Sagebrush Steppe
SageSTEP
Treatment Evaluation Project

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Short and Long-term Effects of PJ Encroachment on Hydrology

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Land managers across the western U.S. are challenged by increased surface runoff and soil erosion caused by pinyon and juniper tree encroachment into sagebrush steppe. Encroaching pinyon and juniper commonly outcompete shrubs and perennial bunchgrasses for soil water and nutrients. Shrub and bunchgrass cover declines as tree cover increases, creating extensive bare ground in the intercanopy. These changes in vegetation and ground cover reduce infiltration of rainfall and promote concentrated overland flow during storms, with high rates of soil loss. Long-term soil loss may hinder re-establishment of sagebrush vegetation. To remedy this, managers use pinyon and juniper fuel-removal practices to re-establish shrub and bunchgrass cover and restore overall ecosystem structure and function. The effectiveness of these practices varies by site, due to site attributes, treatment methods, and post-treatment weather trends.

Over the past decade, SageSTEP hydrologists have been collecting and analyzing data to learn more about the impacts of woodland encroachment on infiltration, runoff, and erosion by water, and the effects of tree removal on water and soil movement in the short- and long-term. Much of this work has also been incorporated into tools that land managers can use to make decisions about tree control. The work spans multiple sites in the SageSTEP network and includes experiments conducted before and after tree removal by burning, cutting, and mastication.

Woodland Encroachment and Hydrology

Scientists intensively studied SageSTEP woodland sites prior to tree removal. They identified the primary factors that increase site susceptibility to high rates of runoff and soil loss following tree encroachment. These include: (1) reduced ground cover, (2) intercanopy bare ground in excess of 50% to 60%, (3) decreased surface roughness, (4) strong soil water repellency, and (5) reduced aggregate stability (reduced resistance to destructive forces). As pinyon and juniper dominate a site, the new community structure is one with extensive bare ground between isolated tree "islands." The areas underneath tree canopies commonly have layers of thick litter that promote infiltration and storage of intercepted rainfall and overland flow and that protect the soil surface against erosion forces. In contrast, the intercanopy area can be more than 80% bare and often represents more than 75% of the total area at a site. Hydrologically, this leaves a site relatively unstable because of the lack of understory vegetation to absorb runoff and prevent flowing surface water from removing critically important surface soil (Figure 1).

Figure 1. Overland flow experiment in degraded intercanopy area of untreated woodland at the Onaqui SageSTEP site. Dye shows area of high velocity concentrated flow and soil erosion.

Fuels Treatment and Short-term Effects on Hydrology

Burning

SageSTEP hydrologists collected data at three SageSTEP woodland sites in 2007 and 2008 after burning. Experimental plots under burned trees and shrubs generally showed a short-term reduction in infiltration and increase in runoff and erosion due to vegetation removal (Figure 2). The largest runoff and erosion increases occurred in areas underneath burned trees where soils were stable before burning, but had high soil water repellency. Fire exacerbated the effects of the pre-existing repellency in these areas. Effects of burning in intercanopy areas varied depending on the amount of ground cover present prior to burning.

