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Decision support for evaluating landscape departure and prioritizing forest management activities in a changing environment

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ABSTRACT

We evaluated changes (hereafter, departures) in spatial patterns of various patch types of forested landscapes in two subwatersheds (“east” and “west”) in eastern Washington, USA, from the patterns of two sets of reference conditions; one representing the broad variability of pre-management era (~1900) conditions, and another representing the broad variability associated with one possible warming and drying climate-change scenario. We used a diagnostic set of class and landscape spatial pattern metrics to compare current spatial patterns of test subwatersheds against the two sets of reference conditions. In a companion decision support model built with the EMDS modeling system, we considered the degree of departure in the subwatersheds, relative to the two sets of reference conditions along with two additional criteria (vulnerability to severe wildfire and timber harvest opportunity), to determine the relative priority of landscape restoration treatments, and the potential for timber harvest to underwrite the treatments. In the decision support model, the current spatial pattern conditions of physiognomic types, cover types, forest structural classes, and those of late-successional and old forest patches of the two subwatersheds were compared against the two sets of reference conditions. The degree of departure in spatial patterns of physiognomic conditions was moderate in both subwatersheds in the pre-management era and climate-change comparisons. The situation was similar for the cover-type departure analysis, but spatial patterns of cover types increased in similarity to the reference conditions in the western subwatershed under the climate-change scenario. Spatial patterns of structural conditions showed a high degree of departure in both subwatersheds when compared to either set of reference conditions, but similarity improved in the eastern subwatershed under the climate-change scenario. Spatial patterns of late-successional + old forest structure were strongly similar to the broad envelope of conditions represented by the pre-management era reference in the western and moderately similar in the eastern subwatershed, but declined in both subwatersheds when compared with the climate-change reference conditions. When the degree of departure in spatial patterns of all patch types was considered along with vulnerability to severe wildfire and timber harvest opportunity, the eastern subwatershed rated higher priority for landscape improvement using either set of reference conditions. We conclude by considering uncertainties inherent in the analysis approach, types of sensitivity analysis needed to investigate model performance, and broad implications for forest managers.

1. Introduction

Forest landscapes throughout the interior Western United States provide both context and constraint to a host of ecological processes, plant and animal interactions; they are places where humans interact with biota and their physical environments (Hann et al., 2001). Conserving native species, key ecological patterns, processes, and human habitats alike, involves managing risk. To identify risks to native species, water and air quality, landscape structure and functionality, and other human interests and values an understanding of natural variation – and the factors controlling it – is essential. The degree of natural variation in ecological conditions is also non-stationary (Millar et al., 2007); i.e., as the

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regional climate shifts in substantive ways, there is likely concordant shifting in the envelopes of conditions that define so-called natural variation. When natural variation is understood in this way, several elements become apparent: (1) landscape patterns of vegetation conditions that are concordant with the regional climate, patterns of disturbances, and other interacting ecological processes represent a very broad array of conditions, not a narrow one; (2) relatively short-lived climate anomalies (e.g., interdecadal and shorter duration) probably distort that broad envelope to a relatively small degree, but longer term and severe anomalies have the potential to distort it a great deal; (3) significant departures in conditions should be evaluated at multiple scales of space and time because climate, management, and environmentally induced changes to patterns and processes may not occur or be detected at the same scales. This study is a first attempt to develop analytical methods to evaluate multi-scale changes in vegetation conditions of two test landscapes relative to two sets of reference conditions: one that represents the broad range of conditions that occurred in these and similar biophysical landscapes during the pre-management era (~1900), and another that represents the broad range of conditions that could occur in similar landscape under a climate-change scenario.

Such information is important to understanding how past and future management may affect wildlife habitat, timber availability, recreation and amenity opportunities, species and landscape diversity, and other ecological services that forest landscapes provide. All these factors are affected by the current and future condition of forests at site, stand, and landscape scales.

On managed public lands, there is an additional need to communicate expected outcomes of management alternatives before they happen (Shifley et al., 2006). Thus, tools that provide transparent explanations of probable landscape changes as well as clear guidance on selection of management tools and strategies can be a significant benefit to natural resource managers (Oliver and Twery, 1999). Numerous decision support systems (DSS) have been developed in the past 30 years to support management of natural resources, but the majority have been developed to support project-scale management, and most only provide support for certain specific steps in the decision-making process (Mowrer et al., 1997; Rauscher, 1999).

