Soil and Vegetation Changes in a Pinyon-Juniper Area in Central Arizona after Prescribed Fire

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Abstract.—Prescribed fire has been used as an inexpensive and rapid method for disposing of slash following fuelwood sales in pinyon-juniper sites. Soil heating during a fire has a direct effect on soil nutrients and microbial activity. The potential for understory cover quantity and quality, along with soil nutrient changes should be the determining factors in management decisions to use prescribed fire for slash disposal. Our investigation measured soil nitrogen and phosphorus changes, and the understory community following a prescribed fire in a pinyon-juniper site in central Arizona.

Introduction

Woodland communities occupy 7 million ha in the Southwestern United States (Miller and Wigand 1994). Conflicting uses of pinyon-juniper woodlands has resulted due to the diversity of products produced such as fuelwood and forage (Clary and Jameson 1981). Demand for commercial and personal-use fuelwood harvesting provides managers with an inexpensive tool for tree removal. Several studies have shown an increase in herbaceous cover following tree thinning (Clary and Jameson 1981, Everett and Sharrow 1985, Bledsoe and Fowler 1992). Establishment of this herbaceous community is critical in preventing soil loss and maintaining watershed condition.

After tree harvesting, leaves, twigs, and smaller branches are left on site. This slash material can interfere with livestock and wildlife movement and is not aesthetically acceptable. Prescribed fire has been used as an inexpensive and rapid method for disposing of this slash.

Soil heating during fire has a direct effect on soil nutrients by oxidizing organic materials (Smith 1970, Stark 1977, DeBano and Conrad 1978, Stednick et al. 1982, Wright and Bailey 1982, Giovanni et al. 1988) and an indirect effect by modifying microbial populations (Ahlgren and Ahlgren 1965, Wright and Bailey 1982). With a volatilization temperature of 200 °C, a significant amount of nitrogen is lost during burning of pinyon-juniper slash (DeBano and Klopatek 1987). A variable amount of the phosphorus contained in soil and litter can also be lost depending on fire intensity.

The economic benefit of pinyon-juniper woodland treatments historically is an increase in forage production (Dalen and Snyder 1986). Current management emphasizes a variety of uses including fuelwood production, wildlife habitat enhancement, and livestock grazing. Our objective was to determine what vegetative community type returned, and the soil nutrient status following a fuelwood sale with slash removal by prescribed burning.

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Material And Methods

Study Site

Hogg Pasture is located in central Arizona on the Coconino National Forest. The soils are classified Typic Haplustalf, fine, smectic, mesic. This site had approximately 60% overstory before harvesting, consisting of *Juniperus osteosperma* (Utah juniper) and *Pinus edulis* (pinyon). We sampled this site in mid-May of 1997, almost 2 years after a prescribed fire was used to remove slash following a fuelwood sale.

Soil

Transects were randomly located at 4 areas within the treated stand. These transects extended into adjacent untreated areas so comparisons between presumably similar treated and untreated sites could be made. Both treated and untreated area soils are classified as fine, smectic, mesic Haplustalfs. Vegetative cover was also assumed to be the same for both treated and untreated sites. Twenty soil cores were randomly taken to a depth of 10 cm along each transect, then composited based on whether they were under canopy or from interspace areas. Additional sampling included an individual tree and associated interspace area randomly picked along the transect from both treated and untreated sites and sampled for litter and soil. Litter was gathered from within a 0.1 m^2 plot frame and 3 soil cores were composited from within the litter frame.

Total organic carbon was determined using a modified Meibus procedure (Nelson and Sommers 1982). Total labile fraction analyses of soil nitrogen and phosphorus were performed using sulfuric acid-hydrogen peroxide digestant. Total nitrogen was determined by ion chromatography. Total phosphorus was determined by the phosphomolybdate method (Murphy and Riley 1962). Available ammonia, nitrate, and mineralizable nitrogen were analyzed using ion chromatography. Total nitrogen and phosphorus in the litter followed the same methods as described for soil.

Vegetation and Ground Surface

Five vegetation transects were randomly located in the treated area, with 3 in adjacent untreated area in close proximity to the soil transects. Again, we assumed the treated and untreated sites are the same before treatment. Each transect was measured using 25 quadrat samples (each 2x5 dm) spaced at 1 m intervals along the transect (Daubenmire 1959). Values at each transect were averaged from the 25 quadrat samples.

Analysis

When burning was done, no provision was made to compare effects of treatment, therefore, there is a lack of a true control. However, soil and watershed potential classification was the same for both treated and untreated sites. Since treated and untreated sites were located in close proximity to each other, we assumed the sites could be compared to provide the best available estimate of treatment effect. Analysis of soil determinations were performed using ANOVA procedures and Tukey's multiple range test utilizing SAS software. Analysis of the vegetation data was performed using a t-test.

Results

Soil analysis showed little difference in total organic carbon and total nitrogen due to burning, yet there was a distinct difference between canopy and interspace areas (table 1). Available ammonia and nitrate were significantly higher in the burned canopy sites compared to the other sites (table 1.). Interestingly, there was little mineralizable nitrogen under the burned canopy (table 1.) Total phosphorus was comparable across all sites, but available phosphorus appeared greater under the burned canopies (table 1.).

Burning resulted in over a 99% decrease in total litter biomass under canopy (table 2.). This dramatic biomass loss also reduced total phosphorus and nitrogen available for decomposition.

