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A spatially explicit model to predict future landscape composition of aspen woodlands under various management scenarios

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ABSTRACT

Quaking aspen (*Populus tremuloides*) is declining across the western United States. Aspen habitats are among the most diverse plant communities in this region and loss of these habitats can result in shifts in biodiversity, productivity, and hydrology across a range of spatial scales. Western aspen occurs on the majority of sites seral to conifer species, and long-term maintenance of these aspen woodlands requires periodic fire. Over the past century, fire intervals, extents, and intensities have been insufficient to regenerate aspen stands at historic rates; however the effects of various fire regimes and management scenarios on aspen vegetation dynamics at broad spatial and temporal scales are unexplored. Here we use field data, remotely sensed data, and fire atlas information to develop a spatially explicit landscape simulation model to assess the effects of current and historic wildfire regimes and prescribed burning programs on landscape vegetation composition across two mountain ranges in the Owyhee Plateau, Idaho. Model outputs depict the future structural makeup and species composition of the landscape at selected time steps under simulated management scenarios. We found that under current fire regimes and in the absence of management activities, loss of seral aspen stands will continue to occur over the next two centuries. However, a return to historic fire regimes (burning 12–14% of the modeled landscape per decade) would maintain the majority of aspen stands in early and mid seral woodland stages and minimizes the loss of aspen. A fire rotation of 70–80 years was estimated for the historic fire regime while the current fire regime resulted in a fire rotation of 340–450 years, underscoring the fact that fire is currently lacking in the system. Implementation of prescribed burning programs, treating aspen and young conifer woodlands according to historic fire occurrence probabilities, are predicted to prevent conifer dominance and loss of aspen stands.

1. Introduction

Widespread population decline of quaking aspen (*Populus tremuloides*) across the western United States has caused concerns that human alteration of vegetation successional and disturbance dynamics in this region jeopardize the long-term persistence of these woodlands (Kay, 1997; Bartos, 2001; Shepperd et al., 2001; Smith and Smith, 2005). Aspen is a critical component of ecosystem diversity in the conifer dominated western mountains and provides a disproportionately diverse array of habitats for flora and fauna for its relatively small area of occurrence on the landscape (Winternitz, 1980;

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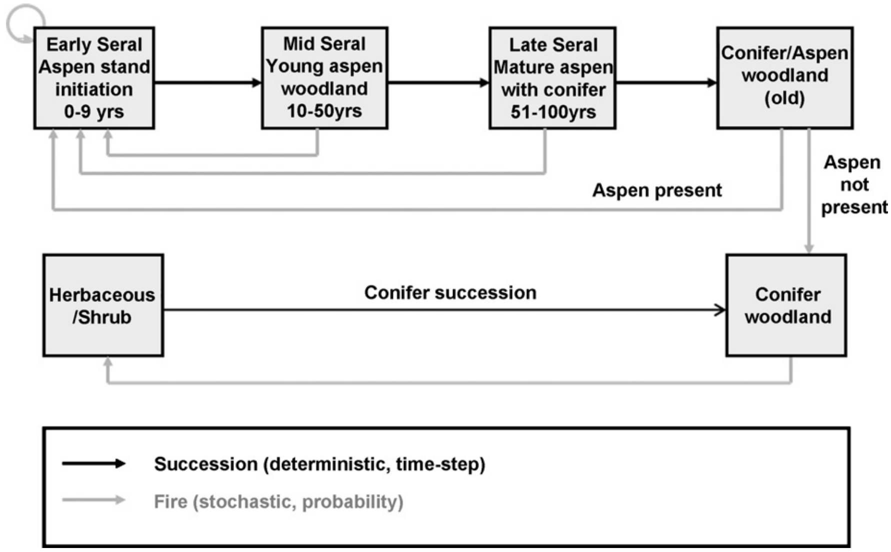

Fig. 1 – Simplified pathway diagram for upland aspen/conifer communities that served as the conceptual model for vegetation dynamics in the Owyhee Mountains.

Jones, 1993; Kay, 1997; Bartos, 2001; Chong et al., 2001; Rumble et al., 2001). In the semi-arid western U.S., aspen commonly occurs as a disturbance-dependent species, seral to conifer species (Bartos, 2001; Kaye et al., 2005; Smith and Smith, 2005). It is well established that in mixed aspen/conifer stands, periodic fires are necessary to prevent conifer dominance and possible loss of the aspen stand (Baker, 1925; Bartos and Mueggler, 1981; DeByle et al., 1987). Although quaking aspen is a prolific seed producer, the conditions required for successful seed germination and establishment are rare in the American West (Mitton and Grant, 1996). Aspen clones in the region reproduce primarily via vegetative suckering and therefore an aspen clone lost in this region is not likely to re-establish via seed. An example of recent successful establishment of aspen seedlings has occurred in response to severe Yellowstone National Park fires of 1988 (Romme et al., 2005). It is important to note that not all aspen stands are seral to conifers. Aspen stands in certain biophysical settings and away from a conifer seed source have been observed to exist as self-regenerating even and uneven aged stands that do not appear to be at risk of rapid decline even in the absence of fire (Mueggler, 1989; Romme et al., 2001; Strand, 2007).

Although successional rates within pure and mixed aspen stands and interactions with fire and herbivory have been studied at the stand level, little work has examined these dynamics at the landscape scale, and over decadal time periods. Computer simulation models may be a means to better understand these dynamics in aspen landscapes. Early vegetation dynamics models were limited to applications at the stand level, for example the forest 'gap' models of the JABOWA family (Botkin et al., 1972), the individual tree model FOREST (Ek and Monserud, 1974) and later, spatially explicit stand level tree models such as SORTIE (Pacala et al., 1993). Due to the limited simulation extent (<0.1–10 ha) these models necessarily focused on succession rather than disturbance. Models capable of simulating landscape change incorporating both succession and disturbance processes have evolved over the last 15 years (McGarigal and Romme, 2003; Mladenoff, 2004). Continued evolvement of such models has been enabled by recent developments in landscape ecology, the availability of remotely sensed imagery, development of image processing techniques, and the improved computer power within geographic information systems (GISs). Landscape scale succession/disturbance models are important tools for evaluating habitat patterns in forests and woodlands (e.g. Klenner et al., 2000; Bunting et al., 2007) and assessment of fire regimes and management scenarios (Keane et al., 1997; Franklin et al., 2001; Bunting et al., 2007).

Modeling change in structural landscape composition through time is challenging because of many interacting factors such as successional rates, disturbance regimes, disturbance agents and management activities. It can be helpful to begin the modeling effort by developing a conceptual model of the ecosystem. Strand (2007) developed such a conceptual state-and-transition model for upland western aspen in mixed aspen/conifer stands. The state-and-transition model describes vegetation states of aspen along the aspen-conifer successional gradient, e.g. stand initiation, young and mature woodlands, and conifer dominated woodlands (Fig. 1). These states are connected by transitional pathways, where natural disturbance or management action enables transitions among states. This conceptual model has been parameterized using field data collected along a successional gradient in the Owyhee Mountains (Strand, 2007) and implemented in the vegetation dynamics computer simulation model VDDT (Kurz et al., 2000; Essa Technology, 2003b; Merzenich and Frid, 2005). Although VDDT is a landscape scale computer simulation model with the capability of estimating landscape proportion within vegetation types and structural stages at user defined disturbance probabilities and pathways, the model is not spatially explicit and does not incorporate disturbance (fire) spread between land cover types adjacent to each other nor the effect of disturbance size on landscape composition. To compensate for these shortcomings, VDDT models can