Site preparation burning to improve southern Appalachian pine-hardwood stands: nitrogen responses in soil, soil water, and streams'

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Three paired watersheds treated with a fell and burn prescription were studied to determine the effects on soil, soil water, and stream water. Soil nitrification and mineralization were measured by in situ closed-core incubation. Soil water was collected with porous cup lysimeters placed at 30 and 60 cm depths, and water samples were collected from streams draining control and burned areas on one of the three sites. All data were collected for 6 months prior to and 12 months after treatment. Soil ammonium (NH_4^+) content increased significantly in all three sites after burning, but the magnitude differed greatly among sites. However, there was no change in soil nitrate (NO_3^-) content. In situ measurements of net mineralization showed increased rates with increasing bum severity. Net nitrification displayed no treatment response. Slight and nonsignificant increases in soil water NO_3^- concentration occurred after burning in two of the three sites. Stream water NO_3^- concentrations increased in the one stream sampled. Thus, while prescribed burning increased available soil N, there was little change in N transformation rates or movement of dissolved inorganic N off site during the first year after burning.

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Trois bassins hydrographiques pairés traités suivant une prescription d'abattage et de brûlage ont étés étudiés afin de déterminer les effets sur le sol, l'eau tellurique de même que l'eau des ruisseaux. La nitrification et la mineralisation dans le sol ont été mesurées in situ à l'aide de cylindres d'incubation fermés. L'eau du sol Ctait récoltée à l'aide de lysimètres à plaque poreuse places à des profondeurs de 30 et 60 cm. Des Cchantillons d'eau ont été récoltés dans les ruisseaux drainant le secteur ttmoin et le secteur brûlé sur une des trois stations. Toutes les données ont été récoltées durant 6 mois avant, de m&me que 12 mois après l'application du traitement. La concentration d'ammonium du sol (NH_4^+-N) a augmenté significative-ment sur les trois stations aprbs le brûlage mais l'amplitude de cette augmentation a varié fortement entre les stations. On n'a toutefois observe aucun changement dans le contenu en nitrates (NO_3^-) du sol. Les mesures in situ de mineralisation nette ont mis en evidence une augmentation des taux de mineralisation avec une augmentation de l'intensité du brûlage. Aucun effet de traitement n'a été détecté sur la nitrification nette. Des augmentations faibles et non significatives de la concentration en NO_3^--N dans l'eau du sol ont été observées sur deux trois stations apres le brûlage. La concentration en NO_3^--N dans l'eau des ruisseaux a augmenté dans le ruisseau échantillonné. Ainsi, m&me si le brûlage dirigé a augmenté la disponibilité en azote dans le sol, peu de changements ont été observes quant aux taux de transformation de N dans le sol ou dans l'exportation de l'azote inorganique dissous durant la premiere année apres le brûlage.

[Traduit par la redaction]

Introduction

Few studies have examined the consequences of site preparation burning in an ecosystem context. As Swift et al. (1993) explain in detail, a major study is being conducted in the southern Appalachians to understand the effects of a fell and bum site preparation treatment on basic ecosystem processes and the integrated response to disturbance. The intent is to determine whether site preparation goals are met without adversely affecting long-term site productivity. This paper examines the influence of the site preparation treatment on soil nitrogen (N) content and transformations and soil and stream water N during the first year after treatment.

Generally, fire in forested systems decreases total ecosystem N (Neary et al. 1984; Rapp 1990). This loss is due to the volatilization of N contained in wood, leaf materials, and the forest floor during the fire. Fire affects the chemical, biological, and physical properties of soil (DeBano 1991); it alters N transformations and the amount and form of soil N. Initial increases in soil-extractable NH_4^+ concentrations are generally attributed to the downward movement of volatilized N and its subsequent condensation in the cool soil layers below. This increase has been noted by several researchers (for example,

Adams and Attiwill 1986; Klopatek et al. 1990; White 1986) and in many cases is observed for less than 1 year. Fire also can affect soil microorganisms directly or indirectly. Heating the soil can decimate microbial populations at the soil surface and alter the availability of carbon and soil nutrients as well as the soil climate. These factors can produce noticeable changes in N transformation rates. Nitrifying microorganisms are particularly sensitive to increases in soil temperature (Dunn et al. 1985). Soil physical properties affected by fire are those dependent on the soil organic matter. These include soil structure, aggregation, and pore space. All of these factors influence soil microbial processes through changes in soil moisture holding capacity, aeration, and heat transfer. The actual impact of fire on soil physical properties depends on both the severity and intensity of the fire.

