Tree Removal and Grass Response: Linking Vegetation with Available Soil Water

By James McIver, Ecologist and SageSTEP Project Coordinator, Oregon State University

This year, SageSTEP researchers are engaged in an effort to compile a number of scientific papers as a special feature in the open-source journal *Ecosphere*. This includes papers on vegetation, fuels and fire behavior, soils, hydrology, and biodiversity. To date, two papers have been accepted, and several more are in the review process. This fall, the collection of ten papers will available for all interested parties on the *Ecosphere* website.

In this piece, I want to discuss how three of those papers are related to one another. But first I need to remind you that SageSTEP was designed to provide managers with information on common land-use treatments, information that could be used for making better decisions at a project-level scale. SageSTEP uses large plots which span disturbance gradients, and is multi-site—factors that provide conditional information on treatment response. The project is long-term, because we know that it requires many years, in some cases decades, for responses to play out. And SageSTEP is a collection of multiple variables and data sets that interact in space and time. This provides the opportunity to identify tradeoffs and relationships among variables. It is this latter strength that is most emphasized by the three related papers I want to discuss.

The first paper is concerned with vegetation response in the ‘woodland’ experiment (sites encroached by pinyon-juniper trees), and was written by Stephanie Freund, a data analyst working with SageSTEP PIs Beth Newingham and Jeanne Chambers. They focused on how the vegetation understory (grasses, forbs, shrubs) responded to tree removal over a
ten-year post-treatment period. The second paper is focused on soil water response at the same woodland sites, and was written by Bruce Roundy (co-authors Rick Miller, Robin Tausch, Jeanne Chambers, and Ben Rau). The third paper presents a model that ties the vegetation and soil water stories together, and is written by myself, James Grace, and Bruce Roundy.

Freund’s paper clearly shows that two of the principal functional groups of the understory vegetation (grasses and forbs) respond positively to tree removal by any means, with grasses—both annual and perennial—showing the greatest increases to both burning and cutting over the ten-year time period. This was an expected result, because it was assumed that understory species were significantly suppressed prior to treatment by pinyon and juniper trees on the landscape as a result of competition for resources, principally water (but possibly also light). If the hypothesis of competition for water were true, then we would expect to also see an increase in water resources in the soil after trees were removed, mirroring the response in the understory vegetation. This is exactly what Roundy observed for the soil water resource – substantial increases in available soil water, particularly for plots that had previously been most dominated by trees. Given these two lines of corroborating information, one would think that the ‘water competition’ hypothesis was now confirmed: that grass and forb cover increased significantly after tree removal because grasses and forbs were freed from tree competition due to the release of available soil water. But we cannot yet say this, because measurements were taken, and data analysis performed on vegetation and soil water separately, using univariate statistics, such as analysis of variance. In addition, while soil water data were taken within the same treatment plots as vegetation data, soil water measuring stations were not exactly within vegetation measurement sub-plots. This means that technically, the mirroring of response in soil water and the vegetation confirms only correlation, rather than cause and effect. This is why Freund and her co-authors use conditional language in their interpretation of vegetation response: ‘Prescribed burning and mechanical treatment likely increased resource availability, promoting growth and seed production.’

To confirm our hypothesis that grasses and forbs would increase after tree removal due in part to increases in available soil water, we need to take one further analytical step. That’s where the paper by McIver, Grace and Roundy comes in. These researchers started with a simple conceptual model that specifically detailed the ‘tree competition’ hypothesis (Figure 1), which states that tree cover explains most of the variation in grass cover pre-treatment (dashed lines indicate negative relationships). Note that we also hypothesize that tree cover will have a greater influence on perennial grass cover, compared to annual grass cover, as indicated by the width of the arrow connecting tree to grass cover.

