In Proc. Second Biennial Southern Silvicultural Research Conference, Atlanta, GA, Nov. 4-5, 1982. USDA For. Serv. Gen. Tech. Rpt. SE-24, pp. 79-86. 1983.

INFLUENCE OF BURNING AND GRAZING ON SOIL NUTRIENT PROPERTIES AND TREE GROWTH ON A GEORGIA COASTAL PLAIN SITE AFTER 40 YEARS[1/]

William H. McKee, Jr., and Clifford E. Lewis[2/]

Abstract.--Soil analysis of a study area in the Coastal Plain of Georgia indicates that 40 years of grazing and prescribed burning have had no adverse effect on concentrations of total nitrogen, available phosphorus, exchangeable bases, or organic matter in mineral soil. Burning alone reduced organic matter and nutrients in the forest floor and tended to increase them in the surface 6 inches of mineral soil. Grazing did not affect soil nutrient properties nor did grazing interact significantly with prescribed burning. Results indicate that well-managed grazing in conjunction with prescribed burning has no adverse effects on site quality for longleaf-slash pine-wiregrass sites.

INTRODUCTION

Burning to improve grass production and woods grazing is common throughout much of the Southern Coastal Plain (Lewis et al. 1982). Most studies on these practices have addressed forage quality, timber reproduction, burning frequency, and direct interaction of grazing and timber production. A subtle problem frequently overlooked is the effect that grazing and prescribed burning, which must accompany the grazing, has on future site quality and nutrient cycling in the forest floor and soil.

In this paper we report effects of grazing combined with biennial prescribed burning over a period of 40 years on nutrient levels on sandy Coastal Plain sites.

MATERIALS AND METHODS

Pastures were intensively sampled in 1980 after 40 years of prescribed burning and grazing research on a Coastal Plain site in Berrien County, Georgia. A portion of the Alapaha Experimental Range, which consists of a variable stand of longleaf and slash pine, was fenced into eight 50-acre pastures in 1942 so that two replications of four different prescribed burning regimes could be established. Burning treatments maintained until 1950 consisted of an unburned "control", triennial burning, biennial burning, and annual burning (Table 1). During 1950-54, the six pastures were burned annually. Beginning in 1954, fire was excluded from all pastures to permit reestablishment of pine by natural regeneration. The old mature trees were removed in 1961. An inventory of the trees in 1963 indicated that fairly similar stocking existed on all pastures. During 1965-67, biennial burning of pastures which has a previous burning treatment was initiated that continued to the present. The two unburned pastures have been protected from fire since 1941, when wildfire swept through the area.

The present timber stand consists of slash and longleaf pine with basal areas averaging 75 square feet per acre from 368 trees per acre (fig. 1). Average tree heights and diameters are 48 feet and 5.7 inches, respectively, with no significant effects on tree growth due to burning or grazing.[3/] Understory vegetation consits of wiregrass range as described in detail by Halls et al. (1956).

All pastures were grazed at 8.3 acres per animal for 7 to 10 months per year from 1942-49. During 1950-54, grazing varied from light stocking at 17 acres per animal to heavy stocking at 4 acres per animal for 10 months of the year. Pastures

[1/] Paper presented at the Second Biennial Southern Silvicultural Research Conference, Atlanta, Georgia, November 5-6, 1982.

[2/] Authors are Soil Scientist and Range Scientist, Southeastern Forest Experiment Station, Charleston, South Carolina 29407 and Gainesville, Florida 32611, respectively.

[3/] Unpublished data: C. E. Lewis, USDA Forest Service, Gainesville, Florida.