The effects of fire on long-term productivity vary widely among forest systems. Sutherland et al. (1991) simulated a decrease in ponderosa pine (*Pinus ponderosa* Laws.) growth for 2 years following burning. Waldrop et al. (1987) examined the long-term effects of periodic and annual summer and winter bums on total soil N pools in *Pinus taeda* L. forests of the southern Coastal Plain. They found that after 30 years soil N was actually increased slightly by annual burning. The increase was attributed to increased symbiotic N_2-fixation. Vance and Henderson (1984) found that the NH_4^+ concentration of soils in the Missouri Ozarks was lower on burned than on control plots. They also found that rates of N mineraliza-

tion decreased, indicating that available N was lower on the burned sites. High-intensity fires can result in increased soil erosion (Tiedemann et al. 1979) and therefore N losses. However, prescribed burns characteristic of this study seldom result in excessive erosion (see Swift et al. 1993). Binkley (1991) concluded that sustained production of western forests is possible over the long term, even with the losses of N that occur with fire, because of atmospheric deposition and N_2-fixation over the forest rotation. He noted that it may be possible to improve site productivity by decreasing N losses associated with burning and other treatments.

Materials and methods

Historic land abuse, oak decline, and southern pine beetle infestations have created a sparse pine-hardwood overstory and a dense understory dominated by mountain laurel (*Kalmia latifolia* L.) on xeric sites in the southern Appalachians. Mountain laurel thickets nearly preclude regeneration of overstory species. The prescription for these highly degraded sites is to fell all woody vegetation on the site, allow it to dry, then bum it under precise environmental conditions (Swift et al. 1993). Sites are then planted with white pine (*Pinus strobus* L.) on a wide spacing (4 x 4 m) to obtain a mixed pine-hardwood forest.

We chose three sites (Jacob Branch East (JE), Jacob Branch West (JW), and Devil Den (DD)) in the Wayah District of the Nantahala National Forest of western North Carolina (35°N,83°W). They were selected from a large number of sites for which the fell and bum treatment was prescribed by National Forest managers. All sites have a south to southwesterly aspect with soils in the Cowee-Evard series, fine-loamy, mixed, mesic Typic Hapludults. Five 15 x 33 m treatment plots were established at each site. Four control plots of equal size were located on adjacent untreated areas. Plots were placed along the elevation gradient present on each area.

The three sites were clear-felled in June through August 1990. Site preparation burning was done on September 18, 19, and 21, 1990, at JE, JW, and DD, respectively. Based on flame temperatures, woody fuel and forest floor consumption, and heat penetration into the soil, fires were characterized as high intensity (aboveground temperature) and light severity (heat penetration into the soil). Fire intensity and severity were greatest at JE (Swift et al. 1993). Control plots were neither clear-felled nor burned.

Soil N transformation rates were determined in situ by the covered-core incubation method (Adams and Attiwill 1986). Measurements began in April 1990, 6 months prior to burning. Initial postburn samples were collected within 48 h of treatment. Soil N content and transformation rates were determined monthly for 6 months prior to and 2 months after treatment. Subsequently, soil N sampling was reduced to a bimonthly schedule. September soil data are the first taken after burning. Two pairs of 4.3-cm PVC pipes were placed 25 cm apart in the soil to a depth of 10 cm on each of the five treated and four control plots. One of each pair was returned to the laboratory for processing ($t = 0$); the other was capped and left in the field for 28 days ($t = 1$). Soils cores were collected, kept cool, returned to the laboratory, and stored at 4°C until processed, normally within 24 h. The two soil cores were composited by plot. Soils were sieved to <6 mm and extracted for 1 h in 2 M KCl at a 1:4 soil to extractant ratio, then centrifuged. NO_3^--N and NH_4^+-N concentrations in KCl solutions were determined on a Technicon AutoAnalyzer using the hydrazine sulfate reduction (Environmental Protection Agency No. 353.1) and alkaline phenol (Technicon Industrial Methods 108-7 1 W) methods, respectively. Rates of nitrification and mineralization are calculated as the difference in NO_3^--N or NO_3^--N plus NH_4^+-N concentrations in soil cores at $t = 0$ and $t = 1$. All soil concentrations and rates of N transformation are reported on a 105°C ovendry weight basis. Bulk density was determined for the 10-cm soil cores on the <6-mm fraction for conversion of data to an area basis.

Soil samples were collected for chemical analysis during the growing season prior to treatment, following the first substantial post-treatment precipitation less than 1 month after burning and 6 months and 1 year following treatment. The A and AB, BA, or Bt1 surface horizons were collected from control and burned plots. Samples represent composites of 24 to 36 individual 2.5-cm soil probe samples separated by horizon. Samples were air dried and sieved <2 mm prior to analysis. Bulk densities were determined on intact soil cores collected from representative soil pits at each site. In Table 1 weights per hectare are estimated from actual horizon depths for each soil layer. Total N and carbon were determined via dry combustion with a Perkin-Elmer 2400 CHN Analyzer.

