Forest Ecology and Management 310 (2013) 777–785

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Tree reduction and debris from mastication of Utah juniper alter the soil climate in sagebrush steppe ☆

Kert R. Young [a,*], Bruce A. Roundy [a], Dennis L. Eggett [b]

[a] Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT 84602, USA
[b] Department of Statistics, Brigham Young University, Provo, UT 84602, USA

ARTICLE INFO

Article history:
Received 29 March 2013
Received in revised form 11 September 2013
Accepted 12 September 2013
Available online 7 October 2013

Keywords:
Mulch
Resistance to invasion
Resource availability
Soil temperature
Soil water
Weeds

ABSTRACT

Juniper (*Juniperus* spp.) trees are masticated to reduce canopy fuel loads and the potential for crown fire. We determined the effects of tree reduction and soil cover in the forms of tree mounds and masticated debris on hourly soil water potential and soil temperature at 1–30 cm soil depth. Measurements were made in masticated and untreated areas at three sites in the western Utah portion of the Great Basin. Cumulative seasonal-response variables included wet days (>−1.5 MPa), degree days (>0 °C), and wet degree days (>−1.5 MPa and >0 °C). Masticated areas had 27 more wet days ($P < 0.001$), 32 more degree days ($P = 0.007$), and 311 more wet degree days ($P < 0.001$) than untreated areas across soil depths and seasons. Soil cover had less influence on these soil climate variables than tree reduction. Most importantly, tree reduction increased wet days ($P < 0.001$) by an average of 44.5 days during the spring and summer growing seasons at depths of 13–30 cm. Managers are advised to masticate trees while desired understory cover remains high in order to minimize water available to weeds.

1. Introduction

Desertification with increased woody plants, reduced perennial grasses, and increased heterogenization of soil resources is one of the most significant changes on rangelands globally in the last 150 years (Schlesinger et al., 1990; Archer et al., 2011). The shift from herbaceous to woody plants in these dryland systems often alters habitat and ecosystem trophic structure (Archer et al., 2011), reduces primary production (Knapp et al., 2008), and increases erosion (Wainwright et al., 2000; Gillette and Pitchford, 2004; Breshears et al., 2009). In the semiarid western United States, juniper trees (*Juniperus* spp.) have encroached on millions of hectares of sagebrush (*Artemisia tridentata* Nutt.) steppe and commonly reduced understory plant cover (Johnsen, 1962; West, 1984; Miller and Wigand, 1994; Miller and Rose, 1999; Miller et al., 2000, 2005). Juniper trees reduce the pre-encroachment plant community through competition for and redistribution of resources (Breshears et al., 1997a; Roundy et al., in press b; Ryel et al., 2010). For example, juniper trees begin transpiration in early spring reducing soil water remaining for understory plants (Angell and Miller, 1994); shallow juniper roots use resources from the same soil depth as grass roots (Emerson, 1932); juniper roots hydraulically move water deeper into the soil profile; and soil water repellant layers below juniper trees funnel water to greater depths away from shallow rooted species and the evaporation zone (Leffler et al., 2002; Robinson et al., 2010).

Reduced fire frequency in the sagebrush steppe during the past 100–150 yr has led to dense juniper encroachment (Miller et al., 2000) and increased woody fuel loads. Increased fuel loads following years of fire suppression and property development in fire prone areas led to extensive wildfire damage during the 2000 fire season (PIC, 2002). This prompted the National Fire Plan that appropriated millions of dollars to hazardous fuels reduction across the United States (PIC, 2002). Mechanical reduction of encroaching woodlands is one such fuel reduction method that has been applied on thousands of hectares in the western US. Mechanical mastication of dense juniper woodlands is often used to convert canopy and bole fuels to surface fuels before prescribed fire can safely reduce fuel loads without the risk of crown fires escaping and damaging neighboring communities. Juniper tree reduction has also helped pre-encroachment plant communities recover by increasing resources available for residual plants (Miller et al., in press; Roundy et al., in press a).

