Journal of the Arkansas Academy of Science

Volume 39 Article 29

1985

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CHANGES IN FOREST SOILS FOLLOWING CLEARCUTTING OF PINE FORESTS IN THE OUACHITA MOUNTAINS OF ARKANSAS

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ABSTRACT

Soil characteristics of the mineral surface soil (0-6 cm) on three small watersheds in the Ouachita Mountains of Arkansas from which the pine forests have been clearcut, crushed, and burned for site preparation were studied for the first two years following clearcutting and compared to soils from adjacent uncut pine forest watersheds. Following clearcutting and burning, soil pH was generally higher than in uncut forest soils. The greatest pH differences occurred within several months of burning and generally decreased through the end of the second year. Soil organic matter content was lower immediately following clearcutting and burning and increased to levels greater than those of the uncut forest soils. Little or no differences in organic matter content were found by the end of the second year. Available soil P levels were significantly higher soon after clearcutting and burning. Available P levels decreased until there were little or no differences between the clearcut and uncut forest soils by the end of the second year. Soil inorganic nitrogen (NH_4 and NO_3) levels were variable but usually were greater on the clearcut sites than on the uncut sites.

INTRODUCTION

Clearcutting of pine forests followed by site preparation for pine plantation establishment has increased in recent years in the Ouachita Mountains of Arkansas. Vegetation development following clearcutting and site preparation is related to wildlife habitat, hydrologic conditions, aesthetics, nutrient cycles, and plant competition. Chemical changes in soils following clearcutting and site preparation might influence vegetation development and thus influence the nature of the conditions noted above. Therefore the purpose of this study was to investigate changes in soil characteristics occurring following clearcutting and site preparation in the Ouachita Mountains.

MATERIALS AND METHODS

Changes in soil chemical characteristics for the first two years following clearcutting and burning compared to uncut forest soils were studied on three clearcut experimental watersheds and adjacent uncut forest areas located on Weyerhaeuser Company and Ouachita National Forest lands in the Ouachita Mountains of central Arkansas. One watershed was located on Cedar Mountain, hereafter referred to as the Cedar Mountain Site (CM). This site is located in Perry Co. in section 24 of T3N, R19W. This watershed has a northern aspect. Two other watersheds were located in the Alum Creek Experimental Forest of the USDA Forest Service. One of these watersheds has a northern aspect and is hereafter referred to as Alum Creek North (ACN) while the other has a southern aspect and is referred to as Alum Creek South (ACS). These watersheds are located in Saline Co. in sections 23 and 26 of T2N, R19W. The slopes in the experimental forest are steep, frequently exceeding 20%. Soils were mainly in the typic hapludults soil order with surface textures mainly stony silt loams.

The clearcut areas previously contained about 25 m^2/ha of pine basal area and 7 m^2/ha of hardwoods. Ages of the merchantable pine and hardwood varied from 65 to 75 years old. All merchantable pine and hardwood were removed in summer of 1980. The clearcut areas were chopped with a drum chopper and prescribed burned in fall of 1980. The sites were planted with shortleaf pine (*Pinus echinata* L.) and loblolly pine (*Pinus taeda* L.) after site preparation in spring of 1981.

Mineral soil was sampled to a depth of 6.0 cm in each clearcut and uncut control forest site. The uncut forest sites were similar to the clearcut sites on the basis of adjacency, slope gradient and aspect, soil, and vegetation. Ten soil samples were collected at random from each site. At each sampling date, samples were taken approximately 20 cm away from the previous sampling site. The six sampling dates were March, May, and August of 1981 and 1982.

Soil samples were passed through a 2 mm sieve prior to chemical analysis. Soil pH values were obtained in a 1:2 soil:water mixture. Soil inorganic nitrogen (ammonium and nitrate) analyses were determined by microKjeldahl steam-distillation methods following extraction with 2 mol L^{-1} KCl. Ammonium N was distilled with Mg0 followed by titration with 0.005 mol L^{-1} HCl. Nitrate N was determined following the addition of Devarda's alloy (Bremner, 1965). Available soil phosphorus was extracted with the Bray #1 solution (Bray and Kurtz, 1945) and determined colorimetrically by the standard ammonium molybdate and ascorbic acid blue method (John, 1970). Organic matter content of the soil was determined colorimetrically by the Walkley-Black method (Allison, 1965).