Porous cup lysimeters were installed for soil water collection on all nine plots at each of the three sites at 30 and 60 cm depths. Soil water collection began in April 1990 and have continued through the present. Postburn lysimeter data are first presented as October 1990 data. Sampling depths were chosen from Soil Conservation Service Soil Survey information, which indicated that these depths bracketed the Bt2 horizon for these soil types. Soil water samples were collected weekly and composited to obtain a weighted monthly sample. NO_3^-- and NH_4^+-N concentrations were determined using Dionex ion chromatograph and Technicon AutoAnaylzer alkaline phenol methods, respectively.

JE was the only site with a perennial stream draining the treated area and an adjacent untreated area. These two streams were sampled via weekly grab samples. Weekly samples were composited to obtain a monthly sample. NO_3^-- and NH_4^+-N concentrations were determined using Dionex ion chromatograph and Technicon AutoAnalyzer alkaline phenol methods, respectively.

Sites were selected for their similarity in topography and soils; however, there were numerous differences. These differences included site history, pretreatment vegetation composition (Vose and Swank 1993), and fire treatment characteristics, intensity, and severity (Swift et al. 1993). We used site as a dummy variable in initial statistical analyses and found that site differences overwhelmed any significant treatment effect. Therefore, in further analyses each of the three sites were analyzed separately. Owing to the seasonal response in N transformations, each sample date was analyzed separately. Analysis of covariance by site for each post-treatment sample date was performed using pretreatment data as the covariate for KCl-extractable soil NO_3^--N, NH_4^+-N, N transformation rates, lysimeter N concentrations, and total soil N contents. These analyses showed that none of the covariates were significant. This led to our use of the I-test to compare treatment means by site and sample date. Variance homogeneity was tested with a folded F statistic. When variances were unequal, an approximate t-test and Satterthwaite's approximation for computing degrees of freedom were used (SAS Institute Inc., Cary, N.C.). Graphs present site means (treatment, $n = 5$; control, $n = 4$). Stream NO_3^--N and NH_4^+-N concentrations represent the monthly composited sample from the stream draining the treated area of JE only. One stream was sampled; therefore no statistical analysis was possible.

Results

Soil samples collected within 48 h after burning showed an immediate pulse of NH_4^+ at all three sites, but differences were not statistically significant for all sites (Fig. 1). Content changes were largest on JE, the most severe bum, with values increasing from <1 to >3.5 kg N·ha^{-1} the first 3 months after burning. NH_4^+ content pulse was smallest on DD, the least intense bum treatment. Soil NH_4^+ content remained elevated for the 12 months after treatment. The magnitude and continuity of the increase varied with site and was only significant during some dates. Soil NO_3^- content displayed no consistent response to burning.

The rate of mineralization increased at JW in August after vegetation was felled, before site burning (Fig. 2). Clear-felling responses were not significant at other sites. Nitrogen mineralization was quite variable during the months after burning. The response generally increased with burning intensity, JE >
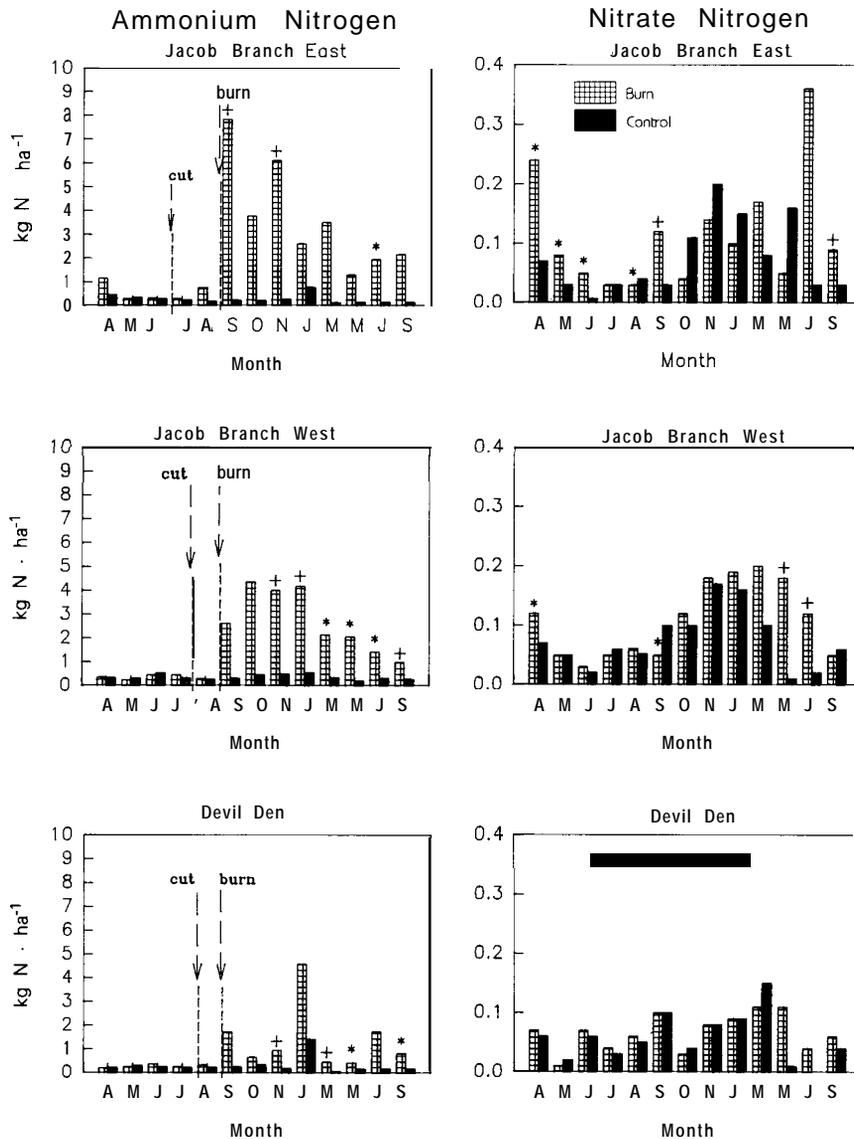
FIG. 1. Ammonium and nitrate nitrogen content of soils before and after fell and bum treatment for control and bum plots. Values represent means of four and five plots for the control and bum plots, respectively. Date of clear-felling and site burning are indicated. September means are the first postburn data. [+] and [*] indicate significant difference between control and treatment means at $p \leq 0.1$ and 0.05, respectively.