Sagebrush steppe communities depend on resources available in resource growth pools when soil water potentials are >−1.5 MPa within the top 0.3–0.5 m of soil for major plant growth and diffusion of nutrients to roots in spring and early summer (Leffler and Ryel, 2012; Roundy et al., in press b; Ryel et al.,

☆ This is contribution number 98 of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP) funded by the U.S. Joint Fire Science Program, the Bureau of Land Management, and the National Interagency Fire Center.

* Corresponding author. Address: Dept of Plant and Wildlife Sciences, 275 WIDB, Brigham Young University, Provo, UT 84602, USA. Tel.: +1 (801) 422 4133.
E-mail address: youngke1@msn.com (K.R. Young).

0378-1127/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.09.024

2010). The stability of resource pools is especially important to plant community assembly because unusually large increases in resources due to disturbance can lead to increased weedy species dominance (Leffler and Ryel, 2012). Wet and wet degree days are important metrics of resource growth pools because they relate these pools to plant growth by quantifying the amount of time resources are adequate (soil water potential >−1.5 MPa) for rapid growth during each season. The resources remaining after plant growth make up the maintenance pool down to 1–1.5 m that enables perennial plants like sagebrush to survive summer drought (Leffler and Ryel, 2012). The accurate use of wet, degree, and wet degree day summations to predict specific plant growth responses depends on adequately modeling the linearity or curvilinearity and temperature thresholds of the response (Bonhomme, 2000), as well as accounting for limiting factors besides soil temperature and water availability (Idso et al., 1978; Wang, 1960). In ecosystems where plant response is highly dependent on short periods of soil water availability when soil and air temperatures are warm enough for growth, these metrics indicate soil microenvironmental conditions that support plant establishment and growth.

Our major objective was to determine the effects of juniper tree mastication on wet, degree, and wet degree days to indicate favorable growing conditions for plants. The effects of juniper tree mastication can be summarized in two categories. The first category is tree reduction associated with reduced juniper resource uptake and canopy shade. The second category is soil cover associated with preexisting tree mounds and newly added masticated-juniper debris. We sought to determine the effects of tree reduction separate from soil cover on wet, degree, and wet degree days. With recent work evaluating harvesting of juniper trees for biofuel energy (Jaeger et al., 2007; Skog et al., 2009) and the potential for this to become an important driver of juniper tree reduction, it was also important to evaluate the effects of tree reduction in areas without masticated-juniper debris cover. We hypothesized that: (1) the reduction of juniper resource uptake and shade with juniper tree mastication will increase wet, degree, and wet degree days compared to untreated areas with live juniper trees remaining; (2) soil cover will reduce degree days during warm periods, increase degree days during cool periods, and increase wet days and wet degree days throughout the year compared to uncovered soil; and (3) wet days will increase with soil depth throughout the year, degree days will decrease with soil depth during warm periods and increase with soil depth during cool periods, and wet degree days will increase with soil depth during cool periods.

2. Materials and methods

2.1. Study locations

We studied the three Sagebrush Steppe Treatment and Evaluation Project (SageSTEP) research locations of Greenville, Onaqui, and Stansbury in the western Utah portion of the Great Basin (McIver et al., 2010; www.sagestep.org). We measured soil water and temperature in Phase III woodland encroachment (*sensu* Miller et al., 2005) of sagebrush-bunchgrass communities. Communities are considered to be at Phase III encroachment when tree cover >67% of the total relative perennial plant cover. High densities of Utah juniper trees or mixed piñon-juniper trees have depleted the previous sagebrush (*Artemisia* spp.) and bunchgrass plant communities. Maximum absolute and relative tree cover before mastication were 31% and 89% at Onaqui, 54% and 97% at Greenville, and 65% and 93% at Stansbury. Maximum tree density (>0.5-m tall) prior to mastication was 586 trees ha^{-1} at Greenville, 444 trees ha^{-1} at Onaqui, and 1030 trees ha^{-1} at Stansbury. Before juniper tree mastication, shrub cover was <5% across study locations and perennial grass cover was <10% at Greenville and Onaqui and <20% at Stansbury.

