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The Importance of Multiscale Spatial Heterogeneity in Wildland Fire Management and Research

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Abstract

The occurrence and effects of fire vary greatly over multiple spatial and temporal scales. At a regional scale, variation in synoptic climate and associated vegetation characteristics results in diverse fire regimes, ranging from systems having frequent, low-severity fires (e.g., pine forests of the southwestern and southeastern United States) to systems characterized by infrequent but stand-replacing fires (e.g., subalpine and boreal forests of North America). At a finer scale, spatial variability in fuel mass and structure may influence fire ignition and severity under a middle range of weather conditions, but effects of fuels may be overwhelmed by effects of extreme weather—either extremely wet (no fire) or extremely dry and windy (large, severe fires). Almost all fire events exhibit a heterogeneous pattern of burning and create a mosaic of fire severity within the burned area, resulting in spatially variable changes in plant community structure, soil characteristics, and ecosystem processes of energy and biogeochemistry. We have a pressing need to better incorporate our understanding of spatial heterogeneity into wildland fire policy and management and to address urgent research questions about spatial patterns in fire history, fire effects, and responses of organisms and ecosystems to the spatial variability of fire.

Introduction

The devastating fire season of 2000 awakened the American people to the need for better understanding and management of wildland fires. More than 120,000 fires burned over 8.4 million acres and destroyed over 860 structures, while firefighting efforts cost approximately $1.3 billion (Machlis et al. 2002; iii). The U.S. Departments of Interior and Agriculture responded by developing the National Fire Plan, and the U.S. Congress implemented the plan with an appropriation of approximately $2.8 billion in 2001 (Machlis et al. 2002; 26). Implementation was barely underway when the devastating 2002

and 2003 wildfire seasons occurred, resulting in calls for even more aggressive action to reduce fire hazards, with a particular emphasis on fuels reduction. Although fire hazard is indeed acute in many areas, the widely touted Healthy Forests Restoration Act of 2003 appears seriously oversimplified from an ecological perspective and may in fact result in little protection from damaging fire but serious damage to the land in many places. Most troubling about the plan is its failure to explicitly acknowledge ecological heterogeneity: it appears to assume tacitly that (i) the fire hazard and its root causes are essentially the same in all forests, so the same basic approach to fire mitigation can be applied almost everywhere; and (ii) fire behavior and effects are controlled primarily by fuel conditions in all types of forests, hence, reduction of fuel mass by any means will reduce damaging fire behavior.

Our current understanding of fire ecology in western U.S. forests is sufficient to begin developing more effective fire management programs that are tailored to unique ecological conditions. A crucial task is simply to incorporate this knowledge into specific policy actions and to integrate the science with the social and economic concerns unique to each community facing a threat of wildfire damage. However, there are many aspects of fire ecology that we do not yet understand adequately, and so we need to identify and prioritize the key scientific questions that bear on major issues of fire policy and management (Veblen 2003).

In this chapter, I examine one component of this developing research framework, viz., the importance of spatial heterogeneity in fire occurrence and fire effects. All fire events, except perhaps the tiniest ones, exhibit a heterogeneous pattern of burning, in response to variation in, and interactions among, ambient weather, fuels, and topography at multiple spatial and temporal scales. For example, relative humidity and moisture content of fine fuels vary over the course of a day (generally lower humidity during the high temperatures of mid-day, then higher humidity when temperatures drop at night) and from day to day as regional air masses bring in wetter or drier air. Thus, fire behavior and fire effects at any point on the ground are influenced in part by the hour and day at which the fire occurs. Moreover, the fuel matrix varies in composition, mass, and arrangement; for example, between younger and older stands, and from moist to dry micro-site conditions. The upshot is that nearly all fires create a heterogeneous mosaic of fire severity; that is, patches of greater and lesser plant mortality, organic matter consumption, and effects on the post-fire microclimate and dynamic processes of energy and matter.

I approach the issue of spatial heterogeneity and fire in three steps. First, I illustrate how gradients in biotic and abiotic conditions influence fire regimes. A fire regime is a summary of central tendencies and variation in the major parameters of fire occurrence, behavior, and effects, including frequency, extent, seasonality, behavior, and effects on soils and biota (Agee 1998; Brown 2000; Heyerdahl et al. 2001; Morgan et al. 2001). Second, I illustrate how the inherent variability of fire itself creates spatial heterogeneity in the responses of organisms and ecosystems. Finally, I consider the implications of