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Climate change, disturbance and the future of northern forest landscapes

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Disturbance is a key source of heterogeneity at multiple scales in forest landscapes. Climate and disturbance regimes are changing rapidly in many north-temperate and boreal forest landscapes and presenting forest managers with formidable challenges. In the Northern Rocky Mountains of North America, the frequency of large fires has increased in recent decades in association with warming temperatures, earlier spring snowmelt, and longer fire seasons. The extent and severity of bark beetle (Curculionidae: Scolytinae) epidemics have also reached unprecedented levels in the past 25 years. These disturbances are altering the age structure and recovery capacity of northern forest landscapes and altering regional carbon dynamics. Where regeneration niches are shifting, vegetation is changing abruptly following disturbance to species better suited to current climate. As a case study, I will discuss how climate, fire and bark beetles are affecting landscape patterns and processes in the Greater Yellowstone Ecosystem (Wyoming, USA), then identify priorities for future study. Established in 1872 as the world's first national park, Yellowstone National Park encompasses approximately 9,000 km^2 and is the center of the Greater Yellowstone Ecosystem. During 1988, severe fires burned under conditions of extreme drought and high winds and affected ~36% of the park and surrounding lands. The fires created a post-fire mosaic of variable burn severity that resulted in substantial heterogeneity in vegetation and ecosystem processes. The most striking variation in postfire vegetation was in the density of lodgepole pine (*Pinus contorta* var. *latifolia)* regeneration, which ranged from zero to > 500,000 stems ha^{-1} and established the template for many ecosystem processes on the landscape. Recent bark beetle outbreaks have further altered landscape patterns of stand structure and ecosystem processes. Post-disturbance heterogeneity in stand age, structure, and composition; productivity; coarse wood abundance; microbial communities; and nutrient pools and transformations have important implications for the resilience of forest landscapes. The long-term dynamics of forest landscapes will depend on the spatial and temporal patterns of disturbance and recovery. Thus, future research in forest landscapes should address questions related to (i) disturbances as catalysts of rapid change in forest communities, (ii) ecological consequences of compound and linked disturbances, (iii) feedbacks from disturbance to other global drivers, and (iv) interactions between land use and disturbance. Studies of the 1988 Yellowstone fires revealed that large, severe disturbances are not necessarily catastrophic. However, it is critical to consider plausible future disturbance regimes and recovery trajectories to predict when and where forests may change qualitatively and to anticipate the future condition of forest landscapes.