Table 1. Organic matter content of the mineral soil (0-6 cm) from areas clearcut and burned in summer and fall 1980 and from uncut forests, Ouachita Mountains, Central Arkansas.

Sites	Sampling Dates					
	Mar-81	May-81	Aug-81	Mar-82	May-82	Aug-82
	% Organic Matter					
Cedar Mountain						
Clearcut	2.4 d[1/]	2.1 e	3.6 a	3.8 a	2.9 c	2.7 c
Control	3.3 b	3.0 c	2.7 c	3.2 b	2.9 c	2.8 c
Alum Creek South						
Cearcut	2.9 e	3.1 c-e	3.7 b	4.0 a	3.3 c	3.0 de
Control	3.3 c	3.3 cd	3.2 cd	3.3 c	3.1 c-e	2.6 f
Alum Creek North						
Clearcut	2.7 e	2.2 f	3.7 ab	3.8 a	3.4 bc	2.7 e
Control	3.2 cd	3.0 c-e	3.0 c-e	3.4 bc	3.0 de	2.7 e

1/ Means followed by a common letter at a specified location are not significantly different using Duncan's multiple range test (p=0.05).

Table 2. Ammonium-N concentrations of the mineral soil (0-6 cm) from areas clearcut and burned in summer and fall 1980 and from uncut forests, Ouachita Mountains, Central Arkansas.

Sites	Sampling Dates					
	Mar-81	May-81	Aug-81	Mar-82	May-82	Aug-82
	Ammonium-N Concentrations (ugN/g Dry Soil)					
Cedar Mountain						
Clearcut	18.5 ab[1/]	14.3 c-e	16.9 bc	20.2 a	11.9 e	7.8 f
Control	14.6 c-e	12.8 e	13.4 de	16.0 b-d	12.5 e	8.9 f
Alum Creek South						
Clearcut	15.7 bc	13.1 d	18.5 b	20.6 a	11.8 e	6.8 f
Control	11.7 de	10.8 e	12.3 e	13.2 cd	13.0 d	9.1 ef
Alum Creek North						
Clearcut	13.3 a-c	10.4 c	14.1 b	16.4 a	13.5 a-e	5.2 d
Control	13.6 a-c	11.3 bc	10.5 c	11.9 bc	10.6 c	6.2 d

1/ Means followed by a common letter at a specified location are not significantly different using Duncan's multiple range test (p=0.05).

Table 3. Nitrate-N concentrations of the mineral soil (0-6 cm) from areas clearcut and burned in summer and fall 1980 and from uncut forests, Ouachita Mountains, Central Arkansas.

Sites	Sampling Dates					
	Mar-81	May-81	Aug-81	Mar-82	May-82	Aug-82
	Nitrate-N Concentrations (ugN/g Dry Soil)					
Cedar Mountain						
Clearcut	4.6 c[1/]	10.3 a	8.2 ab	4.2 c	5.0 c	10.4 a
Control	4.4 c	4.6 c	5.0 c	3.9 c	5.0 c	6.0 bc
Alum Creek South						
Clearcut	6.2 bc	9.5 a	6.9 b	4.2 cd	5.2 b-d	11.1 a
Control	3.5 d	4.3 cd	4.1 cd	3.7 d	3.6 d	4.1 cd
Alum Creek North						
Clearcut	4.0 c	7.0 b	4.8 c	3.6 c	4.2 c	9.1 a
Control	3.4 c	3.7 c	4.0 c	2.9 c	3.0 c	3.3 c

1/ Means followed by a common letter at a specified location are not significantly different using Duncan's multiple range test (p=0.05).

