ABSTRACT: The southwestern United States experienced an extended drought from 1999-2002 which led to widespread coniferous tree mortality throughout New Mexico, Arizona, Utah and Colorado. Piñon-juniper (PJ) woodlands, which occupy 24 million ha throughout the Southwest, proved to be extremely vulnerable to this drought, experiencing 40 to 95% mortality of piñon pine (Pinus edulis) and 2-25% mortality of juniper (Juniperus monosperma) in less than 3 years (Breshears et al., 2005). Understanding the response trajectories of these woodlands is crucial given that climate projections for the region suggest that episodic droughts, and associated conifer mortality, are likely to increase in frequency and severity in the coming century. We used a combination of eddy covariance, high-resolution remotely sensed datasets including full waveform lidar, soil respiration, sap flow and biomass carbon pool measurements made at an undisturbed PJ woodland (control) in central New Mexico and at a manipulation site within 2 miles of the control where all piñon trees greater than 7 cm diameter at breast height within the 4 ha flux footprint were girdled (decreasing LAI by ~ 1/3) to quantify the response of ecosystem carbon, water and energy fluxes in PJ woodlands to widespread piñon mortality.

As expected, piñon mortality triggered an abrupt shift in carbon stocks from productive biomass to detritus, leading to a 25% decrease in gross primary production, and >50% decrease in net ecosystem production in the two years following mortality. The girdled biome remained a carbon sink however, that was similar in strength to a nearby juniper savanna. Because litter and course woody debris are slow to decompose in these semiarid environments, ecosystem respiration initially decreased following mortality, and only increased two years post mortality following a large monsoon precipitation event. We also used a high resolution (5 x 5 meters) remote sensing time series from the RapidEye satellite constellation acquired over both PJ woodlands to test how well the structural changes measured remotely by RapidEye related to the carbon fluxes measured in-situ with the flux towers. In the three years following mortality, reduced competition for water in these water limited ecosystems and increased light availability has triggered compensatory growth in understory vegetation observed in both remote sensing and ground measurements, but not in surviving coniferous trees. Changes in surface energy balance triggered by mortality are largely due to a decrease in LAI and surface roughness which decrease the redistribution of heat and energy from the surface to the atmosphere. The result is an increase in surface temperature triggered by the piñon mortality. We discuss the results in terms of feedbacks triggered by these significant mortality events on the climate system.