

Effects of ecosystem integrity on drought resistance and recovery of forests on a global scale

Pengfu Yao

Abstract

Droughts are intensifying under climate change and increasingly threaten the carbon and water functions of global forests, yet the factors that determine forest resilience to drought remain debated. Resistance—the capacity to withstand a drought—and recovery—the capacity to return to pre-drought function—are two complementary components of resilience that may be shaped differently by forest integrity. How its landscape-level and species-level dimensions act on each component, and whether they trade off against one another, has not been quantified globally. Using monthly satellite-based solar-induced chlorophyll fluorescence and 3-month Standardized Precipitation Evapotranspiration Index-based drought events from 2001 to 2022, we calculated pixel-level resistance and recovery for 611,540 stable forest pixels at 0.05° resolution. Two dimensions of forest integrity—landscape-level integrity (Forest Landscape Integrity Index, FLII) and species-level integrity (tree species diversity)—were modelled against resistance and recovery using Random Forests, and against the resistance–recovery trade-off using a boosted regression tree, controlling for climate, soil, topography, and baseline forest structure. Tropical forests showed higher resistance but lower recovery, while boreal and temperate forests showed the opposite, and a negative event-level resistance–recovery correlation was observed in 72.98% of pixels. Tree species diversity was positively associated with resistance but negatively with recovery, with its effects modified by temperature and precipitation. FLII contributed less strongly, likely reflecting shared variance with tree cover and a scale mismatch between landscape-level processes and coarse pixel-level responses. These results suggest that no single dimension can capture forest integrity, and that resistance and recovery are complementary yet not interchangeable components of forest drought resilience.

Keywords: Geographical Information Science, Drought resilience, Forest landscape integrity, GOSIF, Resistance–recovery trade-off, SHAP, SPEI, Tree species diversity