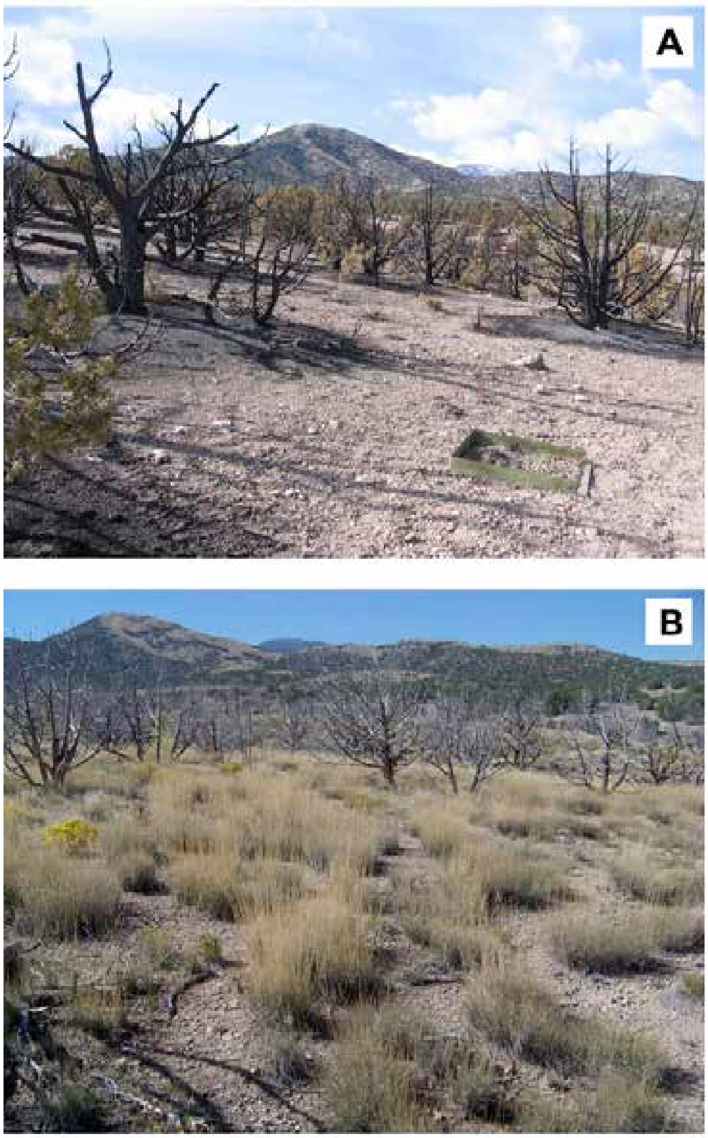

Figure 2. Onaqui SageSTEP Hydrology Site in 2006, the year of prescribed fire treatment (A) and 8 years after prescribed fire in 2014 (B). Note the dramatic change in intercanopy grass productivity after fire.

