, it follows that grazing-impaired hydrologic functioning was viewed with alarm—it was seen as the cause of even less infiltration, increased overland flow, and additional soil loss. The mechanism thus envisioned threatened to greatly accelerate the detachment of soil particles and their transport downslope.

Horton's ideas have become landmarks in hydrologic science and to this day they dominate thinking among many agriculturists and engineers, specialists who often deal with bare and severely disturbed soil where infiltration is demonstrably limiting. Among foresters, Horton's ideas have been superseded by the observation that, compared to rainfall or snowmelt rates, most forested watersheds have unlimited infiltration, and that streams draining them are nourished mostly by subsurface flow (Hewlett and Hibbert 1967).

The complete infiltration of rainfall and snowmelt is the rational basis for the variable source-area concept, abbreviated as follows from a lengthy description by Troendle and Leaf (1980). Streamflow originates as drainage from saturated soil in and near channels, gravity-replenished as water drains from higher adjacent slopes. A host of factors (e.g., land configuration, soil texture and depth, antecedant soil wetness, rainfall amount and intensity) determines the location, extent, and flow productivity of the saturated soil bodies. These flow-producing bodies expand and shrink as rains come and go, hence their designation as the variable source areas of streamflow origin (Hewlett and Hibbert 1967). Where this hydrologic performance prevails, overland flow can occur only when saturation to the soil surface precludes further infiltration, commonly on the source areas (Hewlett and Troendle 1975).

The variable source-area concept was clearly illustrated by flash flood-producing storms in West Virginia. These storms caused varying amounts of overland flow (even in the undisturbed forest), sometimes moving litter from a few inches to several feet, sometimes baring considerable expanses of the fibric and hemic layers of the forest floor, but rarely exposing mineral soil in nonchannel areas (Patric 1981). In only one instance did this hydrologic behavior, so typical of the eastern forest, differ on grazed woodland. Near Moorefield, West Virginia, 4.1 inches of rain fell in 45 minutes. A 35- to 40-percent slope, about 1 acre in extent, had been grazed heavily; there was a complete canopy and dense litter but no understory. Overland flow had swept 3- to 4-foot-wide bands free of litter but had not bared the underlying soil. Such downslope bands were unique to our long experience in forest hydrology. Those who question this interpretation may overlook the obvious; most forest floors—even on grazed woodland—remain litter-covered simply because overland flow is too exceptional an event to disrupt that cover.

Contrasting processes of stormflow generation by Horton's overland flow concept and Hewlett and Hibbert's variable source-area concept are illustrated in Figure 11. Since infiltration into forest soil usually exceeds rainfall intensity, results of the studies reviewed here must be interpreted in light of the variable source-area concept. Those studies demonstrated few alarming effects of forest grazing on soil, water, and nonpoint pollutants. They were not flukes. With overland flow a rare occurrence, it follows that a mechanism rarely exists to transport soil, dung, or other particulate matter across the forest floor. As for bacteria and dissolved substances, most such material is filtered out of subsurface flow during its passage through the forest floor and the underlying soil.

Soil Loss Prediction

The relatively new Universal Soil Loss Equation (USLE) is a direct application of Hortonian hydrology. It has been applied nationwide since 1977 (Dideriksen 1981) to predict erosion caused by many land uses. The USLE was validated for use on agricultural land (Wischmeier and Smith 1978), but the equation's major developer stated specifically that soil losses from woodland are predicted less accurately than losses from cropland (Wischmeier 1976). The following are two examples of the use of the USLE to predict soil losses from grazed forest land.

