Forest Ecology and Management 259 (2010) 904–915

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Spatial variability in microclimate in a mixed-conifer forest before and after thinning and burning treatments

Siyan Ma [a,*], Amy Concilio [b], Brian Oakley [c], Malcolm North [d], Jiquan Chen [e]

[a] Ecosystem Sciences Division, 137 Mulford Hall 3114, Department of Environmental Science, Policy, and Management, University of California at Berkeley, Berkeley, CA 94720-3114, USA
[b] Department of Environmental Studies, University of California at Santa Cruz, Santa Cruz, CA 95064, USA
[c] Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, UK
[d] US Forest Service, Pacific Southwest Research Station, 1731 Research Park Dr., Davis, CA 95618, USA
[e] Department of Environmental Sciences, The University of Toledo, Toledo, OH 43606, USA

ARTICLE INFO

Article history:
Received 8 June 2009
Received in revised form 21 November 2009
Accepted 24 November 2009

Keywords:
Structure
Canopy gap
Logging
Fire
Disturbances
Fuel treatments
Teakettle

ABSTRACT

In the western United States, mechanical thinning and prescribed fire are common forest management practices aimed at reducing potential wildfire severity and restoring historic forest structure, yet their effects on forest microclimate conditions are not well understood. We collected microclimate data between 1998 and 2003 in a mixed-conifer forest in California's Sierra Nevada. Air and soil temperatures, relative humidity, photosynthetically active radiation (PAR), wind speed, soil heat flux, and soil volumetric moisture were measured at the center of 18 four-ha plots. Each plot was assigned one of six combinations of thinning and burning treatments, and each treatment was thus given three replications. We found that spatial variability in microclimate, quantified as standard deviations among monthly values of each microclimatic variable across different locations ($n \leq 18$), was significantly high and was influenced primarily by elevation and canopy cover. The combination of thinning and burning treatments increased air temperature from 58.1% to 123.6%. Soil temperatures increased in all thinned plots. Air moisture variables indicated that treatments made air drier, but soil moisture increased in the range 7.9–39.8%, regardless of treatment type. PAR increased in the range 50.4–254.8%, depending on treatment type. Treatments combining thinning and burning increased wind speed by 15.3–194.3%. Although soil heat flux increased dramatically in magnitude in some plots, overall treatment effects on *G* were not statistically significant. We discussed the significance and implications of the spatial variability of microclimate and the treatment effects to various ecological processes and to forest management.

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1. Introduction

Sierra Nevada mixed-conifer forests, typical of many western U.S. forests, are fire-dependent ecosystems; fire is essential both for nutrient supply and for germination of some species (Kennard and Putz, 2005). Historically, these forests had a frequent (12–20 years), low-intensity fire regime (Miller and Urban, 1999). However, fire has been suppressed for more than 100 years throughout most of the region (McKelvey and Busse, 1996). With such long-term fire suppression, mixed-conifer forests in the region have become denser than analogous historical structures, although the forests still retain a heterogeneous spatial structure consisting of closed-canopy tree groups, shrub thickets, and open gaps (Miller and Urban, 1999; North et al., 2007). Currently, these forests are facing greater risks of fire hazard (NWGC, 2001). From an ecological perspective, high stem densities and canopy cover promote shade-tolerant species (*e.g.*, white fir, incense cedar) but significantly inhibit shade-intolerant species (*e.g.*, ponderosa, Jeffery, and sugar pine) (North et al., 2007; Moghaddas et al., 2008). Current forest management in the Sierra Nevada is aimed at not only reducing stand density but also restoring historic species composition. Mechanical thinning, prescribed fire, or combinations of these are commonly used as restoration/fuel treatments (North et al., 2007). Although the effects of these treatments on many ecological characteristics and processes (*e.g.*, species richness and abundance, forest regeneration, community dynamics, organic matter decomposition, and soil carbon flux) have been addressed (Innes et al., 2006; Wayman and North, 2007; Ryu et al., 2009), the effects of mechanical thinning and prescribed burning treatments on forest structure and microclimate remain poorly understood in our subject forests.

* Corresponding author. Tel.: +1 510 642 2421; fax: +1 510 543 5098.
E-mail address: syma@berkeley.edu (S. Ma).

0378-1127/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.foreco.2009.11.030

Microclimate is important in understanding ecological processes and functions because microclimate determines biophysical environmental conditions or resources (*e.g.*, temperature, water, and light) that in turn determine species composition, plant growth and development, community population, regeneration, soil nutrient cycling, organic matter decomposition, and primary productivity (Zobel et al., 1976; Spies and Franklin, 1989; Chen et al., 1993). However, it remains a challenge to properly evaluate microclimatic conditions under a forest canopy since microclimatic variables are highly dynamic and correlated in space and time (Horne and Scheider, 1995). It is well known that forest management at a stand level can alter vegetation cover and consequently influence forest microclimate (Aussenac, 2000). For example, light levels are directly influenced by the spatial distribution of canopy cover (Lieffers et al., 1999), and forest management practices that affect canopy openness, such as thinning treatments, can increase light levels in the understory (Drever and Lertzman, 2003). Consequently, any changes in radiation could have cascading effects on temperature, water conditions, and energy balance since solar radiation provides primary energy to the ecosystem (Aussenac, 2000). Other forest treatments, such as burning, might have different effects on microclimate, such as increased *albedo* of the forest floor or increased soil temperature and moisture. Although some changes in microclimate due to thinning or burning may be predicable, the two treatment types might interact to produce unexpected patterns, which could vary across the landscape, creating more complicated patterns (North et al., 2007).