JW > DD. On JE, mineralization increased from $<1 \, \mathrm{kg} \, N \cdot ha^{-1}$ before felling and burning to $8.5 \, \mathrm{kg} \, N \cdot ha^{-1}$ the month (September) following the bum. The responses on all sites were quite variable.

Rates of in situ net nitrification did not immediately respond to clear-felling or burning treatment (Fig. 2). However, a trend toward increased rates of NO_3^- production were observed on both JE and JW in May and July following the burning treatment. Felling and burning had not measurable effect on total soil N content (Table 1). Some differences existed between treatment and control areas before site treatment, and these differences were maintained following treatment.

There was no treatment response in soil water NH_4^+ concentrations at either 30 or 60 cm depths (data not shown). Felling and burning did increase soil water concentrations of NO_3^- at both depths for all three sites, but the differences were rarely statistically significant (Fig. 3). The increase in NO_3^- concentration was roughly proportional to the intensity of the bum; it was greatest on JE. While the response to

treatment was quite striking graphically, actual concentrations in solutions from the 30-cm lysimeters were less than 0.5, 0.2, and $0.02 \, \mathrm{mg} \, N \cdot L^{-1}$ for JE, JW, and DD, respectively. Concentrations for NO_3^--N at 60 cm depth were lower, ranging from less than 0.3 for JE to $0.02 \, \mathrm{mg} \cdot L^{-1}$ for DD.

The small response of soil water NO_3^- to the fell and bum treatment was also reflected by a small response observed in the stream draining JE (Fig. 4). Concentrations of stream water NO_3^--N increased after treatment, from $<0.01 \, \mathrm{mg} \cdot L^{-1}$ up to a maximum of $0.075 \, \mathrm{mg} \cdot L^{-1}$ and remained elevated until June of the following year. At that time NO_3^- concentrations in the stream returned to pretreatment levels. The small early increases in September may be partially attributed to the cutting treatment.

