EFFECTS OF SEED SOURCE PATTERN ON POST-FIRE TREE RECOVERY

NORTHERN ROCKIES FIRE SCIENCE NETWORK

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Key Management Findings

- **Distance to nearest seed source is sufficient for predicting tree species presence after fire, but seed source pattern can better anticipate regeneration density.**
- **Seed source pattern must be measured at species-specific spatial scales that reflect tree regeneration traits.**
- **Burn sites require 40% seed source area within a 100 m buffer to reach stocking levels.**
- **Burn sites positioned above seed sources may not restock naturally even with sufficient seed source area.**
- **For serotinous or resprouting tree species, local site conditions are more important than seed source pattern in determining presence and regeneration density.**

Forests rely on processes like seed dispersal from seed sources (live trees containing mature cones) to jumpstart post-fire tree regeneration. Consequently, managers often estimate the potential for seed dispersal when anticipating whether a burn site will restock naturally. Seed dispersal is usually estimated using the straight-line distance to nearest seed source. However, distance does not capture how seed source pattern (area and arrangement) near a burn site influences seed supply and delivery. More seed source area increases the total seed supply, while more complex seed source arrangements can better facilitate seed delivery. But for mixed conifer forests in mountainous terrain, effects of scale, multiple tree regeneration traits, and terrain might create more complexity.

In this study, we investigated how seed source pattern, scale, traits, and terrain interact to shape post-fire tree recovery (Figure 1). Our research questions were: (1) Does seed source pattern outperform distance to nearest seed source when anticipating tree species presence and regeneration density after fire? (2) If yes, do effects of seed source pattern vary with scale or terrain? (3) Under what scenarios is seed source pattern more influential than local site conditions for post-fire tree recovery? Understanding how post-fire tree regeneration unfolds across mountainous terrain can help managers support fire-resilient landscapes and strategically delegate resources to burn sites not restocking naturally.

Pattern Matters (Sometimes)

We identified scenarios in which seed source pattern was associated with post-fire tree regeneration. Interestingly, distance to nearest seed source sufficiently estimated tree species presence, but seed source pattern was better at anticipating regeneration density. These results suggest that distance captured whether seeds could reach a burn site, while area and arrangement approximated number of seeds and ultimately regeneration density.

For predominantly wind-dispersed tree species, seed source pattern shaped regeneration density and whether a burn site restocked naturally. Subalpine fir (*Abies lasiocarpa*) regeneration increased with increasing seed source area, reinforcing that total seed source (not just nearest seed source) shaped regeneration density. Subalpine fir presence at a burn site required at least 10% seed source area within a 100 m buffer, while stocking density (defined as >400 conifer stems/acre) required at least 40% seed source area within a 100 m buffer. Below these thresholds, burn sites were unlikely to restock naturally. But terrain also mattered, as burn sites located below seed sources within a 100 m buffer supported the highest subalpine fir regeneration density. In contrast, burn sites positioned above similar seed source arrangements experienced nearly a fivefold reduction in regeneration density. As a result, even though a burn site was surrounded with sufficient seed source, its position in the landscape impeded recovery.

In contrast to predominantly wind-dispersed tree species, local site conditions were more influential than seed source pattern in regeneration of serotinous and resprouting tree species. For instance, lodgepole pine (*Pinus contorta* var *latifolia*) and quaking aspen (*Populus tremuloides*) regeneration density increased with decreasing seed source area within the smallest buffer (25 m). In these scenarios, high-severity fire likely released seeds from local canopy seedbanks and sprouts from local root structures – prompting regeneration. Consequently, terrain did not influence whether burn sites dominated by lodgepole pine or quaking aspen restocked naturally. In fact, for lodgepole pine, soil nutrients and soil conditions were more important than seed source pattern or terrain for recovery.

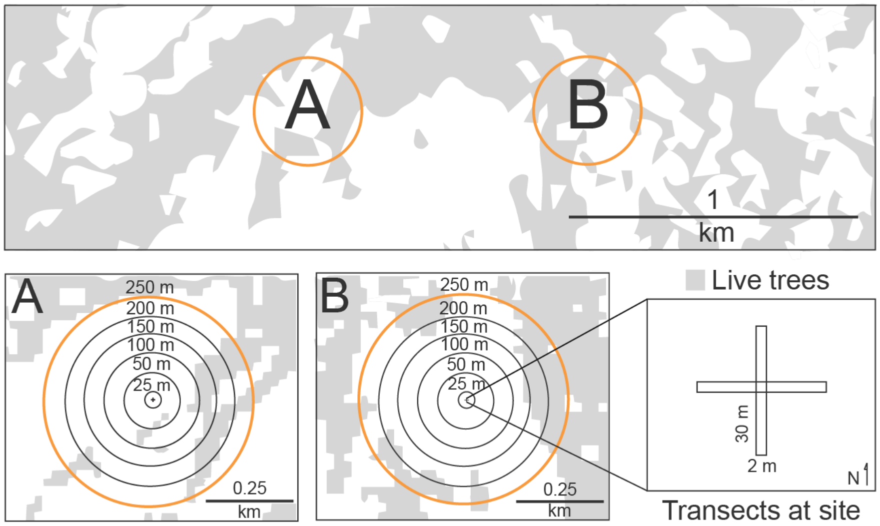

Figure 1. We used aerial imagery to measure seed source area and arrangement around burn sites at nested scales: 25 m, 50 m, 100 m, 150 m, 200 m, and 250 m buffers. In the field, we used transects at each burn site to calculate tree species presence, regeneration density, and stocking level. We then related seed source area and arrangement to the field data, allowing us to test the effect of seed source pattern at different scales on post-fire tree regeneration.

Management Implications

Distance, Pattern, and Resilience

Due to climate change, built-up fuels, and human ignitions, the United States is contending with a new fire era where managing for resilience (the capacity of a system to return to its original composition, structure, or function following disturbance) has become a priority. For example, restoring and maintaining fire-resilient landscapes is a fundamental goal of the National Cohesive Wildland Fire Management Strategy. Resilience is challenging to quantify, but defining the resilience of what to what and accounting for scale are good starting points. Identifying appropriate metrics is also useful. Accordingly, when anticipating resilience of forest composition to fire at the stand-level over successional cycles, measuring distance to seed source works sufficiently. If anticipating resilience of forest structure to fire, then measuring seed source area and arrangement is useful, given associations with regeneration density. However, seed source area and arrangement must be measured at spatial scales that reflect predominant tree regeneration traits.

Tree Planting After Fire

Knowing how post-fire tree regeneration might unfold across mountainous terrain can help managers strategically plan tree planting after fire. Federal law requires managers to devote resources to burn sites that are not restocking naturally. To meet that objective, evaluating burn sites in the context of their surrounding seed source pattern could be fundamental to decision-making. A threshold to consider is that burn sites require 40% seed source area within a 100 m buffer to reach stocking levels (>400 conifer stems/acre). However, at burn sites dominated by wind-dispersed tree species, land managers must also consider surrounding terrain. Under benign or moderate fire weather, complex terrain can protect off-site seed sources. But complex terrain also impedes seed dispersal. Specifically, burn sites positioned above surrounding seed source are least likely to restock naturally. As a result, these locations may need to be prioritized for tree planting after fire.

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