SageSTEP News
Sagebrush Steppe Treatment Evaluation Project
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Using a Human Footprint Map to Assess the Extent of Human Actions Across Sagebrush Landscapes

by Matthias Leu

Human actions have increased dramatically in western U.S. sagebrush (*Artemisia* spp.) landscapes over the past 50 years. For example, many counties in the western U.S. show higher population growth rates than the average U.S. growth rate. The number and kinds of plants and wildlife that remain are directly influenced by human activities such as low-density development, fires, exotic plant introduction, energy extraction, and motorized recreation. Additional and sometimes more subtle influences on these ecosystems result from the roads, powerlines, and other networks and land uses necessary to maintain human actions. Despite the drastic change in human actions and land-use patterns across the western U.S., little is known about how these activities influence ecological processes.

In an effort to quantify the impact of human actions and land-use patterns across the western U.S., we first developed a map of the human footprint that spatially represents the cumulative impact of human activities on the landscape (Leu et al. 2008). We calculated the physical human footprint, the actual space occupied by human features, based on four point features (e.g., campgrounds, landfills), six linear features (e.g., roads, irrigation canals), and two polygon features (e.g., agricultural land and urban areas). All spatial data sets are available at SAGEMAP (http://sagemap.wr.usgs.gov). As of 2003, the physical human footprint occupied 13% of the western U.S. with agricultural land (9.8%), populated areas (1.9%), and secondary roads (1.1%) being the most common human features.

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We then assessed the influence of human actions by mapping the effect area, or the ecological human footprint. Here, we recognize that human features influence ecological processes beyond the physical space occupied by these features. Our mapping effort was a two-tier approach based on predator and habitat-mediated influences of human actions (Leu et al. 2008). Predator-mediated processes are influenced, for example, by linear features such as power lines, railroads, primary and secondary roads, and irrigation channels that serve as potential perch sites, nesting platforms, and travel routes for predators and expand their movements into regions where they naturally occur at low densities. For example, numbers of common ravens (*Corvus corax*), American crows (*C. brachyrhynchos*), black-billed magpies (*Pica hudsonia*), and brown-headed cowbirds (*Molothrus ater*) increase in areas surrounding rural human developments, campgrounds, landfills, rest stops, and agricultural lands because of the availability of new and often highly abundant food sources. Habitat-mediated processes included human features that induce changes in habitat by directly converting habitat or indirectly affecting natural processes. We used four models of habitat-mediated processes: exotic plant occurrence, habitat fragmentation (wildlife connectivity), oil and gas developments, and human-induced fires.

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In our final product, we combined the extent of the three predator and four habitat-mediated disturbance models into a human footprint map. We ranked low human footprint intensity as score of 1 and high human footprint intensity as score of 10 (Fig. 1). We tested the output of the human footprint map with songbird species abundance. For four species that benefit from the human features, we found positive correlations between human footprint intensity and abundance. In contrast, for three of six species that respond negatively to habitat fragmentation or are species of concern, we found a negative correlation between human footprint intensity and abundance.

The Human Footprint across the Sage-grouse Range

Human-footprint intensity varied spatially across the sage-grouse (*Centrocercus* spp.) range (Fig. 1). Areas of high-intensity human-footprint were most prevalent in the northwestern, central, and eastern portion of the sage-grouse range (Leu and Hanser *In press*). Intensity of human footprint also varied among sage-grouse management zones (Fig. 1). We ranked sage-grouse management zones from most- to least-human-footprint effect based on four criteria relating to measures of sagebrush patch size and distribution of patches. On a decreasing scale of human-footprint effect, our ranking was: Columbia Basin, Colorado Plateau, Wyoming Basins, Great Plains, Snake River Plain, Southern Great Basin, and Northern Great Basin.

Human-footprint intensity varied among sagebrush land-cover types (Leu and Hanser *In press*). The least common land-cover classes across the sage-grouse range, black sagebrush (*A. nova*) and little sagebrush (*A. arbuscula*), had the highest proportion of low-intensity and lowest proportion of high-intensity human-footprint area. For big sagebrush (*A. tridentata*) land-cover classes, the moutain sagebrush (*A. t. vaseyana*) steppe and big sagebrush steppe had higher proportions of low-intensity area compared to the big sagebrush shrubland. Overall, the human footprint may have a disproportionate effect on sagebrush systems and sage-grouse populations because human footprint intensity is highest in the most productive systems, such as valley floors, areas of high productivity as measured by Normalized Vegetation Difference Index, and areas with deep soil (Leu et al. 2008). Little is known about how the human footprint affects the annual cycle of sage-grouse demography and survival.