Discussion

The treatment applied in the present study differs from some types of prescribed burning previously studied. Unlike
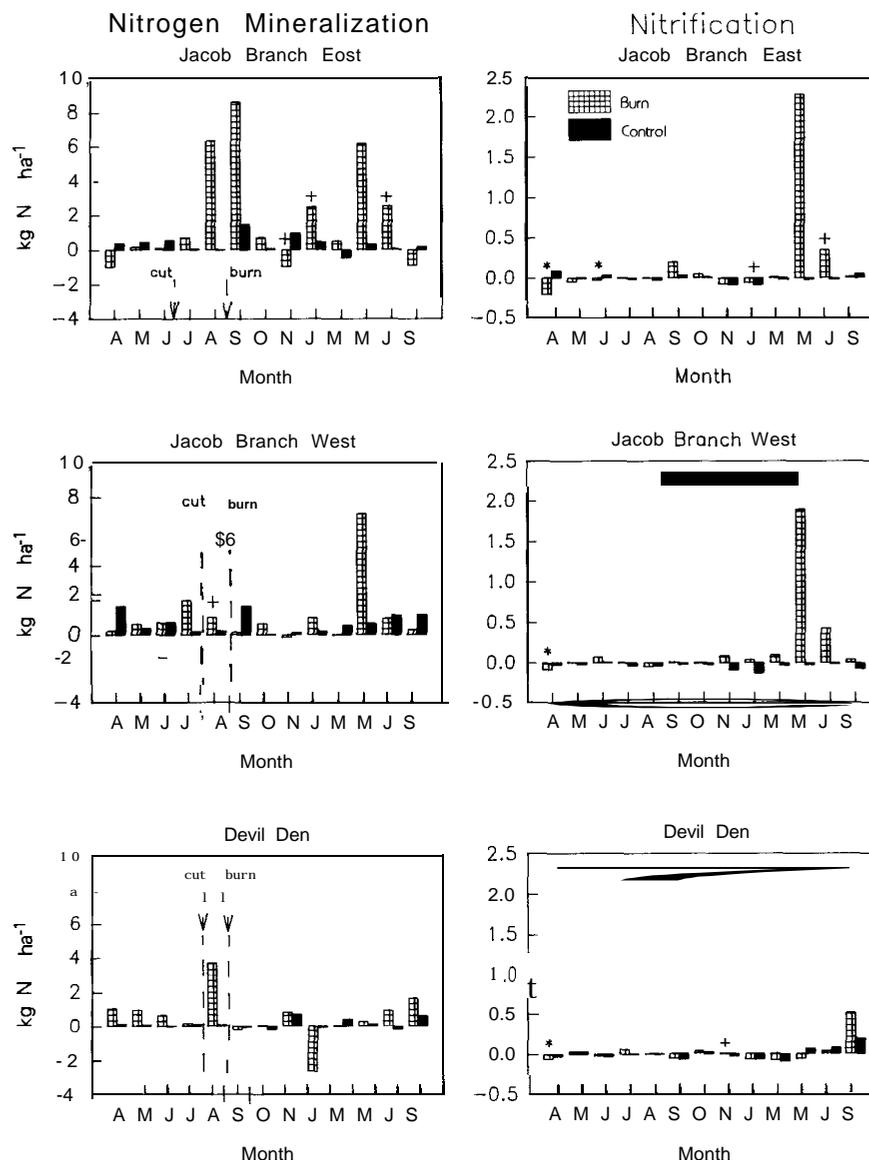
FIG. 2. In situ nitrogen mineralization and nitrification rates as determined using the closed-core incubation method. Data for each month represent the total over a 28-day period. Values represent means of four and five plots for the control and bum plots, respectively. September means are the first postburn data. + and * indicate significant difference between control and treatment means at $p \leq 0.1$ and 0.05, respectively.

the green fuels present during wildfires, our large and small fuels were dry. In understory site preparation bums, fuel loading is low and consists mainly of small woody fuels and forest floor materials. The resulting fire has a low intensity. The fell and burn technique can produce fires of high intensity, similar to the broadcast burns of the western United States. The presence of large woody fuel and considerable amounts of small fuels (mountain laurel) produced total fuel loads from 126 $Mt \cdot ha^{-1}$ on DD to 224 $Mt \cdot ha^{-1}$ on JE. The resulting fires were high in intensity. Site topography, with slopes up to 60%, caused the fires to be of short duration and therefore low severity, with minimal heat pulse into the soil (Swift et al. 1993).

Soil nitrogen and transformations

Increases in soil NH_4^+ result from two processes: *(i)* volatilization of organic N from the soil surface and its condensation after downward movement into cooler soil horizons below and *(ii)* increases in N mineralization rates. Evidence

for NH, condensation was provided by Rauch (1991) in an experiment done in conjunction with our study. Prior to burning, he replaced the forest floor with "N-labeled litter both in the field and in a controlled laboratory experiment using soil cores 10 cm in diameter and 10 cm deep. Movement of "N-labeled N in the field experiment was extremely variable, making results nonconclusive. However, under controlled laboratory burning conditions, 4% of the ^{15}N-label was consistently found in KCl-extractable NH_4^+ in the A horizon of soil cores. Increases in NH_4^+ levels observed after the fire, in the September samples, were probably a result of volatilization and condensation. These samples were collected within 24 to 48 h after burning, not enough time for an increase in N mineralization. Elevated NH_4^+ at later sample dates could be residual NH_4^+ added during the fire or from N mineralization.

