5-2017

SageSTEP News, Spring 2017, No. 30

SageSTEP

Sagebrush Steppe
SageSTEP
Treatment Evaluation Project

Inside this Issue:

Issue 30, Spring 2017

Ecological Consequences of Pinyon and Juniper Removal; Six Years Later

The longer-term consequences of tree removal by prescribed fire or cutting (chainsaw cutting or mastication) is becoming easier to evaluate, thanks to recently published research by Rachel Williams, Bruce Roundy and others. This research details the fate of forbs, grasses, and shrubs (the understory) after treatments designed to address ongoing pinyon-juniper expansion at six years after treatment. The work then compares these patterns with those observed just three years after treatment. The ecological results after chainsaw cutting, or prescribed fire can appear similar in the short-term, but trajectories sometimes diverge over time. The authors measured understory vegetation cover and density at ten sites, and also included a gradient of before-treatment tree dominance (from virtually no trees to crowds of pinyon-juniper) to better understand how understory response differed under varying pre-treatment conditions.

Tree removal through cutting or prescribed fire is commonly used to restore structure and function to sagebrush communities. But how much trees dominate before treatment occurs plays a vital role in the eventual successional trajectory at these sites. Recovery depends on what species remained on site under PJ-encroached conditions, and on what type of disturbance occurred during treatment. At places with higher tree cover before treatment, both shrub and herbaceous cover took longer to recover … if shrub and herbaceous cover are already in decline at a site, treatments like cutting or prescribed fire and a lack of sprouting shrubs and seed sources make native recovery that much harder to achieve. Adding to that, a vacuum in native vegetation tend to be filled by invasive species, especially on warmer and drier sites.

Photo Series 1. A series of photos of a prescribed fire-treated plot at Onaqui, Utah -- pretreatment in 2006, three years after the prescribed fire in 2009, and after six years in 2012.

Prescribed Fire Recovery

Different groups of vegetation respond to prescribed fire in different ways, and patterns have emerged more clearly over time. Prescribed fire initially increased annual and exotic forb cover, as they took advantage of released nutrients and additional moisture in the soil after the removal of trees. Increased cover of annual and exotic forbs was evident three years after treatment, especially at high pre-treatment tree density levels. But by year six, levels had stabilized, and cover for these two groups was essentially back to pre-treatment.

The story of cheatgrass is still unfolding, but some patterns were reinforced with this research. Cheatgrass likes disturbance, and does better after fire than it does after cutting treatments. Cheatgrass cover on burned plots had not yet settled at six years after treatment (Fig. 1), and additional monitoring is necessary to give managers a full grasp of the ultimate outcome at most sites. Over time, cheatgrass increased across all but the highest initial tree density plots. Typically, cheatgrass cover decreases as perennial grass cover increases with time after fire, but the ultimate story of cheatgrass dominance on these sites is still evolving, and future monitoring will be essential to see the complete story.

Tall grass cover continued to follow a recovery pathway over time, exceeding cover on untreated plots at six years after treatment, especially at sites with high pre-treatment tree densities (Fig. 2). Fire burned the aboveground portion of most tall grasses (Photo Series 1 and 2), and may have even damaged the roots, but it clearly wasn't enough to kill them. Although mechanical removal of trees appeared easier on tall grasses, we expect the burn results to look more like mechanical results at ten years out, if the current pattern continues.

Perennial forb cover increased at three years after both fire and cutting treatments, but trajectories converged at six years. While we expect some about-site and among-treatment variation in perennial forbs as time proceeds, it's likely that mean cover of this functional group has stabilized for the most part.

Fire is tough on sagebrush. Shrub cover and density that had been initially reduced by prescribed fire recovered under low to mid pre-treatment tree cover conditions at six years after treatment, mainly with sprouting shrubs, like rabbitbrush. But big sagebrush hadn't recovered even after six years (Fig. 3). The authors noted that sagebrush seedlings are starting to come back in, but they vary greatly from one site to another and have generally decreased from 3 to 6 years since treatment. Recovery of sagebrush canopies could take 15 to 50+ years following fire.

