**PROJECT TITLE:** A REGIONAL EXPERIMENT TO EVALUATE EFFECTS OF FIRE AND FIRE SURROGATE TREATMENTS IN THE SAGEBRUSH BIOME

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# A REGIONAL EXPERIMENT TO EVALUATE EFFECTS OF FIRE AND FIRE SURROGATE TREATMENTS IN THE SAGEBRUSH BIOME

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# SageSTEP: A Regional Experiment to Evaluate Effects of Fire and Fire Surrogate Treatments in the Sagebrush Biome

## PROJECT DESCRIPTION

### I. Abstract

SageSTEP is a comprehensive regional experiment that provides critical information to managers faced with a sagebrush steppe ecosystem that is increasingly at risk from wildfire, invasive plants, and climate change. The experiment provides managers with information that can be used to restore ecological communities across the 100+ million acres of the sagebrush biome. It is designed to match the temporal and spatial scales at which managers operate, is intended to reduce management risk and uncertainty of catastrophic wildfire to the greatest degree possible, and provides managers with information that allows them to better understand tradeoffs inherent in the choice of management alternatives.

The project has several features that make it ideal for testing hypotheses from state-and-transition theory, and for discovering information that can be directly applied in a management context -- it is long-term, experimental, multisite, multivariate, and treatments are applied across condition gradients, allowing for potential identification of biotic thresholds. The project is designed to distinguish communities that have conditions that will allow them to recover on their own following fuel or restoration treatments, versus communities that have crossed biotic thresholds, and will therefore require more expensive active restoration.

SageSTEP is designed as a long-term study, such that measurements are planned for at least 10 years after treatment implementation, or through the 2018 field season. This final report therefore describes the short-term effects of treatments, 2-4 years after treatment implementation., or through the 2010 field season. The Joint Fire Science Program generously funded SageSTEP for its first six years, and this funding was crucial for building an infrastructure that has now set the stage for an unprecedented long-term study that will provide badly needed information on sagebrush steppe restoration and fuel treatment effectiveness. The infrastructure we've built consists of the following eight features:

**1.** A network of 18 sites distributed across the Great Basin, Snake River Basin, and Columbia Basin, 11 sites in a replicated woodland experiment, and 7 sites in a replicated sage-cheat experiment (Figure 1). Each site is equivalent to a statistical block consisting of an unmanipulated control, and a set of fire and fire surrogate treatments.

**2.** A network of weather and soil moisture stations distributed along with the sites, that provides information on inter-annual and geographic variation in moisture and temperature, and that is being used to interpret patterns of ecological response.

**3.** A small by efficient staff, consisting of scientists and technicians, responsible for continued monitoring of ecological variables through time, and maintenance of the projects' infrastructure.

**4.** A funding stream from several agency sources, with current resources adequate to run the project for at least three more years, and with agreements in place to fund the project through fiscal year 2015.

**5.** A web of partnerships among managers, scientists, students, stakeholders, and policy-makers that has worked together to design the study, implement the treatments, and learn about how sagebrush steppe system respond to alternative restoration treatments.

**6.** A highly effective and influential outreach program, anchored by a popular website, designed to interpret and deliver scientific information collected by SageSTEP scientists, and to distribute other relevant information originating from outside the project.

**7.** An on-line database, called the SageSTEP Data Store, that offers fully proofed and validated data to analysts working within SageSTEP, and which will eventually provide the same information to other interested users.

**8.** The Great Basin NEON Site, NSF's atmospheric sampling station that will soon be built at the SageSTEP Onaqui site. This link with NSF provides SageSTEP with leverage for established additional vegetation and soil monitoring facilities at Onaqui.

Over the past three years, since post-treatment data collection commenced, SageSTEP has produced a considerable amount of information, most of it now published in a total of 32 scientific papers. Key outreach products include:

- Active web site (sagestep.org), anchoring a comprehensive outreach program
- User's Guides for Western Juniper & Pinyon-Juniper woodlands
- Two Fuel Guides, one each for pre-treatment and post-treatment conditions
- 15 quarterly newsletters
- Six manager workshops
- 11 tours or field trips
- Three national conference symposia, consisting of 24 papers (2 symposia planned)
- 57 contributed papers at conferences
- Seven Master's Theses and two Ph.D. Dissertations
- 15 papers published in proceedings or reports
- Ten papers published in peer-reviewed journals (17 papers currently in review)

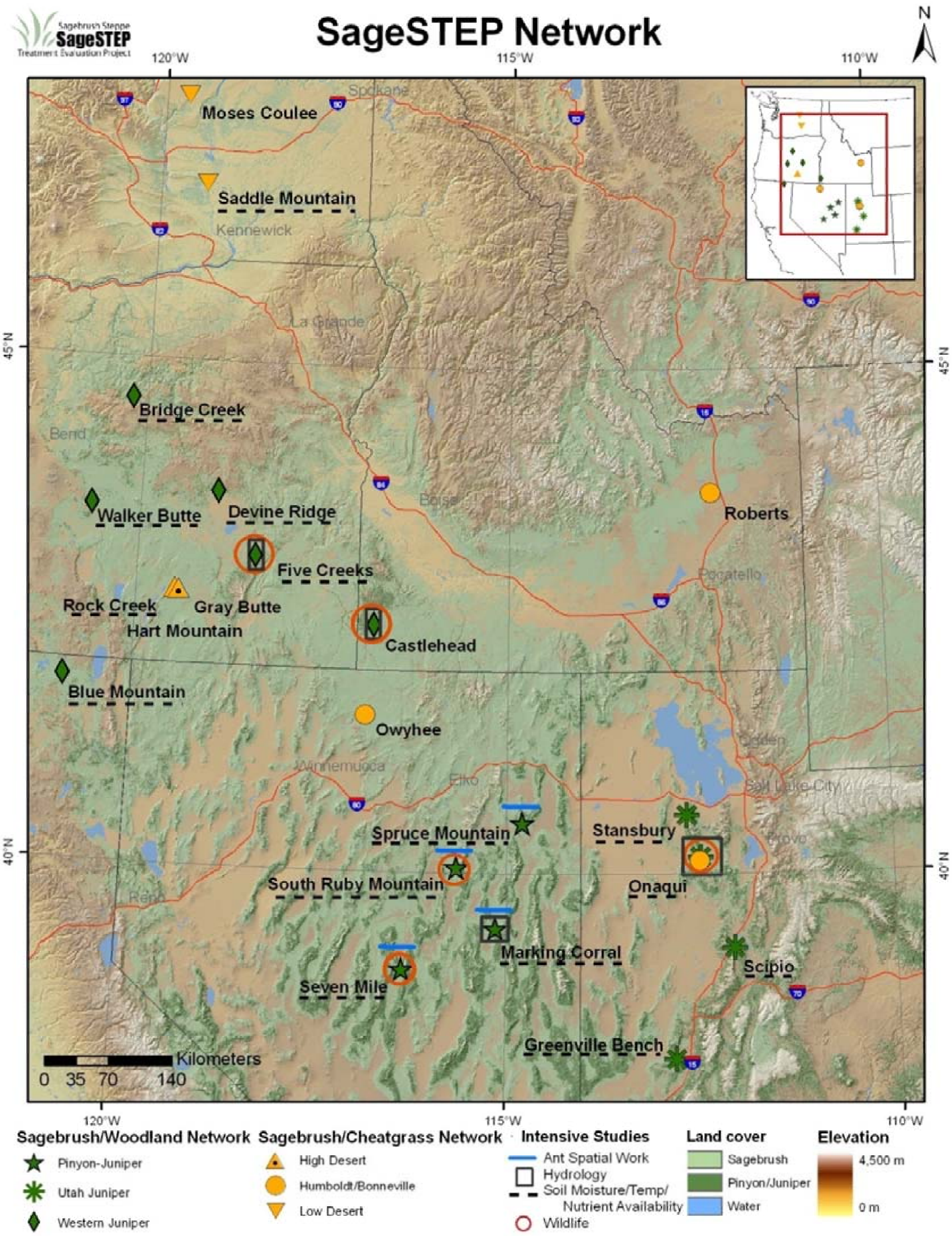
## II. Background and Purpose

The sagebrush biome, largest in North America, occupies 100 million acres in the Interior West (Knick et al. 2003). Home to more than 300 wildlife species, the biome is the primary forage base for the western livestock industry, is an important recreation area, and provides precious water in a semi-arid region that has one of the fastest growing human populations in North America. Public land managers face an increasingly complex task of dealing with an array of competing interests and multiple uses in the sagebrush biome. As the region's population continues to grow and diversify, managers must anticipate the impacts of current decisions on future land condition, while demonstrating accountability to current and future generations. An integrated approach to public lands management requires that managers use the best ecological, social and economic information available to evaluate proposed management actions (Loomis 1993). Unfortunately, much of the scientific information currently available to land managers working in sagebrush steppe tends to be gathered from small plots at a single or a few sites, focuses on no more than a few variables, and tends to be short-term. The Sagebrush Steppe Treatment Evaluation Project (SageSTEP) was designed to fill critical knowledge gaps by employing the same experimental design at many sites having very different conditions, by studying combinations of variables, and by measuring these variables for a much longer period of time. This kind of information is much more useful to managers because it helps them understand how different conditions influence treatment response, it allows them to assess tradeoffs among different components of managed ecosystems, and it steers them away from making hasty decisions that could backfire if system responses change with time.

