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Original Articles

Using remote sensing to quantify ecosystem site potential community structure and deviation in the Great Basin, United States

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ABSTRACT

The semi-arid Great Basin region in the Northwest U.S. is impacted by a suite of change agents including fire, grazing, and climate variability to which native vegetation can have low resilience and resistance. Assessing ecosystem condition in relation to these change agents is difficult due to a lack of a consistent and objective Site Potential (SP) information of the conditions biophysically possible at each site. Our objectives were to assess and quantify patterns in ecosystem condition, based on actual fractional component cover and a SP map and to evaluate drivers of change. We used long-term 90th percentile Landsat NDVI (Normalized Difference Vegetation Index) and biophysical variables to produce a map of SP. Ecosystem condition was assessed using two methods, first we integrated fractional components into an index which was regressed against SP. Regression confidence intervals were used to segment the study area into normal, over-, and under-performing relative to SP. Next, the relationships between SP and fractional component cover produced SP expected component cover, from which we mapped the actual cover deviation. Much of the study area is within the range of conditions expected by the SP model, but degraded conditions are more common than those above SP expectations. We found that shrub cover deviation is more positive at higher elevation, while herbaceous cover deviation has the opposite pattern, supporting the hypothesis that more resistant and resilient sites are less likely to change from the shrub dominated legacy. Another key finding was that regions with significant annual herbaceous invasions tend to have lower than expected bare ground and shrub cover.

1. Introduction

Land degradation in arid and semiarid environments is often related to historical legacies, environmental variables, edaphic properties, and physical perturbations (Peters et al., 2006). Sagebrush (*Artemisia tridentata*) dominated ecosystems are widespread across semiarid portions of western North America (Schlaepfer et al., 2014). Many of these ecosystems have been degraded through complex perturbations including invasive species, fire dynamics, woodland expansion, and land use practices (Wisdom et al., 2005; Chambers et al., 2014a; Stringham et al., 2016), with only 10% estimated to be in a condition unaltered by human disturbance (West, 1999). Some sites are near ecosystem thresholds, and are vulnerable to transitioning to a new steady state (Wisdom et al., 2005). Spatial understanding of which areas are near ecosystem thresholds is critical to avoid shifts to an undesirable state at which point restoration practices have been only modestly successful (Schlaepfer et al., 2014). Identifying healthy plant communities on the other hand, allows better prioritization of management resources and facilitates understanding of which practices and environmental conditions lead to that state.

Good understanding of ecosystem condition over large areas is invaluable for managing and understanding these resources. However, monitoring rangelands has often depended on personal judgement, and collecting objective data over vast landscapes has historically been expensive and difficult (Booth and Tueller, 2003). Condition interpretation requires information on the spatial patterns of reference condition (Bestelmeyer et al., 2009; Maestas et al., 2016). Further, large temporal and spatial variations in weather conditions can obscure the underlying effects of management and long-term climate change (Wylie et al., 2012). State and Transition Models (STM) are a useful concept to describe potential plant communities within an ecological site, based on soils and climate that possess a similar capacity to respond to