In this study, we use the term landscape "departure" to describe a lack of correspondence between the current state of a landscape and a broad envelope of reference conditions. The point of using reference conditions and comparisons with those conditions is to highlight that a very broad range of equiprobable landscape patterns occurs when the climate of a region interacts with its biophysical settings, vegetation, and disturbance processes (Hessburg et al., 2004). In analysis, if correspondence with reference conditions is high, the degree of departure is low, and the converse is also true. This concept of departure analysis is based on the hierarchical patch dynamics paradigm of Wu and Loucks (1995) and is illustrated in Hessburg et al. (1999c,d). Departure analysis using historical reference conditions seeks to discover the primary ways that current structural and compositional patterns of a given landscape differ from those that would be expected considering the recent historical climate, biophysical settings defined by that climate and disturbance processes that were in synchrony with that climate.

Amid mounting evidence of a shifting regional climate, it is reasonable to do similar departure analysis, now asking how current patterns of a given landscape differ from those that would be expected under a plausible future climatic regime. We evaluate landscape departure in our analysis of conditions in a forest reserve located in the rain shadow of the Cascade Range in eastern Washington (United States, US). We focus on landscape departure associated with vegetation patterns under historical disturbance regimes (historical climate scenario) versus those anticipated under one plausible climate-change scenario because these two scenarios provide contrasting land management targets to test prior to implementation.

1.1. Objectives

We demonstrate an approach to evaluating current multi-scale landscape patterns with reference to an historical (pre-management era) climate scenario and a hypothetical warm–dry climate-change scenario, and use of decision modeling to set priorities among landscapes and alternative treatments. For purposes of illustrating the approach, we use a hypothetical, but plausible, climate-change scenario. Our analysis is not about accurately predicting climatic change, but about interpreting landscape consequences, given a plausible scenario.

We use the logic modeling component of the Ecosystem Management Decision Support (EMDS) system (Reynolds et al., 2003) to assess landscape departure from reference conditions under the two climate scenarios. We then used the decision modeling component of EMDS to illustrate how various landscape conditions (e.g., composition, structure, crown cover) can be prioritized for management treatments, taking into account not only considerations of landscape departure, but also logistical considerations that might be pertinent to forest managers.

1.2. Environmental context

Fire historically played an important role in shaping the patterns and processes of the landscape of the interior northwestern US. However, through the influence of Euro-American settlement and land management, fire regimes have changed (Hessburg and Agee, 2003). Federal fire-exclusion policies in the US, starting in the early 20th Century (1930s), have extended fire-free intervals in western states (Covington et al., 1994), and in the mid-elevation forests on the eastern slopes of the Cascade Mountains (Agee, 2003; Hessburg and Agee, 2003). This policy resulted in the widespread occurrence of shade-tolerant and fire-intolerant forest stands, consisting of such species as grand fir (*Abies grandis* (Dougl. ex D. Dun) and Douglas-fir (*Pseudotsuga menziesii* (Mirb. J France) (Camp et al., 1997). This reduction in fire occurrence, combined with livestock grazing, caused significant increases in tree density. Subsequent stand development resulted in the creation of more frequently occurring multi-layered fire-intolerant forest canopies (Hessburg et al., 2000c), replacing previously more open, fire-tolerant stands that once formed the landscape matrix (Hessburg et al., 2007). High competition for growing space (Oliver and Larson, 1996), and periodic and often severe drought stress these dense stands. Moreover, shade-tolerant and fire-intolerant stands are vulnerable to attack by several pathogens and defoliating insects (Hessburg et al., 1994). Mortality caused by insects and pathogens regulates density and species composition in response to stressors, and it increases surface fuel loads (Hessburg et al., 1994). In addition, these denser forests comprised of shade-tolerant species are in spatially contagious arrangements, and are prone to more severe fire behavior because surface fuels and canopy fuels are more abundant, ladder fuels are widely distributed, crown bulk density tends to be high, and the potential for crown fire ignition and spread is elevated (Huff et al., 1995).

In addition to the extant increased insect, disease, and fire danger, there is an increasing risk of landscape alteration associated with a changing climate. As a consequence of climatic change, forests may face rapid alterations in the timing, intensity,