## III. **Objectives**

The goal of SageSTEP was to provide information to managers that would allow them to better predict the extent to which their treatments will result in sagebrush steppe systems that are more resilient to wildfire, and to help them evaluate different treatment options using both

## Figure 1


SageSTEP Network
Sagebrush Steppe SageSTEP Treatment Evaluation Project
N
120°W
115°W
110°W
45°N
40°N
Moses Coulee
Saddle Mountain
Spokane
Kennewick
La Grande
Bridge Creek
Bend
Walker Butte
Devine Ridge
Boise
Roberts
Five Creeks
Pocatello
Rock Creek
Gray Butte
Hart Mountain
Castlehead
Blue Mountain
Owyhee
Winnemucca
Elko
Ogden
Salt Lake City
Spruce Mountain
Stansbury
Provo
South Ruby Mountain
Onaqui
Reno
Marking Corral
Scipio
Seven Mile
Greenville Bench
Kilometers
0 35 70 140
Sagebrush/Woodland Network
Pinyon-Juniper
Utah Juniper
Western Juniper
Sagebrush/Cheatgrass Network
High Desert
Humboldt/Bonneville
Low Desert
Intensive Studies
Ant Spatial Work
Hydrology
Soil Moisture/Temp/ Nutrient Availability
Wildlife
Land cover
Sagebrush
Pinyon/Juniper
Water
Elevation
4,500 m
0 m

ecological and socio-economic criteria. The research design was built around the concept of the 'state-and-transition' model that could be used to predict the types and probabilities of transitions from one state to another (Figure 2). Historically, sagebrush steppe ecosystems within the Great Basin naturally shift from communities with sagebrush as dominant to those with perennial bunchgrasses as dominant. In drier areas, cheatgrass invasion into the sagebrush understory has set up the potential for much more frequent fires, which can eventually eliminate the sagebrush entirely and lead to a community dominated by perennial weeds. For the sagebrush/cheatgrass system, our objectives address the question of how much representation of perennial bunchgrasses there needs to be in order for managers to recover the system without having to conduct expensive restoration (i.e. reseeding of native grasses). Similarly, in more mesic areas, tree encroachment due to years of fire suppression can result in a tree-dominated system in which sagebrush and the perennial bunchgrass understory is also eliminated (Figure 3). Continued dominance by trees can lead to a highly eroded state that features a variety of weedy species. For the sagebrush/woodland system, our objectives address the question of how much representation of the native sagebrush/bunchgrass community there needs to be in order for managers to recover the system without having the conduct more expensive restoration. For both systems, our research is providing better information on the probabilities of transition from one state to another, when a variety of treatments are applied under a wide range of conditions.

This information is critical because managers need to understand where a given system lies with respect to the threshold, and in particular the direction in which a given treatment will push the system. Without information on the probability of system change from one state to another, particularly with respect to critical thresholds, the manager is left with having to make decisions that could result in undesirable outcomes. If the primary goal of management is to increase the resilience of sagebrush steppe systems (especially to wildfire), much better information on transition probabilities within the system is needed. The **objectives** listed below reflect a research program that is aimed at defining critical ecological thresholds, through the application of alternative treatments over a wide array of conditions:

(1) Identify the abiotic and biotic thresholds that determine sustainability of big sagebrush plant communities in sagebrush-steppe and sagebrush semi-desert environments, specifically related to threats posed by cheatgrass invasion and pinyon-juniper encroachment.

(2) Assess the ecological effects of fire and fire surrogates on big sagebrush communities at risk of crossing a threshold of conversion to cheatgrass or pinyon-juniper, beyond which restoration may be difficult or logistically infeasible.

(3) Document how fuel loads change across vegetation treatments and ecological conditions in relation to the objectives above.

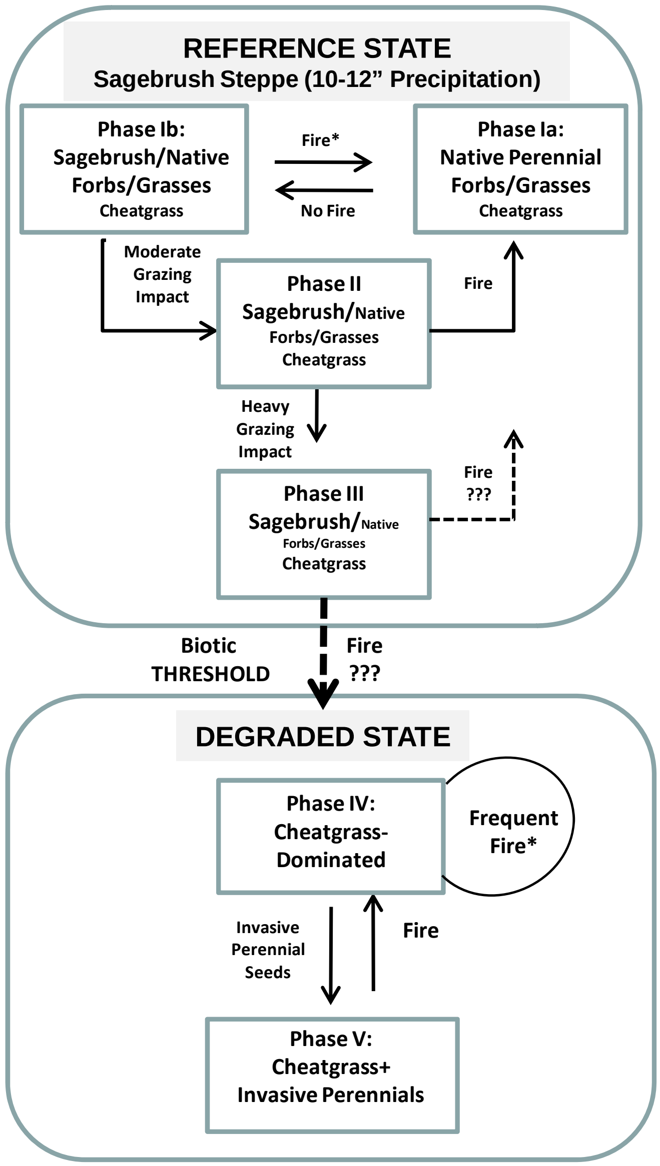
(4) Portray the ecological, economic, and socio-political trade-offs and treatment effects of no action, applying only fire and fire surrogate treatments, and restoration treatments in these sagebrush communities.

(5) Identify and measure environmental benefits affected by conversion to cheatgrass and pinyon-juniper systems, and identify induced changes in welfare to human populations.

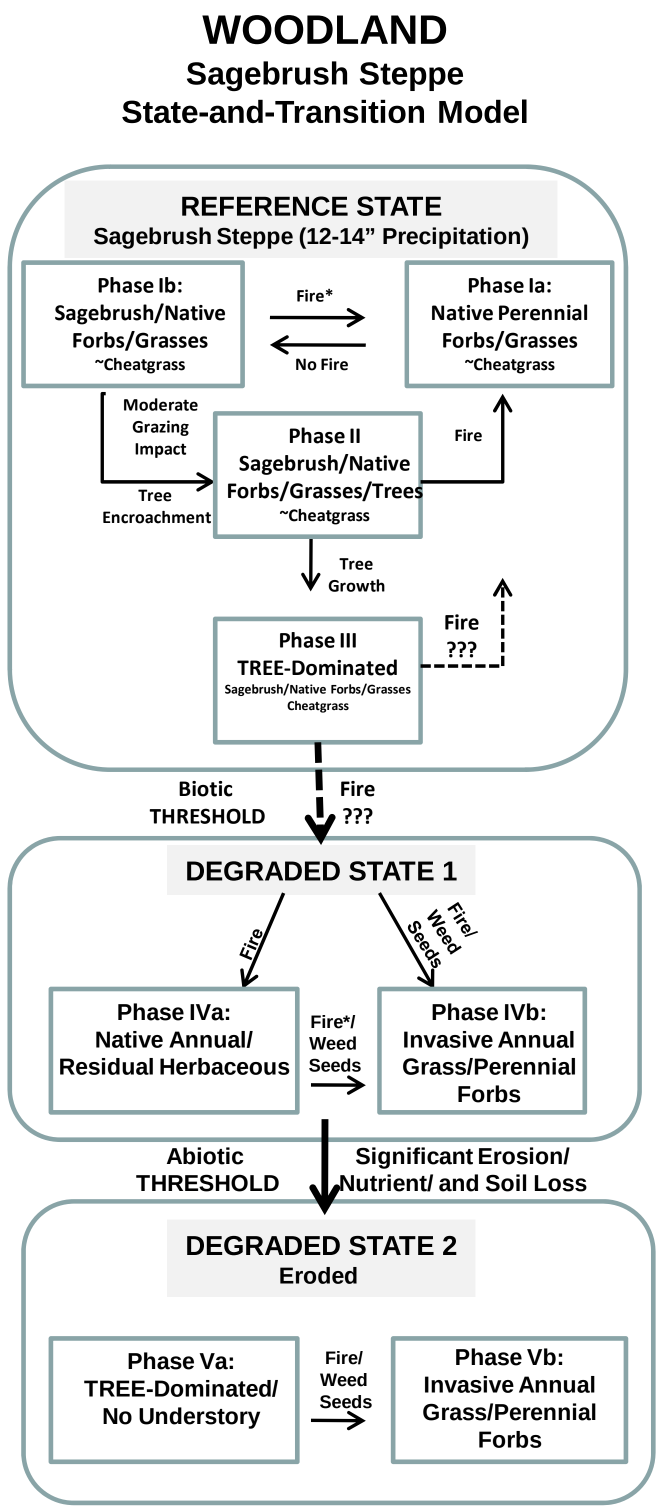
(6) Provide insight and guidance regarding use of our results for effective multi-species and multi-scale planning as part of ecosystem management of sagebrush communities in the Great Basin.