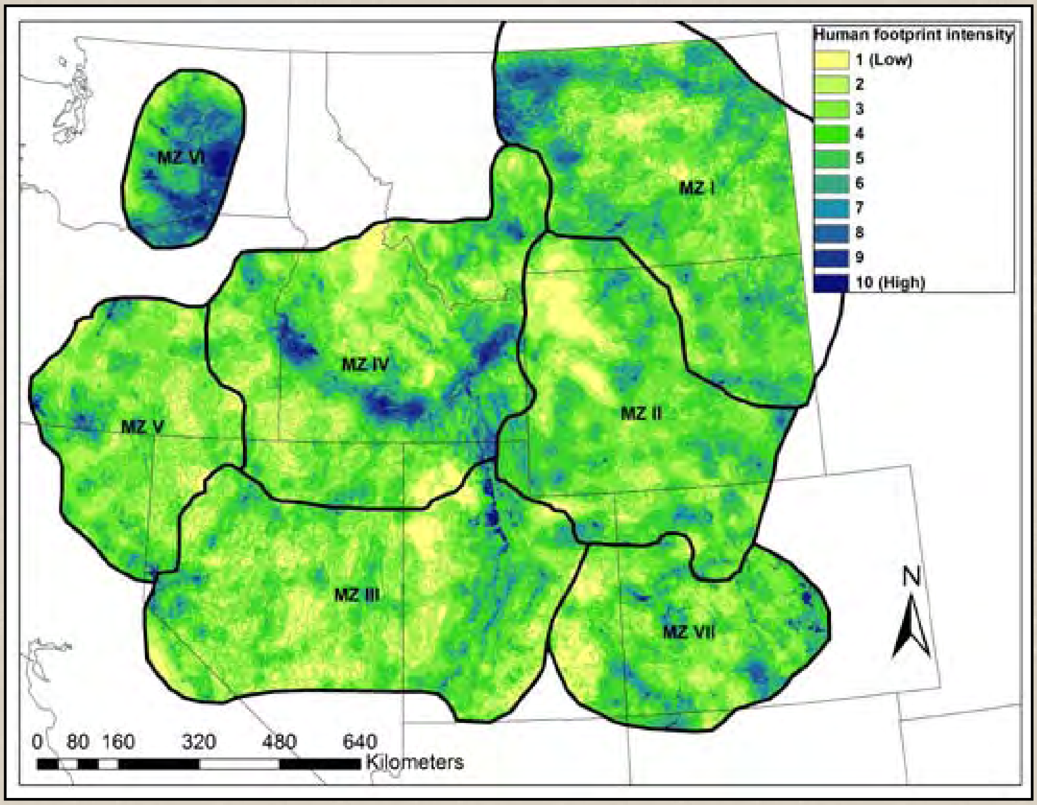

Figure 1: The ecological human footprint for sagebrush landscapes with yellow and light-green representing areas of low human footprint intensity and dark-green and blue representing areas of high human footprint intensity. The human footprint is clipped to seven Sage-grouse Management Zones: I = Great Plains, II = Wyoming Basin, III = Southern Great Basin, IV = Snake River Plain, V = Northern Great Basin, VI = Columbia Basin, and VII = Colorado Plateau.

Additionally, we investigated how sagebrush patches are distributed across scales and sage-grouse management zones (Leu and Hanser, *In press*). Sagebrush patches were dispersed at small scales but clumped at large scales in the Columbia Basin, Colorado Plateau, and Great Plains sage-grouse management zones, all of which are heavily fragmented by human actions. In contrast, sagebrush patches were clumped regardless of scale in the Snake River, Northern and Southern Great Basin sage-grouse management zones; in these zones human-induced fragmentation is minimal and occurring at local scales. The Southern Great Basin sage-grouse management zone, a naturally fragmented area in which sagebrush occurs in valleys between mountain ranges, was intermediate between the two aforementioned sagebrush distribution patterns. Using Greater Sage-grouse (*C. urophasianus*) population viability data at the sage-grouse management zone level (Garton et al. *In press*), sage-grouse populations are predicted to be stable in landscapes that are either naturally fragmented or fragmented by human actions at small scales. In contrast, greater sage-grouse populations are predicted to decrease in management zones in which sagebrush habitat is fragmented across large scales by human actions. This suggests that greater sage-grouse have adapted to sagebrush fragmentation but that human actions may disrupt sagebrush patch arrangements for this species.