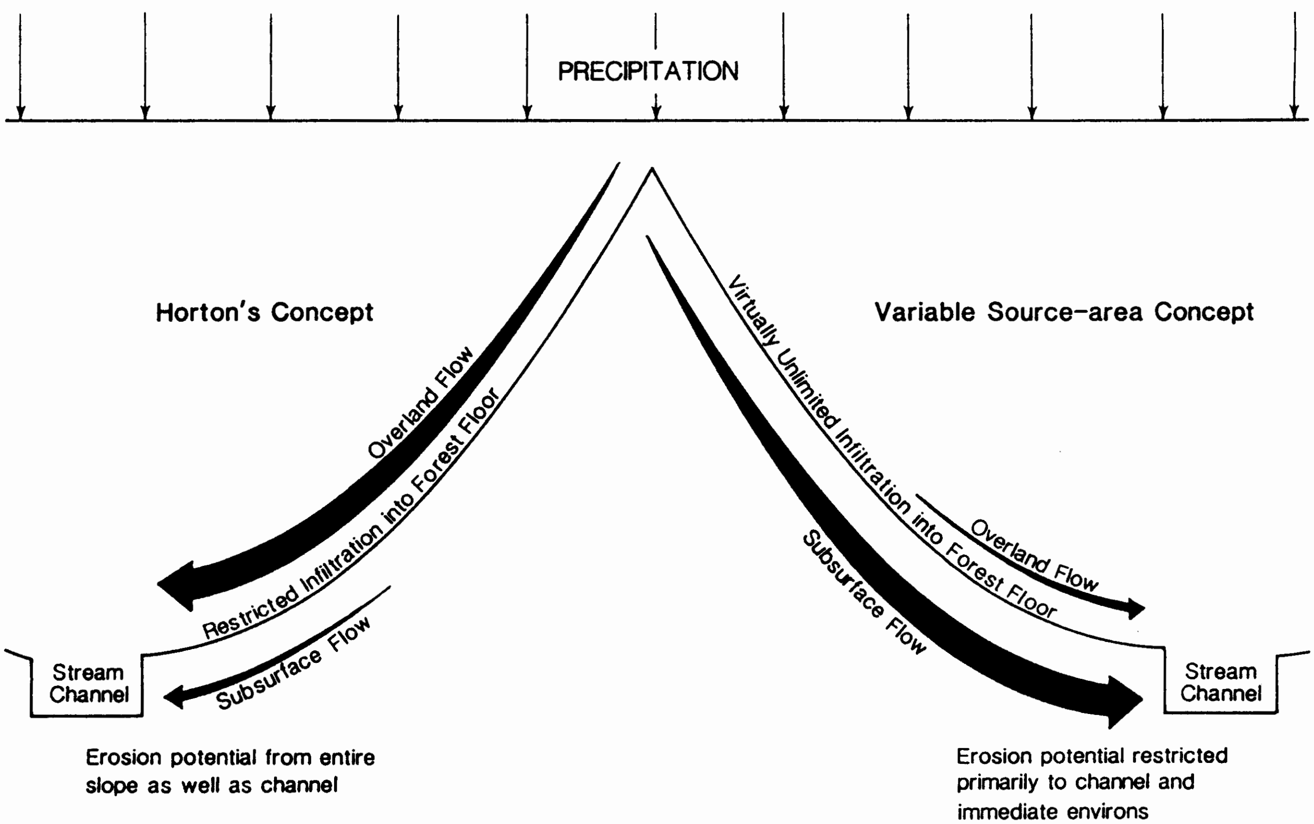

Figure 11.—Expectations of soil erosion are powerfully conditoned by one's acceptance of contrasting mechanisms for the delivery of water from forested slopes to streams.

The Indiana Department of Natural Resources (1978) developed widely variable predictions of soil loss across a four-county district. On nearly 50,000 acres of grazed forest land, soil loss was predicted to range from zero to 183 t/ac/yr. Average soil loss for the four counties was predicted as 23 t/ac/yr, with 22 tons delivered to streams as sediment. To place such quantities in perspective, erosion at 150 t/ac/yr is equivalent to a soil loss of about 1 inch annually. That rarely happens, even on perennially tilled fields. Complete, sustained denudation of forested land in Tennessee did cause nearly 2 feet of soil loss during 17 years (Rothacher 1954), equivalent to almost 200 t/ac/yr. This was the ill-famed Copper Basin, the "Sahara of America," where infiltration was inferred as perhaps 2 percent of the annual rainfall (personal communication, Dr. Roger Betson, TVA, retired) and overland flow literally eroded the land surface to bedrock. As for 22 t/ac/yr of soil delivered to streams as sediment, that is more than twice the rate of about 9 t/ac/yr (Holeman 1968), which makes California's Eel River one of the world's most sediment-laden. It is extremely unlikely that erosion and sedimentation of even the average predicted magnitudes occurred on Indiana's grazed woodlands. On the other hand, neither is zero a realistic prediction of soil loss or of sediment production because erosion at geological rates is universal, regardless of land use.

