Collaborative Proposal: Understanding the potential for a climate change-driven critical transition from forest to chaparral

Overview: The Klamath Ecoregion of Oregon and California is an ideal model system for studying non-linear ecosystem dynamics and for applying this knowledge toward improved science-based ecosystem management. Stabilizing feedbacks between a mixed-severity fire regime and successional dynamics maintain two distinct ecological communities: a high-biomass conifer forest state and a low-biomass shrub-chaparral-hardwood (SCH) state. These feedbacks are closely linked to climate and operate at local and landscape scales to affect regional scale biome distributions. **The goal of the proposed research is to understand if anticipated changes in climate may alter the disturbance-recovery dynamics and force a regional-scale critical transition from mature conifer forest to SCH.** The research plan includes three elements that are key to understanding the potential for such a transition: (1) development of general mathematical models to gain a broad understanding of dynamics underlying critical thresholds in fire-prone ecotones and to identify the functional relationships that control transitions between SCH and mature conifer forest, at local and landscape levels; (2) field research to characterize the climate-dependence of post-fire recovery and to test and parameterize models; (3) process-based simulations of local, landscape, and regional dynamics to characterize the interactive roles of climate, fire, and management in shaping the region's ecological communities.

Intellectual Merit: There is great concern that climate change will disrupt stabilizing feedbacks and force ecosystems over critical thresholds - so called tipping points - wherein the system shifts abruptly from one state to another and is then unlikely to return to the original state. Specifically, climate change may alter disturbance and recovery patterns such that landscapes and entire regions may quickly transition to new states with low probability of returning to their previous state. Improving understanding of critical transitions has been recognized as a fundamental challenge in ecology with global relevance and urgency in the face of climate change. Nonetheless, empirically-based investigations remain rare. Increased understanding of the potential for a critical transition in the Klamath will inform the management of fire-prone forests worldwide. The proposed research will quantify the potential for, and mechanisms underlying, a climate-change induced regime shift. Such a landscape shift in the Klamath region would impair the unparalleled botanical diversity of the region and release massive amounts of greenhouse gasses as some of the most carbon dense forests in North America transition to low-biomass SCH.

Broader Impacts: Eighty three percent of the Klamath region is managed by the U.S. Forest Service (USFS). Through a history of fire suppression, logging, and conifer planting, the USFS has altered the disturbance and recovery dynamics on a significant portion of this landscape. New federal regulations require all National Forests to manage for resilience to climate change and to incorporate the best available science. The research team has a long history of collaboration with USFS and will engage them in designing scenarios to explore alternative management responses to changes in climate and wildfire regimes. The researchers will then incorporate these scenarios into to their landscape simulation framework. Coupling scenarios to simulations will permit analyses of a range of possibilities and uncertainties in quantitative (status of various ecosystem services, maps of ecosystem states, etc.) and qualitative terms (the scenarios themselves). The managers will also be able to utilize a user-friendly decision support and visualization tool that has been designed to permit exploration of the scenarios by linking directly to output from the landscape model.

Including direct participation of decision makers in this fundamental research project will ensure the transparency, credibility, and salience of the science, thereby increasing its impact on environmental outcomes. The stakeholder led, scenario-to-simulation approach will provide a model for bridging science and policy within land management agencies tasked with managing for resilience to climate change.

Objectives:

Our goal is to understand the potential for climate change to force a critical transition from a stable, high-biomass forest-dominated landscape to a stable, low-biomass shrub-dominated landscape. We have selected the Klamath region of Oregon and California as a model system because previous research has identified the existence of two alternative states—mature conifer forest and shrub-chaparral-hardwood (SCH)—which are jointly maintained by a mixed severity fire regime and successional dynamics (Fig 1; Thompson and Spies 2010, Odion et al. 2010). We will use a combination of theory, empirical observations, and regional-scale process modeling to address the following questions:

(i) Under what conditions are forests and SCH maintained as alternative states with evidence of stabilizing feedbacks (i.e. basins of attraction; Fig. 1A)? What is the relative importance of fire regime (size, severity, and frequency) and forest recovery rate in determining the dominant state?