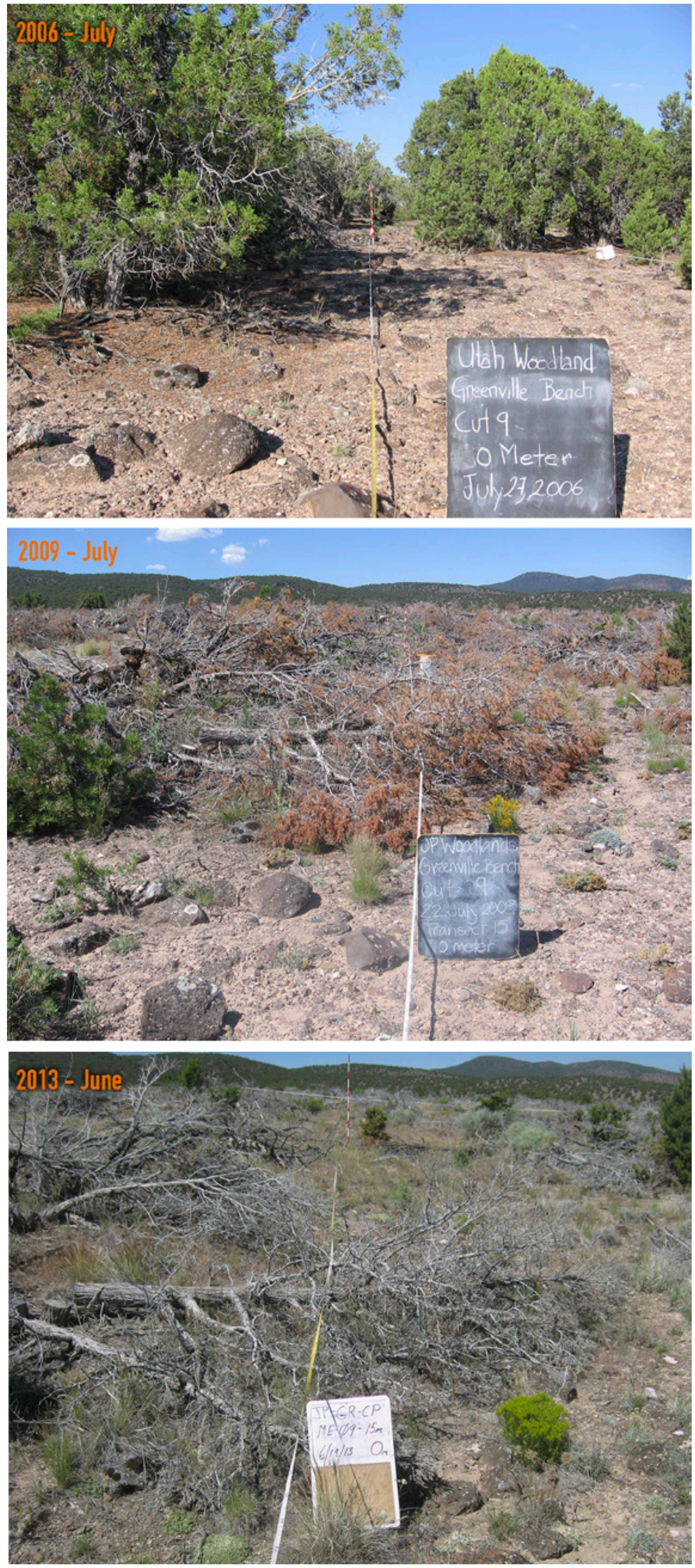

Photo Series 2. A series of photos of a mechanically-treated plot at Greenville Bench, Utah -- pretreatment in 2006, three years after cutting in 2009, and just after the six year mark in 2013.

