Tillers 2002, **3**, 29-32

Annual burning affects soil pH and total nitrogen content in the CERA oak woodlands

CHRIS MITROS, SIOBHAN MCINTYRE, BETH MOSCATO-GOODPASTER
Biology department, Grinnell College, Grinnell, Iowa 50112, USA

Abstract

When considering prairie restoration, researchers and conservationists must consider all aspects of the prairie environment, taking into account, not only the complex relationships of the grasslands, but also acknowledging the relationships between surrounding ecosystems. In our study we observed the effects of burning on the soil conditions in the experimental plots at the Conard Environmental Research Area (CERA) oak woodlands in central Iowa. We examined the variation in pH, total nitrogen and percent organic matter of the soils, as well as the emergence of seeds in greenhouse seed banks comprised of soil from both the burned and unburned plots. By studying these factors, we investigated whether or not fire has a significant effect on the composition of soil from woodland areas. We found no significant differences between soil conditions in the burned and unburned plot. However, upon discovering that not all burned plots were treated uniformly, we discovered a significant difference between the soil conditions of plots burned annually since 1997 and the plots which went unburned in the year 2000.

Introduction

As a co-existing ecosystem within the prairie, the woodland environment plays a crucial role in prairie restoration. In pre-settlement tall-grass prairies a natural balance between prairie, savannah, and forest existed (Reichman 1987). Positioned along the eastern edge of the mid-western rain shadow, Iowa prairies receive enough precipitation to support substantial forest growth. As a result, tall-grass prairies are constantly threatened by the domination of woody species (Reichman 1987). Naturally occurring fires are therefore necessary to preserve prairie dominance and suppress woodland invasion (Abrams 1992). After European settlement, fire frequency decreased resulting in the loss of this natural balance between ecosystems. Without naturally occurring fires, oak forests rapidly expanded at the expense of the once vast tall-grass prairie (Abrams 1992). In order to reestablish the balance destroyed by European settlement, it is important to study the effects of various management practices on the oak woodlands.

Soil conditions are an important factor in determining the relative success of different forms of vegetation. Tester's 1989 study of a Minnesota oak savanna researched the effects that forest fires have on soil. His study found that levels of organic material, as well as nitrogen content, decrease with fire disturbance. Tester's study also noted that pH levels increased within the burned plots. In our study, we tested the burned and unburned experimental plots within the CERA oak woodland, analyzing the effects of controlled burns on the soil. Since soil conditions directly affect vegetation growth, a significant difference in these factors reflects whether or not a disturbance has impacted an ecosystem. For our study we specifically examined levels of pH, percent organic matter, and total nitrogen from the woodland plots. In conjunction with this initial soil study, we also set up seed banks in order to observe the abundance of plant life in experimental plots, a vegetative reflection of the predicted difference between burned and unburned soil samples. Fire disturbance within woodlands creates optimal growth, allowing more seedlings to emerge (Viro 1974).

We hypothesized that fire has an impact on the soil and vegetation of the CERA oak woodlands, creating a significant difference between these two factors in the burned and unburned experimental plots. We predicted that this difference would be reflected through our soil analysis, supporting the findings that fire lowers both organic material and nitrogen content, while increasing pH levels. Finally, we hypothesized that the effects of burning on these soil conditions would be reflected in our seed-banks, resulting in higher seedling abundance within the seed-banks from burned plots.

Methods

We conducted our study in the oak woodlands at the Conard Environmental Research Area (CERA). In 1997, the woodlands were divided into nineteen 25 x 25 m alternating burned and unburned plots (Figure 1). The burned plots were first burned in March 1997, and in November or December of the subsequent years. In 2000, only five of the plots – plots 1, 3, 5, 7, and 9 – were burned (Plots burned in 2000 will be referred to as annually burned plots, while all other burned plots will be called neglected plots for the remainder of the paper).