Human footprint intensity has been found, next to fire extent, to be the second most important variable in explaining Greater Sage-grouse lek persistence from 1965 to 2007.

Management and Conservation Implications

The human footprint model will aid managers in planning and implementing land use actions and in developing strategies to conserve habitats and wildlife. The validity of using human footprint models in conservation approaches has been evaluated in two recent studies using the human footprint map developed by Leu et al. (2008). Human footprint intensity has been found, next to fire extent, to be the second most important variable in explaining Greater Sage-grouse lek persistence from 1965 to 2007 (Knick and Hanser *In press*). In addition, human footprint intensity was an important variable explaining prevalence of amphibian chytridiomycosis (Adams et al. *In press*), a pathogen causing mass mortalities in some


Examples of the human footprint: cattle on rangelands and a road surrounded by exotic plants.

amphibian species. Modeling the human footprint across large landscapes also will allow researchers to generate hypotheses about ecosystem dynamics and to conduct studies in regions differing in potential impact. Because funding for restoration and conservation projects is limited, and because there is little room for errors in the management of endangered and threatened species, land managers will be able to maximize conservation and restoration efforts in areas minimally influenced by the human footprint. As such, the human footprint model is an important first step into understanding the synergistic effects acting on shrublands in the western United States.

For additional information about the human footprint model, contact Matthias Leu, Department of Biology, College of William and Mary, mleu@wm.edu, 757-221-7497.

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Participatory Approaches for Improved Science Delivery in the Great Basin

It is well-known among the science and management communities in the Great Basin that increases in annual invasive grasses combined with changing fire patterns are having detrimental effects on shrublands and lower-elevation woodlands throughout this region. As these issues become increasingly prevalent, they affect land management decisions on a regular basis and lead to the funding of numerous scientific studies (such as SageSTEP) seeking to provide answers to pressing questions. As a result, it is extremely important to improve communication among the many scientists, land managers, private landowners and other interested individuals in the region striving to address these issues.

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Great Basin fire and fuels-related research is very active. However, results from recent science needs assessments conducted by the Bureau of Land Management (BLM) suggest that oftentimes research information is not reaching field-level personnel who might need it most. Conversely, the specific needs of agency personnel are often unknown or assumed by scientists and researchers seeking to design studies with management applications. SageSTEP is currently involved with efforts to improve communication among various groups in the Great Basin with an interest in fire and fuels-related issues to accomplish the common goal of improving rangeland health and reducing the risks associated with fire.

Learning Together: Great Basin Science Delivery Project

A recent proposal funded by the Joint Fire Science Program (JFSP) seeks to address communication shortfalls by creating a technology transfer environment in which the knowledge of all participants is accessible by using the principles of PAME (Participatory Assessment, Monitoring and Evaluation). PAME encourages, supports, and strengthens the agency employees' existing abilities to identify their own needs and objectives and to measure resulting outcomes against their own evaluation criteria. This process seeks to have the end-users of research information (managers) participate from the beginning of the research planning process in order to insure that their needs are being met throughout.

In November and December 2009, a series of focus groups were conducted throughout the Great Basin using the PAME model to determine the science needs of public land management agencies in the region. Field-level representatives from the BLM, Forest Service, US Fish and Wildlife Service and National Park Service participated in the workshops and provided insight into their agency's fire and fuels-related science needs. Results from these sessions will be used by JFSP to fund future proposals aimed at providing the requested resources. For additional information about this project, contact Nora_Devoe@blm.gov.

A group of scientist and managers learn more about the role of ants in the sagebrush steppe during a field trip in the Owyhee Desert as part of the 2009 Learning Together SageSTEP NV-ID Manager Workshop

SageSTEP Manager Workshops

Since 2007 SageSTEP has conducted manager workshops in Utah, Nevada and Oregon to encourage and facilitate communication among researchers, managers and other individuals interested in the research we are conducting. The first workshops focused on lessons learned by researchers and cooperating agency offices to plan the SageSTEP study and implement land management treatments across a network of twenty sites in six different states. More recent workshops have given managers and researchers opportunities to spend time in the field together at research sites as well as indoor presentation sessions to discuss research progress and management applications.