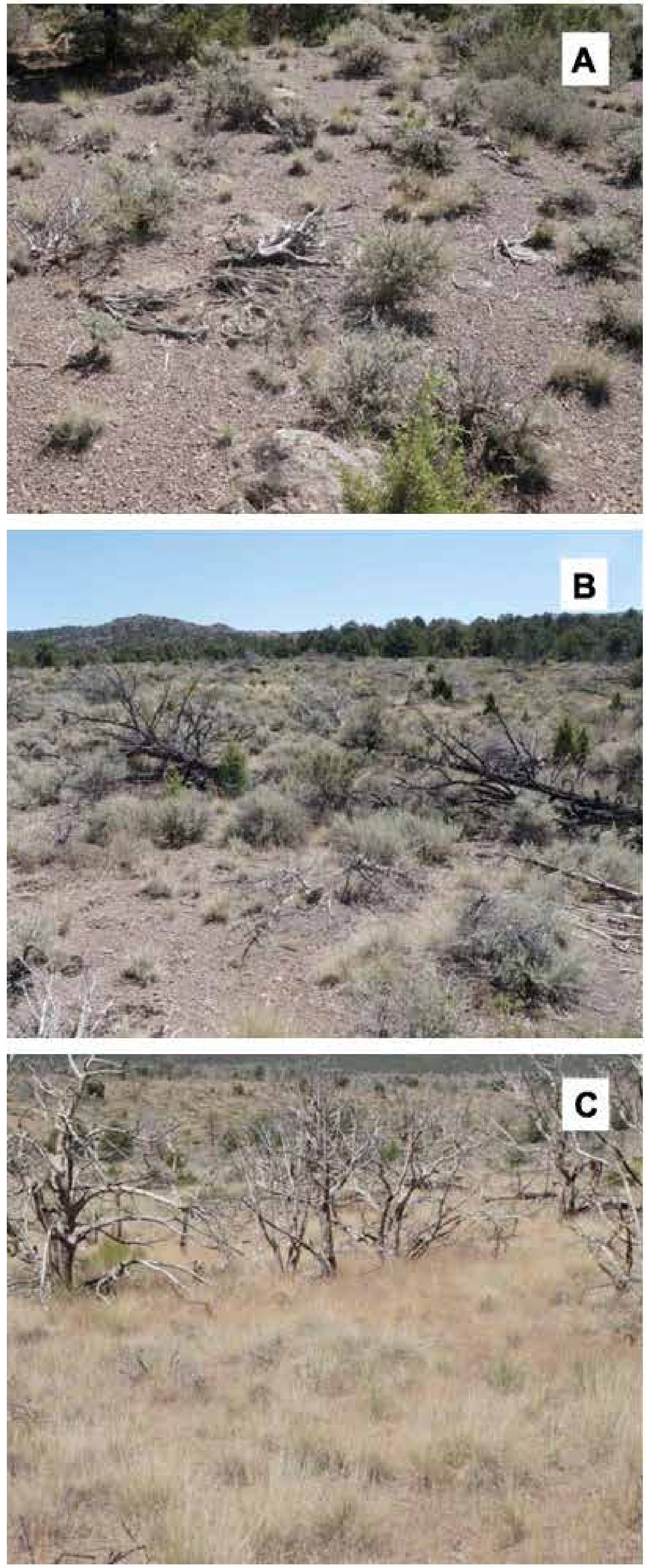

Figure 3. Degraded untreated intercanopy area (A) and cut treatment (B) and burn treatment (C) with increased cover at the Marking Corral SageSTEP hydrology site in 2015.

Intercanopy areas that were primarily bare were minimally affected by burning and had high rates of runoff and erosion before and after burning. Erosion increased slightly after burning of intercanopy areas that were moderately covered by vegetation and litter. After two years, slight increases in intercanopy grasses and forbs reduced erosion during simulated overland flow experiments, suggesting some hydrologic and erosion recovery in the intercanopy after two growing seasons. Erosion from the same experiments remained greater under burned compared to unburned trees two years after burning, but these locations typically represent only about 25% of the total area at these woodland sites.

Tree Cutting and Mastication

Experiments conducted the first few years after tree cutting suggest not much had changed after treatment. Vegetation in the short-term was still changing, and the subtle adjustments that had happened did not change hydrology and erosion relative to adjacent untreated tree-dominated areas. Runoff generated by overland flow experiments after tree cutting tended to route through gaps in contact of tree debris with the ground surface and generated similar erosion rates to woodland conditions. However, application of masticated tree debris on bare patches of the intercanopy within the Bullhog™ treatment improved infiltration and reduced erosion. As applied, the Bullhog™ treatment created clumps of masticated tree debris. Runoff and erosion were limited in these clumps, but were still high on remaining patches of bare ground. The experiments indicate that distributing the masticated tree debris throughout the intercanopy may act to improve infiltration and reduce soil loss on woodland encroached sites.

Longer-term Results

SageSTEP hydrologists returned to two of the woodlands in 2015 to study the longer-term effects of the fuel treatments on vegetation, hydrology, and erosion (Figures 2-4). Preliminary results show burning generally increased infiltration and reduced erosion in the intercanopy. Increased grass and forb cover on interspace plots (Figure 4) in the intercanopy buffered raindrop impact, improved infiltration, and limited soil loss. The impacts of burning on areas underneath tree canopies varied across the sites. At one site, runoff and erosion remained high on burned tree plots after nine growing seasons. In contrast, burning at the second site increased infiltration and reduced erosion. The different responses are associated with site specific

