USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Rocky Mountain Research Station | June 2026

Science You Can Use *in 5 minutes*

Restore ponderosa forests—and reduce fire risk? Study shows the path forward

Forest managers are increasingly looking to restore ponderosa pine forests to more ecologically diverse conditions—forests with clusters of trees, openings, and multiple age classes instead of the evenly spaced, uniform stands produced by traditional forest management.

But a growing concern with this type of forest restoration treatment, explains Mike Battaglia, a Research Forester with the Forest Service Rocky Mountain Research Station, "is that arrangements with groups of trees and openings between them could exacerbate fire behavior because of the biomass of canopy fuels. It would be easy for a fire to transition from the surface to the crown."

Battaglia and a team of researchers from Rocky Mountain Research Station and Colorado State University wanted to find out if such restoration treatments reduce fuel hazards as effectively as traditional fuel reduction approaches.

The results suggest the answer is yes—as long as managers address two critical factors: surface fuels and small trees.

The scientists used sophisticated, physics-based fire modeling to compare how different thinning strategies perform under varying weather and fuel conditions. The team simulated fire behavior across six different thinning strategies in ponderosa pine forests, from uniform spacing that creates "lines of pines" to variable retention treatments that create patchy, clumpy patterns. They tested these treatments at different stand densities, surface fuel loads, wind speeds, and fuel moisture levels.

All thinning strategies reduced fire spread rate by 19–28 percent

Left—Ponderosa pine stand with uniform thinning shows even spacing and similar tree diameter size. Right—Ponderosa pine stand with variable density thinning used to create groups of trees, single trees, and openings: structures that emulate the historical forest structure that was shaped by frequent fire. Forest Service photos by Mike Battaglia.

and decreased canopy consumption compared to untreated stands, regardless of whether trees were arranged evenly, randomly, or in groups with openings. Battaglia said “We can still do density reduction while including things like heterogeneity and still get the outcome that we’re looking for from a fire behavior standpoint.”

But interestingly, surface fuel moisture had a larger effect on fire behavior than tree arrangement or thinning method. In fact, surface fuel moisture alone explained more variance in a fire’s spread rate than any of the forest management variables. Additionally, treatments that incorporated small-tree removal reduced the percentage of forest canopy consumed by fire (canopy consumption) more than treatments without it, especially at lower stand densities.

Battaglia emphasizes a key takeaway: “It’s really more about treating the surface fuels and the small trees.”

For managers balancing multiple objectives, the implications are significant. Variable retention treatments can create the structural diversity needed for wildlife habitat and plant diversity while still achieving fuel hazard reduction—provided surface fuels and small trees are addressed. At moderate thinning intensities, the spatial arrangement of overstory trees did not significantly impact for fire behavior, giving managers flexibility in how they design treatments.

These results are specific to frequent-fire, dry conifer forests such as ponderosa pine and Douglas-fir forests, but not other forest types like spruce-fir where crowns extend to the ground and trees are less fire resistant. For managers working in dry conifer forests, the study demonstrates that treatments can meet multiple objectives without sacrificing fire protection.

Sylvia Kantor is the author of this Science You Can Use.

Key Management Implications

- Ecological restoration and fuel hazard reduction are compatible—variable retention treatments that create structural heterogeneity for wildlife and plant diversity can achieve substantial fire behavior reductions when surface fuels and small trees are treated.
- Surface fuel treatment is key—surface fuel load and fuel moisture influenced fire severity more than overstory arrangement. Thinning without reducing surface fuel limits how much treatment reduces fire severity.
- Small tree removal is significant—removing small trees produced consistent reductions in fire behavior across weather conditions, offering predictable results that are especially important in wildland-urban interface areas.

Further Reading

Davis, K.T.; Peeler, J.; Fargione, J.; [et al.}. 2024. Tamm review: A meta-analysis of thinning, prescribed fire, and wildfire effects on subsequent wildfire severity in conifer dominated forests of the Western US. Forest Ecology and Management. 561: 121885.

Ziegler, J.P.; Hoffman, C.M.; Tinkham, W.T.; [et al.]. 2025. Impact of thinning strategy, surface fuel loading and burning conditions on fuel treatment efficacy in ponderosa pine dominated forests of the southern Rocky Mountains. Forest Science. 71: 759–782.

Ritter, S.M., Hoffman, C.M., Battaglia, M.A., [et al.]. 2022. Restoration and fuel hazard reduction result in equivalent reductions in crown fire behavior in dry conifer forests. Ecological Applications. e2682.

Featured Scientist

Mike A. Battaglia is a Research Forester with the Rocky Mountain Research Station.

Contributors

Wade Tinkham is a Research Forester and Kim Davis and Russ Parsons are Research Ecologists with the Rocky Mountain Research Station.

James Menakis is retired. He previously worked for USDA Fire and Aviation.

Chad M. Hoffman is a Professor and Justin Ziegler is a Fire Ecologist; both work at Colorado State University.