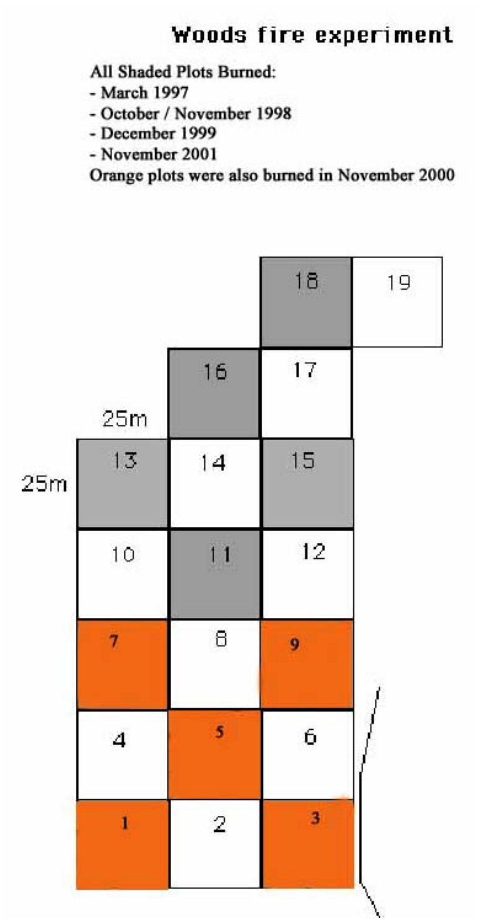

Figure 1: Map of burn treatment at oak woodland at CERA.

We collected 47cm^3 core samples (at a depth of 15 cm) from four randomly selected points within each of the 19 burned and unburned plots in the oak woodlands at CERA on October 9 and October 14. We then spread the combined soil samples over sterile, moistened soil in trays measuring 25x25x6 cm and spread the combined soil samples on top of the sterile soil. We also set up two control trays containing 4 cm of sterile, moistened soil enabling us to monitor for contamination (Blodgett et al., 2000). These trays were arranged randomly in seven rows of three in the Grinnell College greenhouse and watered once every other day and kept under consistent light. Over the course of a month we observed these seed-banks, counting the abundance of seedlings. Because of the distribution of values, we used a Kruskal-Wallis test for treatment of difference.

On October 28 we took 47cm^3 samples at two randomly selected points per plot. These two samples from each plot were combined and sent to the lab at Iowa State University to determine the total nitrogen content of the soil. We analyzed the significance of these results with a t-test.

On November 4, we collected two 47cm^3 core samples from each plot. The soil from these samples was then brought back to the CERA laboratory where we prepared a slurry of four parts water to one part soil stood for ten minutes before pH was tested using an electronic probe. We used a t-test to analyze the significance of the difference between these pH levels.

Finally, we measured the percent organic matter in the soil of the burned and unburned plots. On November 6, six 47cm^3 core samples were taken from each plot to measure organic matter. Soil samples were weighed on the date of collection and immediately dried for 2 days at a temperature of 60° C. We then reweighed the samples to determine the soil moisture content. The dry samples were fired in an oven at 400° C for one hour and then reweighed to determine the amount of organic matter present in the soil. We used a t-test to determine the significance of these results.

Results

The difference between the mean total nitrogen content of the burned plots and of the unburned plots was non-significant (Fig. 2, t= 2.028091,

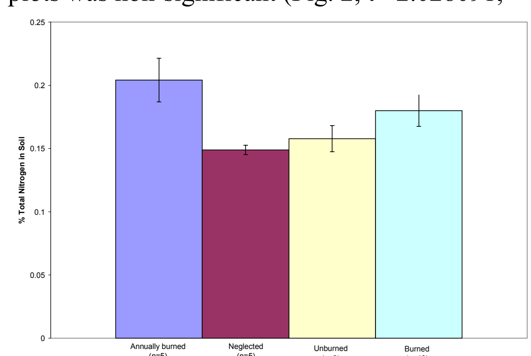

Figure 2: Mean (± SE) percent total nitrogen of soil from the oak woodlands at CERA.

p=.663035). However, the total nitrogen content of the annually burned plots was significantly higher than that of the unburned plots (Fig. 2, t=2.30600, p=.00293). The total nitrogen content of the annually burned plots was also significantly higher than the total nitrogen content of the neglected plots (Fig. 2, t=2.306006, p=.013878).