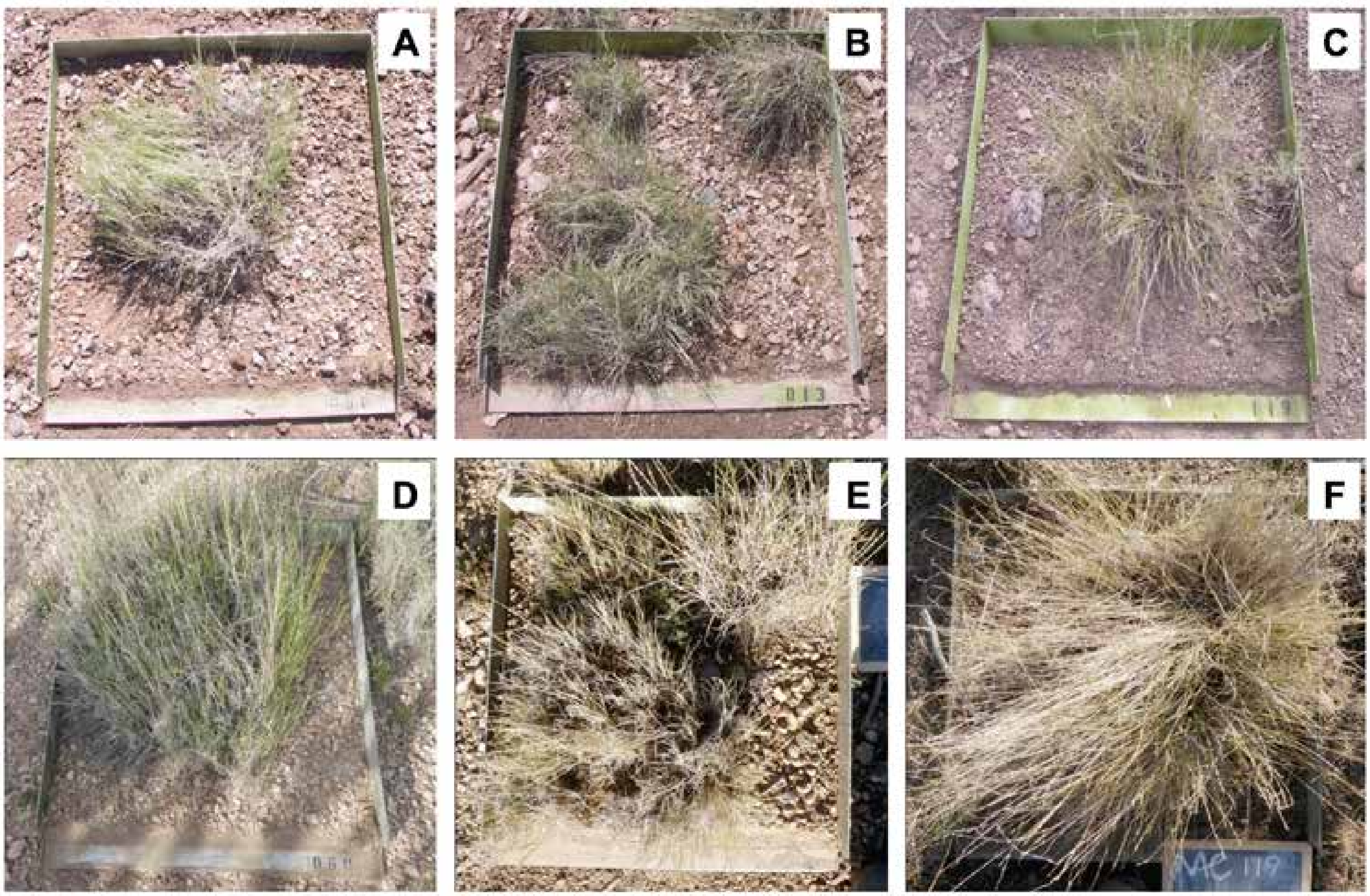

Figure 4. Repeat photographs of interspace plots before tree removal (A-C) and nine growing seasons after tree removal (D-F) at the SageSTEP hydrology sites.

differences in fire-removal of litter and coverage of grass and forb recruitment. Preliminary results also show that increased grass, forb, and litter cover in interspaces following the tree cutting treatment aided infiltration and reduced erosion at both study sites. As with burning, the longer-term effects of tree cutting on infiltration and erosion underneath trees varied across the sites. Cutting induced no longer-term change in infiltration or erosion at one site. At the second site, infiltration remained high for tree plots following cutting, but erosion was amplified slightly due to inherently high soil erodibility of the site soil type and a slight decline in litter cover. Preliminary results from the Bullhog™ treatment suggest placing masticated debris in the bare interspaces of the intercanopy increased infiltration and thereby reduced erosion rates by limiting runoff. Plots that were well-vegetated before the treatment tended to generate similar runoff, but less erosion following the tree mastication. These responses are associated with increased grass, forb, and litter cover following tree removal.

The longer-term results are preliminary, but suggest that hydrologic function and resistance to erosion generally increase where treatments enhance grass, forb, and litter cover in the interspaces between trees and shrubs. This cover acts to increase infiltration, delay runoff where it does occur, protect the soil surface from erosive forces, and filter soil movement. Evaluation of the ecological effects of shrub recruitment will require more time, as shrub recovery following tree removal can take decades. More details on the longer-term effects of vegetation changes on runoff and sediment dynamics, and further implications for management are forthcoming from this work. The longevity of the study presents a unique opportunity to quantify short- and long-term ecohydrololgic responses to pinyon and juniper removal in sagebrush steppe and provides valuable insight for the management of these landscapes.