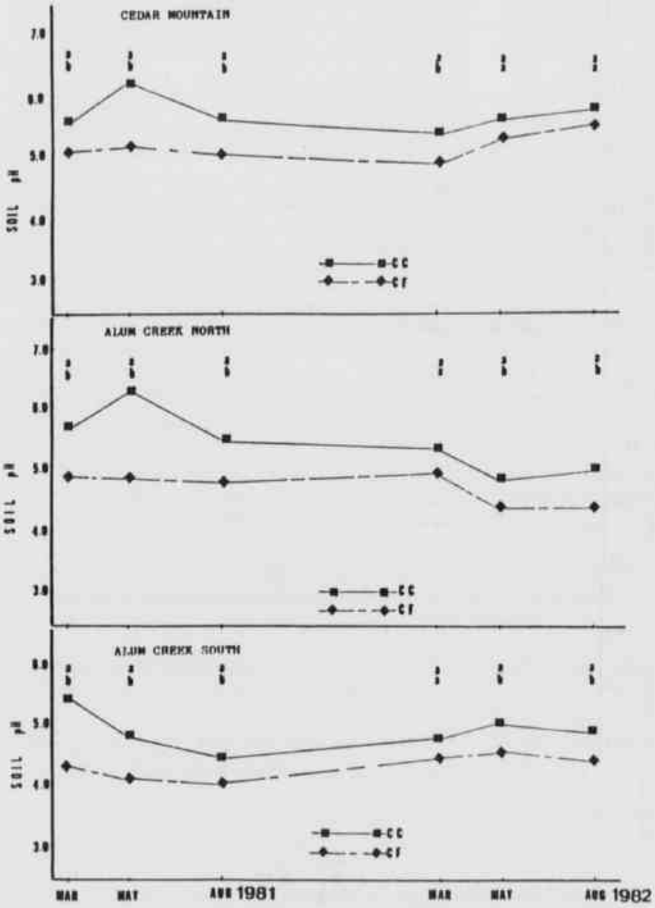

Figure 1. Soil pH of the mineral soil (0-6 cm) from areas clearcut and burned (CC) in summer and fall 1980 and from uncut control forests (CF), Ouachita Mountains, Central Arkansas. Values with a common letter at a specified date are not significantly different (p = 0.05).

The experiment was statistically analyzed as a completely randomized design by analysis of variance and means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

Soil pH

Following clearcutting and burning, pH of the surface mineral soil was generally higher at all clearcut sites than in the uncut forests (Figure 1). The greatest differences between the clearcut and uncut forests, ranging from 1.0 to 1.4 units, occurred within several months following burning and then generally diminished by the end of the second year.

This observed increase in pH was most likely due to accretion of basic ash materials (Grier and Cole, 1971; Stark, 1979). Increases of this magnitude could be expected to have an affect on soil microbial populations (Ahlgren and Ahlgren, 1965) and could influence seed germination and early seedling growth and competition, thus influencing the course of plant succession. Since the pH changes were short-lived, their impact would generally be expected during the first year or so.

Soil Organic Matter

Soil organic matter content was less immediatley following clearcutting and burning than in the uncut forests (Table 1). However, by August 1981, the organic matter content of the soil from the clearcut areas was significantly higher than that from the uncut forest, and remained so through May 1982, but then decreased to only slightly higher or not different by the end of the second year.

The lower organic matter content in the clearcut sites after burning may have been due to the lack of new root growth and increased decomposition since the forest cover was removed and the soil disturbed resulting in higher temperatures and increased oxidation on the site. Also increased soil pH after fire may have stimulated microbial activity and increased decomposition (Ahlgren and Ahlgren, 1965; Wells, 1971). Fire also may have destroyed some of the unincorporated organic residues and, where severe, fire may have destroyed topsoil organic matter (Raison, 1979). Revegetation during the first two years after clearcutting would cause a proliferation of new roots and top litter and would moderate the increases in temperature on the site, perhaps leading to the increases in organic matter noted by the end of the first year. In the uncut forest, the organic matter content was more stable and showed less variation.

Available Soil Phosphorus

The available P concentrations in forest soils from the clearcut sites were significantly higher after clearcutting and burning than those from the uncut forests at all sites and all dates except at the end of the second year when there were no significant differences (Figure 2).