Mechanical Treatment Recovery

Cutting benefited perennial forbs and shrubs, measured at both three and six years. A major advantage of mechanical tree reduction, compared to prescribed fire, is that it also maintains shrub cover. Cutting increased total shrub cover compared to untreated plots, especially at lower pre-treatment tree cover. Sagebrush cover and density paralleled shrub response, with roughly 10% increase in cover by six years at the lowest initial tree cover levels (Fig. 3). However, cutting should not be expected to rapidly recover sagebrush when initiated at mid to high pre-treatment tree dominance.

Cutting favored tall grasses compared to shrubs when implemented at higher pre-treatment tree cover, as tall grasses bounced back six years after mechanical treatment all along the initial tree density gradient. This indicates that tall grasses are not as sensitive to initial tree cover as are shrubs. As such, when trees were removed at mid to high pre-treatment tree dominance levels, tall grasses were in place to use the additional soil water made available after treatment. Tall grass density did not differ significantly on cut plots from three to six years, but the trend was positive.

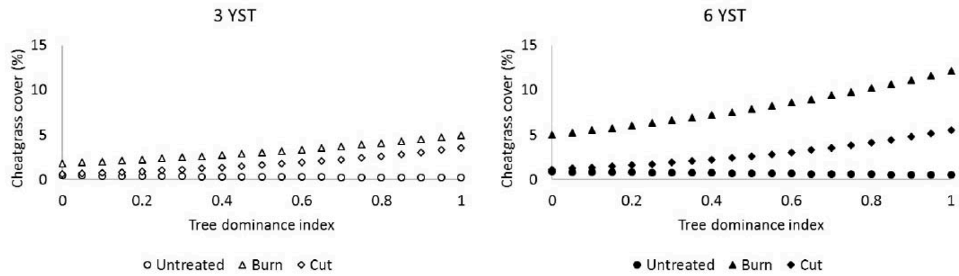

Figure 1. Vegetation cover of cheatgrass 3 and 6 years (YST) after conifer removal treatment in relation to treatment method and tree dominance index at the time of treatment.

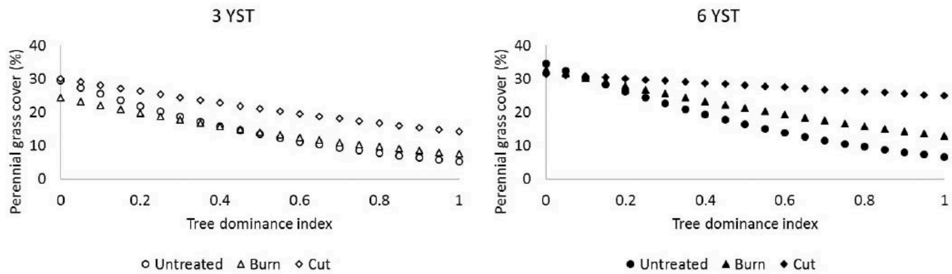

Figure 2. Vegetation cover of perennial grass at 3 and 6 years (YST) after conifer removal treatment in relation to treatment method and tree dominance index at the time of treatment.

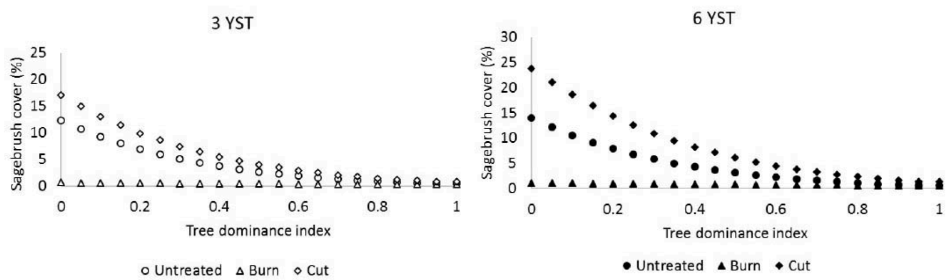

Figure 3. Vegetation cover of sagebrush 3 and 6 years (YST) after conifer removal treatment in relation to treatment method and tree dominance index at the time of treatment.

