Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

Sagebrush steppe, lands of grass, scattered shrub—and limited rain—are changing into wooded ecosystems and weed dominated landscapes.

Sagebrush Steppe: A Story of Encroachment and Invasion

Summary

Sagebrush steppe has been rapidly changing into woodlands of western juniper and pinyon pine since Euroamerican settlement of the West in the middle of the nineteenth century. The change from the dry scattered shrub and grasslands to woodlands has changed more than plants—it has also changed the fire regime. Studies have revealed a threshold at which understory plants may not rebound after a disturbance—when trees have reached 40- to 50-percent cover. Disturbance—by fire and overgrazing—also makes resources such as nutrients and soil water available for weeds to exploit, allowing invasives such as cheatgrass to establish and expand into sagebrush lands. The presence of native, perennial herbaceous plants help a landscape resist weed invasion, and measures to prevent initial establishment by weeds such as cheatgrass may be as, or more effective than reducing or eliminating established populations.

Key Findings

- There has been a 65 to 90 percent increase in the area occupied by pinyon and juniper woodlands since the mid-to-late 1800s.
- As sagebrush ecosystems shift to mid-tree-dominance by pinyon pine/Utah juniper, fuel loads double. As they shift to full-tree-dominance, fuel loads double again.
- In pinyon pine/Utah juniper woodlands, the ability of understory plants to recover after disturbance rapidly declines after pre-fire tree cover reaches about 40 to 50 percent.
- Plant removal and fire increase available soil nitrogen water and invasibility—cheatgrass biomass and seed production increase 2 to 3 times following removal, 2 to 6 times after burning, and 10 to 30 times following removal and burning.
- Native perennial herbaceous plants help a landscape resist weed invasion.

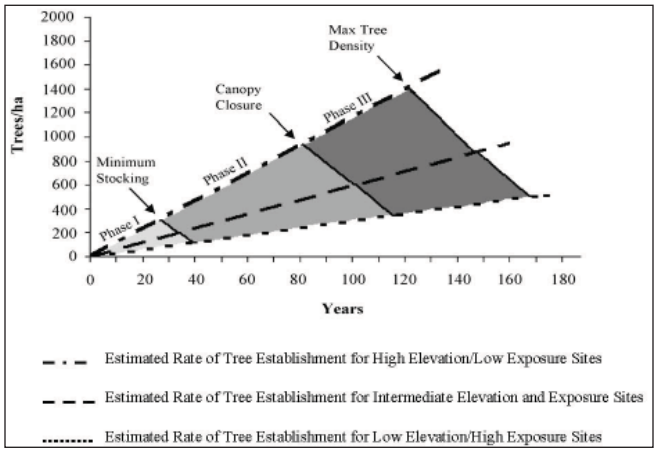
Introduction

The days seem the same. The Great Basin is still an arid landscape, with various ecosystems that specialize in working with the scant water available. But changes are taking place, causing major shifts in plant communities that are affecting fire regimes, wildlife habitat and ecosystem services. What are the consequences of sagebrush steppe—lands of grass and scattered shrub—transitioning to woodlands of juniper and pinyon pine? The rate that woodland encroaches into sagebrush steppe has been rapidly increasing since Euroamerican settlement of the west in the mid nineteenth century. What are the causes of the ongoing invasion and dominance of weedy species like cheatgrass? Introduced into the west in the late 1800s, cheatgrass now dominates 3 million acres, has heavily infested 17 million acres, and threatens another 60 million acres. Jeanne Chambers, Research Ecologist with the USDA Forest Service's Rocky Mountain Research Station, and her colleagues undertook a number of different studies to identify the causes of change, and offer practices managers can use to hamper ecosystem shifts.

Dramatic increase and displacement

The area occupied by pinyon and juniper woodlands has increased dramatically since the mid-late 1800s. Woodlands have displaced shrub steppe communities, influenced wildlife habitat, and altered ecological processes. Rapid expansion of pinyon and juniper is well known to those who observe the land. Western juniper has increased over tenfold since the mid-to-late 1800s, occupying roughly 7.5 million acres. However, the rates of woodland spread across diverse landscapes, and the amount and type of fuels that result when open shrub steppe changes into closed woodlands are still largely unknown. To answer these questions for western juniper, the scientists sampled tree stands in southeastern Oregon and southwestern Idaho. They measured tree density, and the ages of the tallest trees to estimate when conversion to woodland began.

