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SageSTEP

Sagebrush Steppe
SageSTEP
Treatment Evaluation Project

Issue 21, Summer 2013

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Capturing the Big Picture

Research results communicate environmental connections and larger ecosystem story

For eight years, SageSTEP has been working to fill a void. Sagebrush communities in the Great Basin are highly threatened, with half of the original area already lost to cheatgrass invasion and juniper encroachment (Fig. 1). These landscape changes have increased fire risk. They've reduced forage, water, and wildlife habitat, including that of the Greater Sage-Grouse. Management efforts to reset the balance of vegetation in the Great Basin and surrounding areas have been hampered by lack of information. Managers needed more information about the effectiveness of different types of restoration practice like prescribed burning and herbicide application. They needed feedback on how the overall ecosystem would react to treatments. They needed research conducted over multiple sites, yielding data that recorded change over time which could be applied to local environmental circumstances (Fig. 2).

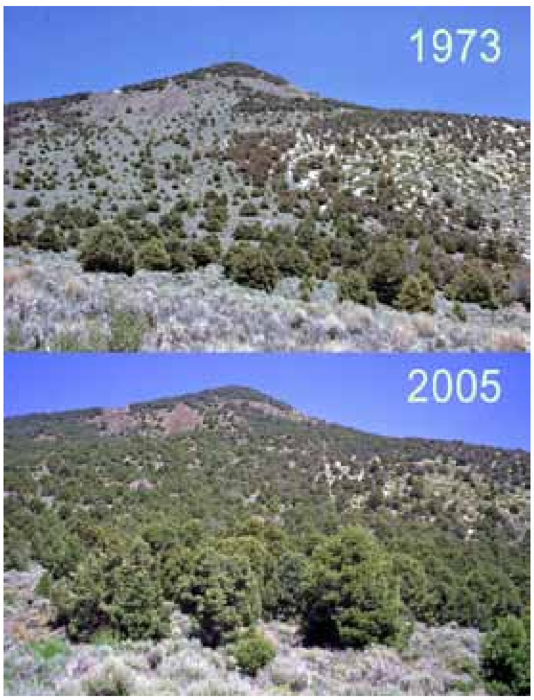

Figure 1. Juniper encroachment over time in the Shoshone Mountains, Nevada. Photos by R. Tausch

In 2006, SageSTEP scientists and their manager partners began using restoration treatments at 18 study sites – prescribed fire, clearcutting, mastication (tree shredding), mowing, and herbicides. They studied response to these treatments across the landscape – in vegetation, the fuel bed, soils, water, erosion, wildlife, and invertebrates. Collaborators at universities and government agencies in six western states are now working together to analyze and interpret field data. SageSTEP scientists have already reported many results: in our newsletter, in conferences and workshops, in tours, and in scientific journals. Our long-term presence and focus on outreach

> "Sagebrush communities are highly threatened, with half of the original area already lost to cheat-grass invasion and juniper encroachment."

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have made SageSTEP a familiar name among those working in sagebrush-steppe systems.

Click the **Blue** links to be connected to more information.

What follows is a compilation of some important short-term results of the SageSTEP experiments through the third year after treatment. As times passes, SageSTEP will be able to provide even more meaningful information about these kinds of trade-offs, as ecosystem components begin to stabilize after their initial short-term responses to the treatments.

The results are separated into three groups; the human dimension, and two land types; woodland experiments that evaluate restoration treatments on sagebrush and bunchgrass communities that have been encroached by woody juniper, and sage-cheat experiments that focus on restoration in areas threatened with cheatgrass invasion.

The Human Dimension

Socio-Political Considerations. Since the Bureau of Land Management and the U.S. Forest Service manage most sagebrush-steppe land in the U.S., the public has a legal say in what these agencies do on the land. Public support for restoration can make it easier for agencies to use treatments, while public opposition can stop things in their tracks. Our social science research has focused on: identifying stakeholder concerns and how they receive information; (Shindler et al. 2007) how groups perceive the current health of sagebrush-steppe lands; (Shindler et al. 2011) and whether they accept land management treatments and trust management agencies. We found that most citizens supported the use of prescribed fire, livestock grazing, felling, mastication, and mowing as useful fuel reduction or restoration practices, but herbicides and chaining received substantially less support. Unfortunately, acceptance of land management practices did not equate to confidence in federal agencies to implement those practices safely or effectively (Fig. 3). Most respondents believed that agencies did not adequately use public input for decision-making, leading to a general lack of trust.

