RESEARCH BRIEF

# Prescription side effects: Long-term, high-frequency controlled burning enhances nitrogen availability in an Illinois oak-dominated forest

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## MANAGEMENT IMPLICATIONS

- Low-intensity annual burning increased concentrations of nitrogen in the soil in relation to carbon and phosphorus.
- Increased soil nitrogen could significantly alter plant community composition, giving a competitive advantage to certain plant species, such as invasive buckthorn, while negatively affecting species adapted to low-nitrogen soils, such as oaks.

In this study, researchers evaluated soil changes in carbon, nitrogen, and phosphorous in an oak-dominated forest in northern Illinois, USA, after annual low-intensity prescribed burning for more than 30 years.

Predicting soil responses to fire can be challenging because reactions vary depending on ecological conditions, fire frequency, fire intensity, and type of vegetation burned. Based on existing literature, researchers hypothesized that annual burning would produce soils with increased pH, higher levels of phosphorus and organic matter, and lower amounts of carbon and nitrogen.

Four centuries ago, the study site, located at the Morton Arboretum near Chicago, IL, was predominantly oak savanna (mainly bur and white oak) with some prairie. Extensive timber harvesting and fire suppression followed European settlement, resulting in a dense forest now dominated by sugar maple, white oak, ironwood, and American basswood. At the site, a thin layer of loess covers glacial till, consisting of deep Alfisols that are primarily silt loams in the Beecher and Ozaukee soil series.

The study area consists of two 25-hectare units, one burned and one unburned. Fourteen small plots (15x15 meters) were established in the burned unit, and 18 were set up in the unburned unit. Low- to moderate-intensity prescribed fires have occurred annually since 1985, usually in the fall season. Fires commonly consumed between 30-100% of the leaf and herbaceous litter.

Soil samples were obtained 14 months after the most recent burn. Soil properties analyzed were organic matter, pH, total carbon and nitrogen, available carbon, and available phosphorus and nitrogen (both organic and inorganic). Inorganic nitrogen was further separated into ammonium or nitrate. Additional measurements were made, by element, of soil microbial biomass, mineralization rates, and quantities of five extracellular enzymes.

Soil organic matter, soil pH, and total soil carbon were higher in burned areas than unburned. Burned areas also contained a slightly higher (but not statistically significant) quantity of available soil carbon. No changes in carbon mineralization or soil phosphorus were observed.

Soils in burned areas contained significantly more soil nitrogen than those unburned. Organic nitrogen concentrations were 27% higher in burned areas, and nitrate concentrations (inorganic) were 54% higher. However, the ratio between organic and inorganic nitrogen was the same between burned and unburned areas. Microbial biomass in burned areas contained increased nitrogen but no substantial increase in carbon or phosphorus.

Differences in soil pH were attributed to increases in potassium, magnesium, calcium, and ash, and the higher organic matter was due to incomplete consumption of vegetation at low fire temperatures. The increase in total carbon was explained, in part, by an increase of herbaceous litter, fostered by the annual fires, as this material charred but did not fully burn.

Researchers expected to find higher concentrations of phosphorus in burned soils because phosphorus volatizes at a higher temperature compared to carbon and nitrogen. The unexpected lack of added phosphorus may have been due to already naturally abundant phosphorus in local soils, which was a result of relatively recent glaciation.

Study authors concluded that the annual, low-intensity fires have produced different soil conditions than would result from high-intensity fires. High-intensity fires are more likely to volatize and reduce soil nitrogen. The authors call the higher soil nitrogen due to lower intensity fires a prescription "side-effect."

Forest soils in the eastern U.S. were historically limited in nitrogen. Though a common management goal of prescribed fire is to promote oaks, study authors