# Figure 2

## SAGE/CHEAT
### Sagebrush Steppe
### State-and-Transition Model



## Figure 3


WOODLAND
Sagebrush Steppe
State-and-Transition Model
REFERENCE STATE
Sagebrush Steppe (12-14" Precipitation)
Phase Ib:
Sagebrush/Native
Forbs/Grasses
~Cheatgrass
Fire*
No Fire
Phase Ia:
Native Perennial
Forbs/Grasses
~Cheatgrass
Moderate
Grazing
Impact
Tree
Encroachment
Phase II
Sagebrush/Native
Forbs/Grasses/Trees
~Cheatgrass
Fire
Tree
Growth
Phase III
TREE-Dominated
Sagebrush/Native Forbs/Grasses
Cheatgrass
Fire
???
Biotic
THRESHOLD
Fire
???
DEGRADED STATE 1
Fire
Fire/
Weed
Seeds
Phase IVa:
Native Annual/
Residual Herbaceous
Fire*/
Weed
Seeds
Phase IVb:
Invasive Annual
Grass/Perennial
Forbs
Abiotic
THRESHOLD
Significant Erosion/
Nutrient/ and Soil Loss
DEGRADED STATE 2
Eroded
Phase Va:
TREE-Dominated/
No Understory
Fire/
Weed
Seeds
Phase Vb:
Invasive Annual
Grass/Perennial
Forbs

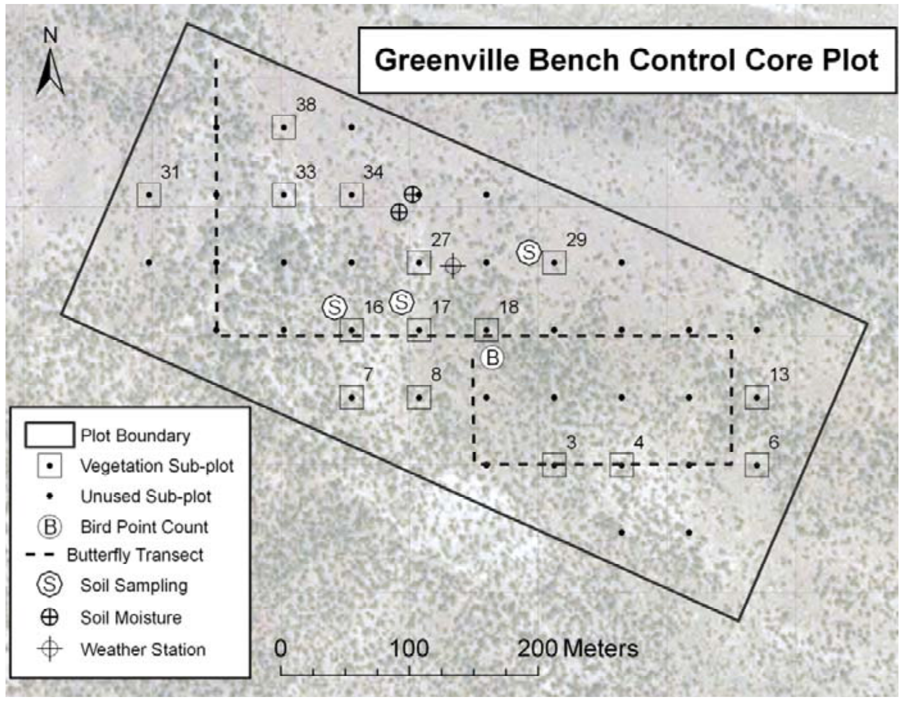
This research is designed to complement related work on assessment and restoration within the Great Basin. Restoration efforts include the Great Basin Restoration Initiative (USDI BLM 1999; led by team member Mike Pellant), the IFAFS Project (led by team members Paul Doescher, Jeanne Chambers, David Pyke, and Eugene Schupp), and local and state-level conservation strategies for sage-grouse and associated habitats (e.g. Anonymous 1997, Canadian Sage Grouse Recovery Team 2001). Sagebrush habitat assessments include the SAGEMAP Project (http://sagemap.wr.usgs.gov; led by team member Steve Knick), ecoregion assessments (Freilich et al. 2001, Nachlinger et al. 2001; led by The Nature Conservancy), and ongoing local assessments by BLM and USDA Forest Service.  ur research is designed to be used to support land use plan revisions underway by the BLM and the Forest Service in the Great Basin, and results will be available for use by these and other federal and state agencies engaged in the recovery and restoration of sagebrush communities across interior North America.

**IV. Research Approach – A Description of the Implemented Experiments**

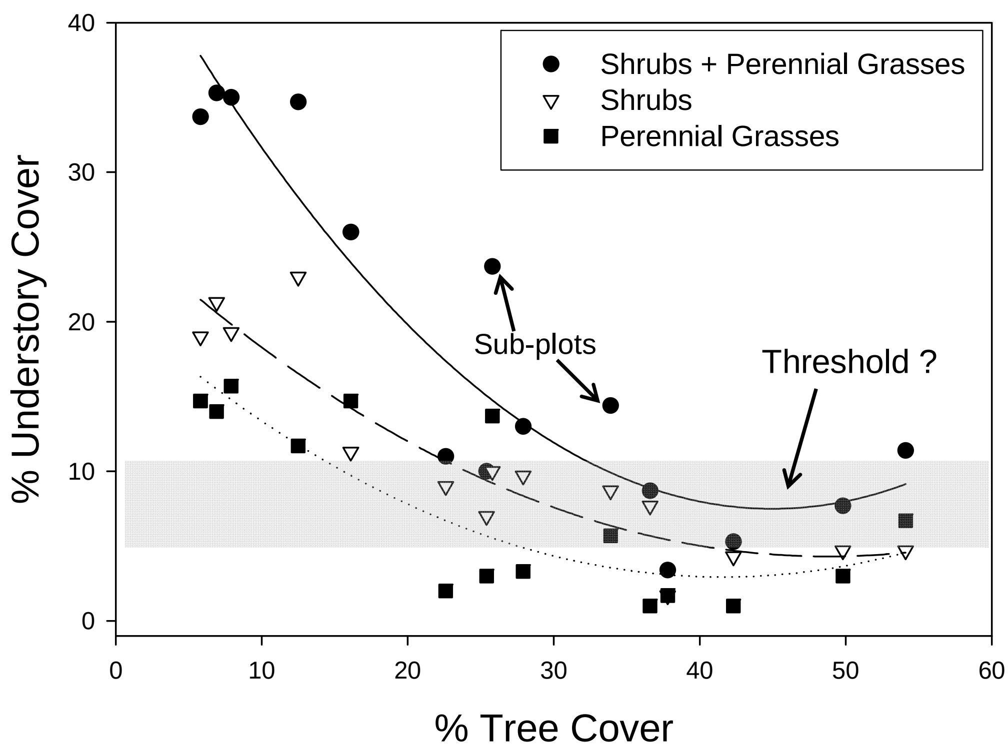
*The Treatment Plot***.** The current management focus in sagebrush steppe is to maintain or restore native sagebrush ecosystems. The dominant shrubs (*Artemisia* spp.) and trees are not fire-tolerant, and initial ecosystem recovery following wildfires or management treatments depends on native perennial herbaceous species that resprout or reestablish following fire and that decrease the susceptibility of these ecosystems to cheatgrass invasion (Chambers and others 2007). Total or partial removal of trees and shrubs through fire or one of its surrogates and removal of cheatgrass by applying herbicides can result in competitive release of perennial herbaceous species. Thus, vegetation recovery may depend on the relative abundance of native perennial herbaceous species, and trees, shrubs, and cheatgrass in woodland and sage/cheat ecosystems and on their responses to the different treatments. SageSTEP is designed to examine vegetation response to specific treatments over theses abundance gradients in woodland and sage/cheat ecosystems. Sub-plots are positioned and sized (relatively large) to capture the range of vegetation conditions within a plot. For example, the Greenville Bench control plot (woodland experiment) has an area of 25 ha (1250 by 200 m), and the differences in tree abundance can easily be seen on the National Agriculture Imagery Program image (Figure 4a). Because tree cover is the primary driver behind declines in understory cover (Figure 4b), an opposing response curve for understory vegetation is evident in each treatment plot. Recovery potential can be assessed with this design by applying the selected treatments across the entire plot, measuring vegetation response within the sub-plots, and then interpreting the response within the context of the vegetation gradient. If a threshold exists in herbaceous vegetation cover, below which recovery does not occur without further intervention, it likely will be identified with this design. After examination of many landscapes prior to site selection, we found that typically at least 15-ha treatment plots were necessary to capture a meaningful gradient for stands encroached by woodland species, and at least 30-ha plots were necessary for the more xeric stands in the sage/cheat experiment.

