RESEARCH BRIEF

Fire frequency and tree canopy structure influence plant species diversity in a forest-grassland ecotone

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In this study, researchers examined the impact of varying fire frequencies on plant community structure, composition, and diversity. They measured resulting changes in both the understory and overstory in oak savannas, woodlands and forests at the prairie-forest transition zone in east-central Minnesota, USA.

Here, a prescribed fire experiment began in the early 1960s, designed to restore and maintain historically important oak savanna ecosystems. Fire frequency treatments ranged from no fire (fire exclusion) to near-annual fires. Management units were burned as many as 26 times from 1962 to 1995, with the most-frequently burned units having about eight fires per decade. Most fires occurred between mid-April and mid-May, were of low intensity, and tended to burn only dead plant material.

Researchers surveyed understory vegetation and tree canopy cover (overstory) to calculate species richness (a count of species) at 26 permanent study plots. In the overstory, tree species richness was calculated and canopy cover measured; in the understory, species richness was calculated for three plant functional groups: forbs, grasses (including sedges), and woody plants (including vines, shrubs and trees).

MANAGEMENT IMPLICATIONS

- Total plant species richness – including forbs, grasses, and woody plants – was highest at about five fires per decade and with 35% forest canopy cover.
- Species richness for grasses and sedges peaked at about six fires per decade and 20% canopy cover; five fires per decade and 10% canopy cover yielded the greatest number of forbs.
- Species richness for woody plants (vines, shrubs and trees) was highest in areas with no fires and about 90% canopy cover.

Researchers found that plant species richness was highest in areas with spatially variable canopy cover (as pictured here), which were burned 6-8 times per decade and characterized by intermediate canopy cover (20-70%); suggesting that savannas and woodlands foster complex ecological conditions.

Catalogued within the study area were 38 grass species, 113 forb species, and 39 woody plant species, for a total of 190 different vascular plants; species counts within plots varied between 32 and 71.

Examining **fire frequency**, researchers found that the fire-exclusion treatment areas contained the greatest number of overstory tree species, which typically included oaks as well as shade-tolerant, fire-sensitive tree species, such as red maple (*Acer rubrum*) and black cherry (*Prunus serotina*). Woody plant species richness was maximized in the understory of the no-fire treatment areas, where the numbers of forb and grass species were both low, with grasses the lowest.

Grass species richness was its highest in the most-frequently burned plots, at about eight fires per decade. Here, only two overstory trees species persisted: bur oak (*Quercus macrocarpa*) and northern pin oak (*Q. ellipsoidalis*). In general, as fire frequency increased, grass species richness increased until leveling off once fire frequency exceeded five fires per decade.

At an intermediate fire frequency – about five fires per decade – total understory plant species richness was maximized. Forb species richness was also maximized at this fire frequency, and decreased when fire frequency increased further.

Examining how species richness varied by changes in **canopy cover**, researchers found the highest overall plant species richness in savanna and woodland plots, defined in this study as locations with mean tree canopy cover ranging from 20% to 70%. Forb and grass species richness was highest on plots with canopy cover of 50% or less, and decreased as canopy cover increased. The number of woody

Fire frequency and tree canopy structure

plant species increased as canopy cover increased.