We began this study in the Teakettle Experimental Forest (TEF) in 1998 to determine how alternative forest management might affect understory microclimate. We collected below-canopy microclimate data with automated microclimate stations at 18 different locations over 4 years (from before to after our treatment). This long-term, forest-wide microclimate dataset allows us to better examine microclimate variability in pre-treated forests and to quantify the degree of treatment effects. Our objectives were to (1) examine microclimate spatial variability in the fire-suppressed forest (pre-treatment period), and (2) quantify treatment effects on microclimate. We hypothesized that treatment effects on light levels would depend primarily on the degree of canopy removal but that other microclimate variables, such as temperature and moisture, would be affected by additional factors as well (such as forest floor conditions).

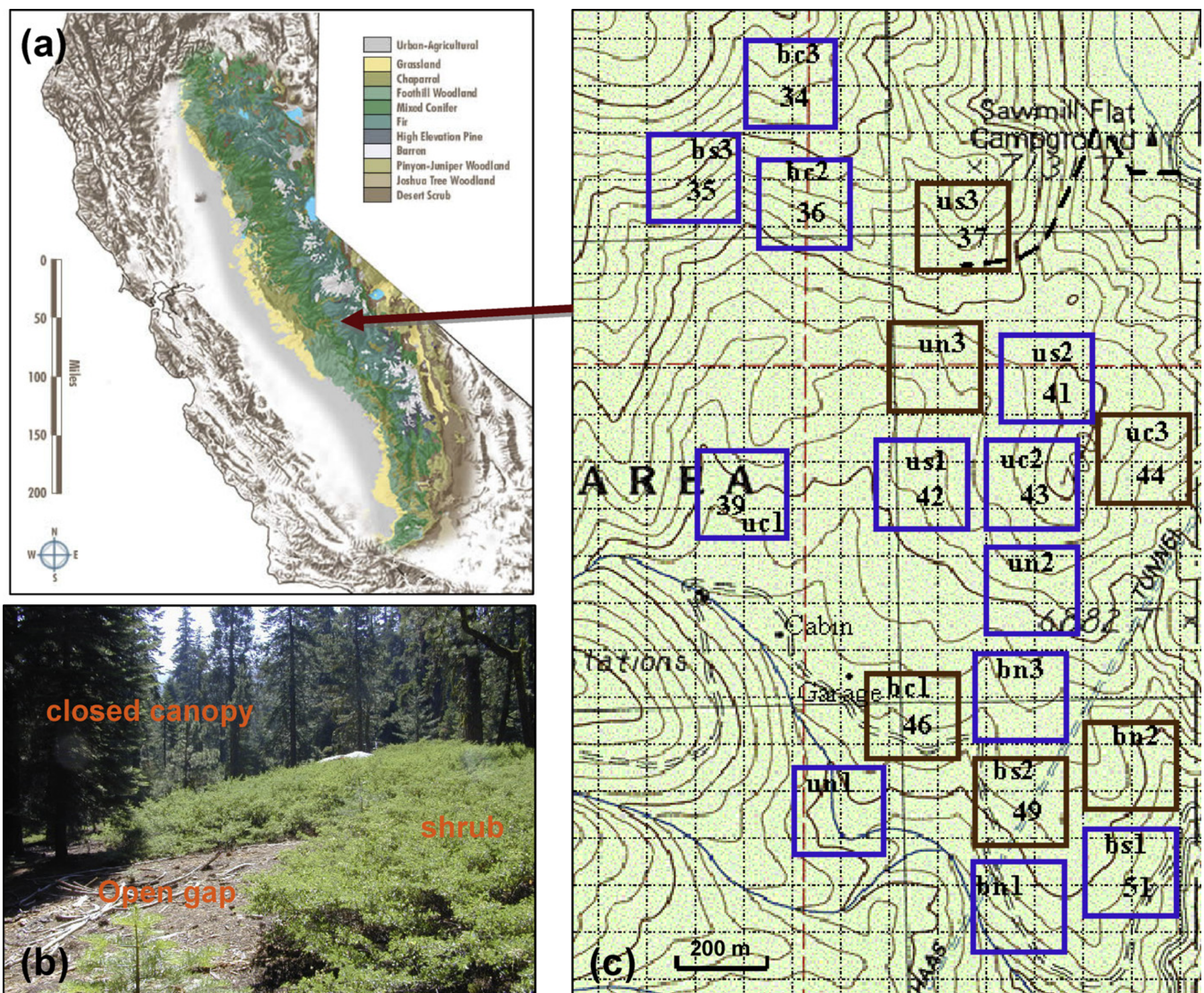

Fig. 1. The Teakettle Experimental Forest in California's Sierra Nevada: (a) site location on California regional map; (b) three dominant mixed-conifer patch conditions: closed-canopy forest, shrub, and open gap; (c) locations of treatment plots, labeled with treatment type (refer to Table 1).

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