They found woodland expansion rate and tree density increased with elevation and northerly exposure. In less than twenty-five years, stands on moderately moist sites achieved a minimum density of over 250 trees per hectare (approximately 2.5 acres), whereas drier sites required forty or more years to achieve a minimum density of fewer than 100 mature trees. They discovered that as the canopy of the woodlands closed, around the late 1950s or early 1960s, understory plants, especially shrubs, rapidly declined. Drier sites supported fewer total trees in a closed state than moderately moist sites, with closure occurring within 120 to 170 years on warm dry sites, and 80 to 120 years on cool moist sites. Pre-settlement juniper occurred in 16 to 67 percent of stands in the four woodlands and accounted for 1 to 10 percent of the population of trees greater than 3 feet tall. Pre-settlement trees were generally widely scattered and more common in lower elevation stands with greater surface rock cover and higher solar exposure.



Woodland expansion rates.

Pinyon Pine and Utah Juniper

The researchers examined pinyon pine and Utah juniper expansion into sagebrush steppe in the Shoshone Mountains in Nevada, and East Tintic Mountains in Utah, Study transects crossed the north-south trending mountains in the east-to-west direction. In Nevada, one of the transects was part of a Joint Fire Science Program (JFSP) demonstration area examining the effects of elevation, tree cover, and prescribed fire on the woodlands. The data collected included tree age, stand density and cover as well

as cover of the shrubs, grasses and forbs. Plant size and height also were recorded to determine fuel loads.

The scientists found that on all sites an increase in tree dominance began in the mid to late 1800s, and accelerated in the early 1900s. In Nevada, 65 to 75 percent of the current woodlands have established in the last 130 years. In Utah, this recent expansion represents 90 percent of the current woodlands. These tree density increases are similar to those observed for western juniper on the Oregon and Idaho sites.

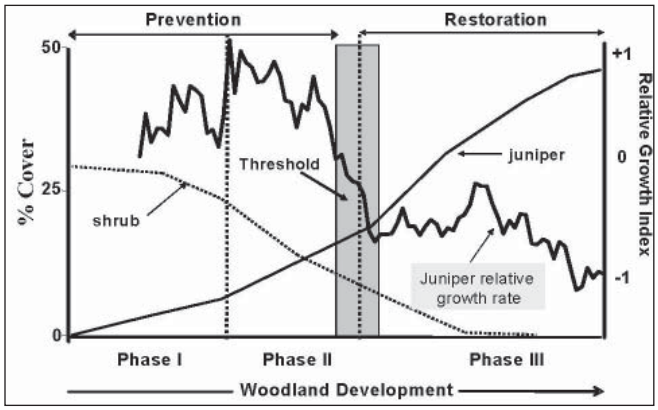
Three phases

In looking at their data, the scientists found a pattern of woodland development across sites that could be separated into three phases. In phase one, trees establish, and seedling and sapling trees are scattered throughout mountain big sagebrush and perennial grasses. In phase two, trees rapidly encroach and codominate with shrubs and herbs. Growth rates of trees increase until they mature; then the growth rate declines as the canopy closes. In phase three, trees dominate. As the ecosystem transitions from phase two to three, the presence of herbaceous plants and shrubs plummets, and the scientists found an important shift occurs—the fire regime changes. In Nevada, changes in fuel loads contributed by the trees doubled between phase one and phase two tree dominance levels, while fuel loads contributed by the understory decreased by half. From phase two to phase three, fuel loads contributed by the trees doubled again while understory abundance decreased to a small fraction of its pre-tree levels. Fuel loads in the tree dominated plots were as much as eight or more times what was present in the sagebrush ecosystems prior to tree encroachment.

The shifting ecosystem—trees encroaching; trees dominating.