As we look toward the future of the SageSTEP study, we continue to plan workshops and field trips in which managers and researchers can interact and discover new and better ways of collaborating. We are working to implement some of the PAME principles into our communication process in order to more adequately share much needed research information resulting from this expansive project. Our next workshop will be held in northern Utah in May of 2010 and will focus on evaluating sites being considered for fuels treatments. Anyone who is interested in participating is invited to attend the workshop and information will be posted as it becomes available at www.sagestep.org/events.html.

These, as well as other projects currently taking place in the Great Basin, aim to improve the health of sagebrush rangelands by encouraging collaboration and information-sharing among those with an interest in the health of these systems. There is a wealth of information available about fire and fuels-related issues in the Great Basin, and there are many studies currently underway to fill information gaps. The SageSTEP team looks forward to being part of a future in which researchers and managers work together to improve communication and make use of available information resources to improve the health of Great Basin ecosystems.

Mycorrhizae in Sagebrush Steppe Community Restoration

The invasion of cheatgrass (*Bromus tectorum*) in sagebrush communities has led to a reduction in native species establishment due to the cheatgrass-fire cycle in which cheatgrass fuels fire and then fire enables increased growth of cheatgrass. As land managers and researchers have struggled to restore these highly disturbed sagebrush systems, it has become evident that alternatives to the typical seeding treatment need to be researched and developed. One possibility is the use of mycorrhizae. Mycorrhizae are fungi that can form a symbiotic association with the roots of a plant, and can help plants capture nutrients, especially during initial colonization. They have been used for decades to improve establishment and restoration of desired plant species. However, studies assessing the use of mycorrhizae in cheatgrass-invaded areas of the Great Basin are limited. A recent study conducted on SageSTEP plots by Dara Scherpenisse of Utah State University, proposes that the use of arbuscular mycorrhizal fungi (AMF) in restoration may help increase the competitive ability of native perennial grasses.

Restoration of sagebrush landscapes after fire may benefit from the use of arbuscular mycorrhizal fungi (AMF), which are found naturally in soil and may help with the establishment of new plants.

AMF occur naturally in wildland soils throughout the Great Basin. When moderate- or high-intensity fires occur they can greatly reduce or eliminate AMF propagules near the soil surface, but AMF propagules from nearby unburned areas or from deeper in the soil profile can re-colonize the upper soil layers quickly. However, even a temporary post-fire reduction of AMF propagules or changes in AMF species composition may prohibit the re-establishment of desirable perennial species and help perpetuate the cheatgrass-fire cycle. Scherpenisse took soil samples from the SageSTEP Onaqui study site to culture the local AMF innoculum, and then conducted greenhouse pot experiments with two main objectives:

- Evaluate the general response of bluebunch wheatgrass (*Pseudoroegneria spicatum*), squirreltail (*Elymus elymoides*), and cheatgrass to mycorrhizal symbiosis by measuring how these species' morphology and physiology change under different environmental conditions (levels of phosphorus (P), water availability, and plant density).
- Determine the role of different inocula in competition among the three grasses. A competition study evaluated how the three species responded to local and commercial inocula under competition among the three species (interspecific) and within each species (intraspecific).

Two greenhouse pot experiments were conducted to provide information about when and how mycorrhizae could be used in restoring sagebrush communities.

This study was conducted in collaboration with SageSTEP. A collaborative project is a study outside of the core SageSTEP study that takes place on or in relation to one or more of the SageSTEP study plots. More information about current collaborative projects and how to submit proposals can be found at http://www.sagestep.org/collaborative_projects.html.