When we re-assessed the same group in 2010, however, we discovered subtle changes in the results

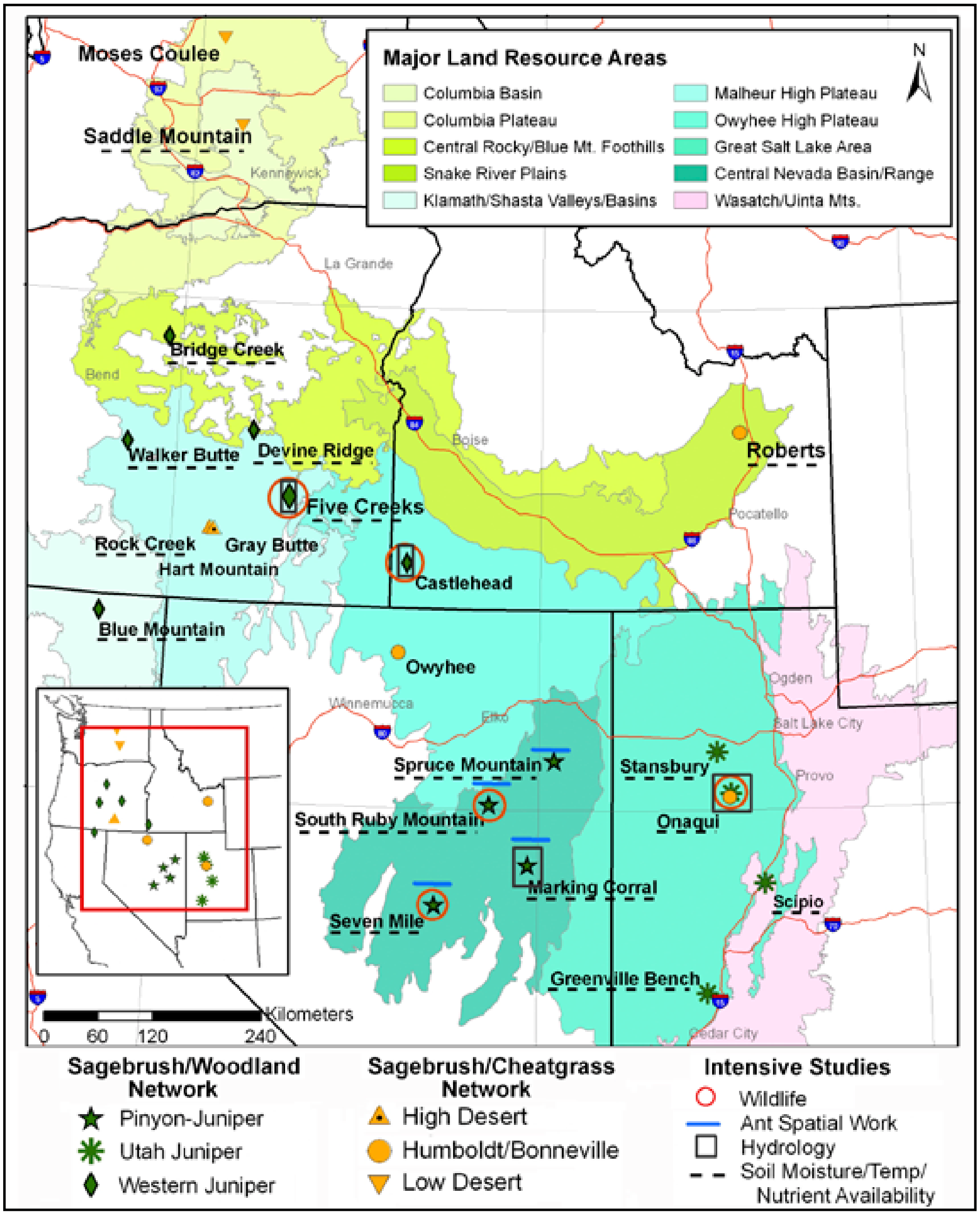

Figure 2. SageSTEP research sites and major land resource areas.

(Gordon et al. 2013, in review): Great Basin residents became more aware of key threats facing rangelands and were more interested in having a role in making management decisions. They were slightly more positive about their interactions with agency personnel, although a gap between trust and acceptance remained. Findings suggest that efforts to build trust at the field office level through communication and collaboration will have the greatest influence on acceptance of management practices in the Great Basin.

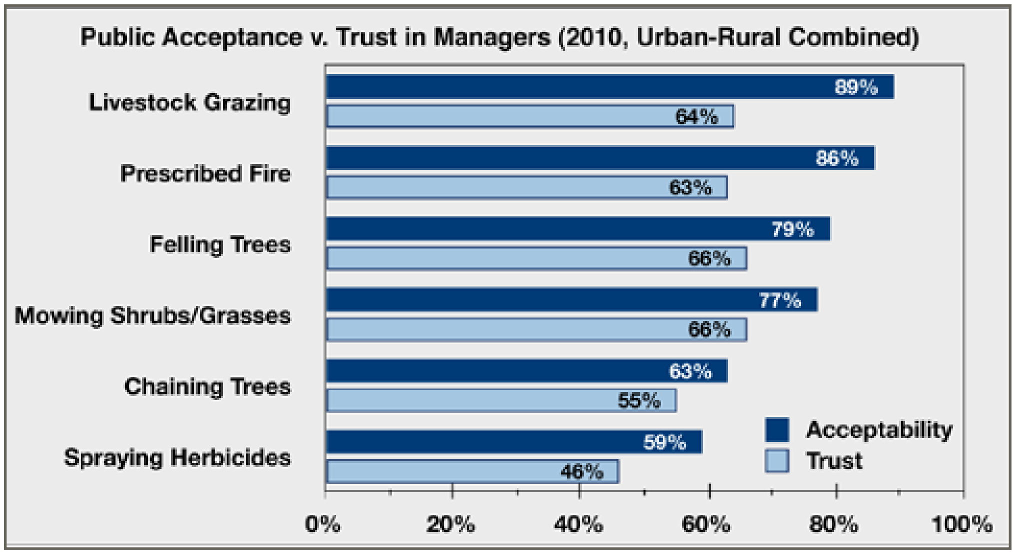

Figure 3. Public acceptance of fuel reduction/restoration practices versus trust in managers to conduct those practices.

