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Restoring Future Forests: How Fire, Deer, and Canopy Gaps Shape Forest Seed Banks and Regeneration Potential

Soil seed banks are the hidden reservoir of forest plant diversity. Seed banking is a reproductive adaptation that allows plants to persist belowground as dormant seeds, where the soil serves as a buffer from aboveground disturbances. They play a key role in the recovery of forests post-disturbance, and it's the post-disturbance plant recovery that replenishes, or makes seed deposits, in the seed bank. Since certain plant species are favored or disfavored by the type of forest disturbance, seed banks can vary depending on the disturbance affecting aboveground plants, and the abundance and diversity of seed banks wanes over time. Because of this, seed banks are strongly influenced by the reintroduction of disturbances and may be influenced by future disturbance regimes.

Across temperate hardwood forests in the eastern United States, regeneration challenges have mounted as historical disturbance regimes—such as fire, windthrow, and herbivory—have been altered or suppressed. Low-intensity fires have been largely excluded from eastern forests for nearly a century. Changes to natural disturbance regimes have led to an increase in mesophytic species such as maple over fire-adapted species such as oak, with long-term implications for forest composition, resilience, and biodiversity. These changes aboveground are then potentially reinforced belowground through the seed bank.

A new study by Reed et al (2025) investigates how forest seed banks—a crucial driver of forest regeneration and successional trajectories—respond to combinations of three common forest management actions:

- low-intensity prescribed fire
- deer exclusion
- canopy gap creation

Scientists' findings emphasize that what's happening underground in the seedbank may hold the clearest signals of how today's forest management decisions will shape tomorrow's forests.

Forest disturbance regimes have changed across the eastern United States, leading to current day plant communities that are significantly different from historical species composition and diversity. While active management is underway or planned across many public lands, scientists and land managers do not fully understand how combined disturbances change soil seed banks—a critical knowledge gap land managers need filled to ensure long-term forest productivity.

ACTIVE MANAGEMENT

Active management is essential for long-term forest resilience and productivity. Thoughtful reintroduction of disturbances—particularly in combination—can catalyze regeneration, reshape seed banks, and restore trajectory toward resilient forests in the Appalachian region.

At the Fernow Experimental Forest, in the Monongahela National Forest, Reed and colleagues established an experiment to examine the soil seed bank 13 years after disturbance initiation. Scientists examined how prescribed fire, deer exclusion, and canopy gap creation applied individually and in combination influenced seed bank diversity and composition in an Appalachian hardwood forest. Seed bank samples were analyzed for species composition, density, and diversity to assess how different combinations of management tools interact, and how active management—or the absence of management—can influence successional dynamics.

The Fernow Experimental Forest focuses on silviculture and watershed studies. USDA Forest Service photo by Andrea Brandon.

Synergistic Disturbances—But Fire Is the Driver

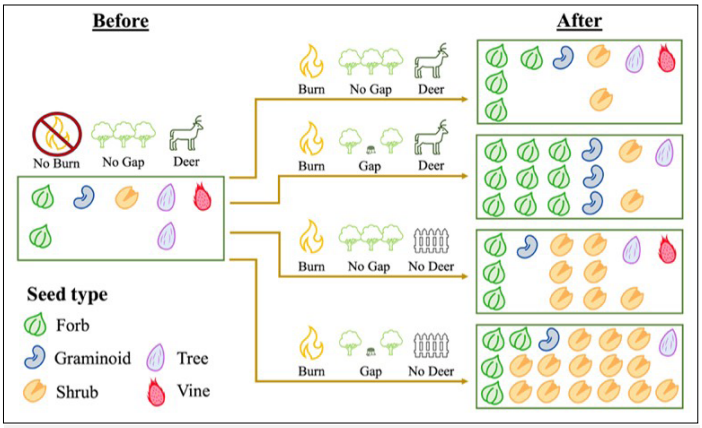
Researchers found that fire had the strongest independent effect, increasing the density of viable seeds in the soil. Neither canopy gaps nor deer exclusion alone produced major changes to the seed bank; it was only when these disturbances were combined with fire that substantial changes were observed. The most unique and diverse seed bank communities came from plots where all three disturbances—fire, canopy gaps, and deer presence—were applied, while the least diverse seed bank communities came from plots that had fire, canopy gaps, and deer exclusion. These low diversity plots had shrub seed densities that were 1400 percent higher than in undisturbed controls. This finding suggests that stacking the right disturbance regimes may be necessary for managers seeking to trigger meaningful ecological shifts and reduce competing vegetation.

What's Underground Matters

Interestingly, in all treatment plots analyzed, the seed bank composition was distinct from the current aboveground vegetation, regardless of disturbance treatment. This finding suggests that the soil may hold a legacy of past management and a reservoir of future regeneration potential that is not always visible aboveground.

Conclusion

Restoring fire was the major contributing factor that enhanced seed bank abundance and richness, replenishing the seed reservoir for future forest renewal. These disturbance-altered seed banks highlight how the restoration of disturbance can strongly and indirectly influence temperate forest community dynamics.



Schematic representing disturbance pathways to different seed bank communities found in study results. Burning with a closed canopy and deer presence led to an include in forb seed abundance, and burning with deer presence and a canopy gap led to a substantial increase in forb and graminoid abundance. In contrast, burning and deer exclusion led to a substantial increase in shrub seed abundance, particularly with a canopy gap overhead. Source: Reed et al. 2025.

KEY FINDINGS

- Seed banks store future forest potential, and their composition is often different from what is visible aboveground. Monitoring soil seed banks can be a useful measure for managing future regeneration potential and identifying competing vegetation risk.
- Scientists found that restoring fire regimes to the landscape was the major contributing factor to enhanced seed bank abundance and richness.
- Combinations of three common forest management actions—canopy gap creation, prescribed fire, and deer management—lead to a more unique seed bank community.
- The restoration of disturbance regimes will likely influence future biodiversity and successional patterns of temperate Appalachian forests.

PROJECT LEADS

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FURTHER READING

Reed, Samuel P.; Royo, Alejandro A.; Carson, Walter P.; Olmsted, Castilleja F.; Frelich, Lee E.; Reich, Peter B. 2025. Multiple disturbances, multiple legacies: fire, canopy gaps and deer jointly change the forest seed bank. Journal of Ecology. 113: 353–370. https://doi.org/10.1111/1365-2745.14459.

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