The researchers found that the majority of woodlands are still in the early to mid phases of stand closure, which means they often support an understory of shrubs and herbaceous vegetation. In the absence of disturbance or management the majority of these landscapes will become closed woodlands in the next 40 to 70 years resulting in the loss of understory plant species and significantly greater costs for restoration.

Adding a ripple of urgency, the scientists found a rapid decline in the ability of understory plants to rebound after prescribed fire as tree cover increased beyond 40 to 50 percent on the JFSP Demonstration Area. This, the scientists feel, may be the threshold at which sagebrush steppe communities can not recover without revegetation.



As the ecosystem transitions to tree dominance, the opportunity for preventative management declines.

Changing fuels affect fire behavior

Because fuel loads affect fire behavior, the scientists studied how western juniper changes fire regimes in low sagebrush and mountain big sagebrush.

The researchers collected fuels data and environmental variables for the sagebrush dominated communities and Phases I, II and III woodlands. They then used BEHAVE to predict flame length and rate of spread, and FARSITE to predict fire behavior on mixed landscapes. For mountain big sagebrush, flame length and rate of spread increased between sagebrush dominated communities and Phase I woodlands and then declined as Phase III woodland developed. For low sagebrush, flame length and spread increased between sagebrush communities and Phase I woodlands. From Phase I woodlands to Phase III woodlands, the researchers observed a 73 percent average reduction in flame length. Mountain big sagebrush had higher flame length and rate of spread than what the researchers observed in low sagebrush communities. The scientists attributed this to the greater biomass and height associated with mountain big sagebrush. In the Phase I and III woodlands, low sagebrush exhibited higher flame length and rate of spread than mountain sagebrush, which the scientists believed was due to the retention of the sagebrush component in the later stages of woodland development in low sagebrush communities. In general, the models

predicted an increase in fire size as mid-successional phases of western juniper increased on the landscape, and a decrease as late-successional phases increased.

As lands transition from sagebrush steppe to pinyon pine woodlands, fuel loads double at the low- to mid-tree-dominance levels.

With trees at the mid-to-full tree dominance level, fuel loads are doubled again.

"Prescribed fire and fire use strategies will be more effective in controlling western juniper encroachment if they occur in the earlier stages of succession before the shift to declining understory fuel loads takes place." The scientists offer that higher fuel loads for the herbaceous species and shrub component give the manager a wider range of environmental conditions under which prescribed fire objectives can be achieved. The combination of young western juniper being more susceptible to fire damage and fuel loads that are conducive to prescribed burning increase the chances of minimizing the encroachment of western juniper into sagebrush grasslands. These suggestions, the scientists caution, should only be applied to western juniper woodlands without pinyon pine, as western juniper does not burn as readily as pinyon pine.

"Prescribed fire and fire use strategies will be more effective in controlling western juniper encroachment if they occur in the earlier stages of succession before the shift to declining understory fuel loads takes place."

Invading species, a land imperiled

What makes sagebrush steppe ecosystems susceptible to invasion by non-native invaders? The scientists undertook a number of studies to provide answers to these questions.

Disturbances, including prescribed fires, increase available soil nutrients and water allowing weeds such as cheatgrass to invade sagebrush communities.

Cheatgrass

How does cheatgrass invade sagebrush communities? In many cases, plant invasions are influenced by factors that increase available soil resources, including disturbances such as overgrazing by livestock, and fire. The researchers designed an experiment to examine the effects of removing herbaceous plants (0, 50 percent and 100 percent removal) and burning (control, burned) on common sagebrush types, Wyoming big sagebrush and mountain big sagebrush, along elevational gradients in the Shoshone Mountains of central Nevada and the East Tintic Range of west-central Utah. They measured several response variables including plant available soil nutrients and water, response of the native community, and cheatgrass establishment, growth and reproduction. "Increasing our understanding of the environmental and ecological factors that influence cheatgrass invasion and invasion processes will allow us to develop management techniques aimed at preventing initial invasion," Chambers offers. "From a regional perspective, this approach may be as or more effective than management schemes designed to reduce or eliminate established populations of cheatgrass."