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**CONCEPTUAL MODEL: VEGETATION AND SOIL WATER**

**Figure 1.** Conceptual model representing hypothesis that tree removal will cause an increase in soil water, which will in turn cause an increase in grass growth, measured as cover. Dashed lines indicate negative relationships. Note that we also hypothesize that tree cover will have a greater influence on perennial grass cover, compared to annual grass cover, as indicated by the width of the arrow connecting tree to grass cover.
indicated by the width of the arrow connecting tree to grass cover. We then tested this hypothesis for the ‘cut and leave’ plots by analyzing both vegetation and soil water data together with a multivariate ‘structural equation’ model (SEM). SEM runs a series of algorithms with the data, that iteratively find the simplest and best-fit solution to the relationships among variables in the conceptual model. If significant relationships are found among variables that align with the predictions of the conceptual model, we can say that the resulting model is consistent with the hypothesis described by the conceptual model. This is exactly what we found in the SEM analysis (Figure 2). First note the percentage above each grass box: this indicates the percentage of variation in each grass group that the model explains. Notice that the post-treatment model explains more variation in each group than the pre-treatment model, and this is mostly due to the fact that the post-treatment side of the model represents a second measurement event, which strengthens our confidence. Next notice that in the pre-treatment world, we found significant negative relationships only between trees and the perennial grasses, but not cheatgrass. Now notice in the post-treatment model, that tree removal caused a significant increase in early spring water (as indicated by the solid black line), which in turn caused an increase in both perennial tall grasses and cheatgrass. Interestingly, perennial short grass cover actually went down slightly with tree removal. Finally, notice that tree removal also was related directly to perennial tall grass and cheatgrass – this is the variation in plant cover not explained by soil water, and indicates that soil water increases only partly explained plant response, as reflected in the data. We can now go one step further than authors could go in the two univariate papers, and now say that vegetation response to tree removal was due in part to increases in available soil water.

Science can be a messy process, especially when you embark on the analysis of comprehensive, multi-site, mixed-gradient, multivariate, long-term data sets like that from SageSTEP. But with careful thought and persistence, sometimes we can nail things down with more confidence. Hopefully, the extensive univariate analyses that are currently being done, will increasingly be bolstered by the multivariate analyses that can offer cause and effect insight on the processes that govern vegetation growth and recovery in sagebrush steppe.

**Resultant SEM Model: Vegetation and Soil Water**

*Figure 2. Resultant SEM model showing that data are consistent with the hypothesis that tree removal by cutting increased soil water, which in turn increased grass cover. The percentage above each grass box indicates the percentage variation in each grass group that the model explains. Tree removal caused a significant increase in early spring water (as indicated by the solid black line), which in turn caused an increase in both perennial tall grasses and cheatgrass. Tree removal also was related directly to perennial tall grass and cheatgrass – this is the variation in plant cover not explained by soil water, and indicates that soil water increases only partly explained plant response, as reflected in the data.*
Do fuel treatments modify fire behavior in the sagebrush steppe?

By Lisa Ellsworth, Assistant Professor and Rangeland Fire Ecologist, Oregon State University

Invasive species, land cover change, altered fire regimes, and a changing climate interact to imperil sagebrush steppe ecosystems that are critically important for local economies, as well as for species of conservation concern (e.g. Greater sage-grouse). One of the major challenges in sagebrush steppe conservation is altered fire regimes and the resultant uncharacteristic fire behavior now widely exhibited across the sagebrush biome. The increasing emphasis on sagebrush conservation and the reduction of large, invasive grass-fueled wildfires suggests that increased use of fuel treatments could be beneficial. While expansion of invasive annual grasses is creating more fire-prone situations across the sagebrush biome, increasing shrub cover threatens to outcompete understory native herbaceous vegetation in other areas. In these areas, fuel treatments may have the added benefits of breaking up continuous woody cover, providing anchor points for fire suppression, and reducing flammable fuel loads.