The average elevation at these locations is 1700–1900 m. Annual average temperatures at these locations are 9–10 °C with minimum average temperatures of 0–3 °C and maximum average temperatures of 16–19 °C. Annual average precipitation ranged between 193 and 389 mm. Most precipitation comes as snow during winter and rain in spring and fall but summers are mostly dry. Greenville (38°12′N, 112°48′W) in Beaver County is on the north side of the Black Mountains with soils classified as loamy-skeletal, carbonatic, mesic Typic Calcixerepts (Rau et al., 2011). The dominant vegetation includes Utah juniper trees, two-needle piñon trees (*Pinus edulis* Engelm.), Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), rabbitbrush [*Chrysothamnus viscidiflorus* (Hook.) Nutt.], bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) A. Löve], needle-and-thread [*Hesperostipa comata* (Trin. & Rupr.) Barkworth], and Indian ricegrass [*Achnatherum hymenoides* (Roem. & Schult.) Barkworth]. Onaqui (40°13′N, 112°28′W) in Tooele County is on the east side of the Onaqui Mountains with soils identified as loamy-skeletal, carbonatic, mesic, shallow Petrocalcic Palexerolls (Rau et al., 2011). The dominant vegetation includes Utah juniper trees, Wyoming big sagebrush, bluebunch wheatgrass, Sandberg bluegrass (*Poa secunda* J. Presl), and Indian ricegrass. Stansbury (40°35′N, 112°39′W) in Tooele County is on the west side of the Stansbury Mountains with soils identified as loamy-skeletal, mixed, active, frigid Pachic Haploxerolls (Rau et al., 2011). The dominant vegetation includes Utah juniper trees, Wyoming big sagebrush, antelope bitterbrush [*Purshia tridentata* (Pursh) DC.], bluebunch wheatgrass, Sandberg bluegrass, and cheatgrass (*Bromus tectorum* L.).

2.2. Treatment implementation

A Tigercat® M726E Mulcher (Tigercat Industries, Inc., Brantford, Ontario) with Fecon® Bull Hog® (Fecon, Inc., Lebanon, OH) attachment masticated Utah juniper trees at Onaqui in the fall of 2006 and at Stansbury in the fall of 2007. A skid steer loader with Fecon® Bull Hog® attachment masticated Utah juniper and two-needle piñon trees at Greenville in the fall of 2007. Greenville and Onaqui had 20-ha treatment areas while Stansbury had 5-ha areas. Most of the masticated-juniper debris had diameters <2.54 cm and nearly all of the debris had diameters <7.62 cm with lengths varying widely from less than a centimeter to a couple meters. We did not measure residual plant cover or seed banks in this study but removed volunteer plants from microsites where soil climate was measured. Plant growth did not appear to change in untreated areas during our study. Herbaceous plants appeared to increase at Stansbury 1 yr after juniper tree mastication and 2–3 yr after mastication at Greenville and Onaqui. Across the Great Basin, Miller et al. (in press) and Roundy et al. (in press a) found that invasive annual and native perennial herbaceous cover increased 2–3 yr after mechanical reduction of trees at moderate to high levels of juniper-piñon encroachment.

2.3. Study design and field measurements

We paired masticated and untreated control areas with similar soils and pretreatment vegetation at each location to test the effects of reduced juniper tree resource uptake and shade on wet, degree, and wet degree days. We installed a randomized complete block design within each masticated and untreated area. Sixteen juniper trees in masticated areas and eight juniper trees in untreated areas were grouped into four replicate blocks. We selected trees with at least a 2-m diameter tree mound to allow room for soil climate measurements. One tree per block was selected for soil water and temperature measurements in this study.