The amplitude of the soil NH_4^+ response to treatment followed the same order as the fire intensity; i.e., JE > JW > DD. This relationship has been identified by others examining soil

TABLE 1. Total soil nitrogen content of A horizon and total surface to 20 cm depth (A + AB-BA-Bt 1 horizons) for one prebum and three postburn dates

Site	Soil"	Date	Treatment (kg N·ha⁻¹) Burn	Control	df	$P > t$
JE	A horizon (4.2 cm)	Preburn Postburn	343	313	7	0.65
		1 month	388	344	4.5	0.58
		6 month	421	373	7	0.67
		12 months	323	238	7	0.11
	Total (20 cm)	Preburn Postburn	1157	986	7	0.07
		1 month	1605	1280	7	0.03
		6 months	1448	1120	7	0.05
		12 months	1375	832	6	0.002
JW	A horizon (3.0 cm)	Preburn Postburn	271	483	7	0.03
		1 month	255	469	7	0.05
		6 month	281	430	7	0.12
		12 months	259	405	7	0.12
	Total (20 cm)	Preburn Postburn	1160	1384	7	0.14
		1 month	1341	1446	7	0.45
		6 months	1376	1369	7	0.93
		12 months	1248	1268	7	0.85
DD	A horizon (5.1 cm)	Preburn Postburn	708	644	7	0.43
		1 month	594	667	3.4	0.53
		6 month	502	598	7	0.15
		12 months	584	580	7	0.96
	Total (20 cm)	Preburn Postburn	2297	1867	7	0.10
		1 month	2160	1854	7	0.20
		6 months	1747	1750	4.1	0.97
		12 months	1998	1420	7	0.001

NOTE: Values represent plot means (n = 5 and 4 for bum and control plots, respectively).

responses to fire. Marion et al. (1991) found that soil NH_4^+ concentration increased with fire severity in chaparral systems, and similar trends were observed by Kovacic et al. (1986) on ponderosa pine sites in New Mexico. Levels of soil NH_4^+ remained elevated for 1 year after burning. While increases in extractable NH_4^+ are normally found after fires, the duration of increases is quite variable. Phillips and Goh (1985), Adams and Attiwill (1986), and Klopatek et al. (1990) found NH_4^+ increases were short-lived, i.e., 3-4 months. Jurgensen et al. (1981), White (1986), Ryan and Covington (1986), and Kutiel and Naveh (1987a, 1987b) found increases in soil NH_4^+ for 6 to 14 months after bum treatments. Duration of elevated soil NH_4^+ response is probably influenced by the timing (season) of burning, variability in N immobilization rates as suggested by Adams and Attiwill (1986), and environmental conditions.

Soil texture and organic matter content play an important role in losses or removal of NH_4^+ from a site following burning. In a review of fire effects in the southern region, Christensen (1987) suggests that losses of nutrients due to leaching vary greatly with the adsorptive capacity of the soils. The clay

accumulation in the Bt horizon in our study soils would prevent any losses of NH_4^+, even in the event of low plant uptake. Christensen (1987) also points out that ash is a long-term source of N and other nutrients in burned sites. Our prolonged elevated NH_4^+ levels are thus explainable. The Bt horizon prevents leaching or movement of NH_4^+ with soil water, and the ash on site acts as a N source, replenishing any NH_4^+ lost from the soil by plant uptake or transformation to NO_3^-. The potential for rapid movement or transformation of NH_4^+ is discussed by Rapp (1990). Immediately after fire in a mediterranean forest he found a fourfold increase in soil NH_4^+ in the O-2 cm soil layer, but no increase was apparent at the 2–10 cm depth. Six weeks later, NH_4^+ and NO_3^- were elevated at O-2 cm, but only NO_3^- increased at the 2-10 cm depth. Covington and Sackett (1986) examined the long-term effects of burning on NH_4^+ levels in soils of a ponderosa pine stand. They found elevated NH_4^+ levels in plots burned every 1, 2, or 4 years. On a 5-year cycle, however, soil NH_4^+ levels were equal on treated and control plots.

While burning substantially increased the amount of soil NH_4^+ in our study, the response of mineralization and nitrification varied by site. Response was again linked to fire severity, being greatest at JE and less pronounced at JW and DD. Other prescribed burning studies also show a wide range of response for these processes. Schoch and Binkley (1986) found no change in rates of N mineralization 1 day after burning, but after 6 months, increases in the top 10 cm of soil were noted. Klopatek et al. (1990) performed bums under controlled laboratory conditions using microcosms. They reported an increase in soil NH_4^+ concentrations but no increase in mineralization. However, over the 90 days during which they incubated the burned soil cores, nitrification did occur. Kutiel and Naveh (1987a) found increasing soil NO_3^- content for the 8 months they sampled after a very intense summer bum. In a southern pine stand, 2 years after chopping and burning, Burger and Pritchett (1984) found a decrease in N mineralization rates compared with the control plots. These conflicting results point out the variability of microbial response to fires. Adams and Attiwill (1986) found that fire increased mineralization and the amount of mineralizable N in *Eucalyptus* spp. They suggest that sites with high productivity and N capital are the most susceptible to N losses after site disturbance. This conclusion contradicts our findings. In our study the site with the highest soil N capital is DD, with 650-750 kg·ha⁻¹ in the A horizon. However, this site showed the least response to burning, the lowest inorganic N concentrations, and the lowest N transformation rates. In our study it seems more likely that response differences result from differences in soil temperatures reached during the fire, carbon availability, and the amount of soil organic matter consumed. Hungerford et al. (199 1) concluded that the presence of readily available carbon determines whether mineralization and nitrification increase after site burning or other disturbance.