Gosz et al. (1973), indicated a steady increase in soluble P during ordinary decomposition of leaves. Increased microbial activity (Ahlgren

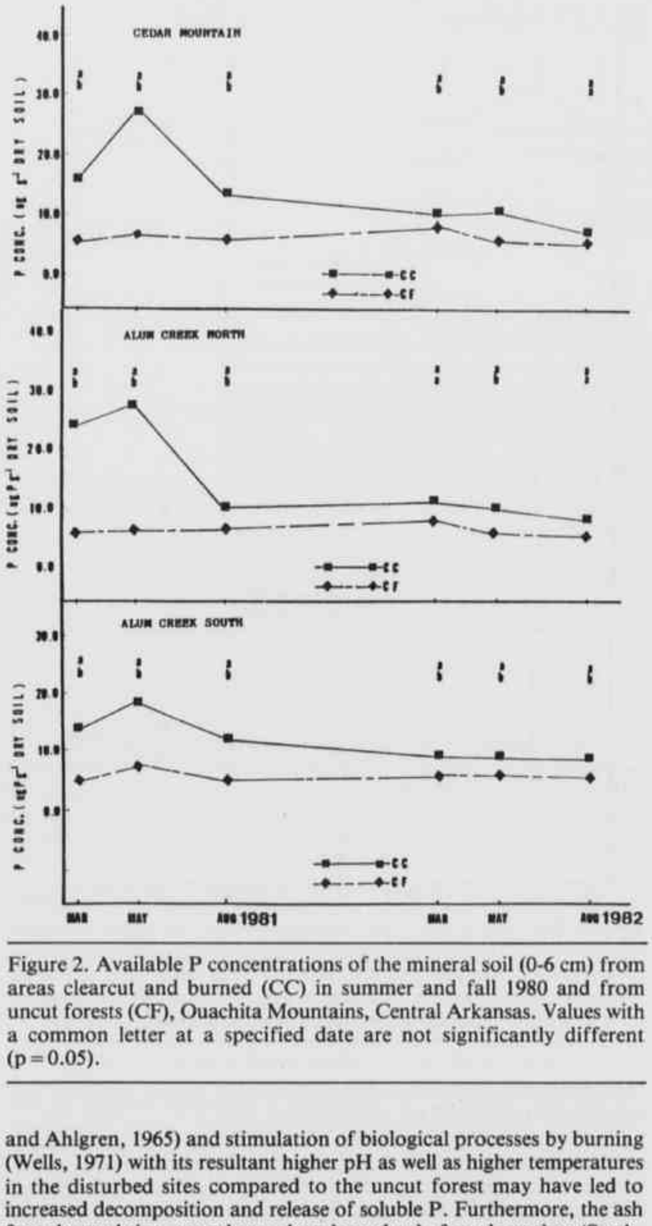

Figure 2. Available P concentrations of the mineral soil (0-6 cm) from areas clearcut and burned (CC) in summer and fall 1980 and from uncut forests (CF), Ouachita Mountains, Central Arkansas. Values with a common letter at a specified date are not significantly different (p = 0.05).

and Ahlgren, 1965) and stimulation of biological processes by burning (Wells, 1971) with its resultant higher pH as well as higher temperatures in the disturbed sites compared to the uncut forest may have led to increased decomposition and release of soluble P. Furthermore, the ash from burned sites can release phosphate slowly for a long time (Stark, 1977 and 1979).

Higher concentrations of P were observed immediately after clearcutting and burning, but differences decreased as time went on, possibly due to P uptake by plants as the area was revegetated or because of increased fixation of that P released with time, or both. In addition, some of the mineralized P in clearcut sites may have been absorbed by the abundant residual surface charcoal on the site (Smith, 1970).