Prescribed Fire v. Cutting

Prescribed fire effectively controls trees and woody fuels, but it opens the door for cheatgrass invasion, and almost eliminates sagebrush cover. At six years post treatment, in areas with high initial tree dominance, cheatgrass levels increased under both treatments, but fire allowed cheatgrass to flourish more than cutting did. Perennial grasses especially did better at six years post-treatment under cutting than with fire (Fig. 2). Sagebrush at low initial tree dominance did best with cutting. Six years after a burn was not enough to record even partial recovery for sagebrush. Cutting, of course, puts all of the woody canopy fuels on the ground. Follow-up treatments may be required to control tree saplings on most sites. Saplings occurred on 50% of burned and 70% of cut subplots after six years.

Implications

To retain the shrub component on sagebrush sites and increase ecosystem resilience and resistance, the authors recommend mechanically reducing conifers at lower tree cover to best maintain perennial herbaceous cover and resist cheatgrass. But prescribed fire best controls trees and woody fuels, and can be effective for increasing perennial herbaceous cover on cooler and wetter sites where risk of cheatgrass is minimal. But fire should be avoided in areas where sagebrush is considered an important component, and on warmer sites where the risk for cheatgrass is high.

If treatments are delayed until PJ tree cover is high, tree reduction could create annual or perennial grassland instead of a grass/shrub mix, leading to a need for expensive revegetation. How initial tree dominance effects the outcome of tree-reduction treatment needs to be incorporated into managers' models to better predict the ultimate outcome of these long-term projects.

Rachel Williams is a Fish and Wildlife Biologist with the US Fish and Wildlife Service in Bishop, California.

Bruce Roundy is a professor in the Department of Plant and Wildlife Sciences at Brigham Young University in Provo, Utah.

Research Highlight

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

Developing Technology to Reduce Seeding Failure

Implementing seeding projects in sagebrush steppe communities after wildland fire offers a major opportunity to restore ecological function and wildlife habitat. Unfortunately, arid land seedings often fail, as newly germinated seedlings are lost to harsh environmental conditions. To counter this, Matthew Madsen and Bruce Roundy at Brigham Young University are developing new technologies to improve seeding success on these complex and sometimes inhospitable landscapes.

In the western United States, seeding projects are usually done in late autumn or early winter. Dispersing seeds within that time period allows seed dormancy to be released over the cold winter months and ensures that seeds are in place when soil temperature and moisture are right for germination and growth in the spring. But in the time between the cold autumn nights and spring thaw, significant seed loss and seedling mortality occurs. Over 70% of grass seeds planted in autumn germinate prior to winter onset. Freezing may be a significant source of mortality to these young seedlings. In a recent analysis of soil temperature data from 14 SageSTEP sites, Roundy and Madsen (2016) found that sagebrush steppe surface soils had more than 60 freeze-thaw cycles between October and late March (Fig. 1). Seeds and seedlings may also experience mortality over the winter from predators or pathogens, drought, and expenditure of seed food resources (Fig. 2a).