The literature indicates that the effect of burning on total soil N is highly variable. In our study, there was no change in total N. Klopatek et al. (1990) and Covington and Sackett (1986) reported similar findings in western conifer stands. Burger and Pritchett (1984) measured a decrease in total N 2 years after burning with chopping. Loss of N from the soil and forest floor is directly proportional to the amount of organic matter consumed by the fire (DeBano 1991). In our study Vose and Swank (1993) found that only the Oi layer of
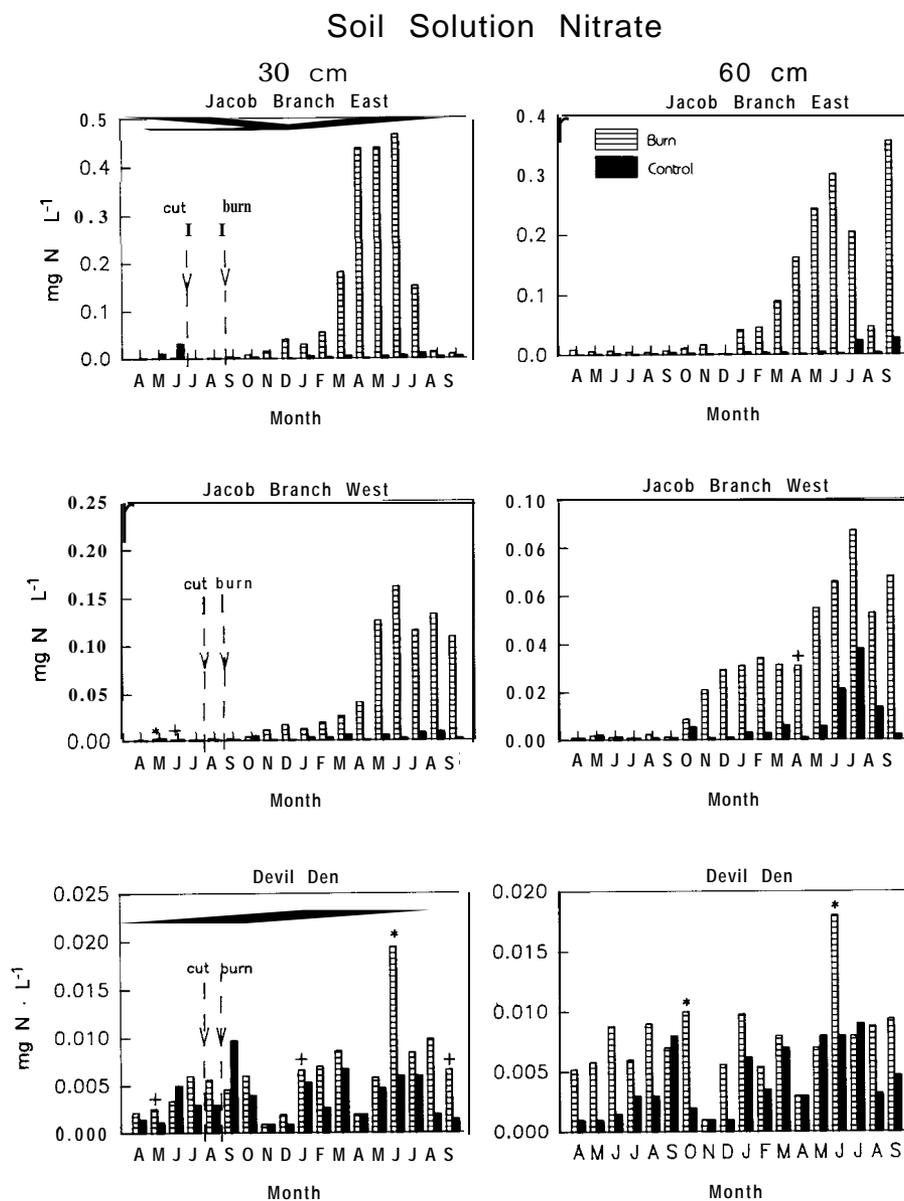
Soil Solution Nitrate

