A perfect storm: Multiple stressors interact to drive postfire regeneration failure of lodgepole pine and Douglas-fir forests in Yellowstone

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Background/Question/Methods

Twenty-first century forests will experience increasing stress as environmental conditions and disturbance regimes change. Whether forests retain essential structure and function or transition to alternate states, particularly when simultaneously affected by multiple stressors, remains unresolved. Subalpine forests in Yellowstone National Park (Wyoming) experience stand-replacing wildfires, and successful postfire-tree regeneration is necessary to assure resilience. Drying is projected in Yellowstone, causing frequent, larger wildfires that could reduce seed supply, plus droughts that could constrain postfire-seedling establishment. We asked *how might warming-drying conditions and changing wildfire regimes interact to cause postfire-regeneration failure in conifer forests of Yellowstone?* We conducted a factorial simulation experiment with an individual forest process model, iLand, to identify combinations of fire frequency (10yr-100yr interval), fire size (50m-1000m patch size), postfire climate (historical, mid-21st century, late 21st century), soil type, and elevation where regeneration of lodgepole pine (*Pinus contorta* var. *latifolia*) and Douglas-fir (*Pseudotsuga menziessii*) failed. We expected postfire densities would be reduced if burned-patch sizes exceeded effective dispersal distances, sequential fires burned before trees reached reproductive maturity, or drought occurred during the regeneration window. We also expected regeneration failure only where multiple stressors occurred simultaneously at low elevation or in stands underlain by soils with poor water retention.

Results/Conclusions

Douglas-fir stands were more vulnerable to regeneration failure than lodgepole pine. 98% of simulated Douglas-fir stands located in the middle of large burned patches failed to regenerate 30 years post fire, irrespective of other factors. Lodgepole-pine stands in the middle of large burned patches failed to regenerate if they were also located at low elevations (90% of stands) or located at higher elevations on soils with poor water retention (57-88% of stands). Stands of serotinous lodgepole (i.e., trees with closed cones that open when heated) also failed to regenerate if a fire recurred before trees had reached reproductive maturity (92% of stands). Drought constrained regeneration of all species in many years. However, enhanced establishment due to release from cold-temperature limitation during mid-to-late 21st century outweighed consequences of drought on postfire regeneration. Forest processes unfold slowly and disturbances occur infrequently, making it difficult to study how forests will respond to projected stressors and whether and why forests may transition to alternate states. Application of a forest process model helped identify the perfect storm of conditions that could initiate postfire-regeneration failure in Yellowstone.