The scientists found that underlying ecosystem properties had the greatest overall effects on invasibility of cheatgrass. Cheatgrass establishment, growth and reproduction was limited by colder temperatures at upper elevations. Precipitation, and its effects on available soil water, appeared to be the primary controls when temperature was not a factor.

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Effects of the removal and burning treatments were consistent for the different sagebrush types. The scientists showed that both removal and burning resulted in increases in available soil water and soil nutrients. Fire often increases soil nitrogen, and this increase may help to explain the expansion of nitrogen-loving cheatgrass. Although removal and burning had only minor effects on cheatgrass

establishment, their effects were multiplicative for biomass and seed production. Biomass and seed production of cheatgrass both increased 2 to 3 times following plant removal, 2 to 6 times after burning, and 10 to 30 times following plant removal and burning.

The scientists found that resistance of sagebrush steppe to cheatgrass was relatively high for sites in high ecological condition, i.e., those with relatively high cover of native perennial grasses and forbs. Although available soil water and nitrate increased as a result of burning, in the absence of plant removal the cover of native perennial species increased and the establishment of cheatgrass was low on burned plots. The scientists suggest that while it may not be possible to eliminate cheatgrass once it has invaded native ecosystems, it may be possible to limit its abundance by managing for perennial herbaceous grasses and forbs.

Reflecting on the pace of change, a pace that has accelerated since the last century for many systems—social, geopolitical, economic—Chambers and her colleagues provide some answers to the pace of change in the physical world in which our human-centered systems exist. Land managers, facing the strain, can plan for the alterations in the lands that connect our communities.

Further Information: Publications and Web Resources

Blank, R.S., J.C. Chambers, B.A. Roundy, S.E. Meyer, and A. Whittaker. 2007. Nutrient availability in rangeland soils: influence of prescribed burning, herbaceous vegetation removal, over-seeding with *Bromus tectorum*, season, and elevation. *Rangeland Ecology and Management*. 60:644-655.

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Johnson, D.D.; Miller, R.F. 2008. Intermountain presettlement juniper: distribution, abundance, and influence on post-settlement expansion. *Journal of Range Ecology and Management*. 61:82-92.

Kinter, C.L.; Mealer, B.A.; Shaw, N.L.; Hild, A.L. 2007. Postfire invasion potential of rush skeletonweed (Chondrilla juncea). *Rangeland Ecology and Management*. 60: 386-394.

Management Implications

- As woodland expansion and infilling progresses, fuel loads will increase magnifying the risk of high severity fires.
- Fire and fire surrogate treatments will be more effective in phase one and phase two woodlands before the shift to declining understory fuel loads takes place.
- The ability of sagebrush ecosystems to recover without revegetation following wildfire or management treatments will be greater before the loss of understory grasses and forbs at about 40 to 50 percent tree cover.
- Preventing the initial invasion or expansion of weeds may be as, or more effective than reducing or eliminating established populations.
- Restoring or maintaining perennial herbaceous grasses and forbs that can effectively compete with invasive species can significantly increase the resistance of sage steppe to invasives like cheatgrass.

Miller, R.F.; Tausch, R.J.; McArthur, D.E.; Johnson, D.; Sanderson, S.C. 2008. Development of post-settlement pinyon-juniper woodlands in the Intermountain West: a regional perspective. Res. Pap., RMRS-RP-69. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Great Basin Ecology Lab Website: http://www.ag.unr.edu/gbem/

Scientist Profiles

Jeanne C. Chambers, a Research Ecologist with the USDA Forest Service, Rocky Mountain Research Station, has been studying disturbance processes and developing restoration approaches in the Intermountain Region for 25 years. Chambers is the Team Leader of an Ecosystem Management Unit on Restoring and Maintaining Great Basin Watersheds and Riparian Ecosystems. She enjoys working in research and management partnerships with Forest Service Research, Agricultural Research Service, USGS, the Humboldt-Toiyabe National Forest, the Bureau of Land Management and the region's universities.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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