Soil Inorganic Nitrogen

In general, the concentrations of soil ammonium were higher after clearcutting and burning in early spring and late summer of the first year and spring of the second year but were not significantly different at the other sampling dates (Table 2). The ammonium concentrations reached their highest levels in March of the second year in the clearcut sites. Ammonium concentrations were higher than nitrate concentration in all samples except for a few at the end of the second year (Tables 2 and 3). Soil ammonium concentrations were higher immediately after clearcutting and burning at CM and ACS and slightly lower at ACN site. The ACN site was probably slower to warm up in the spring because of its north facing slopes and was also lower in pH than the CM site. The increased ammonium in the clearcut sites could be due to increased mineralization of nitrogen following clearcutting and burning due to the abundant reservoir of oranic N available for mineralization (Christensen, 1973; DeBell and Ralston, 1970). Viro (1974) found that burning increased ammonium concentrations in mineral soil surface layers. The release of ammonium could also have been from direct heat oxidation of organic materials (Raison, 1979), increased microbial activity following fire which may have been stimulated by the higher pH and temperature of the clearcut sites (Ahlgren and Ahlgren, 1965; Wells et al., 1979), or increased frequency and intensity of wetting and drying cycles (Campbell et al., 1971). In general, all these processes increase N mineralization and ammonium production in excess of the requirements of new vegetation.

We observed a slight decline in ammonium in May 1981. This may have been due to increased nitrification which was indicated by the higher nitrate concentrations observed on that sampling date. Ammonium could also have been taken up by regrowing vegetation which rapidly invaded these sites, undergone fixation (Brady, 1974), or been immobilized by decomposers due to a high C:N ratio.

Nitrate concentration was greater in the ACS clearcut site by March of the first year but not higher until May at the CM and ACN sites (Table 3). Nitrate concentrations remained higher in the clearcut soils than in the uncut forests through August 1981 at CM and ACS but not at ACN. There were no significant differences in soil nitrate concentrations in the spring and early summer of the second year, but in late summer of the second year the soil from the clearcut areas had much higher nitrate concentrations than those from the uncut forests.

The high nitrate concentrations were most likely due to increased soil nitrification which would be favored by increases in moisture and temperature, soil pH, and a lower N uptake by plants until new vegetation occupied the sites. Several workers (Christensen, 1973; Adams and Attiwill, 1982), observed that burning may initiate or increase soil nitrates, mainly due to the nitrification of ammonium and not the result of direct addition in the ash. Christensen (1973) found that the nitrate content of ash was relatively low, and Stark (1979) indicated that most of the nitrates were retained in the ash after burning.

Higher nitrate concentrations were observed during the summer months of 1981 and 1982. The warmer temperatures of the clearcut sites probably favored an increase in nitrate production. Also, differences in uptake of nitrate by growing vegetation on the clearcut sites and uncut forests may have been involved in the differences observed. The increase in soil pH that occurred after clearcutting and burning would also have favored an increase in the growth of microbes (Ahlgren and Ahlgren, 1965) and autotrophic nitrifying bacteria (Matson and Vitousek, 1981), which would increase soil nitrification.

A reduction in N uptake by plants (briefly) following clearcutting may increase nitrate concentrations and loss to the ecosystem (Gorham et al., 1979). Once ammonium is converted to nitrate, it can more easily be leached through soils and lost. Nitrate may be immobilized by microflora or taken up by regrowing vegetation. Foster et al. (1980) indicated that annual herb communities can take up substantial quantities of N within disturbed ecosystems. However, we found the nitrate concentration during summer of 1982 higher than in 1981 in the clearcut sites. Since there was more vegetation present the second year, the higher nitrate was evidently due to increased mineralization since more uptake should have occurred than during the first year. Further study is needed to determine how long these elevated nitrate levels would occur.

CONCLUSIONS

Significant changes occurred in soil chemical characteristics following clearcutting and burning in the Ouachita Mountains. With the exception of soil ammonium and nitrate, the effects appeared to be short-lived approaching values of the uncut forest soils by the end of the second year. Further study is required to determine how long the observed differences in the ammonium and nitrate levels will persist. The soil pH, available P, and soil ammonium and nitrate concentrations were significantly higher at some times during the first two years following clearcutting and burning and could influence early vegetation establishment and succession as well as nutrient cycling. Further studies and experimentation will be required to elucidate the effects any of these observed changes might have on vegetation development and nutrient cycles.

ACKNOWLEDGMENT

Appreciation is expressed to Dr. Ed Lawson, USDA Southern Forest Experiment Station, Fayetteville, Arkansas for making the experimental watersheds available for this study and providing information on the treatments used on the watersheds.

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