*Site Distribution.* While treatment of a single large plot can identify thresholds for that particular place at that particular time, managers need to know if application of the same treatment elsewhere will produce similar results. The issues of site-specific responses to treatments and variation in the position of the biotic threshold, were addressed by conducting the same experiment across a wide range of environmental conditions. The two experiments in SageSTEP's core study are applied at 19 sites located across much of the land area occupied by

# Figure 4a




# Figure 4b



sagebrush steppe vegetation in the western United States (Figure 1). All sites fall within the same Major Land Resource Area (i.e., lands that have similar vegetation and land use patterns (Bestelmeyer and others 2009). Each of 18 sites received the full suite of treatments. Although all sites are classified as Cool Desert, weather patterns differ markedly across this geographic range. Sites in California, Oregon, Washington, and southwest Idaho have a Pacific Maritime climate, with nearly all precipitation originating in the Pacific Ocean, and falling between November and June. The majority of the western juniper ecosystem lies north of the polar front gradient where temperatures are cooler, summer precipitation is decreased, and winter precipitation is increased (Mitchell 1976). In contrast, sites in Nevada and Utah have a more Continental climate, with less precipitation falling from November to June, and relatively more summer rains originating from the Gulf of Mexico, usually in July and August. Since weather systems in the Pacific and in the Gulf are somewhat independent, we expect different patterns of inter-annual weather variation across the SageSTEP network, and we expect that this variation may affect recovery after treatment. If among-site recovery rates and/or patterns mirror vulnerability, then more xeric sites, or sites with higher inter-annual variation in weather, may be slower to recover relative to more mesic, or less variable sites (Chambers and others 2007). We collect weather data at each site throughout the study period from weather stations located in the control plot of each site. These data are used as a covariate in the analyses to help explain vegetation response.

The 11 woodland sites can be organized into three regions, each reflecting the dominant tree species (Figure 1). With four sites located in Oregon and Northern California, the Western Juniper Region is roughly defined by a triangle 300 km on the side. The four sites within the Pinyon-Juniper Region are more tightly clustered in east-central Nevada. The Utah Juniper Region consists of four sites in western Utah, spanning a north to south geographic range of roughly 400 km. Altogether, the 12 woodland sites span a geographic range of more than 800 km, from Bridge Creek in the northwest to Greenville Bench in the southeast, and represent conditions that vary considerably in elevation, topography, soils, current vegetation, and climate.

The cheatgrass experiment consists of seven sites, all within the sagebrush biome but separated by more than 1000 km from south-central Washington to west-central Utah (Figure 1). Four of these sites are located in the western part of the sagebrush range, two are in central Oregon (High Desert Region), and two are in the Columbia Basin of southern Washington (Low Desert Region). Three of the sites are located in the eastern portion of the range (Bonneville Region), with one in Utah, one in eastern Idaho, and one in northern Nevada. Although all seven sites are typical sagebrush steppe systems, they also encompass a range of soil types, plant communities, and weather patterns.

While most sampling occurs within the plots and sub-plots, analyses are conducted not only at the plot level, but at the site, region, and network levels. The hierarchical organization of the study reflects the sampling orientation and sets the stage for different kinds of analyses. If native perennial herbaceous vegetation has an effect on recovery and thresholds as originally predicted, we will be able to determine its relative importance at both site and regional levels for the woodland and sage/cheat experiments. Because other factors like soil characteristics, weather patterns, and abundance of other plant life forms, especially cheatgrass likely have additional effects, we also will be able to determine their relative contribution to recovery and thresholds.

*Treatments.* For both the woodland and sage/cheat core experiments, a full set of treatments was applied at each site to achieve a statistical block. These treatments are commonly used to decrease woody fuels and to maintain or restore sagebrush ecosystems. The woodland experiment features three plot-level treatments: prescribed fire, cut and fell, and mastication. Treatment plots range in size from 10 to 30 ha, each of which has 15 measured sub-plots positioned to cover a broad condition gradient. Prescribed fire was applied first, between August and November of 2006, 2007, or 2008. The goal was to accomplish 100 percent tree mortality within each treatment plot. However, due to considerable variation in weather conditions, prescribed fires only burned between 20 and 95 percent area. For those plots in which percent area burned was low, we blackened every sub-plot where the low measurements were taken. Cut and fell and mastication treatments were implemented within six months of fire treatments. All trees >2 m tall were cut down and left on the ground across the contour. An additional treatment was applied at the four Utah juniper sites—all trees >2 m tall were masticated with the Bullhog®, a machine with a rotary mower capable of shredding even the largest juniper trees. An untreated plot serves as a control to complete the three-treatment ensemble for each woodland site (four treatments for the Utah juniper region).

The sage/cheat experiment includes four plot-level treatments per site: prescribed fire, application of the herbicide tebuthiuron, rotary mowing, and application of the herbicide imazapic nested within each of the other treatments. Treatment plots range in size from 20 to 80 ha, each of which has 18 measured sub-plots positioned to cover a broad condition gradient. Prescribed fire was applied first, from May to October of 2006, 2007, or 2008. The goal was to accomplish 100 percent fire coverage. In some cases, weather conditions did not cooperate, with the result that some plots were not completely burned. In these cases, fire crews blackened every sub-plot where measurements occurred. Once fire was implemented for each site, both herbicide and mowing treatments were applied to two other plots within the following eight months. Both treatments were designed to remove about 50 percent of sagebrush cover to reduce woody fuels and release the understory herbaceous species. The herbicide tebuthiuron (N -[5-1,1-dimethylethyl-1,3,4-thiadiazol-2-yl]- N,N' –dimethylurea) was applied over the entire plot at a rate dictated by prior testing to remove 50 percent of the overstory. Rotary mowers were set at a pre-determined height to remove 50 percent of sagebrush biomass, over the entire plot. An untreated plot served as the control to complete the four-treatment ensemble of plot-level applications for each site. The pre-emergent herbicide imazapic (3-Pyridinecarboxylic acid, 2-(4,5-dihydo-4-methyl-4-(1-methylethyl)-5 –oxo-1H-imidazol-2-yl)-5-methyl-monoammonium salt) was applied to half of the sub-plots within each of the three or four plot per site (including control) simultaneous to each of the other treatments. At low rates, imazapic selectively acts on annual plants.

*Measured Variables.* Well over 100 distinct variables are measured in SageSTEP, roughly classified as response (dependent) or explanatory (independent) variables. To evaluate ecological response, a comprehensive set of variables are measured within each of the 1050 sub-plots, capturing both structural and compositional elements of the system. These variables are measured pre-treatment and for at least 10 years post-treatment within each of the 0.1-ha sub-plots (30 by 33 m) in the two experiments. Cover and density of trees, shrubs, forbs, and grasses are measured, and analyses focus on how these vegetation components respond to treatment in relation to the vegetation gradients. Biological crust cover, bare ground cover, harvester ant mounds, and ant community structure were also measured within each sub-plot because of their potential relevance to vegetation recovery. A number of critical explanatory variables are measured to aid in interpretation of vegetation response, including: (1) inherent features of the sub-plot, such as slope, aspect, topographic position, and elevation; (2) all components of the fuel bed within sub-plots, such as standing and down woody fuel, litter, duff, and live fuels; (3) inherent soil properties, such as depth, texture, and moisture; (4) soil chemistry, with a focus on nitrogen availability and carbon; and (5) air temperature and precipitation, at weather stations placed in the center of each control plot. Each time a sub-plot is measured, two photo points are taken at the 0- and 30-m marks of the central (15 m) transect using a digital camera. These geo-referenced photo points are used to document vegetation recovery over the long-term and to aid in interpretation of vegetation response. This suite of variables will aid in quantifying STM differences among sites because recovery processes likely will largely depend on how different variables interact in the context of climate zones and weather patterns. Including variables that managers or scientists believe are potentially relevant maximizes the likelihood of capturing indicator patterns that are connected to critical processes (Pyke and others 2002). Finally, it is imperative that variables be measured for at least 10 years post-treatment because of uncertainty about the length of time required for vegetation recovery and because of the community's potential to return to the reference state). In fact, time frames must be fully understood in order to complete an STM (Bestelmeyer and others 2004).