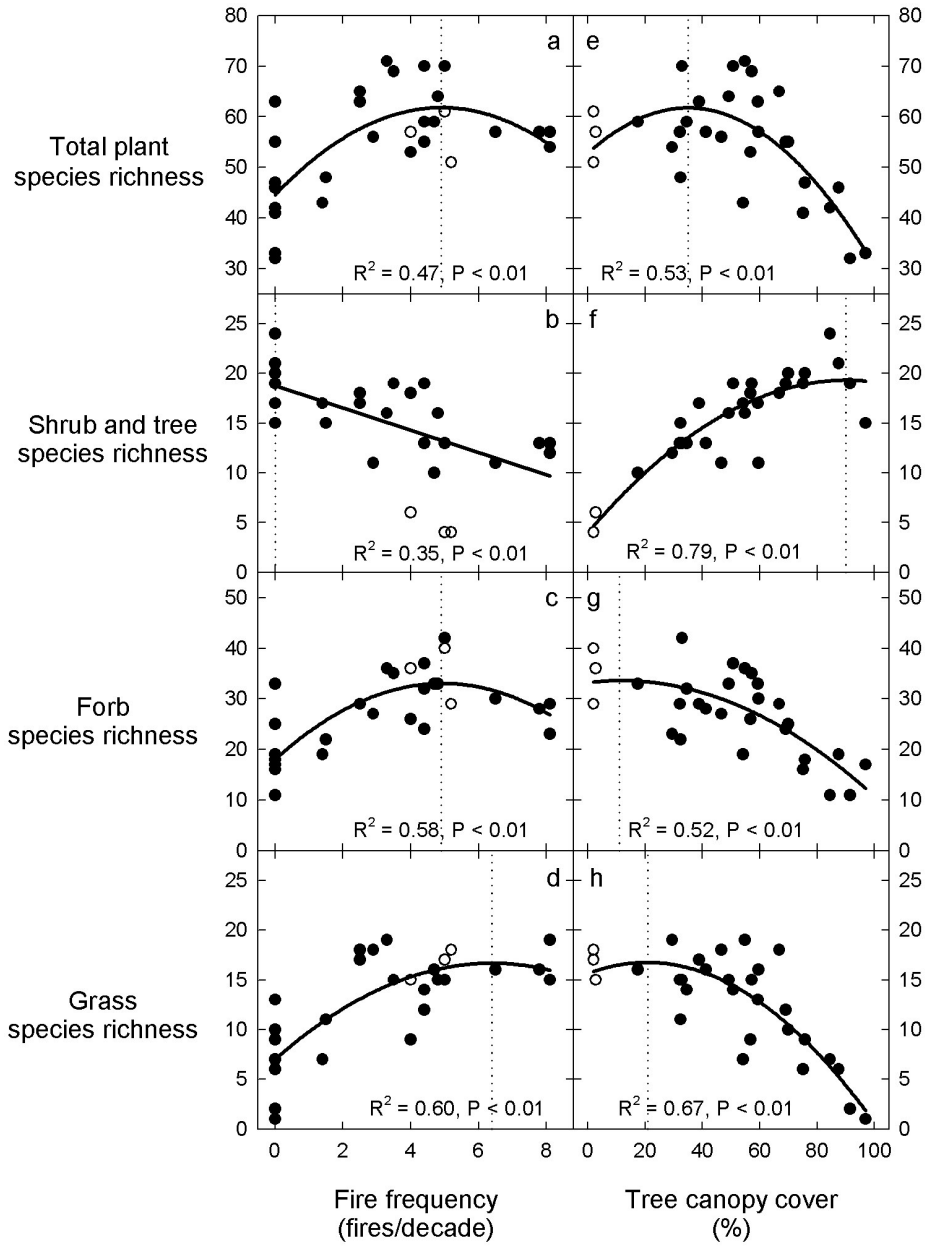
Examining **fire frequency and tree canopy cover combined**, researchers found that total plant species richness was highest in areas with 30% to 60% canopy cover that were burned 6-8 times per decade. Forb species richness was maximized on sites with 10% to 50% canopy cover that were burned 4-7 times per decade. Grass species richness was highest in areas burned nearly annually with canopy cover of 0 to 60%. Grass species richness decreased with greater shade and lower fire frequency. Species richness among understory woody plants was highest where fire was excluded and canopy cover was 70% to 100%, and declined where shade was reduced and as fire frequency increased.

In intermediate canopy cover (20% to 70%), where plant species richness was highest, no particular plant functional group dominated. It appears that these canopy conditions allowed many forbs, grasses, and woody species to coexist. Study authors suggest that savannas and woodlands may support high levels of plant community heterogeneity because their differing canopy cover fosters complex ecological gradients. Variations across gradients include available light, moisture, soil fertility, and disturbance frequency. In this study, the combination of fire frequency and canopy cover explained 57% of the variability in plant community heterogeneity.

Low-intensity fire applied biennially produced the highest overall species diversity. Biennial fires reduced, but did not eliminate, woody plants in the understory, while forb and grass species richness increased. However, at fire frequencies greater than biennial, woody plant species decreased but a corresponding increase in forb and grass species did not occur.

These findings support an established ecological principle, the intermediate disturbance hypothesis, which predicts that species diversity will be greatest following disturbances of intermediate severity and frequency, which offer opportunities for new species to establish with minimal loss of existing species (for more on this, see Huston, 1979).

The authors concluded that plant species richness in the study area appeared to be affected by both overstory canopy structure and fire frequency. Without fire, overstory trees and understory woody plants dominated sites, and competitively excluded native forbs and grasses. However, without shading from overstory trees, grasses held the competitive edge and displaced other species.



Fire frequency and tree canopy cover effects on plant species richness at the plot level. Species richness values are for all plants (a,e), woody plants (b, f), forbs (c, g), and grasses (d, h). Open circles indicate old-field grassland plots. Solid lines indicate significant linear or quadratic relationships based on regression analysis. Vertical dotted lines indicate fire frequency or mean tree canopy cover values with maximum predicted species richness.

FOR FURTHER READING

Huston, M. (1979). A general hypothesis of species diversity. *American Naturalist, 113*, 81-101.

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