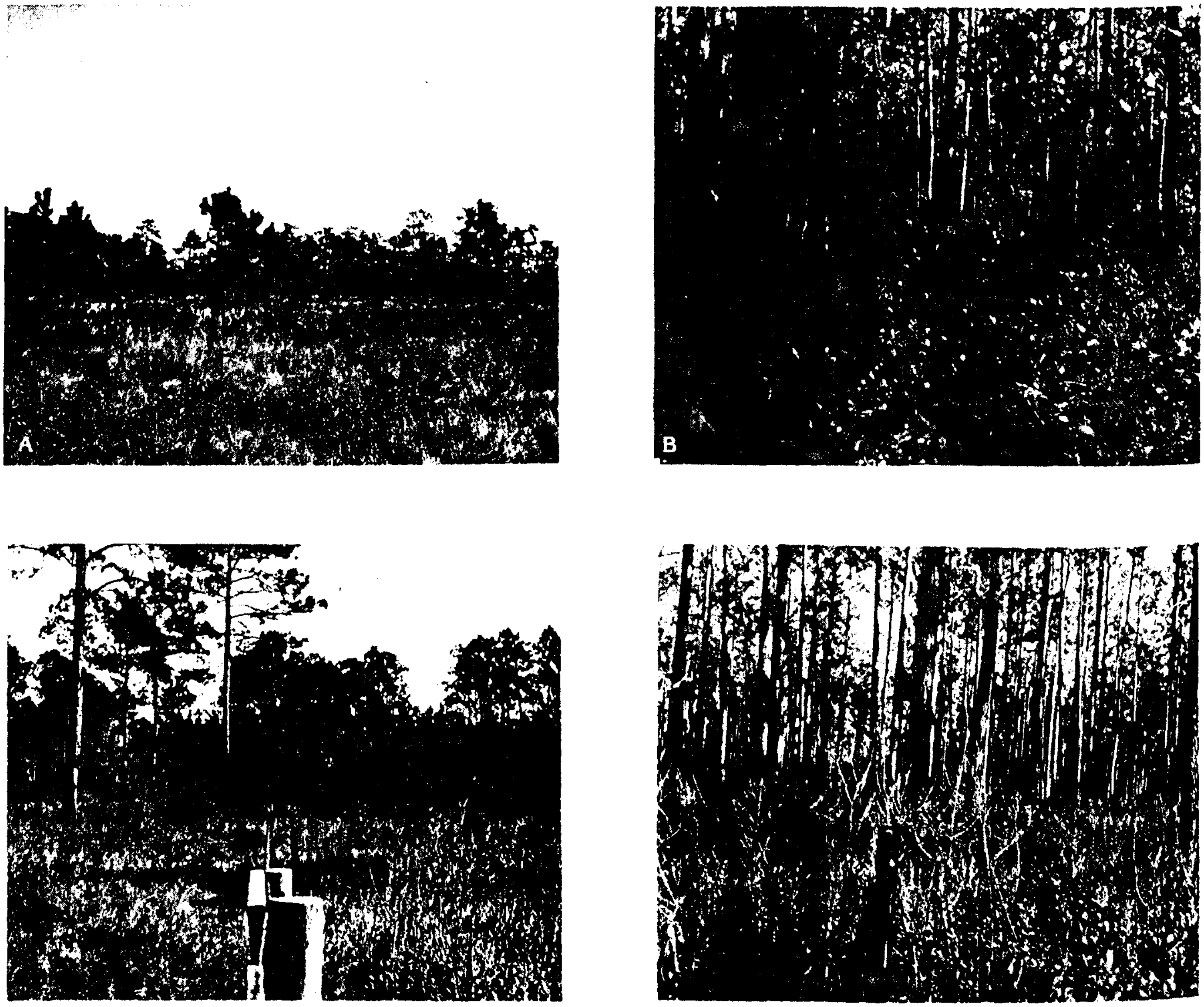

Figure 1.--Changes in trees and understory vegetation are evident on areas burned in 1941 as they appeared in 1942 on an unburned treatment initially (a) and again in 1980 (b); and on a burned treatment initially (c) and again in 1980 (d).

Table 1.--History of burning treatments for pastures on Alapaha Range.

	Initial burning treatments and subsequent changes in fire management			
Years	Control	Triennial	Biennial	Annual
1941[1/]	Wildfire	Wildfire	Wildfire	Wildfire
1942-1949	Unburned	Triennial burns	Biennial burns	Annual burns
1950-1954	Unburned	Annual burns	Annual burns	Annual burns
1955-1964	Unburned	Unburned	Unburned	Unburned
1965-1982	Unburned	Biennial burns	Biennial burns	Biennial burns

[1/]The area was protected from fire from 1934 but a widlfire in 1941 burned about half of the experimental area.

were neither grazed nor burned from 1954-59 to allow for natural regeneration of pine. From 1960-66, pastures were stocked at 20 acres per animal along with 0.6 acres of improved pasture per animal for 10 months per year. From 1967-82, pastures have been grazed at this same intensity, but for only 6 months each year.