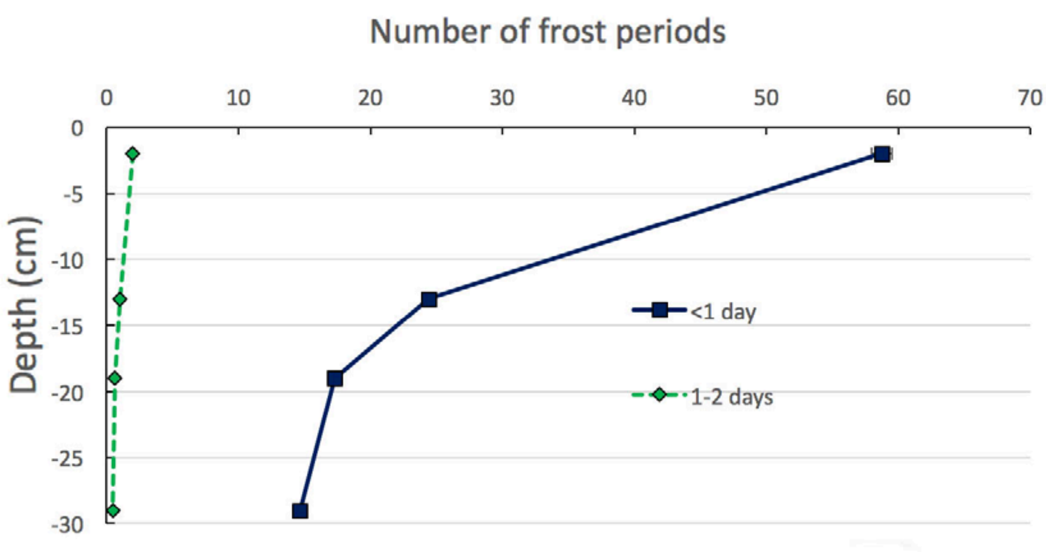

Figure 1. Most frost periods last less than one day, but that is enough to be a significant source of mortality to young seedlings.

But delaying restoration efforts until spring does not guarantee success either. The springtime soil is either frozen or too muddy for seeding equipment to muck its way through. Plus, seeds dispersed in the spring often don't have time to germinate because of short soil incubation periods, cool spring temperatures or dry conditions. And when germination does happen, seedlings may not have adequate root development to survive through the summer drought period (Fig. 2b).

Seed enhancement technologies may boost the success of seeding restoration projects by manipulating the timing of germination (Madsen et al. 2016). Madsen and Roundy are developing new seed enhancement technologies and planting strategies that would allow seeds of native plants (grasses, forbs, and shrubs) to mimic germination patterns of invasive annual weeds, and to germinate at times that