Tools for Managers

Results of the hydrology study are being used in the USDA Rangleland-CEAP (Conservation Effects Assessment Project) as part of an effort to assess the benefits of conservation practices on US rangelands. The Great Basin is one of the initial focus areas of CEAP, and ARS scientists are working with the Natural Resources Conservation Service (NRCS) to combine SageSTEP data with other Great Basin data to create the NRCS-approved Rangeland Hydrology and Erosion Model (RHEM). Land managers and landowners can use the RHEM tool to better understand potential hydrologic impacts of various management actions.[1] See also RMRS-GTR-351: Ecohydrologic impacts of rangeland fire on runoff and erosion: A literature synthesis.

References

[1]Williams, C.J., et al. 2016. Incorporating hydrologic data and ecohydrologic relationships into Ecological Site Descriptions. *Rangeland Ecology and Management* 69:4-19. doi:10.1016/j.rama.2015.10.001.

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Research Highlight

A look at what the Great Basin science community is studying:

Using SageSTEP Data to Model Climate Change

Almost ten years after launch, data from the SageSTEP project is still bearing fruit. Scientists from Utah State University have tapped into an innovative method to model how sagebrush responds to climate change, partly inspired by the robust data available from the SageSTEP project.

Andrew Kleinhesselink and Peter Adler are using long-term field observations of big sagebrush (*Artemisia tridentata*), to estimate its sensitivity to changes in annual precipitation and temperature. Their model draws from 19 published and unpublished data sets and includes 7934 observations of year-to-year change in sagebrush cover or production from 131 monitoring sites across western North America. Among the data sets used, data from SageSTEP make up the largest proportion of the data in the analysis constituting nearly 35% of the total. They matched sagebrush data with seasonal weather data for each site and analyzed the effects of temperature and precipitation on year-to-year changes in sagebrush cover at each plot.

What's New Here?

Estimating climate change impacts on biodiversity is usually tackled in one of two ways – with species distribution models (SDMs -- observing where species occur, and using that to predict where they will be in the future) or with population models (predicting species abundance based on effects of climate observed at one site). Both of these approaches have limitations – distribution models lack the finesse of population dynamics and usually can't predict changes in population abundance, while population models based on only a few sites may not be applicable when scaled up to an entire species' range. Combining the strengths of both approaches may improve predictions for how widespread species respond to climate change.

The Best of Both Worlds

By using data from many sites spread across the range of sagebrush, Kleinhesselink and Adler were able to scale-up the population modeling approach to the size of a species distribution model. They found that sagebrush cover at each site tends to go up and down depending on the annual temperature experienced by the sagebrush populations at the site: sagebrush cover at cold sites increased in response to above average temperature, but cover at hot sites decreased in response to above average temperature. In contrast, precipitation did not have such a logical effect on sagebrush: sagebrush tended to increase in response to dry years at dry sites, but increase in response to wet years at wet sites. These findings suggest that temperature change will likely be a good predictor of sagebrush response in the future, but more work needs to be done to understand why sagebrush growing at drier sites did not respond positively to increased moisture.

While previous distribution models for sagebrush have predicted that global warming could drive sagebrush increases in cold regions and declines in hot regions, Kleinhesselink and Adler reach this conclusion using a new model with an entirely different approach and an independent set of data. Their finding should strengthen our confidence that sagebrush will respond to temperature increases across its range. This result will be of immediate value to ongoing conservation planning for the Greater Sage-Grouse (*Centrocercus urophasianus*), among other conservation goals.

How SageSTEP Helped

Obtaining data for such a large-scale analysis is a challenge. The scientists needed data sets that had both repeat measurements and covered a broad scale. SageSTEP data had both. It covered a large geographic range, and included the most individual observations. In fact, Kleinhesselink noted that he could theoretically remove most of the other data and use just SageSTEP numbers, and get similar results. He also noted the importance of SageSTEP making its data available to him as an outside researcher early on in his project. Going forward, long-term data sets such as SageSTEP will be essential for validating new models such as this one, he said.

For more information about using SageSTEP data as part of your research, contact Jim McIver at james.mciver@oregonstate.edu **or call 435-797-8455.**

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