Faunal response was also measured at the treatment plot level, particularly passerine bird and butterfly response. Passerine bird point counts are conducted annually in each treatment plot for the woodland experiment only, while 1000-m butterfly transect surveys are conducted within treatment plots for both the woodland and sage/cheat experiments. Thus, the effects of fire and fire surrogates on both passerine bird and butterfly abundances can be assessed with this design. Because average home range size for passerine birds is too large to study populations within typical SageSTEP treatment plots, bird research also includes intensive demographic work on seven species of sage-obligate passerine birds within 10 400-ha plots—one control and one prescribed burn plot for each of five woodland sites (Figure 1). Because sage-obligate passerines are known to have similar habitat preferences to sage grouse (a species of concern), research on these birds should provide insight into treatment effects on grouse populations. More generally, an important rationale for measuring faunal response to treatment is to understand the extent to which other components of the system not directly related to vegetation management track the response of vegetation over time. Understanding faunal effects will provide managers with more confidence on how their treatments influence the whole system. SageSTEP can identify inconsistencies in treatment response between the flora and fauna and potential time lags in faunal response as key components of habitat recovery after treatment. SageSTEP biodiversity research will help patch the schism that has developed in recent years between rangeland professionals focused exclusively on vegetation and production, and those more interested in the health of whole ecosystems, which is commonly expressed as various measures of biodiversity (Bestelmeyer 2006).

Finally, the extent to which woodland encroachment affects water relations has been a significant concern in recent years among managers of the sagebrush biome. Variations in site infiltration, runoff, and erosion are closely correlated with variations in vegetation and surface soil conditions (Pierson and others 2002, Rau and others 2005). In particular, pinyon and juniper trees are highly competitive for soil water, and tree dominance typically results in major declines in understory vegetation (Figure 4b). Under these conditions, undesirable hydrological conditions can develop on steep slopes, causing increased erosion and sediment transport (Degraded State 2; Figure 3). SageSTEP hydrology research focuses on the conditions under which the most deleterious effects occur to determine if critical thresholds exist in vegetation and ground cover that significantly influence hillslope erosion and if management treatments influence these thresholds.

*Analyses.* Both univariate and multivariate analyses are being used for the two ecological experiments. For univariate analyses, we will use PROC GLIMMIX (SAS Institute Inc. 2004), with replication provided at the site level for both woodland (n = 12) and sage/cheat (n = 7) experiments. This ensures a statistically valid design for the overall experiment in which differences among sites, treatments, and treatment years can be tested for the suite of ecological variables examined. Variables believed to be influencing ecosystem trajectories, like tree cover, cheatgrass biomass, or soil texture, will be treated as covariates to examine their overall influence on other response variables. To capture whole system responses to fire and fire surrogate treatments, we will use multivariate methods. Information on whole system response is valuable to managers because it allows them to evaluate treatment tradeoffs for key variables. Multivariate methods such as ordination and classification are best used for investigations on how plant and animal communities vary along spatial gradients and how they respond to treatments (McCune and Grace 2002).

To evaluate how *relationships* among components within a system respond to treatment, we will use structural equation modeling (SEM) (Grace 2006). This analysis tool requires that the investigator build hypothetical models from prior knowledge that include the key variables and their causal relationships not only to the dependent variable but to one another, and then test the models with data from the experiment. For example, we can examine how soil type influences the degree to which fire and fire surrogates affect plant species diversity. Factors such as slope, elevation, aspect, and initial fuel loads can also be evaluated in the context of a structural equation model. In summary, analytical results are used not only to identify significant differences in responses among sites, but also to provide confidence intervals for the more detailed STMs that will emerge from the study.

**V. Human Aspects**

SageSTEP is largely a comprehensive field study focused on ecological aspects of woodland expansion and cheatgrass invasion on sagebrush steppe lands of the Interior West. However, to improve public understanding of invasion and recovery processes in sagebrush steppe and to gain acceptance of applying recommended treatments, certain socioeconomic aspects need to be addressed. For instance, treatments will not be applied if the public doesn't accept them or if they are too costly relative to other land management options. Further, research results must be communicated to key stakeholders in order for the results' full potential to be realized. In this section, we briefly outline activities underway to assess sociopolitical, economic, and outreach aspects of SageSTEP.

*Sociopolitical.* Each management treatment evaluated in this project is a potentially controversial practice that might meet resistance from citizens and/or managers when applied to public lands. Because National Environmental Policy Act (NEPA) prescribes that Federal land managers must closely involve the public whenever treatment decisions are made, it is important to understand how treatments are perceived and accepted by various sectors of the public. The sociopolitical component of SageSTEP assesses the social and political feasibility of alternative treatments, with feasibility defined as a function of positive or negative perceptions of the general public, interest group members, and land managers. Our intent is to identify factors in the treatments, or the conditions those treatments produce, that constrain or facilitate implementation of practices. Also included in those factors is the current state of ecological systems, relative to ecological thresholds. While the research questions focus on the practical issue of choosing among potential restoration actions, the study also explores more basic questions about decisionmaking with uncertainty and about using the foundations of social acceptability (Shindler and others 2002) as guiding principles of contemporary land management.

*Economic.* The goal of SageSTEP economics work is to provide a comprehensive understanding of the tradeoffs and incentives that face decisionmakers at various levels when they consider whether to treat sagebrush steppe lands. The economic research consists of four parts:

(1) a dynamic bioeconomic model that combines features of a state-and-transition ecological model with fire, invasives, and economic decision variables (treatment and grazing levels) to predict how system resilience changes with management decision variables;
(2) a ranch-level model to predict ranchers' incentives in decisions regarding treatment options;
(3) a model to predict county-level impacts on employment and income by sector associated with alternative landscape characteristics caused by treatment or lack of treatment; and
(4) a valuation of expected changes in flows of non-priced goods and services brought about by decisions to treat sagebrush steppe lands that have been degraded by cheatgrass invasion or woodland encroachment.

## VI. Outreach

Although SageSTEP generates information for a wide variety of people, its principal outputs consist of applied ecological and socioeconomic information designed to be useful to **land managers.** A Communication Plan guides the project through the outreach process by providing both conceptual and process frameworks at the network and site levels. Principal products and activities include:

- a Website that is designed and maintained by a dedicated outreach coordinator;
- a newsletter produced three times per year that informs stakeholders on the progress of SageSTEP;
- annual workshops for managers to maintain clear lines of communication;
- field tours for a variety of audiences;
- presentations at scientific and management-oriented meetings;
- scientific publications, in which primary findings are published;
- other outreach materials that are developed as opportunities arise in order to serve a variety of audiences including general or specific publics and land managers; and
- a set of three User's Guides to be used by managers in the field.

The User's Guides exemplify the approach we have chosen: to deliver scientific information to managers hands. Each User's Guide is focused on a Land Resource Unit with similar characteristics and issues to the perspective of the land manager (e.g. Western Juniper, Pinyon-Juniper, Wyoming Big Sagebrush). Each is grounded in scientific literature and provides a list of key publications that support its perspective and can be cited in NEPA documents. Each leads the user through a series of questions designed to help the manager make decisions on a particular stand or watershed. We anticipate that results from both experiments will be used to update and expand Ecological Site Descriptions for each of the distinct sites within the SageSTEP network, and to update each of three User's Guides. Finally, the effectiveness of the outreach program will be evaluated regularly with surveys taken at the annual manager workshops.

## VII. Summary

As a single study focused on sagebrush steppe ecosystems of the Interior West, SageSTEP has several features that make it unique as a research project that tests hypotheses associated with state-and-transition theory. SageSTEP is: (1) Experimental—allows for controlled manipulation of ecological factors that are considered to be drivers in the woodland and sage/cheat experimental systems; (2) Long-term (10 years post-treatment)—provides sufficient ecological post-treatment time to measure and interpret ecological response; (3) Multisite—evaluates responses across the range of environmental conditions that characterize the region; (4) Multivariate—measures both dependent and independent variables, not only to evaluate response but to identify mechanisms behind that response; and (5) STM-based—applies treatments across the range of ecological conditions that characterize the states and phases within the woodland and sage/cheat STMs. Information from SageSTEP will improve existing Ecological Site Descriptions, including details on among-site soil variation, vegetation, threshold dynamics, and the form of state-and-transition models, as they apply to both the flora and the fauna of sagebrush steppe systems. SageSTEP also explores human aspects of the invasion on sagebrush steppe lands, including social acceptability of alternative treatments, economic tradeoffs that face land managers dealing with woodland and cheatgrass invasion, and alternative methods for disseminating research results to key stakeholders.

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# IX. FINDINGS AND DELIVERABLES

**Principle Findings**. The table below lists the principle findings of SageSTEP thus far. Findings are organized by experiment: woodland experiment first, then sage-cheat, then general.