Soils in the study area are: Alapaha loamy sand (Arenic Paleaquult loamy siliceous thermic), a poorly drained soil making up about 2/3 of the study area; Leefield loamy sand (Arenic Plinthoquic Paleudult loamy siliceous thermic), a somewhat poorly drained soil representing about 1/4 of the study area; Irvington loamy sand (Plinthic Fraguidult fine-loamy siliceous thermic), a moderately well drained soil found on a relatively small portion of the study area; and Pelham loamy sand (Arenic Paleaquult loamy siliceous thermic), a poorly drained soil representing about 1/4 of the eight pastures but only 2 sampling areas in different pastures in the study (USDA, SCS 1975-80).

On upland portions (low ridges 2 to 5 feet above drainageways) within each of the eight pastures, six randomly located 1/4-acre fenced exclosures were established to exclude grazing. Adjacent to each exclosure is a like area with established corners but no fence. Samples were collected on two subplots in these 1/4-acre sample plots. At each subplot, forest floor and mineral soil samples were collected at four random points.

The forest floor was a mor humus that mixed little with the mineral soil. The forest floor samples included all material from the L, F, and H layers (litter, fungal, and humus) from within a 6-inch-square frame. No attempt was made to segment the forest floor by layers. Two 1-inch diameter soil cores were then collected from within the 6-inch squares. The cores were segmented into depths of 0-3 and 3-6 inches. The 0-3 inch sample represents the A1 horizon and the 3-6 inch sample, in most cases, the A2 horizon, 6 inches being the lowest depth on which a measurable effect of burning was expected.

Forest floor samples were oven dried at 70°C for 24 hours, weighed, and ground to pass a 40-mesh screen. Nitrogen was determined by a modified micro-Kjeldahl procedure; 0.1 g of material was digested in a test tube, and ammonia content was determined by the salicylate-cyanurate procedure (Nelson and Sommers 1973). Other analyses were made on material dry-ashed for 2 hours at 450°C and taken up in 0.03 N HNO_3. Phosphorus was determined by the molybdovanadate procedure (Jackson 1958) and K, Ca, Mg, and Na by atomic absorption. A separate sample was dry-ashed at 500°C for 2 hours to determine mineral content, which was subtracted from the dry weight. Thus, weights of forest floor material represent only the loss on ignition component.

Soil samples were air-dried and crushed to pass a 2-mm sieve. Organic matter content was assayed by wet oxidation (Jackson 1958). Particle-size distribution was determined by the hydrometer method (Day 1965). Exchangeable bases were determined by atomic absorption on extracts made with 1 N NH_4OAC (Jackson 1958). Available phosphorus was determined by extracting 2.5 g of soil with 20 ml of Bray P2 solution (Bray and Kurtz 1945). Soil pH was measured with a glass electrode on a 1:2 soil/water mixture. Total soil nitrogen was determined by micro-Kjeldahl digestion of a 1.0 g sample with ammonia being determined by the salicylate-cyanurate method (Nelson and Sommers 1973).

Results are expressed as concentration of nutrients in the soil components and as total amounts in the surface soil and forest floor. Bulk density values are taken from results published in an earlier report (Suman and Halls 1955). Comparisons of burning and grazing treatments are made by analysis of variance and "t" test with significance reported at the 0.05 level.

RESULTS

Soil

Nutrient concentrations were altered by the burning and grazing treatments (Table 2). Clay content of soils for the burning and grazing treatments ranged from 3 to 6 percent in the 0-3 inch soil layer and from 4 to 7 percent in the 3-6 inch soil layer. These soil textures are typical of many wet flatwoods.