General Response Study

In this study, bluebunch wheatgrass, squirreltail and cheatgrass were examined for their responses to commercial inoculum. The inoculum used had a mixture of AMF species, increasing the likelihood that the AMF would be compatible with the grass species. Plant density, P, and water availability were altered to test the effect of different stressors on responses to inoculum. Contrary to expectations, mycorrhizae had minimal effects on the invasive and native grass species. When mycorrhizae did have an effect it was often negative, which is not unusual for cheatgrass since it is not considered a mycorrhizal-dependent species. However, the negative effect is atypical for bluebunch wheatgrass and squirreltail, which are considered mycorrhizal-dependent species. These neutral and negative effects of mycorrhizae were likely evidence of resources being readily available, particularly P, but also water, rendering the mycorrhizal fungi unnecessary. The mycorrhizal effects could also be due to the artificial conditions in the greenhouse. These results suggest that mycorrhizal relationship range along a parasitic-mutualistic continuum depending on environmental conditions. Under poor environmental conditions, mycorrhizae are beneficial because they increase access to resources whereas when resources are readily available, the plants can access resources without mycorrhizal help, possibly resulting in a parasite-like mycorrhizal fungal effect. This highlights the importance for land managers and researchers to evaluate the abiotic status of their system before applying mycorrhizae in restoration. In some cases, mycorrhizae may not be a successful restoration tool and may be detrimental to the native species if not used wisely.

Competition Study

This study addressed how mycorrhizae altered the competitive relationship between cheatgrass and the native perennial grasses, and whether the mycorrhizal effect on competition varied with local inoculum versus commercial inoculum. In this experiment, plants experienced greater water and P stress compared to the first experiment. While both inocula generally benefited all three species in this experiment, the local inoculum tended to have a greater benefit, especially for cheatgrass. However, some of the mycorrhizal responses of the native perennial grass species suggest that during interspecific competition the commercial inoculum may be more beneficial than local inoculum for these perennial species.

Interestingly, the local inoculum in general was beneficial to the perennials, but it was even more beneficial to cheatgrass. Some response variables suggested that cheatgrass took greater advantage of the local inoculum when competing with squirreltail. The mean number of tillers (sprouts or stalks) per cheatgrass plant suggested that this plant took advantage of local inoculum when there was a greater proportion of native plants than of invasive plants in a pot.

The question of whether or not to use mycorrhizae and what type to use does not have a simple answer due to the ever changing conditions of ecological systems.

Management Applications

The results of this study demonstrate the complex dynamics of the mycorrhizal plant-fungus relationship. One particular inoculum is not necessarily always the best choice for a particular plant species. The choice of inoculum may depend on what plant physiological or morphological trait land managers and researchers consider the best indicator of competitive ability. Is greater shoot growth, root growth, or seed production ultimately desired? Land managers must also take into account how the inoculum will affect the desirable species' competitors and how the response of desirable species to AMF will fluctuate with varying environmental condition. The question of whether or not to use mycorrhizae and what type to use does not have a simple answer due to the ever-changing conditions of ecological systems. The competition study clearly shows that inoculum can greatly benefit the non-desirable species, in some cases even more so than the desirable species.

In any case, unless land managers are working in a static system and have thorough knowledge of their plant community's response to different AMF species, an AMF mixture is likely the best choice for inoculum. Ideally before applying inocula on a large scale project, land managers could do trial experiments to determine the desirable and non-desirable plant species responses to inocula, though given time constraints this might be difficult to achieve. Over the long-term, land managers and researchers may ultimately be able to determine the best mixture of AMF species to use for inoculum in systems that have a wide range of environmental conditions.

A complete description of the studies discussed above can be found in Dara Scherpenisse's master's thesis at http://digitalcommons.usu.edu/etd/394/. For more information about this study, contact darasusanne@yahoo.com.

Upcoming Events

63rd Annual Meeting of the Society for Range Management and the 50th Annual Meeting of the Weed Science Society of America
February 7-11, 2010
Denver, Colorado
www.rangelands.org/events.shtml

Association of American Geographers 2010 Annual Meeting
April 14-18, 2010
Washington, DC
www.aag.org/annualmeetings/2010/index.htm

16th Wildland Shrub Symposium Threats to Shrubland Ecosystem Integrity
May 18-20, 2010
Utah State University
Logan, Utah
http://wss2010.usu.edu/

SageSTEP Manager Workshop
May 25-26, 2010
Tooele, Utah
www.sagestep.org/events.html

SageSTEP is a collaborative effort among the following organizations:

- Brigham Young University
- Oregon State University
- University of Idaho
- University of Nevada, Reno
- Utah State University
- Bureau of Land Management
- Bureau of Reclamation
- USDA Forest Service
- USDA Agricultural Research Service
- US Geological Survey
- US Fish & Wildlife Service
- The Nature Conservancy

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For more information and updates, visit our website:

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