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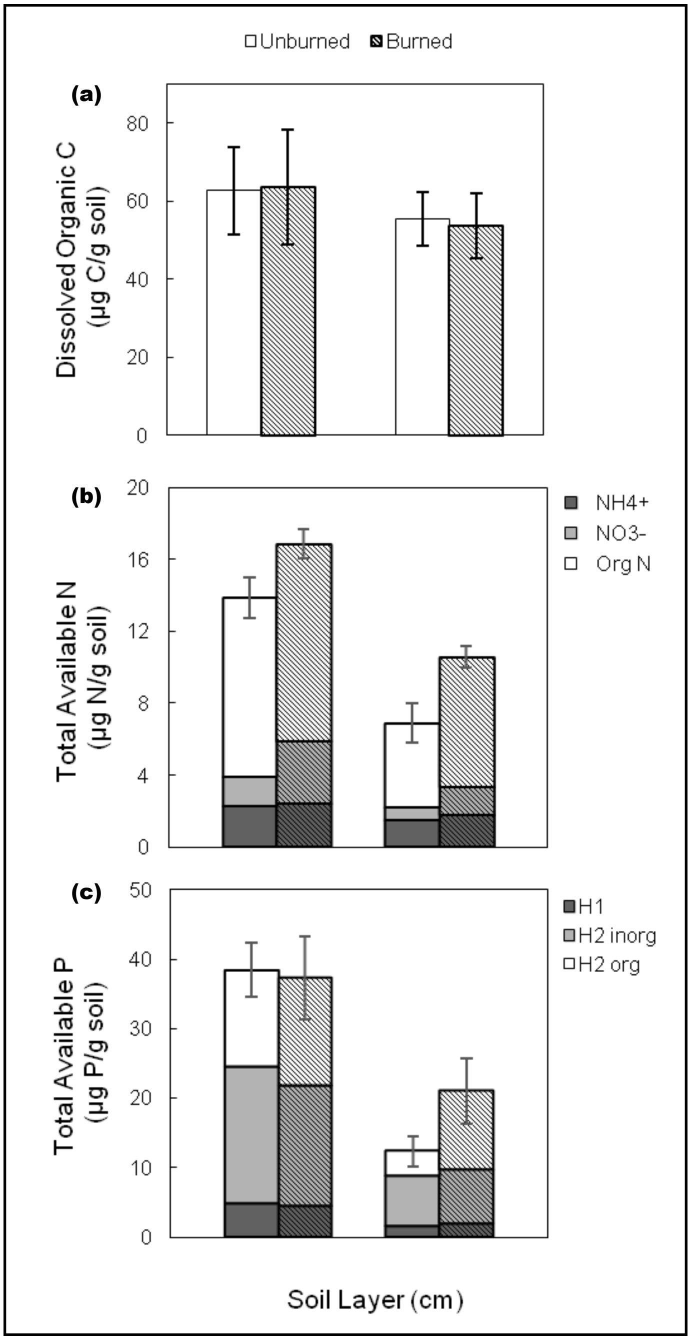


*Fig. 1. (a) Dissolved organic C, (b) total available N split into organic and inorganic (ammonium and nitrate) components, and (c) total available P split into fractions of H1 (inorganic resin extracted P) and H2 (inorganic and organic bicarbonate extracted P) components in 0-5 and 5-15 cm samples of burned and unburned soils from plots in the Morton Arboretum's East Woods. Soil layers are measured in cm below the surface. Bars are mean ratios of totals; one standard error of the mean is presented. Open, unburned plots; hash marks, burned plots.*

suggest that the increased nitrogen in burned soil may actually hinder oak regeneration or growth, and instead promote invasive species such as buckthorn. Higher intensity fires would potentially create soil conditions better suited to oaks.

Another potential side effect of higher soil nitrogen is a slowing of the colonization of tree roots by ectomycorrhizal fungi, which have a symbiotic relationship with oak trees. Changes in soil biomass observed during the study may indicate a shift from a fungal-dominated to a bacteria-dominated microbial community. (See Avis et. al., 2008, and Treseder 2004, below, for more about nitrogen's impact on soil organisms.)

## AUTHOR'S POSTSCRIPT

*The (study's) findings don't indicate that land managers should stop using controlled burning as a restoration tactic; however they do suggest that there are trade-offs for native plants and that more research is needed to understand them. As fire has significant impacts on soil carbon and nutrients, continuing to evaluate the impacts of repeated, low-intensity prescribed burning on oak forest soil will be critical to understanding and predicting burning effects on vegetation dynamics and ecosystem functions in the future.*

— *Meghan Midgley, co-author*

## FOR FURTHER READING


Avis, P.G., Mueller, G.M., Lussenhop, J., 2008. Ectomycorrhizal fungal communities in two North American oak forests respond to nitrogen addition. New Phytol. 179 (2), 472–483.

Treseder, K.K., 2004. A meta-analysis of mycorrhizal responses to nitrogen, phosphorus, and atmospheric CO2 in field studies. New Phytol. 164 (2), 347–355.



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