Soil pH ranged from 3.50 to 4.39 for burning and grazing treatments in the 0-3 inch depth and from 3.77 to 4.52 in the 3-6 inch depth (Table 2). High acidity is typical of Ultisols throughout the Coastal Plain. Suman and Carter (1954) reported pH values of 4.7 in the 0-3 inch layer of soil and 4.8 to 4.9 in the 3-10 inch soil layer for this study area. Differences between their analysis and the present sampling may in part reflect different sampling techniques and seasonal variations in the soils.

Total nitrogen ranged from 282 to 435 parts per million in the 0-3 inch soil layer and from 144 to 213 parts per million in the 3-7 inch layer. These concentrations in the top 6 inches of soil are low in comparison to other sites in the Coastal Plain (McKee 1982); they reflect the sandy nature of the study site and its low nutrient holding capacity. Of interest is the slightly, but not significantly, higher level of nitrogen on grazed compared to ungrazed plots.

Concentrations of available phosphorus ranged from 2.4 to 3.3 parts per million in the 0-3 inch soil layer and from 1.7 to 2.3 in the 3-6 inch layer. These values fall in the range of those observed on a sandy site in Alabama (McKee 1982). As in other prescribed burning studies, concentrations of available phosphorus were higher on burned plots than on unburned control. Grazing had no noticeable effect on phosphorus levels.

Table 2.--Average chemical and physical properties for mineral soil as related to initial grazing and prescribed burning treatments during 1942-49. All burned pastures have been burned biennally since 1965-66.

Original burning treatment	Grazing treatment	Soil pH	Total nitrogen	Available phosphorus	Exchangeable bases: Calcium	Potassium	Magnesium	Sodium	Total bases	Clay	Organic matter
			ppm	ppm	meq/100 g	meq/100 g	meq/100 g	meq/100 g	meq/100 g	percent	percent
0-3 Inch Soil Depth											
Control	None	4.07	282	2.4	0.12	0.01	0.05	0.09	0.27	5	1.78
	Grazed	4.05	304	2.5	0.11	0.02	0.04	0.07	0.24	6	1.82
Triennial	None	3.52	305	3.0	0.18	0.02	0.05	0.08	0.33	3	1.66
burning	Grazed	3.50	309	3.3	0.18	0.02	0.06	0.07	0.33	4	1.75
Biennial	None	4.39	378	3.2	0.33	0.02	0.08	0.08	0.51	5	2.17
burning	Grazed	4.31	435	3.3	0.26	0.03	0.07	0.06	0.42	5	2.21
Annual	None	4.14	406	2.6	0.16	0.02	0.05	0.09	0.32	4	1.59
burning	Grazed	4.13	412	2.8	0.15	0.02	0.05	0.08	0.30	4	1.72
3-6 Inch Soil Depth											
Control	None	4.38	203	2.1	0.09	0.01	0.02	0.06	0.18	6	1.38
	Grazed	4.41	209	2.1	0.09	0.01	0.02	0.06	0.18	6	1.31
Triennial	None	3.77	144	2.1	0.11	0.01	0.02	0.06	0.20	4	1.25
burning	Grazed	3.82	165	2.3	0.12	0.01	0.03	0.06	0.22	4	1.40
Biennial	None	4.52	213	2.2	0.14	0.01	0.03	0.06	0.24	7	1.68
burning	Grazed	4.52	198	2.1	0.11	0.01	0.02	0.05	0.19	6	1.64
Annual	None	4.20	189	1.7	0.12	0.01	0.02	0.07	0.22	4	1.14
burning	Grazed	4.22	193	1.9	0.12	0.01	0.02	0.07	0.22	4	1.16

Concentrations of total exchangeable bases in the upper soil layer ranged from 0.24 to 0.27 milliequivalent per 100 g for the unburned control and from 0.42 to 0.51 milliequivalent per 100 g for the areas receiving biennial prescribed burns. All burning treatments contained slightly more exchangeable bases. Grazing had no noticeable effect on bases. In the 3-6 inch soil layer base concentrations ranged from 0.18 to 0.24 milliequivalent, and effects of treatments were even less apparent. The trend for burning to increase concentrations of most exchangeable bases in the A horizons is consistent with determinations made on other sites where prescribed burning was studied (McKee 1982, Wells et al. 1979). Although burning may have increased Ca slightly in the A2 horizon, it appears unlikely that burning mobilized any element to the extent that it moved beyond the upper part of the soil profile where roots are concentrated.