(ii) What is the role of climate in shaping alternative landscape states (forest dominated vs. SCH dominated) through its influence on fire regime and forest recovery rate? Is there evidence that climate change could trigger a transition between these states?

(iii) What is the role of land management in shaping alternative landscape states through its influence on fire regime, forest composition, and forest recovery rate? Could management actions delay or prevent critical transitions at the landscape or regional scale?

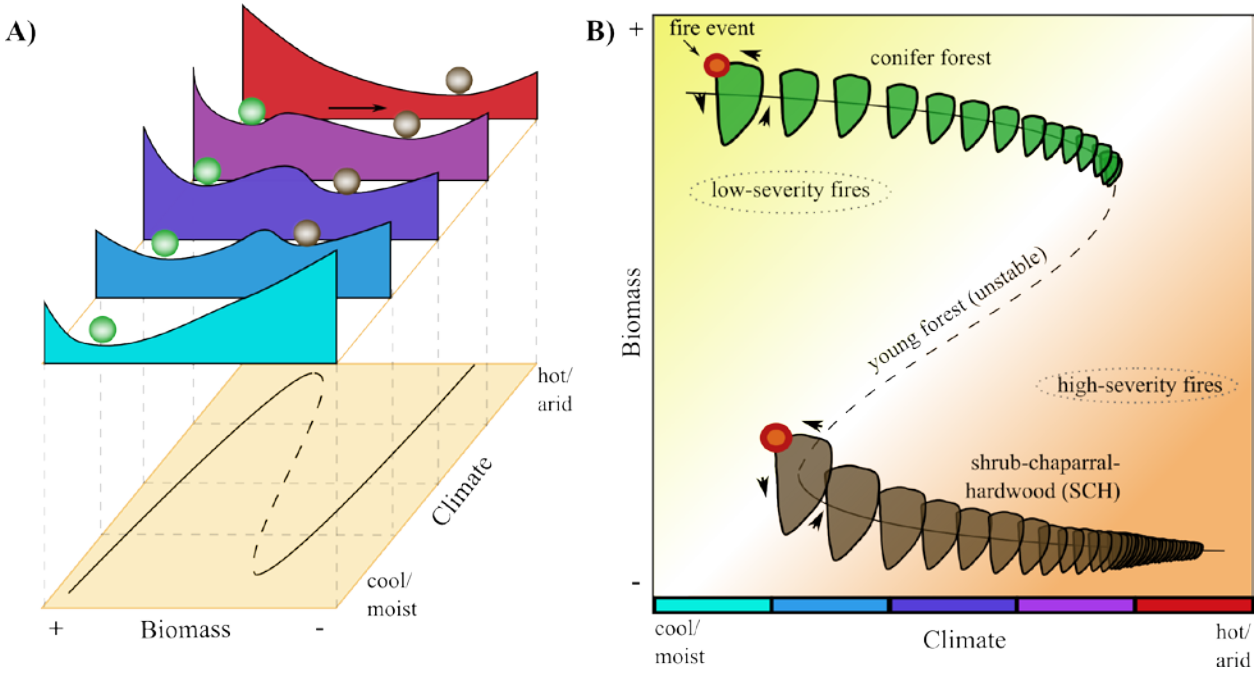

Figure 1. **A)** Many fire-prone regions situated at a ecotone, such as the Klamath, can support two local stable ecosystem states: a low-biomass SCH state and a high-biomass, mature conifer state. When the climate is cool and moist (turquoise), the basin of attraction around the high biomass state dominates the region (e.g. during the Little Ice Age, when most of the remaining old growth established). When the climate is intermediate (purple), both states coexist within the region. When the climate is warm and dry (red), as it is anticipated to become, the low biomass state dominates. (Figure adapted from Scheffer 2009). **B)** Cycles of severe wildfires and rapid recruitment maintain the pyrogenic SCH condition. Mature conifer is maintained by a cycle of low severity fires that remove ladder fuels without killing the increasingly resistant overstory trees. Young forest is vulnerable to high severity fire, and is thus locally an unstable state. Individual components of these stabilizing cycles are shown in Figure 2.