Economic Incentives. This research has focused on understanding economic incentives to do fuel reduction and restoration activities. For land management agencies, economic models (based on treatment costs versus wildfire suppression costs) predict that the biggest payoff comes from treating land that is 'intermediately degraded.' (Landis 2010; Rollins 2010: SageSTEP Newsletter 12). Treating areas that have been heavily infiltrated with non-native species doesn't pay, because treatment is generally ineffective in returning them to a healthier state. Treating native vegetation without significant levels of non-native infiltration and low levels of ground fuels also has little economic benefit.

For ranchers, ranch income is not likely to ever be sufficient to support the adoption of preventive land treatments of the type studied by SageSTEP (Kobayashi et al. 2009). Because economics are driven by relatively short-term considerations, it may never pay for a rancher to conduct preventive management, even though a single wildfire that burns through his allotment would very likely put him out of business (Maher et al., in review).

Woodland Experiment

Treatment Effectiveness. For the woodland experiment our target was to reduce the dominance of pinyon pine and/or junipers. We used mechanical treatments (i.e. clearcutting, mastication) to reduce trees, and prescribed fire to reduce both trees and shrubs. At 11 treated sites, we reduced tree canopy cover to less than 1% in mechanically treated plots and to less than 5% in prescribed burn plots (Roundy et al. 2013, in review). Areas treated with prescribed fire had a lower shrub biomass after two years than areas treated mechanically (Bernau and Bunting 2013, in review). Woodland treatments were generally effective in accomplishing the reduction in woody vegetation.

Fuels and Potential Wildfire Behavior. Treatments were designed to change the fuel bed so the projected fire regime would shift to lower intensity/higher frequency fires. There are two components of the fuel bed that are relevant to this objective: down woody fuel and herbaceous fuel. In younger stands where trees don't drive ecological processes (phases I and II), prescribed fire consumed enough small down wood to decrease the relevant fuel bed; in older phase III stands, down wood mass either did not change or increased after burning, probably because fire killed trees, and some of that burned material ended up on the ground surface (Bernau and Bunting 2013, in review). Mechanical treatments had nearly the opposite effect in the short term, typically doubling or tripling small down wood mass, particularly in phases II and III areas. Mechanical treatments, therefore, clearly are not surrogates for prescribed fire. They tend to increase down woody mass and change the distribution of those fuel components.

For the herbaceous part of the fuel bed, treatment of any kind significantly increased burnable fuel,

especially in phase III woodlands. This is likely because the removal of woody vegetation resulted in an increase in available soil water during the growing season, which was then captured by grasses and forbs as they grew back to re-claim the site. Prescribed fire removed live canopy fuels and consumed much of the down woody material, leading wildfire intensity (flame height, rate of spread, etc.) and severity (ecosystem effects) to decline. More herbaceous vegetation would increase the rate of wildfire spread, especially if treated stands were dominated by cheatgrass, but because flame heights would be so low, fire intensity would still be low. Stands treated by prescribed fire therefore, would serve as more reliable defensible space in a wildfire suppression effort and would have less severe effects on soils, seed banks, and vegetation.

Phase I: Shrubs and grasses dominate and influence ecological processes.

Phase II: Trees are co-dominant with shrubs and grasses.

Phase III: Trees are dominant.

As with prescribed fire, we expected the mastication treatment (tree shredding) to reduce wildfire intensity. The biggest difference between the areas treated with mastication and those with prescribed fire, we expected, would be in wildfire severity. Because mastication leaves behind a compact fuel bed and doesn't impact the litter mat at the base of larger trees, fire severity would increase. Dry fuel beds would ignite and smolder after the flaming front of the wildfire passed. The combination of heat and duration on the ground would heat the soil, killing microbes and seeds, changing soil chemistry, and killing the roots of the grasses and forbs that managed to survive the fire.

As it happened, these predictions were actually put to the test naturally in 2009 at our Stansbury site, when the Big Pole wildfire burned through all of our 2007-treated plots (Fig. 4). When we returned to Stansbury to measure vegetation in the spring after the wildfire (2010), we found that vegetation cover losses were much greater on the mechanical and control plots (around 50%) compared to the prescribed burn plots (less than 10%)(Roundy et al. 2013, in review). These results support the prediction that treatments to reduce downed wood will be effective tools for changing the fire regime in woodland-encroached sagebrush-steppe systems. Of the treatment tested by SageSTEP, only the prescribed fire treatments reduced relevant fuel components in the short-term.