Fig. 3. Nitrate nitrogen per litre of soil solution collected using tension lysimeters, at 30 and 60 cm depths. Values represent means of four and five plots for the control and bum plots, respectively. October means are the first postburn data. $^+$ and * indicate significant difference between control and treatment means at $p \leq 0.1$ and 0.05, respectively. Note that scales for the three sites are different.

the forest floor was consumed by the fire. Burning produced no significant change in the total Oe + Oa layer. However, taken across sites, N losses from aboveground vegetation plus the Oi layer were about 20% of the total soil N pool to 20 cm depth (Vose and Swank 1993). The soil heat pulse from our fires did not greatly elevate temperatures (Swift et al. 1993). Retention of the Oe and Oa layers and low soil temperature during the fire contributed little to initial effect on the soil organic matter. The longer term effects on soil and forest floor N pools will continue to be measured.

Soil and stream water nitrogen

Decreases in nitrate concentration in soil water between 30 and 60 cm in our study are consistent with trends found in other studies in southern Appalachian forests (Swank and Swank 1984; Waide et al. 1988). The 30-cm sample is col-

lected from soil in the very active rooting zone of the soil profile, whereas the 60-cm samples represent water that can potentially be lost from the site. The depletion of NO_3^- in soil water moving from 30 to 60 cm decreases further in moving to the stream. Even during the 8 months when NO_3^--N levels were elevated, a maximum concentration of 0.075 $mg \cdot L^{-1}$ was not great enough to result in net losses of N from the site, since inorganic N inputs from rainfall (average annual concentration of 0.30 $mg \cdot L^{-1}$) would more than compensate for this loss.

Stream N increases due to disturbance vary greatly with the site and the type of disturbance. Neary and Courier (1982) studied the impact of wildfire on pine sites in the South Carolina Blue Ridge Mountains. Wildfires covering more than 30% of the watershed resulted in a threefold increase in NO_3^- concentration of stream water compared with a control watershed.
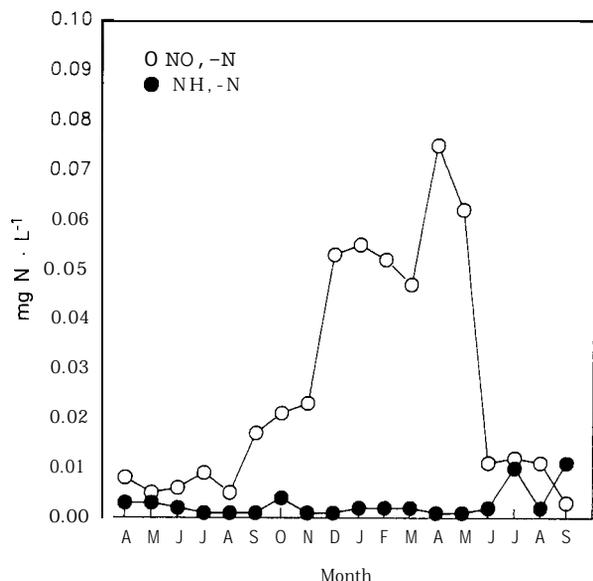
FIG. 4. Nitrate and ammonium nitrogen concentration of a stream draining one of the three study sites, Jacob Branch East. Values represent monthly composites of weekly samples. October values are the first postburn data.

Values of *0.004* mg N·L^{-1} increased to 0.012 mg N·L^{-1}; this increase, though small, was statistically significant. There was no change in NH$_4^+$ concentration. Douglas and Van Lear (1983) examined the effects of site preparation burning in the Piedmont of South Carolina. They found no increases in NO$_3^-$ or other nutrients after burning. In Oregon, Tiedemann et al. (1988) found that harvest without burning resulted in no NO$_3^-$ in stream water. However in clearcuts with as little as 17% of the area machine piled and burned, there were significant increases in stream NO$_3^-$ concentration.

Summary

Soil NH$_4^+$ content increased immediately after prescribed burning on pine-hardwood stands in the southern Appalachians because of the volatilization and condensation of N, though values were not always significant. However, levels of extractable NO$_3^-$ and rates of in situ mineralization and nitrilkation showed small and highly variable responses to the treatment. Soil water NO$_3^-$ levels responded to the disturbance, resulting in slight increases during the growing season after treatment. Stream water draining one of the treated areas showed an increase in NO$_3^-$ concentration immediately following the treatment. Losses of N in ground and stream water are below levels of concern for either water quality or site productivity. The fell and bum prescription carried out on these sites resulted in increased N availability without soil N losses in the first year after treatment.

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