The difference between the mean soil pH of the burned and unburned plots was marginally non-significant (Fig. 3, t=2.144789, p=.08858). There was a significant difference between the mean soil pH of the annually burned plots and that of the unburned plots (Fig. 3, t=2.30600, p=.00293). Also, although the difference in the soil pH of the annually burned plots and the neglected plots was marginally non-significant (Fig. 3, t=2.306006, p=.066093), the mean soil pH appears to be higher in the annually burned plots (6.54 to 5.86).

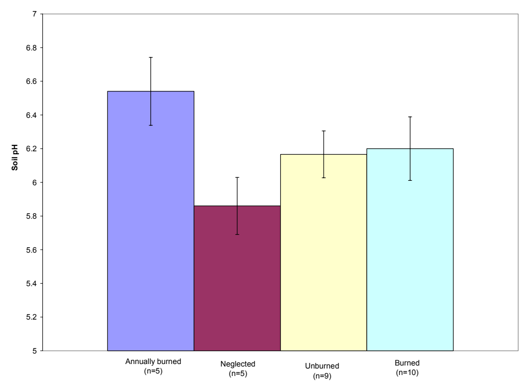

Figure 3: Mean (± SE) pH of soil from the oak woodlands at CERA.

There was no significant difference between the percent organic matter of the burned and unburned plots (Fig. 4, t=2.144789, p=0.172239). The difference between the percent organic matter of the annually burned plots and the unburned plots was non-significant

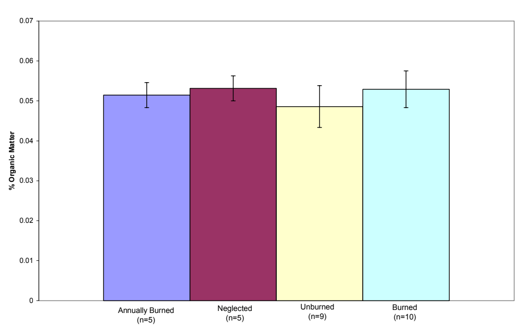

Figure 4: Mean (± SE) percent organic matter of soil from the oak woodlands at CERA.

(Fig 4, t=2.178813, p=.481403), as was the difference between the annually burned plots and the neglected plots (Fig 4, t=2.306006, p=.89686).

The mean abundance of the burned plots was not significantly different from that of the unburned plots (Fig. 5, t=2.109819, p=.434732). The difference between the mean abundance of the annually burned plots and the unburned plots was also non-significant (Fig. 5, t=2.178813, .523625), as was the difference between the annually burned plots and the neglected plots (Fig. 5, t=2.306006, p=1).

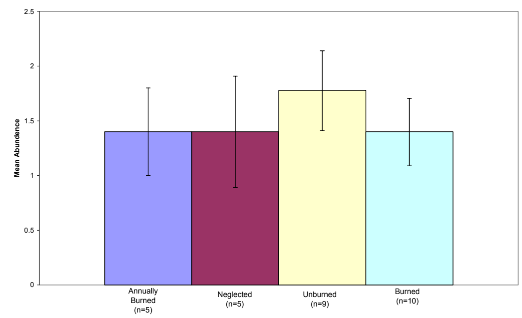

Figure 5: Mean (± SE) abundance of emerged seedlings from the seed banks of the experimental plots at the CERA oak woodlands.

Discussion

Our initial data comparing the burned and unburned plots in the oak woodlands at CERA indicates that fire does not significantly affect the pH, the percent organic matter, or the total nitrogen content of the soil. However, after examining the history of the oak woodlands, we discovered a flaw in the burn treatment of the experimental plots. Since the neglected plots were not burned in 2000, they should be treated as a separate burn treatment. The pH levels and the total nitrogen content of the neglected plots were significantly lower than those of the annually burned plots. After eliminating the neglected plots from our data analysis, we found that the soil pH and the total nitrogen content were significantly higher in the annually burned plots than in the unburned plots.

In accordance with J.R. Tester's (1989) study, which states that annual burning in oak woodlands should increase the soil pH over time, the mean soil pH of the annually burned plots is higher than that of the unburned. In their previous forest fire studies, both Tester (1989) and Viro (1974) found that soil pH increases with increased burn frequency, accounting for the higher soil pH found in the annually burned plots than that of the neglected plots.