Soil Water Availability. Both mechanical and prescribed fire treatments set into motion a cascade of effects, beginning with the increased availability of soil water. Tree removal increased the time water was available in the soil during the spring by up to 26 days (Fig. 5). The largest increases in soil water were observed in treated phase III woodlands, where trees had filled in and appropriated most of the water before treatment. These results show that it is best for managers to treat encroached woodlands in areas when there is still enough cover of desirable plants to use the increased water after tree removal. Otherwise, phase III woodlands will be at risk of invasion from species

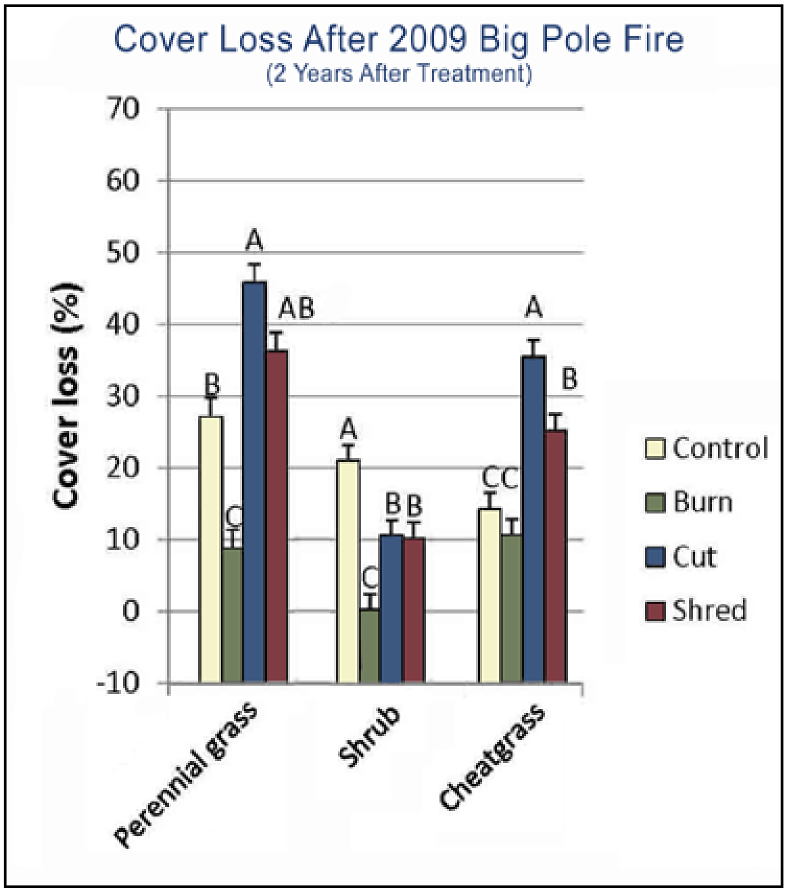

Figure 4. Cover loss 1 year after the Big Pole wildfire burned untreated control and fuel control treatment plots at the Stansbury Mountain site, Utah. Bars with different letters above for a functional group indicate a significant difference (P<0.05) among those treatments. Inferences apply to this Stansbury site only.

like cheatgrass. While these short-term findings identify the risks of certain types of treatments (e.g. prescribed fire) in certain types of areas (e.g. phase III woodlands), there are still important questions to answer. It may take several years before these semi-arid sagebrush systems settle into patterns stable enough to give us confidence in predicting future conditions.

Hydrology. Because trees are such effective competitors for water, woodlands in an advanced stage of encroachment tend to be devoid of understory vegetation, such as shrubs, grasses, and forbs. When a moderately steep hillslope lacks this understory vegetation, erosion and runoff rates become problematic. Working at the Onaqui and Marking Corral pinyon-juniper sites, we found that prior to treatment, runoff and erosion rates were relatively low in the litter-rich areas underneath the tree canopy (tree coppices), primarily due to high water infiltration rates. In the intercanopy between trees however, erosion rates were 3 to 6 times as high. In particular, when the proportion of bare ground on a hillslope exceeds 50%, erosion begins to increase exponentially (Pierson et al. 2010) (Fig. 6). These observations confirm that when left untreated, highly tree-encroached sagebrush steppe lands pose a substantial risk of soil loss, especially during high intensity convective storms.

When we treated hillslopes with prescribed fire, we saw that burned tree coppices yielded substantially more sediment than unburned coppices, as did the burned shrubs between trees (Pierson et al. 2013, in review). Mechanical treatments were more effective in reducing short-term runoff and sediment transport rates, both in tree coppices and in interspaces between shrubs and trees. The most effective treatment was mastication, in which shredded tree residue reduced runoff and erosion rates, and increased water infiltration rates (Cline et al. 2010). Although prescribed fire did cause short-term increases in runoff and erosion, these effects should be evaluated in the context of the big picture – avoiding more serious hydrological consequences of woodland persistence and severe wildfire.