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| **Woodland Findings** | | | |
| Duncan et al. In review (28); Woodlands; Vegetation | No significant relationships detected between tree cover and seed bank ruderal species richness of the seed bank at either site or in either year. | Consequences of tree removal will be predictable only through pre-treatment densities of adult plants, and not by seed bank features. | 1-year studies show that varying levels of pinyon-juniper cover had no effect on seedbanks in a dry year (Allen and Nowak 2008) but did influence seedbanks in a wet year (Koniak and Everett 1982; Bakker et al. 1996). |
| | In years receiving above average precipitation, site resilience will be higher in areas of low juniper cover. | In advanced stages of woodland encroachment, reseeding with native perennials is needed for restoration after tree removal. | |
| Ratchford et al. In review (32); Woodlands; Vegetation | Canopy volume was the best predictor of total tree biomass, followed by canopy area and basal diameter. | Measuring canopy volume allows managers an easy way to estimate fuel loads and above ground carbon mass. | Everett and Thran (1992) and Grier et al. (1999) evaluated biomass and nutrients of pinyon, and Strand et al. (2008) explored remote sensing for western juniper. |
| | The smallest fuel size class (<0.64 cm), of which foliage comprised 80.5%, accounted for the largest proportion of tree biomass. | | |
| | Proportion of total biomass made up by each fuel class was significantly related to all allometric variables. | | |
| | Carbon made up ~ 50% of juniper biomass within each fuel class; nitrogen, sulphur, and phosphorous concentrations were highest in the <0.64 cm size class. | | |
| Tausch et al. In review (45); Woodlands; Vegetation | Patterns of tree growth and stand dynamics are organized around the efficient distribution and support of the stand foliage biomass, within a resource steady state. | Woodlands regions vary in how competition occurs among growth forms, indicating that tree removal may have different understory consequences across the Great Basin. | No literature available on this topic. |
| Stebleton and Bunting In press (27); Woodlands; Fuels | Mass of trees, litter, duff, and dead/live herbaceous were significantly different among woodland phases. | Potential fire behavior will depend in large part on the stage of woodland encroachment. | Very little work has been done on characterizing fuel beds across gradients of woodland encroachment. |
| | Western juniper woodland had greater mass of dead down woody fuel than other woodlands. | Western juniper stands may burn in distinctly different ways compared to pinyon-juniper stands. | No literature available on this topic. |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| Rau et al. 2010 (23); Woodland; Soil Carbon | Prescribed fire reduced aboveground fine fuel mass, releasing carbon to the atmosphere, but incorporating some carbon into soils. | While prescribed fire does release carbon into the atmosphere, more carbon may be incorporated into soils in repeat burns than would be incorporated in a single intense wildfire. | Working on juniper woodland of the Colorado plateau, Klopatek et al. (1991) reported on effects of fire on forest floor carbon and nitrogen. |
| Rau et al. In press (24); Woodland; Soil Carbon | Woodland expansion increases aboveground carbon, but has little influence on belowground carbon. | While woodland expansion increases carbon sequestration aboveground, this is only short-term storage, because these forests will burn in the intermediate term. | There is no literature which adequately adresses this question for Great basin woodlands. |
| Rau et al. In press (36); Woodlands; Soils | Woodland expansion increases belowground carbon by increasing root biomass and increased litterfall, but carbon sequestration is limited by nitrogen. | Restoration efforts that result in greater nitrogen fixation will also tend to sequester more carbon belowground. | Neff et al. (2009) report on carbon/nitrogen dynamics in juniper woodland of the Colorado Plateau. |
| Cline 2008 (16); Woodland; Hydro | Tractors with a rotating-toothed masticating drum compacted sub-surface soils in bare ground, grass interspace, and shrub mound microsites. | While mastication is an effective fuel reduction technique, heavy machines must be deployed with caution, as compaction is likely to occur. | No research has reported on soil effects of mechanical shredding in sagebrush systems. Hatchett et al. (2006) showed that tractors used for shredding did not significantly compact soils or increase runoff in a mixed conifer forest near Lake Tahoe. |
| | Only pre-wet grass interspaces had significantly decreased infiltration rates from compaction. | Deploy heavy masticating machinery when ground surface and soils are dry. | |
| | Shredded residue significantly increased infiltration rates and decreased sediment yield on bare ground. | Mastication debris can be used to increased infiltration rates and thereby decrease runoff and erosion on treated sites. | Hastings et al. (2003) showed that leaving juniper slash on rangelands may decrease sediment yields one to three fold. |
| Pierson et al. 2008 (9); Woodland; Hydro | Tree coppice, shrub coppice, and interspace areas on wooded shrublands exhibit different responses to convective rainfall events. | If Phase III woodlands are allowed to persist, their interspaces can be expected to generate substantial runoff and sediment yield downslope. | During convective rainfall events, runoff and eroison from degraded woodlands is related to spatial expanse of bare interspace area (Davenport et al. 1998, Ried et al. 1999). |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| Pierson et al. 2010 (15); Woodland; Hydro | Hydrologic impact of woodland encroachment depends on the expanse andconnectivity of bare intercanopy, and on site specific erodibility. | Tree removal decisions should consider amount of bare intercanopy area, site-specific erodibility and climate, and potential vegetation response. | Hydrological risk of encroached sagebrush steppe depends on the spatial expanse of bare intercanopy, soil type, and precipitation regime (Wilcox et al. 1996, Davenport et al. 1998, Reid et al. 1999, Wilcox et al. 2003, Pierson et al. 2007). |
| Pierson et al. 2010 (15); Woodland; Hydro | Erosion on wooded shrublands depends on the quantity and type of ground cover between canopies. | Litter and vegetative basal cover of 30-50% is required to protect intercanopy areas from amplified runoff and erosion during high-intensity convective storms. | Intercanopy and canopy zones of pinyon-juniper woodlands exhibit different hydrologic behavior (Roundy et al. 1978, Wilcox et al. 1996, Reid et al. 1999, Wilcox et al. 2003, Pierson et al. 2007). . |
| | Intercanopy areas are capable can generate 3-6 times more runoff and greater sediment yield than tree canopy areas during high-intensity, short-duration convective storms. | Litter and vegetative basal cover of 30-50% is required to protect intercanopy areas from amplified runoff and erosion during high-intensity convective storms. | Runoff and erosion increase exponentially where bare ground exceeds 50% in the intercanopy (Gifford 1985). |
| Pierson et al. In review (39); Woodlands; Hydro | Altered fire regimes associated with plant community transitions have significant implications for post-fire hydrologic risk assessment. | Increased spatial and temporal vulnerability to amplified runoff and erosion pose serious risks of resource/property/infrastructure damage and loss of human life. | Historical accounts of extreme post-fire flooding demonstrate the danger that these events pose to downstream resources and communities (Moody and Martin 2001; Pierson et al. 2002; Klade 2006). |
| Pierson et al. In review (39); Woodlands; Hydro | The increased role of fire necessitates development of a probabilistic framework for post-fire hydrologic risk assessment. | Post-fire hydrologic risk assessment should define post-fire site susceptibility and evaluate risk in a framework that links likelihood of particular storm events and site susceptibility. | Hydrologic response should be evaluated as probabilistic function of storm likelihood of occurrence and post-fire surface conditions (Robichaud et al. 2007). |
| McIver and Macke, In review (50); Entomology | Prescribed burning increased butterfly species richness at treeless sage steppe sites. | Butterflies are adapted to fire in sagebrush steppe ecosystems. | There is no information on butterfly response to prescribed fire in sagebrush steppe, but Waltz & Covington (2001) reported that prescribed burning in dry ponderosa pine forest in N. Arizona increased richness of butterfly community 1-3 years after treatment. |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| McIver and Macke, In review (50); Entomology | Prescribed burning increased abundance of blues and sulphurs at woodland sites. | Supports the idea that butterflies are adapted to fire in sagebrush steppe ecosystems. | Both blues and sulphurs increased in abundance after prescribed burniing in ponderosa pine (Waltz & Covington 2001). |
| McIver and Macke, In review (50); Entomology | White butterfly abundance declined in tebuthiron plots at five of seven sage-cheat sites. | Broadleaf herbicides may cause unintended consequences in sagebrush steppe systems. | There is no experimental information on butterfly response to tebuthiron in sagebrush steppe. |
| McIver and Macke, In review (50); Entomology | Removal of trees decreased abundance of Juniper Hairstreaks where they occur, larvae of which are obligate feeders on juniper. | Declines in butterfly species having larvae that feed on woodland vegetation are expected with woodland removal treatments. | There is no information on butterfly response to mechanical treatments in sagebrush steppe., but Tyler Hicks (WSU) observed that mechanically treated woodland plots in Colorado had subtle effects on butterflies. |
| McIver and Macke, In review (50); Entomology | Abundance of local butterfly species was positively related to perennial grass cover, and negatively related to annual grass cover. | Managing for healthy perennial grass stands will likely result in healthy butterfly populations. | No published literature. |
| McIver and Macke, In review (50); Entomology | Abundance of local butterfly species was only weakly related to forb cover, even for species with larvae that develop on perennial forbs. | Monitoring perennial forb cover will not allow prediction of butterfly abundance. | No published literature. |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| **Sage-Cheat Findings** | | | |
| Burnham, In review; Sage-Cheat; Vegetation | In the first three years following application of Imazipic as a pre-emergent herbicide (6-8 oz/acre), cheatgrass cover declined by an average of 79%, 84%, and 50%, while exotic forb density was reduced by an average of 95% and 49% in the first two years following treatment. | Single Imazipic applications can provide managers with a high level of annual vegetation control for multiple years after a variety of disturbance types (including no disturbance), during which time competition from invasive annual range plants on more desirable species will be substantially reduced. | |
| | Desirable native vegetation can be negatively affected by Imazipic application, including native annual forb cover (strongly inhibited), native perennial grass and forb cover (slightly inhibited). | Because Imazipic can inhibit desirable native species (especially annual forbs), the lowest possible application rate that still provides control should be used. | |
| Pyke et al. In press (26); Sage-Cheat; Vegetation | A landscape triage method is recommended for prioritizing lands for restoration. | Spatial models can indicate where to protect and connect intact quality habitat with other similar habitat via restoration. | |
| | The ecological site concept of land classification is recommended for characterizing potential habitat across the region along with their accompanying state and transition models. | These models assist in identifying if passive, management-based or active, vegetation manipulation based restoration might accomplish the goals of improved habitat. | |
| Pyke et al. 2010 (30); Sage-Cheat; Vegetation | Plant resistance and resilience to fire can be categorized by a combination of life form, size, and ability to disperse or protect seeds. We use a combination of life form, vital plant attributes, and fire regime to suggest a simple way to use fire to reduce or enhance particular species. | Questions regarding perennating bud and seed characteristics direct restoration practitioners to fire regimes that may achieve their management objectives of either increasing or decreasing plants with specific life form characteristics. | |
| Reisner 2010 (55); Sage-Cheat; Vegetation | Sagebrush competed with the two native perennial grasses with the strongest competitive abilities (Sandberg's bluegrass and squirreltail) when stress (heat, water, cattle grazing) was low, but facilitated both species when stress was high. | Managers need to understand where their systems are on the stress gradient: at low to intermediate stress levels, sagebrush might be useful to help re-establish bunchgrasses in formerly stressed systems. | Huber et al.(2005) suggested that sagebrush might be useful to facilitate native seedlings. |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| Reisner 2010 (55); Sage-Cheat; Vegetation | Sagebrush competed with cheatgrass at the same level regardless of stress level. | Not all herbaceous species will respond the same. | |
| | Under high stress, facilitation of native grasses by sagebrush can destabilize community when fires occur, because native grass mortality is much higher when growing under sage canopy. | Managers should try to reduce the stressors that are manageable (e.g. cattle grazing), when other stress levels (water, heat) are high. | Pyke et al. (2010) makes this recommendation. |
| | Landscape orientation and soil physical properties set the stage for invasion by cheatgrass. | Thresholds are conditional -- managers need to protect the most vulnerable portions of their systems. | Stewart and Hull (1949), Hinds (1975), and Davies et al. (2007) discuss the role of landscape features/soils, while Beatley (1996) focuses on soils. |
| | As basal gaps get bigger and more connected, resistance to invasion declines. | Basal gaps are very important and they are easy to monitor. | Herrick et al. (2007) predicted that gap size might be an indicator of invasion potential. |
| | Bunchgrasses and biological crusts can limit cheatgrass invasion potential. | Biological crusts and perennial grasses can protect a site from cheatgrass invasion, especially if certain grass mixes are used. | James et al. (2008) talks about combinations of species that offer spatial and temporal resistance to invasion. |
| | After controlling for conditional factors, cattle grazing reduced resistance of these systems to invasion by cheatgrass. | If managers can maintain grazing stress below stress thresholds, cheatgrass invasion will likely be inhibited. | Pyke et al. (2010) talk about passive restoration (removal of stressors) as part of an overall management approach. |
| Wijayratne and Pyke, In Review (44); Sage-Cheat; Vegetation | After 24 months, seeds buried at least 3 cm below the soil surface retained 40-60% viability whereas viability of seeds on the surface and under litter declined to 0 and < 20%, respectively. | Use of seeding techniques that promote burial of some seeds in the soil seed bank may increase restoration potential. | |
| | Abundance of viable seeds did not change substantially between sampling times in the first year, but the seed bank was heterogeneous both spatially and temporally. | | |
| Rau et al. 2011b (51); Sage-Cheat; Soils, Carbon | Transition to annual grass (Cheatgrass) dominated understory reduces belowground carbon stocks. | Exotic annual grass (Cheatgrass) invasions have the potential to create large and persistant carbon emission sources in arid and semi-arid rangelands. | Our region-wide findings most cloesly resemble data presented in Norton et al. (2004). |