The total nitrogen content of the soil from the annually burned plots was significantly higher than that of the soil from the unburned plots, indicating that an increase in soil pH corresponds to an increase in the total nitrogen content of the soil. During a fire, the humus layer of the soil is exposed to extreme heat, which causes the mobilization of nitrates into ammonia. The ammonia increases the pH of the soil (Viro 1974). Fowells's and Stephenson's (1934) study on the effects of burning on forest soils indicates that certain processes such as nitrogen fixation and nitrification are enhanced by the higher pH and ammonia levels associated with burned areas, resulting in an increase in total nitrogen. However, this increase in total nitrogen in unlikely to last as increases in soil nitrogen content following fire typically last only one or two years (Binkley et al. 1992). The ephemeral effects of fire are visible in the neglected plots, which have a significantly lower soil pH and total nitrogen content than the annually burned plots.

The mean abundance of seedlings emerged from the seed banks of the unburned plots is non-significantly higher then from the burned plots, but not significant. This trend is supported by Ferrandis's (1998) study which indicates that burning decreases seed bank density by damaging the seeds in the upper 2 cm of the soil of prairie soils. Viro's 1974 study shows that fire removes seeds from the soil of a pine forest. Also, since burning produces optimal growing condition by clearing the soil surface of litter and increasing soil temperature (Ehrenreich and Aikman 1963), the germination rate on the burned plots increases, removing seeds from the seed bank. Due to the accumulation of litter, less germination occurs in the unburned plots (Ehrenreich and Aikman 1963). Therefore, more seeds are present in the seed banks of unburned plots.

Since our data suggest that the effect of burning on the soil pH and nitrogen content of forest soils is ephemeral, it would be of great interest to study the effects of interval burning on woodland soils. It is unlikely that burn intervals greater than 2 years apart would produce in increase in either soil pH or nitrogen content (Binkley et al. 1992). Also, it would be interesting to test for nitrate and ammonium concentrations in the soil of the experimental plots to determine if, in accordance with Fowells's and Stephenson's (1934) study, the higher total nitrogen content of the burned soil corresponds to higher levels of usable nitrogen . Hopefully, by studying the effects of fire on the soil of the oak woodlands, scientists will be able to determine the best management practices for maintaining a healthy prairie ecosystem.

Acknowledgments

We would like to thank Professor Jonathan Brown and mentor Georgia Hart for their guidance in writing this paper. Additional thanks to Larissa Mottl and Sue Kolbe for their help in the greenhouse and in the lab.

Literature Cited

Binkley, D., D. Richter, M. David, and B. Caldwell. 1992. Soil chemistry in a longleaf pine forest with interval burning. *Ecological Applications*. **2**: 157-164

Blodgett, H., G. Hart, and M. Stanislaw. 2000. Annual burning decreases the seed density in the upper soil layers of the seed bank. *Tillers*. **2**: 31-38.

Ehrenreich, J.H. and J.M. Aikman. 1963. An ecological study on the effect of certain management practices on native prairie in Iowa. *Ecological Monographs*. **33**: 113-130.

Ferranndis, P., and J.M. Herranz. 1999. Effect of fire on hard-coated cistaceae seed banks and its influence on techniques for quantifying seed bank. *Plant Ecology*. **144**: 103-114.

Fowells, H.A. and R.E Stephenson. 1934. Effects of burning on forest soils. *Soil Science*. **38**: 175-181.

Mottl, L. 2002. Documentation of oak woodlands burn history at CERA. (personal communication)

Reichman, O.J. 1987. *Konza Prairie.* Lawrence, KS: University Press of Kansas.

Risser, P.G., E.C. Birney, H.D Blocker, S.W. May, W.J. Parton, and J.A. Wiens. 1981. The true prairie ecosystem. Hutchinson Ross Publ. Co., Stroudsburg, PA. 557 p.

Tester, J.R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. Bulletin: Torrey Botany Club. **116**: 134-141.

Viro, P.J. 1974. Effects of forest fire on soil, pp. 7-45. *In* T.T Kozlowski and C.E. Ahlgren [eds.], Fire and ecosystems. Academic Press, New York.