That said, it is important to note that work from our western juniper hydrology site demonstrates that not all wildfires are created equal, and that burning may

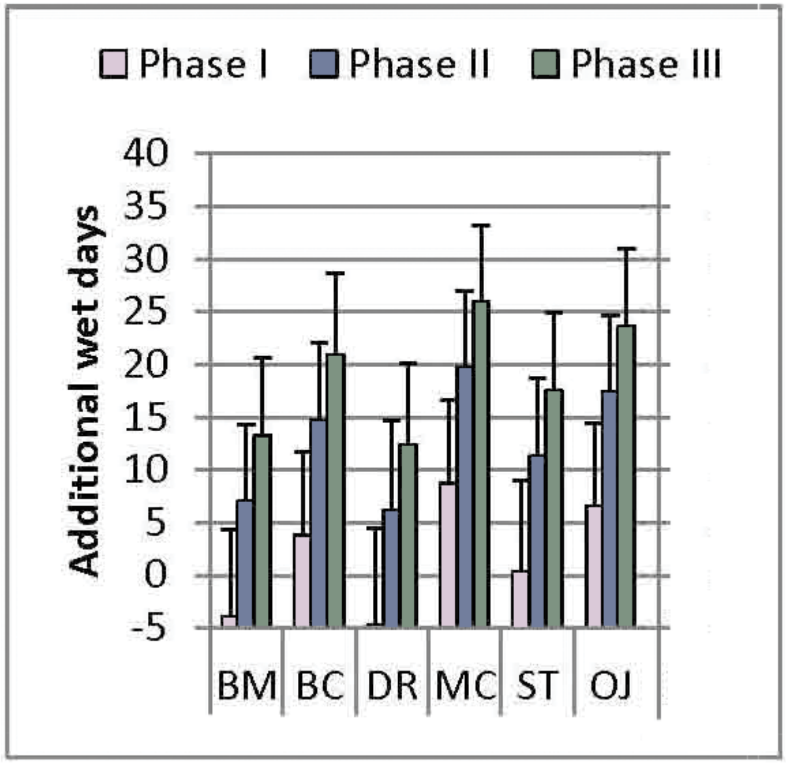

Figure 5. Water production: The number of days of additional water made available by treatment at six SageSTEP site two years after treatment.

actually reduce intercanopy erosion rates within the first few years after wildfire (Pierson et al. 2013, in review; Williams et al. 2013, in review). In July 2007, the huge Tongue Complex wildfire burned through untreated encroached woodland at our Castlehead site in southwestern Idaho. While this wildfire did increase short-term erosion rates, the magnitude of these effects was only slightly greater than what we observed at our prescribed fire sites at Onaqui and Marking Corral (Williams et al. 2013, in review). Furthermore, substantial re-growth of herbaceous vegetation in the interspaces after the wildfire significantly reduced erosive energy and sediment transport on our hillslopes there. Certainly, this wildfire-burned woodland remains highly vulnerable to convective storms in the short-term, at least until sufficient herbaceous vegetation re-grows to reclaim the site. But this regrowth process is now well underway, thus demonstrating that wildfire can, under certain conditions, reverse the soil erosion trajectory that characterizes highly tree-encroached sagebrush steppe lands.

Vegetation. Tree removal by fire had markedly different effects on vegetation and ground surface compared to removal by cutting (Miller et al. 2013,

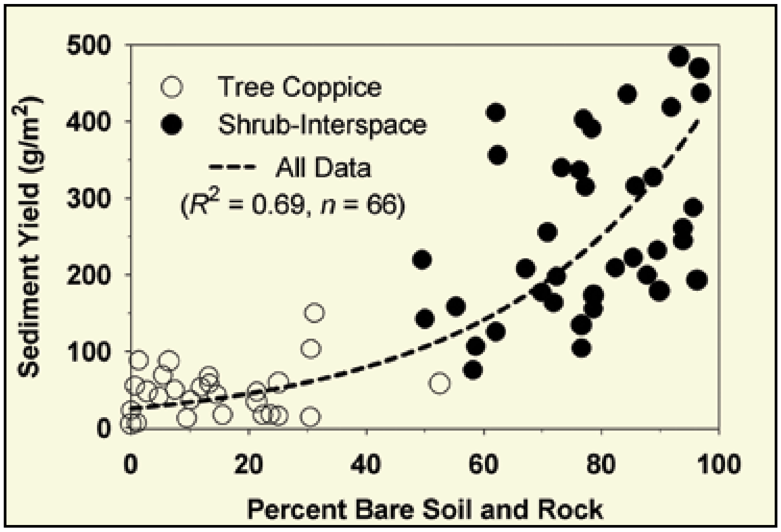

Figure 6. Relationship between bare soil/rock and sediment yield for tree copices and shrub interspaces at tree-encoraoched sagebrush steppe sites.