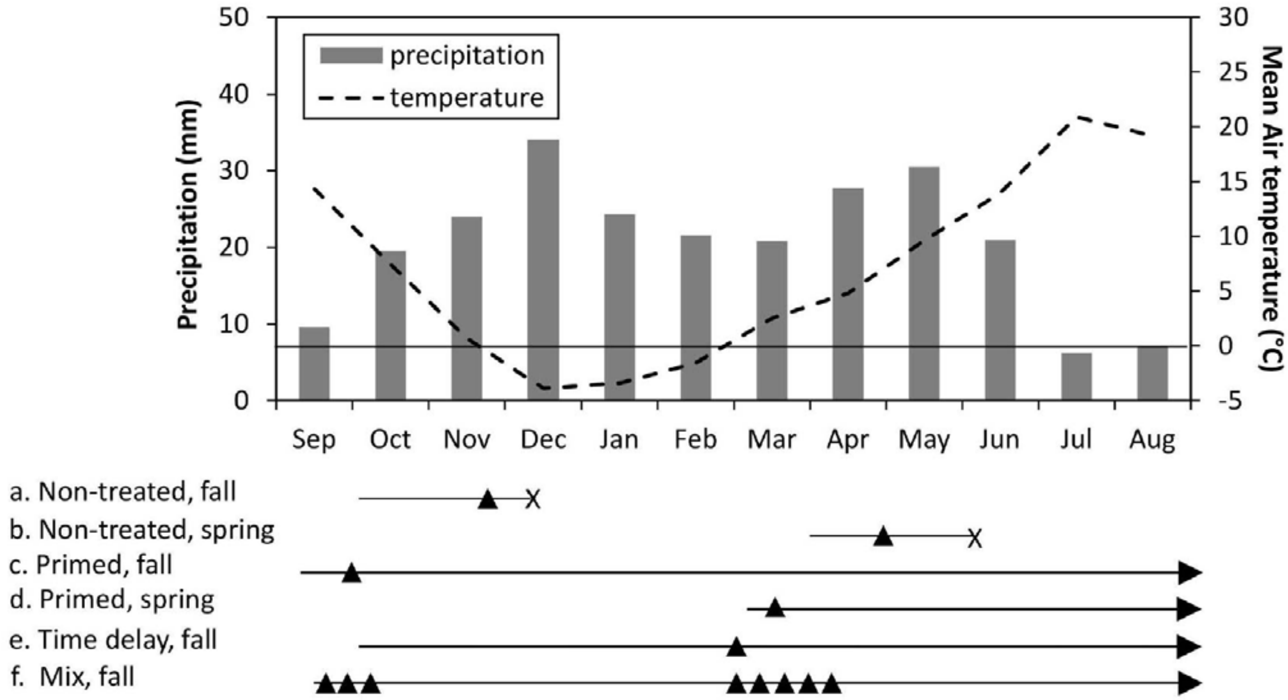

Figure 2. (Top) The long-term average monthly precipitation and mean air temperature near Rush Valley Utah. (Bottom) Possible seeding scenarios based on planting date and seeding technology. Start of the line = seeding date, "▲" = germination timing, "X" seedling mortality, "►" seedling survival. a. Nontreated seed sown in fall germinate in winter and experience high mortality. b. Non-treated seed sown in the spring germinate just prior to summer and then desiccate due to lack of soil moisture. c. Primed extruded seed pellets allow germination to occur early in the season so plants can grow to a point they can survive through the winter. d. Primed extruded seed pellets allow for faster germination, which increases the time seedlings can grow during conditions of high soil moisture to improve seedling survival. e. Time-release seed coating avoids winter mortality by delaying seed germination until spring. f. Mix of non-treated seed and seed enhancement technologies planted in the fall increases the probability that some seeds will germinate during a period that is optimal for plant establishment.

are more favorable for plant establishment. These technologies either speed up or delay seed germination at predicable rates. They can be used together within the same seeding mix to expand the period that seed germination timing can occur and increase the probability that some seeds will germinate during periods that are best for plant establishment.

Seed Priming and Time Delay

For more rapid germination, seeds can be primed. Partially hydrating seeds allows the germination processes to begin. The primed seeds are incorporated into pellets that can be drilled or broadcast seeded. These seeds have a more rapid germination and emergence in autumn, which increases the period plants can grow and may make it more capable of surviving harsh freezing conditions later on (Fig. 2c). For spring plantings, priming may allow germination to occur early in the season and improve the probability that seminal roots of seedlings stay ahead of an advancing drying front and allow sufficient time for adventitious roots to develop before the extended drought period of summer (Fig. 2d).

On the flip side, a manipulated delay that prolongs the germination process could work advantageously for seeds sown in autumn – if it puts off seed germination until late winter or early spring. Madsen and Roundy are developing an approach to delay seed germination through the use of abscisic acid (ABA). Under laboratory conditions, their research is showing that the amount of ABA applied to the seed is correlated with the length of time it takes the seeds to germinate. Madsen hopes that in the field this technology will minimize seedling mortality over the winter while allowing seeds to capture early spring moisture resources (Fig. 2e).

Hedging the Bet

Without a crystal ball, it is impossible to know from one year to the next when the optimal time is for seed germination in arid and semi-arid regions. To hedge their bet, Madsen and Roundy are banking on strategies that minimize mortality by staggering the timing of seed germination through the population (Fig. 2f). Many invasive weeds

use similar strategies. Cheatgrass, for example, has multiple germination events, from late summer until mid-May of the following year.

Use of these technologies will increase the cost of restoration efforts. But given the typically low success rates of arid land seeding, Madsen and Roundy think that these costs will be offset through improved establishment success rates. If seed enhancement technologies increase the success rates of individual seeds, it is also conceivable that direct cost savings could be made because less seed would be required to complete the restoration project. Indirect savings may also be pocketed by maintaining functioning ecosystems through lowering wildfire suppression costs and maintaining landscapes that support both anthropogenic activities and a diversity of wildlife habitats.

Matthew Madsen and Bruce Roundy are from the Department of Plant and Wildlife Sciences at Brigham Young University.

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