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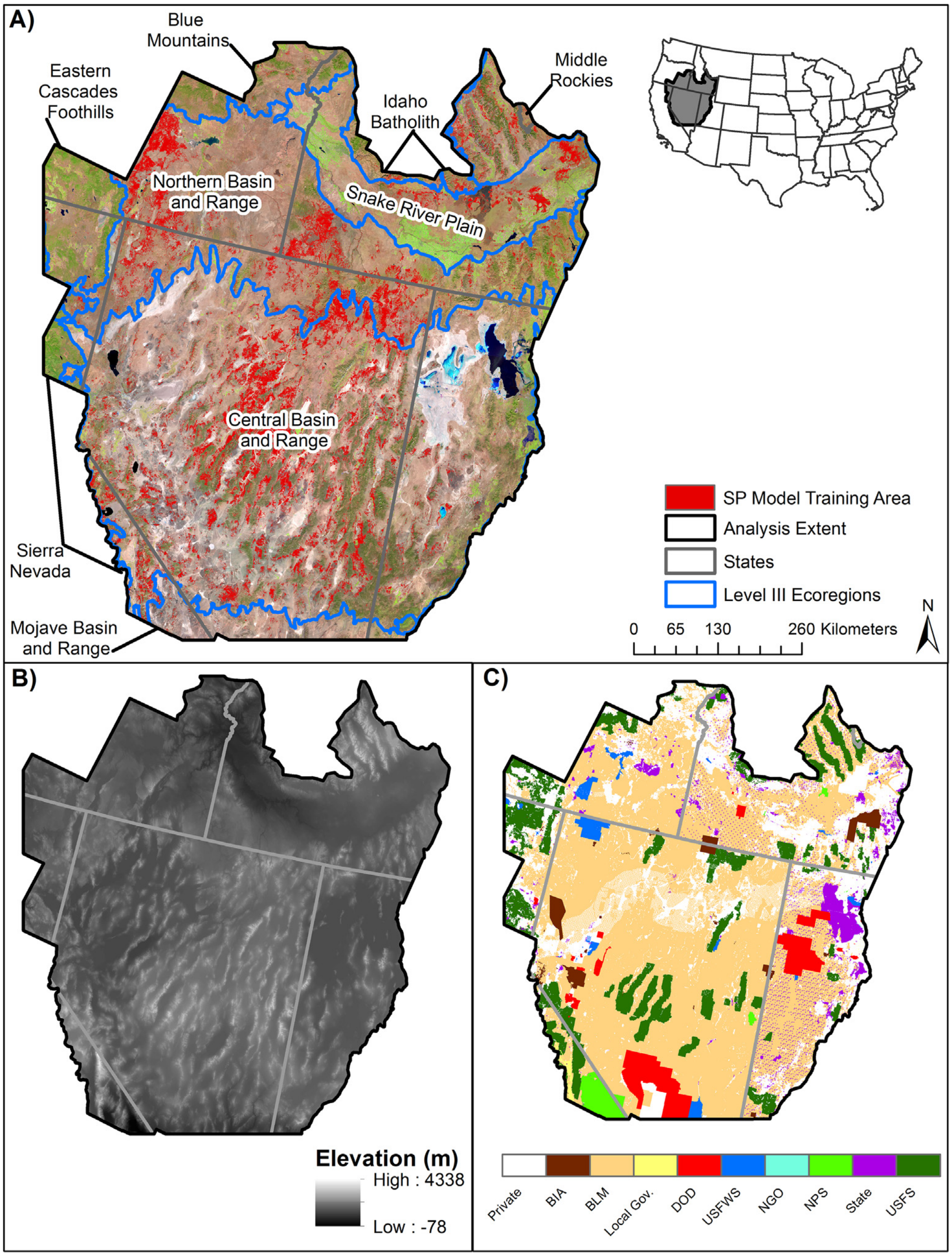

Fig. 1. Overview of study area location and features. A) Level III ecoregions superimposed and Site Potential (SP) model training extent on a summer 2017 Landsat 8 image composite, B) elevation, C) land management; abbreviations: BIA; Bureau of Indian Affairs, BLM; Bureau of Land Management, DOD; Department of Defense, USFWS; United States Fish and Wildlife Service, NGO; Non-Governmental Organization, USFS; United States Forest Service.

management and disturbance. Composition, cover, and production for communities of varying states within an ecological site are provided in a STM. STM describe the disturbance or management pathways among states and documents shifts that are difficult to reverse (Bestelmeyer et al., 2009; Bestelmeyer et al., 2011). Modelling variation in potential vegetation is difficult, however, so the reference state for STMs are often based on extrapolations from similar systems of current well managed areas. STM have not yet been completed for much of the western U.S., and their spatial scale sometimes prevents adoption by federal land managers (Stringham et al., 2016).

Wylie et al. (2008, 2012) developed an approach that separates yearly weather influence on ecosystem condition from that of management, disturbance, or long-term climate changes. This approach evaluates ecosystem performance anomalies in biomass productivity by comparing actual measured conditions using remote sensing to those expected by a modelled site potential condition. A key component of this research determines the long-term average ecosystem site potential, which represents the ecosystem potential biomass production in an average year in a non-degraded or disturbed state (Wylie et al., 2012; Rigge et al., 2013b). Growing Season averaged NDVI (Normalized Difference Vegetation Index), or GSN, served as a proxy of biomass production. Site Potential (hereafter; SP) was calculated using a Cubist regression tree model trained on intact sites, using multiple biophysical variables as inputs. The goal of SP is to approximate the historical climax through a GSN map produced using a combination of biophysical data and a long-term archive of satellite imagery developed at 30 m resolution.

Remote sensing offers new approaches to quantifying and