| Citation | Finding | Management Implication | Key Literature |
| --- | --- | --- | --- |
| **General SageSTEP Findings** | | | |
| Shindler et al. 2007 (6); Socio-political | Rural residents see the Great Basin as healthier overall than urban residents, and feel that economic factors should dominate decision-making. | Managers will likely gain more public support if they structure communication strategies to best fit diverse audiences. | Understanding and gaining acceptance for proposed actions is more challenging because public opinion tends to vary geographically (Toman et al. 2006; McCraffrey 2004). |
| | While people are more familiar with 1-way forms of communication (newspapers, television, radio, brochures, newsletters), they are scored lower for effectiveness. | One-way communication methods should not be relied upon as the staple of an outreach program. | |
| | The highest rated forms of communication involve two-way citizen-agency interaction, such as demonstration sites, guided field trips, and interactive workshops. | There are clear opportunities for agencies to create more positive and useful experiences for citizens by focusing on two-way forms of outreach. | Interactive forms of communication tend to be more effective for influencing citizens' attitudes and behavior (Toman et al. 2006). |
| | Rural residents rated usefulness of agency communications lower than urban residents, and preferred getting information from ranching and range groups, extension agents, or family and friends. | A one-size-fits-all approach to communicating with multiple publics is not sufficient. | |
| Shindler et al. In press (38); Socio-political | Most respondents believe the region's rangelands are moderately healthy but rural residents rate conditions healthier than do urban residents. | The complexity of restoring rangelands will require an understanding of both sets of publics. | |
| | Most respondents recognized threats to sagebrush ecosystems, especially from invasive species, development, impacts to riparian systems, off-highway vehicles (OHVs), overgrazing, and wildfire. | Public concern about threats to rangelands provides an a way for managers to shape the discussion around restoration activities. | Providing opportunities for citizens to assess information about familiar places, including risks and uncertainties of alternative treatments, can bring them closer to support management decisions (Shindler et al. 2002). |
| | Urban residents were more likely to see risks posed by human activities, while rural residents were more likely to perceive risks from biological processes. | There are substantial difference between publics about which processes produce more threats, and how those threats can be mitigated. | Managers will need to respond to the needs of rural citizens without ignoring perspectives of urban stakeholders, and this will involve attention to both economic and cultural differences (Nelson 2002). |

| Citation | Finding | Management Implication | Key Literature |
|---|---|---|---|
| Shindler et al. In press (38); Socio-political | Urban residents are more concerned with preserving natural conditions with little interest in economic consequences. | Recognizing differences can lead to considering different methods for interactions with urban and rural groups. | Limiting planning activities to smaller areas to avoid major conflicts may help bring agencies and citizens together (O'Neill 2005). |
| | Most citizens support the use of several practices for sagebrush rangelands in the Great Basin, particularly prescribed fire, livestock grazing, felling, and mowing; herbicides and chaining received substantially less support. | Citizens endorse the validity of active management approaches us by federal agencies; as urban residents become more familiar with these practices, it is likely they will become more comfortable with their use. | |
| Shindler et al. In press (38); Socio-political | Respondents exhibited low levels of public trust and confidence in federal management agencies throughout the Great Basin. | Trust and confidence are probably the most important factors in determining public support for programs targeting restoration and wildland fire management. | Citizen trust in natural resource agencies is linked to suport of management activities (McCaffrey 2006; Lilyeblad and Borrie 2006). |
| Shindler et al. In press (38); Socio-political | Levels of trust in managers to use prescribed fire, grazing, felling, and mowing treatments were relatively low, with only minor differences among the urban and rural groups. | Because trust is variable and complex, managers can use this kind of information to determine causes and to build stronger relations with their public partners. | Citizen trust toward agencies and their activities is directly related to the history of interactions between managers and stakeholders (Shindler et al. 2002). |
| Shindler et al. In press (38); Socio-political | When acceptability scores are paired directly with trust in managers to use these same practices, willingness to accept a practice does not equate to confidence in federal agencies to implement that practice safely or effectively. | Trust in specific practices is not solely a function of perceived competence, but more likely due to an interaction of multiple factors. | Studies in ranching, forestry, and fishing communities show that trust and public acceptance of management change depends on a suite of factors (Brunson and Evans 2005; Brunson and Steel 1996; Shindler and Toman 2003). |
| Shindler et al. In press (38); Socio-political | Most repondents believe that agencies do not adequately use public input for decision-making, leading to lack of trust among citizens on management activities. | There is little evidence that agencies are using public outreach and communication strategies that resonate with the public. | Outreach strategies vary by management location and by agency (Olsen and Shindler 2010). |
| Rau et al. 2011a (47); Soils | Rotary cores are an acceptable alternative to quantitative pit sampling to quantify soil carbon and nitrogen. | Use of rotary core device allows mangers to make measurements of soil carbon and nitrogen to quantify effects of management and climate change. | There has been no other comparison of these two methodologies. Although Ponder and Alley (1997) proposed the device for use of sampling rocky soils. |