Organic matter concentrations in mineral soil were not strongly or consistently influenced by the prescribed burning treatments. These soils are typically low in organic matter. Of interest is the 0.04 to 0.13 percentage points higher organic content on grazed compared to ungrazed areas at the 0-3 inch depth. This trend was not apparent at the lower depth.

Forest Floor

Prescribed burning significantly reduced amounts of organic materials and nutrients in the forest floor (Table 3). However, any effects of the initial burning treatments (1942-54) on the forest floor properties did not persist in the 1981 samples. Amounts of organic matter and nutrients were somewhat higher on areas burned annually than on areas burned less frequently. Grazing effects were not consistent and do not appear to affect measured forest floor properties.

Burning reduced the weight of organic matter in the forest floor by 69 to 88 percent and reduced that of nitrogen by 76 to 90 percent. The reductions in nitrogen content of the forest floor are similar to those of other burning studies (McKee 1982).

Phosphorus in the forest floor ranged from 12.1 to 17.2 pounds per acre without burning and from 2.0 to 4.0 pounds per acre with burning. Prescribed burning also decreased the amounts of cations (calcium, potassium, and magnesium) by 66 to 89 percent. These changes are similar to those found on other Coastal Plain sites following burning (McKee 1982, Wells 1971).

Total Nutrient Budget

The changes in the forest floor and mineral soil are seen together (fig. 2). Bulk density values published by Suman and Halls (1955) for the soils in this study area were used to estimate quantities of nutrients per acre in the surface 6 inches of soil. At the time of sampling, the top 3 inches of soil in the grazed areas which were burned had higher bulk densities (1.48) than areas unburned (1.40) or areas burned and ungrazed (1.40).

Since only the biennial burning treatment has been applied consistently since the study began, and since the soils on this treatment's plots are similar to those of control plots, comparisons involving only this treatment and the control were

Table 3.--Organic matter and nutrient contents in forest floor as related to initial grazing and prescribed burning treatments. All burn pastures have been burned biennially since 1965-66.

Treatments		Forest floor content					
Original burning treatment	Grazing treatment	Organic X1000	Nitrogen	Phosphorus	Calcium	Potassium	Magnesium
		- - - - - - - - pounds per acre - - - - - - - -					
Control	None	59.7 [1/]	514	17.2	85	15.1	24.5
	Grazed	46.5 A	369 A	12.1 A	64 A	10.9 A	16.5 A
Triennial	None	11.2	75	3.0	20	2.3	3.5
burning	Grazed	11.0 B	70 B	2.8 B	17 B	2.1 B	2.9 B
Biennial	None	6.3	46	2.0	12	1.5	2.3
burning	Grazed	7.0 B	54 B	2.1 B	15 B	1.5 B	2.4 B
Annual	None	13.6	97	3.5	24	2.9	4.0
burning	Grazed	16.2 B	107 B	4.0 B	25 B	3.6 B	5.1 B

[1/] Burn treatments with the same letter in columns are not significantly different at the 0.05 level.