in review). As expected, cutting had no effect on shrubs, while fire reduced shrubs to about one-tenth their original cover. Fire also increased bare ground in the first season after treatment, due to the removal of surface fuels and litter, and decreased the cover of tall perennial grasses and biological soil crusts. Mechanical treatment also decreased crust cover. Differences between treatments persisted through the second growing season, with some of the growing space captured by non-native plants in the burn treatment, versus perennial forbs in the mechanical treatment. The difference between fire and mechanical treatments began to disappear by the third season after treatment, as both perennial grasses and shrubs began to fill in some of the bare ground initially exposed by fire. Most herbaceous vegetation – perennial grasses, perennial forbs, and non-native plants – increased significantly after fire or mechanical treatments; only biological soil crusts remained at reduced levels three years after treatment. Tree dominance before treatment had a marked effect on the balance between desirable perennial herbaceous vegetation and non-native vegetation, particularly cheatgrass (Roundy et al. 2013, in review). Importantly, at no site have we seen a threshold type of response to any treatment. Even where initial herbaceous levels were as low as 8-10%, we observed steady recovery of the herbaceous perennial vegetation after treatment. It remains to be seen however, if perennial herbaceous vegetation will be able to capture the newly available water resource in the coming years, especially in stands initially dominated by trees (Chambers et al. 2013, in review). In particular, will cheatgrass be the species to step in and take up that additional water? Certainly, burning increased cheatgrass cover even at very low initial tree dominance levels, and because the perennial native vegetation did not respond quite as well, the balance in phase I woodlands tipped slightly in favor of cheatgrass. Mechanical treatments caused a greater increase in cheatgrass cover relative to total perennial herbaceous cover where tree cover was greater before treatment. Tree removal can have both positive and negative effects on vegetation, but the balance between native perennial and non-native annual grasses will depend in part on pre-treatment site conditions. Time will tell how the additional removal of shrubs after burning will influence the balance between native perennials and non-native annuals, and how site-specific differences will play out.

Carbon. In October 2009 President Obama directed all federal agencies to measure, report, and reduce carbon emissions. Ever since, there has been considerable debate on how current sagebrush-steppe and pinyon-juniper management in the Great Basin might influence carbon budgets. Work at Underdown Canyon, a Joint Fire Science demonstration project which served as a pilot study for SageSTEP (Rau et al. 2012), showed that woodland expansion substantially increases above ground biomass and carbon, which supports the idea that woodland encroachment could serve to sequester carbon (Fig. 7). Yet the same study also showed that very little additional below ground carbon is sequestered as woodlands fill in, which means that sequestration is only effective as long as woodlands do not burn (Rau et al. 2010). SageSTEP expanded this work to 13 sites (Rau et al. 2011), further indicating that soil carbon sequestration may be limited by nitrogen. Thus when large pulses of carbon are emitted due to wildfires in woodlands, only a small proportion of this carbon is incorporated into the soil, which is the only place where long term carbon sequestration is effective in a fire-prone region such as sagebrush-steppe. It is interesting to consider that repeated prescribed fires may actually be more effective at introducing carbon into the soil than wildfire in the long run, because the severity of prescribed fire is much lower each time, and a greater proportion of carbon is thus incorporated each time prescribed fire is applied (Rau et al. 2010; Rau et al

2012). These studies show that the goals of carbon management generally parallel those of fuel and vegetation management in sagebrush-steppe woodlands, in which maintaining low density woodlands with healthy herbaceous vegetation and historic fire regimes at the landscape level seems to be a good idea.

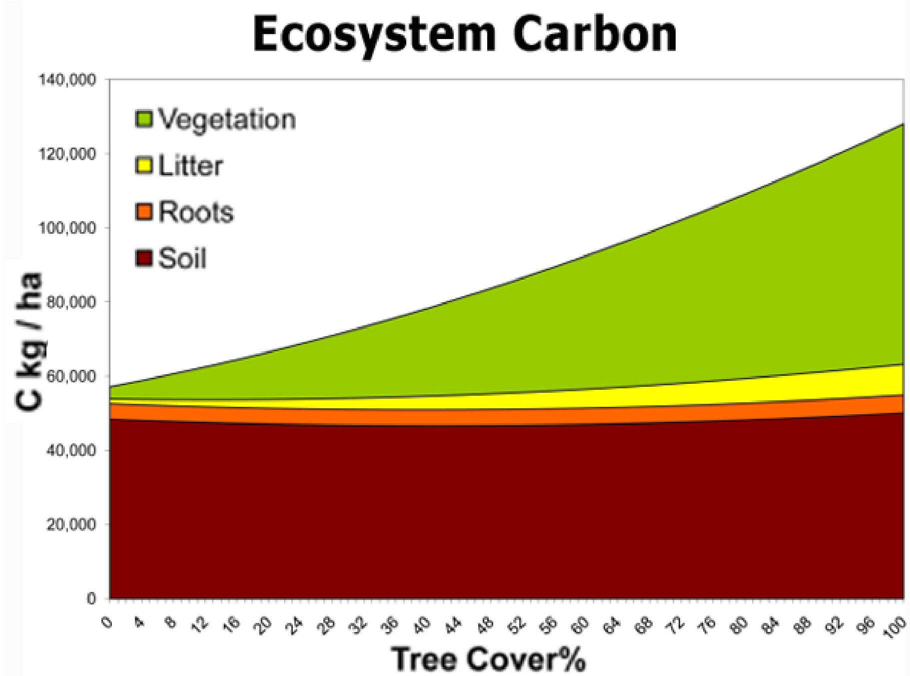

Figure 7. Mass of ecosystem carbon with increasing tree cover in Pinyon-Juniper Woodlands.