Fuel treatments are activities that reduce burnable material with the ultimate goal of decreasing fire behavior. In the SageSTEP plots, fuel treatments included mechanical thinning, application of tebuthiuron (herbicide), and prescribed fire. Untreated control plots were also measured. Mechanical treatments (i.e. mowing) were used to remove top growth of sagebrush and other shrubs, reducing shrub canopy cover and enhancing herbaceous understory. Applications of tebuthiuron were applied to partially kill sagebrush canopies and enhance understory vegetation. Plants rooted within a 50 cm radius of application were impacted, but plants farther away are unharmed, giving a patchwork thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire broke up woody thinning treatment. Prescribed fire b...
the year after fire treatment. In the years following fire treatment, shrub biomass slowly increased and reached 25-35% of the pre-treatment level after ten years (Figure 3).

Mechanical treatment initially reduced herbaceous biomass by about 30%, but by 10 years post-treatment herbaceous biomass had increased about three times above pre-treatment levels. Ten years after mechanical treatment shrub biomass was on average 50-55% of the pre-treatment level. Tebuthiuron treatment had a delayed effect on vegetation response compared to fire and mechanical treatment. No change in herbaceous biomass was observed the first couple of years post-treatment. After ten years the increase in standing herbaceous biomass was similar to that observed ten years after fire or mechanical treatment. Shrub biomass also decreased slowly over the first six years of treatment; at the sixth year post-treatment shrub biomass was 50% of the pre-treatment level. Ten years post-treatment, shrub biomass had begun to increase again and was about 55% of the pre-treatment level.

**Fire behavior**

Before treatment, modeled fire rate of spread averaged 13.6 m min⁻¹ when herbaceous fuels were fully cured (i.e., late in the fire season). In the first post-treatment year, fire and mechanical treatments reduced rates of spread to 2.2-4.0 m min⁻¹; in contrast, tebuthiuron treatments did not reduce rate of spread. By 10 years after treatment, fire and mechanical treatments continued to reduce fire behavior, with rates of spread of 1.0-2.2 m min⁻¹. Untreated control and tebuthiuron treatments had rates of spread of up to 2.6-3.0 m min⁻¹ when fully cured (Figure 4).

In control plots, flame lengths averaged 2.1 m when herbaceous fuels were fully cured. In the first post-treatment year, fire and mechanical treatments reduced flame lengths to 0.6-1.0 m, but tebuthiuron treatments did not reduce flame length. By 10 years post-treatment, fire and mechanical treatments continued to reduce fire behavior, generating flame lengths of 1.0-2.2 m. Untreated control and tebuthiuron treatments had higher flame lengths, at 2.6-3.0 m when fully cured (Figure 5).

These differences in flame length have strong implications for fire management. The hauling chart, a standard for how firefighters can approach a fire, sets thresholds at 4 and 8 ft (1.2-2.4 m) flame lengths. Below flame lengths of 4 ft, fire crews can fight the fire with just hand tools. Between 4-8 feet, heavy machinery, such as dozers, and air resources such as helicopters and retardant drops from airplanes are used. Above 8 ft flame lengths, fire control is extremely difficult and spot fires, crown fires, and extreme fire behavior are expected. Prescribed fire and mow treatments maintained fire behavior below this threshold for extreme fire behavior, and in early years even kept it within the 4 ft control mark. Control and tebuthiuron treatments can be expected to have fire behavior that is more difficult to control.

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*Figure 3. Herbaceous, litter, downed woody debris (woody), and live shrub biomass in control, prescribed fire, mechanical, and tebuthiuron treatment plots at seven Wyoming big sagebrush sites across the Great Basin, USA. Error bars represent standard error for total fuel load.*
Figure 4. Rate of spread (m/min) in control, control+imazapic, prescribed fire, prescribed fire + imazapic, mechanical treatment, mechanical + imazapic, tebuthiuron, and tebuthiuron + imazapic plots in a fully cured moisture scenario in SageSTEP plots across the Great Basin, USA.
Figure 5. Flame length (m) in control, control+imazapic, prescribed fire, prescribed fire + imazapic, mechanical treatment, mechanical + imazapic, tebuthiuron, and tebuthiuron + imazapic plots in a fully cured moisture scenario in SageSTEP plots across the Great Basin, USA.

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