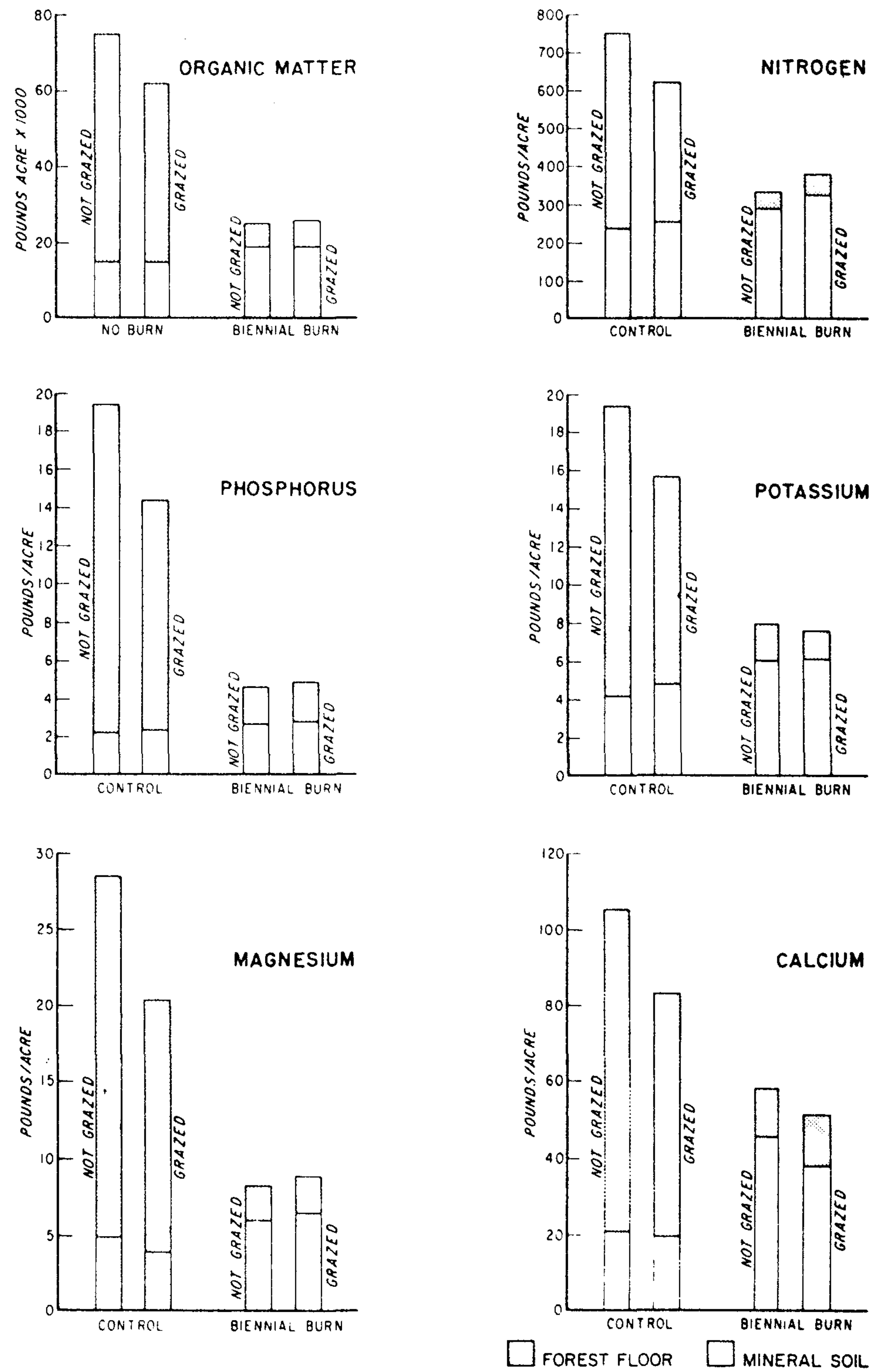

Figure 2.--Nutrient and organic matter content of forest floor and the surface 6 inches of mineral soil as they contribute to the total nutrient budget.

drawn. Amounts of organic matter and nutrients were compared by the "t" test of paired subplots at the 0.05 level.

While burning decreased the organic matter in the forest floor by approximately 40,000 pounds per acre, it increased organic matter in the surface 6 inches of soil by 25 percent or 4,000 pounds per acre. Grazing had no significant effect on organic content of the forest floor or soil with or without burning.

Nitrogen decreased in the forest floor and increased significantly in the mineral soil in much the same way as organic matter. The indicated increase of nitrogen in the mineral soil may result from mobilization of nitrogen by burning. In any case, the increase in readily available nitrogen stimulates plant growth. Grazing did not alter nitrogen content significantly.

A decrease in the ratio of forest floor organic matter to nitrogen found in other areas of the South with prescribed burning (McKee 1982) was not observed at this site. Here, ratios of organic matter to nitrogen appear to be unaffected by burning.

Burning decreased total phosphorus in the forest floor but significantly increased available phosphorus from 1.84 to 2.18 pounds per acre. A true comparison of phosphorus contents in the forest floor and soil is impossible because the forest floor analysis represents the total phosphorus present but the values for the soil are for available phosphorus. Grazing had no significant effect on phosphorus content in the total nutrient budget.