Sagebrush-Obligate Songbirds. Recent declines in populations of Greater Sage-Grouse are a major concern in sagebrush steppe lands of the Interior West. Its eventual listing as a threatened or endangered species is thought to be likely. Restoration treatments of the kind studied by SageSTEP could provide higher quality habitat for the sage grouse, and thus aid in recovery of populations (Knick et al. 2012, in review; SageSTEP Newsletter #17). Because of the difficulty of studying the large home range of sage grouse, smaller songbirds such as sage sparrow, Brewer's sparrow (Fig. 8), and sage thrasher can be used as proxies to evaluate restoration treatments. We've studied the response of the distribution, abundance, and demography of sagebrush-obligate songbirds in large plots (more than 1000 acres) where prescribed burns were used to modify woodland landscapes. Although prescribed burning did remove some trees, tree cover, still ranged between 6% and 24%, and tree height still ranged between 3 and 6 meters (Knick et al. 2013, in review). Given the habitat preferences of sagebrush-obligate songbirds, this kind of plant architecture is unlikely to be highly attractive to birds like Brewer's sparrow, sage sparrow, and sage thrasher. We did observe a slight shift in the overall structure of bird communities in burned plots, from those dominated by woodland birds to those dominated by shrubland species. Even though prescribed fire did not result in the establishment of functional sagebrush bird communities in the short term (3 to 5 years post-treatment), stronger changes in bird community structure might occur over longer periods.

Butterflies**.** SageSTEP experiments were designed to observe how ecosystems respond to restoration treatments. We wanted to determine whether there are 'unintended consequences' in those ecosystem components that are not direct targets of management (beyond trees or the fuel beds). This is particularly important for management practices with which species don't have evolutionary history: mastication (tree shredding), tree felling, mowing, and herbicides. A striking result of our research was that both woodland and sage-cheat sites exhibited distinct patterns of butterfly species composition tied to flowering plant composition (McIver and Macke 2013, in review). Butterfly links to the flora were also evident when we looked at the balance between native bunchgrass and cheatgrass cover. The likelihood of obtaining a high butterfly count (more than 30 individuals) was contingent on there being at least 15% bunchgrass cover, and no more than 10% cheatgrass cover. Responses to treatments tended to be subtle, but fairly persistent at least four years after treatment. At woodland sites, we observed no treatment-induced changes in *overall* community structure. However, numbers of Melissa blues increased after treatment, along with their larval host plants, lupin and vetch. On the other hand, sulfurs, which are strong fliers increased after treatment because they were attracted from afar by nectar 'bulls-eyes.' These bulls-eyes were created by increased forb flower production after treatment, possibly due

Figure 8. Brewer's Sparrow. Photo by Muriel Neddermeyer

to enhanced soil water availability (Roundy 2013, in review). Finally, the juniper hairstreak declined at all sites at which it was initially present, due to removal of its larval food source. This result was expected, and is no cause for alarm, as this species is common and widespread, and current management plans for pinyon-juniper do not include reduction of stands to a point where concern for this host-specific butterfly species would be warranted.

Sage-Cheat Experiments

Treatment Effectiveness. In the sage-cheat experiment we wanted to reduce the dominance of shrubs with all treatments. Effectiveness averaged higher for the four western sites, and lower for the three eastern sites. The most effective treatment was mowing, which consistently reduced shrub cover to between 23% (west sites) and 38% (east sites) of initial values. Prescribed fire was clearly less consistent, probably due to relatively low, spatially discontinuous fuel loads. Still, fire lowered shrub biomass to less than 1% in the west, and to an average of about 60% in the east. The least effective treatment was the herbicide tebuthiuron, which significantly reduced sagebrush biomass only in the west, and only for those measurement sub-plots that had initially high shrub cover. These patterns suggest that we interpret other sage-cheat results with a bit of caution: while we can be certain that mowing caused the changes we intended, fire effects varied regionally, and herbicide effects were problematic at best.

Fuels and Potential Wildfire Behavior. For the sage-cheat experiment, the mowing treatment created the most uniform fuel bed, lowering the shrub crown, but substantially increasing both down wood and vegetation (Bernau and Bunting 2013, in review). These changes, we expect, would increase potential fire rate of spread, but lower average flame height, which would make plots more defensible during wildfires. However, as in the woodlands, fire severity in these areas may increase, due to the addition of substantial fuel close to the soil. Effects on the soil and seed bank would be much less severe compared to the woodlands, however, because the additional fuel is partially shredded shrubs, rather than completely shredded trees. While short-term fuel effects of the broadleaf herbicide tebuthiuron would be negligible, in time, shrubs killed by the herbicide would deteriorate and contribute to surface fuels similar to a mowing treatment.