National resources inventories by the USDA Soil Conservation Service (1982) provide predictions of soil loss from grazed forest for states within the eastern forest region (Table 7). The soil losses so predicted raise more questions than seem answerable. Did Arkansas and Georgia really achieve 95-percent reductions of soil loss from grazed forest lands? If so, why weren't those apparently effective measures used to control soil loss from grazed forest lands of Illinois and other high-loss states in the Ohio River Basin? Did soil loss really increase substantially on grazed forest in Maryland, New Jersey, and Pennsylvania? Was the 1977 soil loss from pastured woodland in Illinois identical to the measured soil loss for cropland as shown in Table 2? It seems highly improbable that average soil loss on grazed forest land decreased by nearly 50 percent throughout the Eastern United States. What acounts for that claim (see Table 7) over so vast an area in so short a time? Incidentally, average soil loss from ungrazed eastern forest was predicted to decrease from about 0.6 t/ac/yr to about 0.4 t/ac/yr during that same 5-year period. Do the 1982 predictions incorporate some sort of revised technique in the application of the USLE? How much credence do such numbers deserve?

Table 7.—Soil loss predictions by states in 1977 and 1982 for grazed forest land

	Soil loss	
State	1977 inventory	1982 inventory[a]
	-----Tons/ac/yr-----	
Alabama	1.99	0.9
Arkansas	14.06	0.6
Connecticut	0.78	0.1
Delaware	0	0.2
Florida	0.26	0.1
Georgia	14.25	0.7
Illinois	17.13	13.1
Indiana	5.38	6.1
Iowa	4.42	3.5
Kentucky	8.20	8.5
Louisiana	0.67	0.2
Maine	0.08	0.1
Maryland	3.59	6.5
Massachusetts	0.54	0.1
Michigan	3.10	0.6
Minnesota	3.76	0.9
Mississippi	1.72	2.3
Missouri	7.92	4.4
New Hampshire	1.54	0.1
New Jersey	0.77	3.2
New York	1.76	0.6
North Carolina	0.85	1.3
Ohio	11.96	5.2
Pennsylvania	4.75	6.1
Rhode Island	0.50	0.1
South Carolina	0.51	0.4
Tennessee	2.21	2.2
Vermont	3.76	0.4
Virginia	6.04	3.0
West Virginia	11.77	9.2
Wisconsin	7.22	3.1
Regional average	4.57	2.7

[a]1977 data published by the USDA Soil Conservation Service (1982); unpublished 1982 data furnished by USDA Soil Conservation Service, Washington, DC.

Apart from these unanswerable questions, did the people who devised both applications of the USLE familiarize themselves with the relevant research? We refer not to studies for predicting soil losses from tilled fields, but to reports of measured and estimated losses from grazed and ungrazed forest land. And would familiarization with the relevant research have prevented the publishing of soil losses that seem absurd in light of more appropriate research? The senior author (Patric 1982) has addressed some of the forest hydrologist's concerns with respect to the uncritical use of USLE to predict soil losses from forested land. The following are his definitions for three terms commonly used in the quantification of soil loss and are relevant to that concern.

- Measurement. A complete numerical value concerning the size or extent of any discernable entity. For example, a cubic foot of soil might weigh 75 pounds. Scientists prefer quantifications based on measurements.

- Estimate. An inference based on sample data concerning some numerical value of interest. A sample is a partial observation concerning a value of interest not easily measured. Rainfall, for example, cannot be measured stormwide. Instead, trained observers collect samples in rain gauges to provide a tested basis for estimating daily, monthly, and annual rainfall. Scientists carefully design, schedule, and conduct sampling to ensure representative estimates.

- Prediction. In modern English, a foretelling based on inference from natural law. The daily weather forecast is a prediction.

To realistically evaluate soil losses predicted by the USLE, one must fully appreciate that neither measurement nor estimate is involved in applying the equation. Each prediction is the product of six major factors whose most likely values are deduced by some user at some location and expressed numerically. Within any state, predictions by Soil Conservation Service personnel necessarily reflect local interpretations of the six factors and varying care and skill in deducing them.