Although burning doubled calcium content in the mineral soil, it reduced the amount in the forest floor sufficiently to lower total calcium in the total nutrient budget. Grazing did not significantly alter totals for calcium or other cations. Calcium contents for this site are 1/3 to 1/10 those of other sandy Coastal Plain sites where burning was studied (McKee 1982). A deficiency of calcium may develop without burning and affect either timber or forage production on such a site. However, no effects of burning on timber have been observed in the study.

Prescribed burning reduced the total potassium in the forest floor but increased exchangeable potassium in the soil. Grazing had no effect on potassium content. The increase in availability of potassium may be more important to forage production than to timber production since it is uncommon to find southern pine species responding to potassium fertilization (Pritchett 1979).

Magnesium contents of the forest floor and soil responded to treatments similarly to calcium and potassium. Burning reduced magnesium 7 to 10 fold in the forest floor but increased it by 1.6 pounds per acre in the A horizon. Higher amounts in the mineral soil may be important in maintaining a balanced nutrient pool for plant growth. Certainly, understory plants respond favorably to prescribed burning (Lewis et al. 1982).

CONCLUSIONS

Apparently any removal of nutrients over a long period by grazing or burning of understory plants on this site has not measurably reduced pine production. The intensity of grazing has been moderate, and it has not changed the nutrient status of the soil. If the cattle had any detrimental effects on the site quality, it would probably be through physical compaction of the soil (Suman and Halls 1955). It is possible on poorly drained sites that soil compaction will restrict organic breakdown and nutrient cycling; however, such an effect is not apparent on our study area.

Based on this long-term study, it appears that the combination of burning and grazing has no detrimental effects on the nutrient budget or on pine height or volume growth. Burning may in fact be beneficial to site quality through more rapid mineralization of nutrients. The responses of herbaceous vegetation and forage quality to prescribed burning have been described in other papers (Lewis et al. 1982).

ACKNOWLEDGMENT

This was a cooperative study by the Georgia Coastal Plain Experiment Station, University of Georgia, College of Agriculture, Tifton, GA and the USDA Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

LITERATURE CITED

Bray, R. H., and L. T. Kurtz.
1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39-45.

Day, P. R.
1965. Particle fractionation and particle-size analysis. In Black, C. A., ed. Methods of soil analysis. Agronomy 9: 545-567.

Halls, L. K., O. M. Hale, and B. L. Southwell.
1956. Grazing capacity of wiregrass-pine ranges of Georgia. Ga. Agri. Exp. Stn. Tech. Bull. N.S. 2, 38 p.

Jackson, M. L.
1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliff, NJ. 498 p.

Lewis, C. E., H. E. Grelen, G. E. Probasco.
1982. Prescribed burning in southern forest and rangeland improves forage and its use. South. J. Appl. For. 6: 19-25.

McKee, W. H., Jr.
1982. Changes in soil fertility following prescribed burning on coastal plain pine sites. USDA For. Serv., Research Paper SE-234, 23 p.

Nelson, D. W., and L. E. Sommers.
1973. Determination of total nitrogen in plant material. Agronomy J. 65: 109-112.

Pritchett, W. L.
1979. Properties and management of forest soils. New York: John Wiley & Sons. 500 p.

Suman, R. F., and R. L. Carter.
1954. Burning and grazing have little effect on chemical properties of coastal plain forest soils. USDA For. Serv., Southeastern For. Exp. Stn. Res. Note 56, 2 p.

_____, and L. K. Halls.
1955. Burning and grazing affect physical properties of coastal plain forest soils. USDA For. Serv., Southeastern For. Exp. Stn. Res. Note 75, 2 p.

U.S. Department of Agriculture, Soil Conservation Service.
1975-1980. Soil interpretation records for individual soil series. USDA Soil Conservation Service Reports.

Wells, C. G.
1971. Effects of prescribed burning on soil chemical properties and nutrient availability. In Proc: Prescribed Burning Symp., pp. 86-99.

_____, R. E. Campbell, L. F. DeBano, and others.
1979. Effects of fire on soil. USDA For. Serv. Gen. Tech. Rpt. WO-7, 34 p.