Prescribed fire would change both fire intensity and severity. While potential fire rate of spread would increase due to increases in vegetation, flame heights would likely be much lower compared to mowing due to the lack of shrubs. Potential fire severity would also be lower because of the prior consumption of fuels, and the lack of any fuels generated by mowing. The only remedy that will likely alter the current fire regime in the treeless sagebrush steppe is periodic prescribed burning. That carries with it the risk of increasing cheatgrass and negatively affecting sagebrush species. Cheatgrass risk is so high in the more arid areas of the Great Basin that it is unlikely that managers will choose prescribed fire as a tool, instead using mowing to create defensible boundaries.

Nitrogen. When we reduce or remove woody vegetation, we set into motion a cascade of effects that we hope will lead to an increase in the dominance of native herbaceous vegetation. When we initially planned the experiments, we predicted that herbaceous vegetation would respond positively with most treatments. We knew from the outset that sagebrush-steppe systems are water- and nitrogen-limited, so removing the dominant competitor would increase the herbaceous vegetation previously suppressed by shrubs. As predicted, in the sage-cheat experiment,

we observed that almost all fire and "fire surrogate" treatments increased available ammonium for a short period following treatment, but only burning increased levels of nitrate. The largest and longest-lasting increases in nitrogen availability were derived from fire, followed by an application with the pre-emergent herbicide imazapic, which is most effective against non-native annuals (Rau et al. 2013, in review). Most likely, imazapic reduced the establishment of cheatgrass and native annuals on treated areas, and the only plants left to pick up the increased available nitrogen were perennials unaffected by the herbicide or by fire. This supports growing evidence that cheatgrass prizes nitrogen, and when you combine the fire-induced nitrogen increases with increases in available water through removal of shrubs, you set up an environment in which cheatgrass can thrive. Imazapic may be useful in reducing cheatgrass, but it is important to first get nutrient management and healthy perennials in place. Restoration needs to be managed to be certain there is adequate perennial vegetation to capture the resource spikes.

Vegetation. Our preliminary results show in sage-cheat plots, reducing shrub cover and biomass with prescribed fire or mowing caused a slight increase in the herbaceous understory. (Pyke et al. 2013, in review). Unfortunately, the balance between cheatgrass and native bunchgrasses shifted in favor of cheatgrass (Chambers et al. 2013, in review). While the ratio of cheatgrass to perennial tall bunchgrass cover remained at about 1:1 for the untreated control plots through three years post-treatment, the ratio increased on average for both prescribed fire and mowing treatments. Plots treated with tebuthiruron saw cheatgrass decrease post-treatment from 1.2:1 to about 0.9:1, although this decrease was not significant. Interestingly, while burning depressed perennial grass cover up to two years post-treatment, bunchgrasses had rebounded to well above pre-treatment levels by year three. This rebound is reflected in the slightly lower percentage of gaps less than 2 meters in diameter. The application of the imazapic to half of our measurement sub-plots changed these ratios significantly. In particular, this herbicide, which is commonly used to target non-native annual grasses, reduced cheatgrass cover to an average of only 2% the first year after treatment, and cover remained suppressed (less than 25%) compared to non-imazapic sub-plots through the three-year measurement period. Imazapic also depressed annual forbs, although the size of the reduction relative to controls became gradually less by year three. Perennial forbs were not significantly affected by this herbicide (outside of a temporary reduction and recovery in perennial forbs between year 2 and 3), but Sandberg's bluegrass was significantly affected, showing a reduction to about 50% of untreated controls. Again, we must continue measurement of these plots for several more years to see whether the rebound of native perennials will continue, whether cheatgrass will subside, and how imazapic will ultimately influence the balance between the native perennial and non-native annual grasses.

Butterflies. Prescribed fire caused an increase in butterfly species richness and abundance at most sage-cheat sites, due to increased nectar resources available to adults. It also caused an increase in the abundance of skippers, possibly due to an increase in the availability of their most common larval host plant: native bunchgrasses. The broadleaf herbicide tebuthiuron caused a significant decline in numbers of whites at some sage-cheat sites, which persisted through four years post-treatment. While a mechanism for this effect has not been identified, it is possible that the herbicide caused some direct mortality of larvae, suggesting caution before it is used on a broad scale. SageSTEP work on butterfly communities has demonstrated their close ties to native plant communities. In general, while it is probably not wise to generally assume that management for native plants will always favor butterflies, our findings suggest that unintended consequences are not likely to arise for most butterflies following the application of prescribed fire or its mechanical surrogates.

SageSTEP is a collaborative effort among the following:

- Brigham Young University
- Bureau of Land Management
- Bureau of Reclamation
- Joint Fire Science Program
- National Interagency Fire Center
- Oregon State University
- The Nature Conservancy
- University of Idaho
- University of Nevada, Reno
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