Total vegetative cover appeared greater in the burned area compared to the unburned area, along with a proportional increase in the number of species sampled (table 3.). However, no statistical differences in vegetation were found due to the high variability in the measured parameters. Most of the apparent difference was due to annuals, primarily *Heliomerius multiflora* (showy goldeneye), which was 11% higher in the burned areas. Other increases were in *Gutierrezia sarothrae* (snakeweed), *Hymenoxys* spp. (actinea), and *Menodora scabra*. Other notable forbs found in the burned areas were *Melilotus officinalis* (sweetclover)

Table 1. Soils analysis (0-10 cm) from Hogg Pasture in central Arizona following prescribed fire[a].

Nutrient	Mean burned canopy	Mean unburned canopy	Mean burned interspace	Mean unburned interspace
% total organic carbon	2.72a	2.61a	1.63b	1.09c
% total nitrogen	0.39a	0.27ab	0.12bc	0.07c
Mineralizable nitrogen (ug/g)	2.35b	28.76a	14.77ab	6.27b
KCl-extractable ammonia (ug/g)	28.25a	<0.01b	1.67b	0.99b
KCl-extractable nitrate (ug/g)	25.67a	1.29b	1.85b	1.03b
% total phosphorus	0.0068a	0.0057a	0.0045a	0.0045a
Extractable phosphorus (ug/g)	15.02a	3.06a	3.88a	0.96a

[a]*Means with same letter were not significantly different using ANOVA with Tukey's Studentized Range test (alpha=0.05, df=16).*

Table 2. Analysis of litter from Hogg Pasture in central Arizona following prescribed fire[a].

Nutrient	Mean burned canopy	Mean unburned canopy	Mean burned interspace	Mean unburned interspace
Total litter biomass (g/m^2)	37.50b	4805.00a	102.5b	165b
Total phosphorus (g/m^2)	0.002b	0.27a	0.0044b	0.0017b
Total nitrogen (g/m^2)	0.90b	48.80a	0.75b	0.60b

[a]*Means with same letter were not significantly different using ANOVA with Tukey's Studentized Range test (alpha=0.05, df=8).*

and *Linaria dalmatica* (toadflax). There was also a small decrease in the mean of bare soil, along with a slight increase in litter and rock-gravel cover, but the variability was very high for these parameters (table 3.).

Discussion

Soils organic-matter decomposition from the burned canopy areas was significantly reduced as evidenced by the dramatic decrease in mineralizable nitrogen. This could be either depression of the microbial community or lack of a readily available carbon source. Higher available nitrogen and phosphorus indicates that burned sites are more fertile than unburned sites, but the loss of mineralizable nitrogen indicates otherwise. The litter layer in these burned sites is greatly diminished, which decreases the organic-matter pool and increases soil temperatures, raises potential evaporation losses, and exposes the topsoil to greater raindrop impact and erosion potential.

Table 3. Vegetation and ground cover in 1997 at Hogg Pasture[a], (n = number of transects).

Vegetation (% cover)	Burn (n=5)	Control (n=3)
Perennial grasses	6 (2.5)	2 (1.9)
Perennial forbs	2 (1.4)	0.03 (0.03)
Annuals	12 (10.4)	0.03 (0.03)
Shrubs	7 (2.7)	9 (3.2)
Unidentified herbs	2 (1.1)	0.05 (0.05)
Species (number/transect)	24 (1.9)	16 (5.5)
Ground Surface (% cover)		
Litter	10 (3.2)	6 (4.1)
Rock-gravel	38 (7.5)	33 (14.8)
Soil	49 (10.9)	59 (14.6)
Basal area	2.3 (0.8)	0.7 (0.5)
Cryptograms	na	0.4 (na)
Coarse woody debris (CWD)	1.4 (0.9)	1.9 (na)
Total (litter to CWD)	101	101

[a] *Values in parenthesis are standard error of the mean.*

Perennial grasses were apparently 4% higher in the burned openings, with the greatest difference attributed to a single, unpalatable weedy composite. The remaining apparent increase is also from species that benefit neither cattle \ or wintering elk. An increase in forage is needed to justify the expense of treatment, but unpalatable, noxious, or ephemeral plants were the main respondents. Toadflax, recognized as a noxious alien, is rapidly increasing on the Coconino National Forest. From our observation, toadflax increases faster on bare soil such as occurs after a prescribed fire following fuelwood cutting. In terms of biomass, perennial grasses totaling 6% cover, would convert to less than 56 kg / ha.

Conclusions

The goal of this prescribed burn was to increase forage for livestock and wintering elk, and to improve the watershed condition by increasing vegetative cover. Slightly higher amounts of palatable species produced little overall increase in forage and little decrease in bare soil. Before fuelwood cutting, the overstory provided protection from raindrop impact, but following harvesting and prescribed fire, almost 50% of the soil was exposed. This degree of exposed soil poses a high potential for surface erosion, compounded with the loss in total and mineralizable nitrogen further degrading the soil resource.

From this study and observation of other similarly treated sites, our recommendation when the understory community is sparse with little perennial grass cover, is that slash should remain on site following fuelwood cutting. Other slash treatments are available such as lop and scatter, crushing, or leaving in place. The expense of crushing may not be recoverable by an increase in forage, but both of the other treatments would cost nothing and would provide soil erosion protection and seedling protection from grazing.

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