Moreover, even the most expert use of the USLE on forested land necessarily applies Hortonian hydrology on lands where the variable source-area concept is more appropriate. Finally, measured soil losses and estimated sediment yields always are more accurate than those based on predictions (Allen 1981). For all of these reasons, we hold that scientist-developed soil losses, based on measurements and estimates, are more trustworthy than predictions. The uncritical acceptance of USLE-predicted soil losses, apparently in disregard of measurements and estimates, probably perpetuates the specter of forest grazing as a cause of widespread erosion and sedimentation in the eastern forest.

Our emphasis on erosion reflects near universal agreement that sediment is the major nonpoint pollutant resulting from forest grazing. Further, the hydrologic processes causing erosion also deliver most of the other nonpoint pollutants (particulates, bacteria, and dissolved substances) to streams. Hence, as erosion diminishes, so do other forms of nonpoint pollution. And erosion on grazed forest land, at measured rates (Table 3), actually approaches nonproblem status. By Soil Conservation Service standards, soil loss less than 2 t/ac/yr is tolerable (Wischmeier and Smith 1978), i.e., soil productivity is sustainable, economically and indefinitely, on most of the grazed forest land in the Eastern United States.

The probability of sustained productivity based on results of research cited here is even more tenable in light of Martin's (1954) comment that some studies employed such high rates of stocking that experimental animals lost weight, even during the growing season. Such was the case at Coweeta, where experimenters deliberately tried to develop worst-case conditions (Johnson 1952), and at LaCrosse, where existing worst-case conditions were deliberately used for study (Sartz 1970). Given that erosion remained below tolerable limits under those worst-case conditions, there seems little reason to doubt that soil losses will remain below tolerable limits under the less severe grazing typical of the average farm woodlot. Unfortunately, it has become a tenet of conservation wisdom that data from studies designed to produce overgrazing effects are typical results of even prudent grazing in the eastern forest. We maintain that soil loss on the order of 0.18 to 0.30 t/ac/yr—"geologic rates" (Patric 1976)—is a reasonable approximation of erosion when most of the eastern forest is subject to any but the heaviest of long-term overgrazing.

Given that soil loss in the vicinity of geologic rates is realistic, then USLE-predicted rates for all but the most heavily grazed land in the eastern forest often are an order of magnitude or more in excess of more probable geologic rates. Such inflated claims of great loss not only serve no useful purpose but also cause diversion of resources needed to deal with real problems elsewhere. If soil loss from grazed forest land must be predicted, we recommend the development and use of a method with a sound scientific basis which provides data reasonably consistent with measured and estimated losses from conventionally grazed woodlots. Dissmeyer and Foster (1984) have moved in this direction, having modified the USLE to predict sheet and rill erosion on land intensively prepared for tree planting in the Southeastern United States.

It is frequently overlooked that erosion rates accelerated by misuses of the eastern forest readily return to pre-misuse rates. In most cases, climates are sufficiently moist and mild to foster the vigorous regrowth of depleted forest vegetation, soon healing most damages to soil and water—"the forgiveness of nature." Simple elimination of misuse usually halts accelerated erosion and restores water quality within a year or so. Where elimination of grazing is not feasible, fencing cattle away from the source areas of streamflow, especially those surrounding live channels, will amply protect most of the forest soil and water resources. Even fencing may prove unnecessary where slight and transitory diminishment of water quality is tolerable, during and immediately after storms. There will, however, always be "sore spots," localized areas of exceptionally severe misuse where these simple remedies will not suffice (Fig. 2). There, in addition to excluding livestock, some sort of cultural and/or structural measures will be needed to restore and maintain hydrologic functioning typical of the unabused forest. However, the great majority of grazed forest land need not and should not be regarded and treated as is appropriate for these common but usually small "sore spots."

Regardless of its environmental consequences, good or ill, grazing in the eastern forest has decreased from about 180 million acres in 1938 (Marsh and Gibbons 1940) to less than 25 million acres a little more than 4 decades later (USDA Soil Conservation Service 1982). Laws eliminating open range undoubtedly played a major role in this reduction. Possibly, concern about soil erosion and water quality also prompted some of that decrease, but more often, economics must have been the deciding factor because "Even the farmer knows that starving cattle will not pay the grocery bill" (Martin 1954). For years, students of forest grazing (Den Uyl 1948; Sluder 1958; Welton and Morris 1928) have argued that cattle graze more profitably on properly managed pasture than in woodland. Perhaps this idea was illustrated most graphically by Bjugstad et al. (1968), who found that 180 acres of oak-dominated woodland in the Ozarks were needed to feed one cow and calf for 6 months. These animals could be expected to fare nicely on 2 acres of well-tended pasture.

