

Ecohydrology of Piñon-Juniper Woodlands in the Jemez Mountains, New Mexico: Runoff, Erosion, and Restoration

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Woodlands of piñon (*Pinus edulis*) and oneseed juniper (*Juniperus monosperma*) in the Jemez Mountains at Bandelier National Monument in northern New Mexico exhibit greatly accelerated rates of soil erosion, triggered by historic land use practices (livestock grazing and fire suppression). This erosion is degrading these woodland ecosystems and damaging thousands of archaeological sites in this national park unit, with similar patterns evident in woodlands across much of the Jemez Mountains.

In 1993 long-term research began on the runoff and erosion dynamics of a piñon-juniper woodland hillslope at Bandelier National Monument in northern New Mexico (USA). In the 1.09 ha Frijolito watershed, erosion has been continuously studied at 3 spatial scales: 1 square meter, about 1000 square meters, and the entire watershed. This site is currently representative of degraded woodlands of piñon and oneseed juniper in this region, exhibiting substantial connectivity of exposed bare soil interspaces between tree canopy patches and obvious geomorphic signs of accelerated soil erosion (e.g., pedestalling, actively expanding rill networks). Ecological and land use histories show that this site has undergone a number of dramatic ecohydrological shifts since ca. 1850, transitioning from: 1) open ponderosa pine (*Pinus ponderosa*) overstory with limited piñon-juniper component and substantial herbaceous understory that supported surface fires and constrained soil erosion, to; 2) ponderosa pine with reduced herbaceous cover due to livestock grazing after ca. 1870, resulting in collapse of the surface fire regime and increased establishment of young piñon and juniper trees, to; 3) mortality of all of the ponderosa pine during the extreme drought of the 1950s, leaving eroding piñon-juniper woodland, to; 4) mortality of all mature piñon at or above sapling size during the 2002-2003 drought, with juniper now the only dominant woody species. Detailed measurements since 1993 document very high rates of soil erosion that are rapidly stripping the local soils. Runoff and erosion show extreme variability at multiple time scales since 1993, reflecting the inherently variable nature of monsoon convective thunderstorms (and occasional multi-day fall rainstorms) that drive the local hydrology. The multi-scale erosion data from the Frijolito watershed reveal surprisingly little drop off in erosion rate between the one meter-square scale and the 1.09 ha scale, in sharp contrast to the expected pattern that is observed at a nearby (7 km distance) relatively stable woodland watershed (cf. Wilcox and others 2003).

Since 1990 researchers and land managers have teamed up to experiment with restoration techniques in local PJ woodlands (Jacobs and others 2002). Our primary restoration treatment (thinning and application of slash mulch) is demonstrated to be an effective remediation technique for increasing herbaceous cover, stabilizing soils, and supporting surface fire. Monitoring shows that the restoration treatment also increases the resiliency of vegetation to drought effects. Long-term monitoring is essential to distinguish short-term variability from longer term trends, particularly in such climatically sensitive and highly dynamic ecosystems.

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