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## Deliverables Crosswalk

| Proposed | Delivered | Status |
|---|---|---|
| **Table 3 (Included in Project Proposal)** | | |
| Papers/presentations on socio-economic trends, and ranch-level baseline budgets | | Completed |
| Field Guide to interest group concerns | Hoffmann et al. 2010. *A guide to stakeholder groups for Great Basin sagebrush steppe restoration.* Also developed into an online version: www.sagestep.org/pubs/stakeholderguide/intro.html | Completed |
| Papers/presentations on social acceptability | | Completed |
| Papers/presentations on non-market values | | Completed |
| Production of 'Fuels Guide' | Stebleton and Bunting 2009. *Guide for Quantifying Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin.* BLM Tech. Note 430. Also developed into an online version: www.cnr.uidaho.edu/GBFuelsGuide | Completed |
| Handbook on legal/institutional constraints on management | *Guide to Legal and Institutional Resources for Restoration and Management of Great Basin Rangelands.* Developed as an online guide: www.sagestep.org/pubs/leg_inst_res/index.html | Completed |
| Production of 1st Edition 'User's Guides' | (1) Miller et al. 2008. *Western Juniper Field Guide: Asking the Right Questions to Select Appropriate Management Actions.* USGS Circ. 1321.<br>(2) Tausch et al. 2009. *Piñon and Juniper Field Guide: Asking the Right Questions to Select Appropriate Management Actions.* USGS Circ. 1335.<br>(3) Cheatgrass Users Guide is in outline form at present, awaiting information from short-term SageSTEP results. | (1) Completed<br>(2) Completed<br>(3) In progress |
| Papers/presentations on economic optimization | | |
| GTR: Site-Level Establishment Reports | McIver et al. 2010. *The Sagebrush Steppe Treatment Evaluation Project (SageSTEP): A Test of State-and-Transition Theory*. RMRS-GTR-237. | Completed |
| Papers/presentations on economic comparison of treatments | | Completed |
| Educational Assessment: What tech transfer tools work? | In 2009, we helped conduct focus groups with federal land managers to learn more about what tech transfer tools are most effective as part of the planning phase of the Great Basin Science Delivery Project. Then, in 2010, we administered an online | Completed |

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| | survey to determine the effectiveness of the SageSTEP outreach program and communication methods. Results of this survey are currently compiled in an unpublished report, and will soon be published. | |
| 1st Major Symposium: Presentation of 1st Round Results | *Ecological Society of America 2009 Annual Meeting Organized Oral Session: Ecological Knowledge to Enhance Stewardship and Restoration of Sagebrush Steppe Communities*<br>August 2-7, 2009<br>Albuquerque, New Mexico | Completed |
| Papers/presentations on economics of reducing risk of wildfire with prescribed fire treatments | | Completed |
| Production of 2nd Edition 'User's Guides' | These will be published five years after implementation of 2008 treatments, to allow sufficient time for post-treatment response to manifest and for SageSTEP short-term information to be published in peer-reviewed journals. | |
| 2nd Major Symposium: Presentation of 2nd Round Results | *Association for Fire Ecology Interior West Fire Ecology Conference: SageSTEP Symposium*<br>November 14-17, 2011<br>Snowbird Resort, Utah | In progress |
| Publication of Papers in Special Journal Issue | | |
| Annual: Research Briefings, Site Field Tours, Annual Reports | | |
| Quarterly: Progress Report to JFSP Board | | |
| **Additional Items from Communications Plan** | | |
| Website | www.sagestep.org | Updated as needed |
| Publication Series | See *SageSTEP Publication List*. | In progress |
| Brochure and Fact Sheets | A project fact sheet with a map of study sites and project information as well as nineteen separate fact sheets for individual study sites were developed in 2006 and updated in 2009. These are all available online at: www.sagestep.org/pubs/facts.html. | Completed |
| PowerPoint Presentations | Presentations outlining the SageSTEP research for the (1) general public and (2) the scientific community were created in 2005 and have been updated periodically and presented at a variety of meetings. | Completed |
| Poster | A large-format poster outlining the SageSTEP | Completed |

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| | research was created in 2005 and presented at several scientific and professional meetings in subsequent years. | |
| Audiovisual/Extension Product | *Restoring Sagebrush Rangelands in the Great Basin: An Introduction to Alternative Land Management Strategies.* DVD. Utah State University and the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), 2008. www.sagestep.org/pubs/DVD.html | Completed |
| Study Plan | McIver et al. 2011. *Regional Experiment to Evaluate Effects of Fire and Fire Surrogate Treatments in the Sagebrush Biome (SageSTEP): Study Plan*. | In progress |
| Establishment Report | This reports awaits implementation of treatments at the final SageSTEP site at Spruce Mt. (PJ Region), which has to date been held up in litigation. | In progress |
| Corporate Database | Data needed for meta-analysis and other network analyses has been archived and structured in a corporate database available to all principal investigators. | Completed |
| Outreach Database | Outreach efforts and products have been compiled in an outreach database, attached to the Final Report. | Updated as needed |
| Press Releases/Research Briefs | Press releases have been released periodically, as needed and have resulted in articles in university newspapers and newsletters and other local newspapers. | Completed |
| Meetings, Workshops, Field Days and Site Tours | Yearly land manager workshops and field tours were conducted from 2006−2011 in various Great Basin states. Additional field tours, office visits and presentations were conducted as needed (see Outreach Database) | Completed |
| Presentations at Scientific/Professional Meetings | See outreach database? | Completed |
| Interpretive Activities | Interpretive products and activities have been incorporated into our outreach efforts as needed, including creation of informational handouts, signs at sites, web content development, and presentations and discussions at NGO meetings and activities. | Completed |
| National Conference | At the SRM 2012 Annual Meeting in Spokane, WA, SageSTEP researchers will present in a special session entitled *Disturbance, Resilience and Thresholds in Sagebrush Ecosystems*. Presentations will use findings from SageSTEP research to inform a series of discussions about sagebrush-steppe ecosystem resilience and our ability to predict thresholds between alternative states. | In progress |
| Invited Feature | Negotiations underway with Editors of Rangeland | |

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| | Ecology and Management; anticipated submission date early 2012 | |
| **Additional Deliverables** | | |
| Outreach Website | In 2006, an outreach website was created to store and share information used by the SageSTEP research team for outreach purposes. http://outreach.sagestep.org | Updated as needed |
| Second Project Poster | A large-format poster describing plans for long-term monitoring of SageSTEP study sites and their relationship to climate change research was created in 2009 and has been presented at several scientific and professional meetings and workshops. | Completed |
| Post-treatment Fuels Guide | Bourne and Bunting 2011. *Guide for Quantifying Post-treatment Fuels in the Sagebrush Steppe and Juniper Woodlands of the Great Basin*. BLM Tech. Note 437. | Completed |
| Field Guide to Sagebrush Birds | Pitkin and Quattrini 2010. Pocket Guide to Sagebrush Birds. The SageSTEP outreach program assisted with editing, review and printing of this guide. | Completed |

**X. The Future of SageSTEP.**

From its inception, SageSTEP has always been envisioned as a long-term study. The cost of the infrastructure, the benefits that accrue from sustaining existing partnerships, the substantial outreach SageSTEP offers to the management agencies in the Great Basin, and the role SageSTEP will play in NSF's NEON monitoring program, all argue for creating a funding environment that can sustain SageSTEP well beyond the original 6-year period. Our goal is to continue the study for at least 10 years post-treatment, to allow sufficient evaluation of ecological response into the intermediate term. This is critical because it is very unlikely that short-term results (1-4 years post-treatment) will tell a complete story of how these ecosystems respond to land management treatments. For example, we have always expected cheatgrass to respond positively to prescribed fire treatments in the short-term, primarily because of the short-term release of nitrogen (N) after burning, and the concomitant tendency for cheatgrass to seize N more efficiently than perennial bunchgrasses. But in the intermediate term (4-10 years post-treatment), we expect bunchgrasses to begin to claim critical resources from cheatgrass at some sites, as N comes into balance with other nutrients. Thus intermediate-term results are expected to differ substantially from short-term results. The transition of SageSTEP into a long-term study has other benefits as well, many of which are management related.  We anticipate that SageSTEP will continue to offer valuable information for fire and ecosystem management (Figure 5), and will also contribute to the understanding of how climate change may impact sagebrush steppe ecosystems, through validation of climate models, and through management opportunities regarding carbon sequestration.

Figure 5.