Long ago, Cheyney and Wentling (1926) observed: "On a large number of farms, the woodlot is regarded as a shaded pasture and grazed continuously, little thought being given to the effect on wood-producing capacity. This has gone on year after year until the land has in fact become a shaded pasture." We suspect that this attitude prevails among farmers who continue to graze their woodlands. Perhaps there is merit in that conventionally deplored attitude. Landowner preference should have some place in the well-managed rural environment. It seems possible that a few acres of shaded pasture can afford more owner satisfaction and fit better into his or her livestock operation than those same few acres managed to maximize the production of unappreciated wood products. Conservation-minded people enthusiastic to further the cause of best land management might remember that the income received from a small tract of wood-producing land, no matter how well managed, may, in terms of owner satisfaction as well as monetary return, be too small to justify the loss of land as shaded pasture. That is a legitimate decision so the "red flag" of soil erosion and stream sedimentation should not necessarily be waved before the landowner. We must not forget the probable ill effects of severe overgrazing nor that grazing in moderation can have negligible effects on forest soil and water.

At present, land is termed forest when it is at least 10 percent stocked with trees of any size.[3] Note that the purpose of land management is omitted from this almost meaningless definition. Land so defined could be used to produce trees, grass, water, recreational opportunity, or nothing at all. Pasture, on the other hand, is defined as land used primarily to produce native or introduced forage plants for livestock grazing. Here, the purpose of land management is clear. Given so loose a definition of forest, there is no way for conservationists to separate well-managed shaded pasture from poorly managed woodland. When clearer definitions make that separation possible, perhaps there will be less cause for concern about forest grazing.

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[3] Unpublished national resources inventory for 1982.

The findings of other reviewers (Adams 1979; Blackburn et al. 1982; Gaither and Buckhouse 1981; Moore et al. 1979; Platts 1981) closely approach our own. Gifford and Hawkins (1978) could not distinguish between the influences of light and moderate grazing on infiltration, but they reported distinctly lower rates caused by heavy grazing. Perhaps Smeins (1975) best summarized grazing effects on soil loss: "Generally, severe overgrazing must occur before significant changes in erosion can be observed . . . It appears that moderate grazing may not increase erosion . . . ."

These reviewers drew heavily on western experience but we cannot differ with their conclusions. We add that the carefully nurtured disbelief of those conclusions must be overcome before the noneffects of prudent grazing are fully accepted by conservation professionals and the concerned public. As noted by Sartz (1969), the harmful effects of woodland grazing on water have been exaggerated and many of the supposed ill effects on soil are "folklore." But until a relatively few and small eyesores attributable to forest grazing can be cleaned up, it will remain nearly impossible to dislodge these widely held misconceptions.

Conclusions

1. Heavy grazing in eastern woodlands depletes the arboreal vegetation and reduces water intake rates into the soil.

2. Accelerated soil erosion and augmented stream sedimentation are widely perceived as the major ill effects of forest grazing. All results of forest hydrology research point to average soil losses on the order of geologic rates (0.18 to 0.30 t/ac/yr) for all but the most heavily grazed woodland. Stream sedimentation of similar magnitude seems probable.

3. There is no evidence that woodland grazing, as typically practiced, has substantial adverse effects on water quality or flooding in streams draining the grazed woodland.

4. Removal of foraging animals usually rectifies ill effects of overgrazing on forest soil and water within 2 or 3 years.

5. The conservation-minded public wlil continue to perceive forest grazing as an urgent environmental problem until (a) results of forest hydrology research are more widely known and applied, (b) present uncritical misuse of the unmodified USLE ceases as the means of predicting soil loss from grazed forest land, and (c) some validated method is devised to predict soil loss from grazed forest land more realistically.

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Although woodland grazing in the Eastern United States has greatly decreased during recent decades, it still is widely practiced. This literature review indicates minimal damage to the soil and water resource unless grazing intensity greatly exceeds the land's carrying capacity.

ODC 116.36

Keywords: erosion; forest grazing; infiltration; nonpoint pollution; sedimentation; woodland grazing

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
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*U.S. GOVERNMENT PRINTING OFFICE:1986-646-160:40006