The effects of drought on Engelmann spruce regeneration in Southwest Colorado

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Introduction

Climate modeling suggests that drought will become more frequent in the southwestern United States over the next century (Andreadis et al. 2005). Modeling studies have been used to predict the effect that increasing drought will have on the range of Engelmann spruce in southwest Colorado (Rehfeldt et al. 2015). In this work, we investigated the effects of interannual variation in climate on seedling establishment to ascertain whether hot, dry conditions that are expected to become more common in the future are likely to result in regeneration failures in Engelmann spruce stands.

Methods

We aged seedlings from 24 stands on the Gunnison NF across a range of elevations and precipitation normals (Fig 1, Table 1). All stands were partially cut in the late 1980's to mid-1990's, so they had a seed source and conditions conducive to Engelmann spruce regeneration during a series of droughty growing seasons in 2000-2004 (Fig 2).

Table 1: Summary statistics of sites sampled

# of Seedlings	8654
Elevation range (m)	3135-3504
Precip. range (mm)	531.4-924.6
Average seedlings ha^{-1}	6303

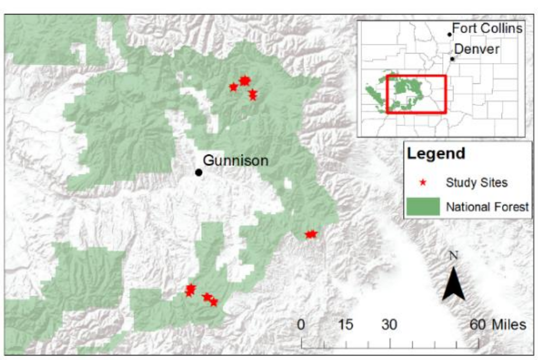

Figure 1: Map of study areas on Gunnison NF

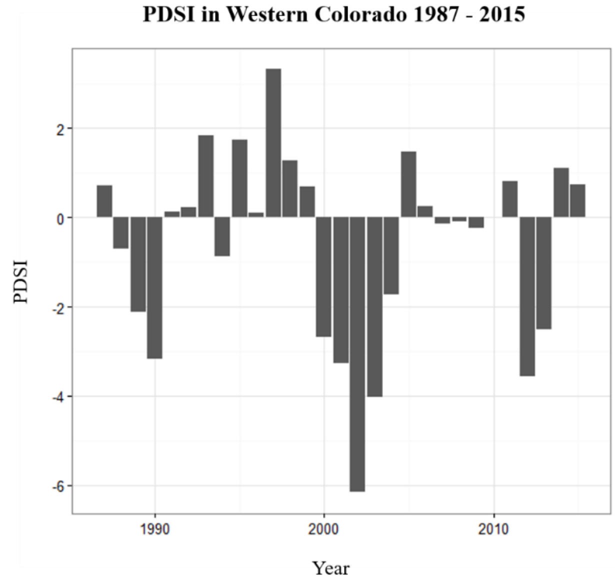

Figure 2: Palmer Drought Severity Index values in Western Colorado from 1987 to 2015. More negative values indicate severe levels of drought. Data acquired from National Climatic Data Center (NCDC 2017).

Analysis

We used mixed effect modeling for repeated measures to identify relationships between patterns of seedling establishment and:

- Stand characteristics
- Topographic variables
- Climate variables

Climate variables were chosen based on their relevance to spruce ecology.

Results

Patterns of seedling establishment in our model were related to mean annual temperature (MAT), annual precipitation (AP), an interaction between MAT and AP, and June precipitation (PPT06) (Table 2). Climate variables were only weakly related to seedling establishment in the stands we examined. MAT was the best single variable for predicting seedling establishment (establishment was greater in warm years), but it explained only a small proportion of the year-to-year variation in seedling establishment (Fig. 3). PDSI was not related to establishment.

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Table: Summary of model parameters

Variable	p-value	Slope	Intercept
MAT	0.0013	3.804	2.289
AP	0.3679	0.002	
PPT06	0.0036	-0.072	
MAT:AP	0.0134	-0.004	

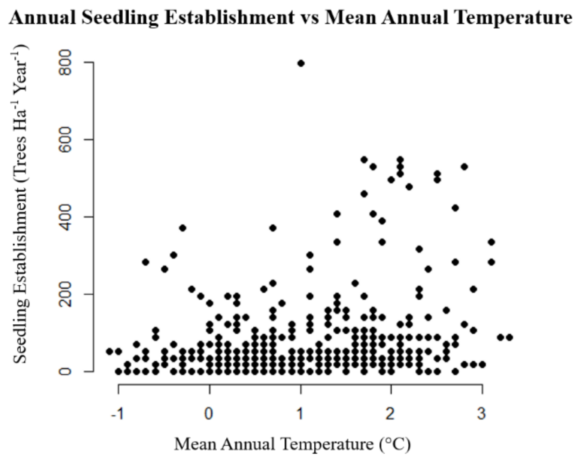

Figure 3: Scatterplot of yearly seedling establishment density vs. mean annual temperature

Management Implications

Our stands fell within the “threatened” and “persistent” categories of the bioclimate modeling done by Rehfeldt et al. (2015). In these relatively cool, wet stands summer drought has apparently not been a major impediment to seedling establishment in recent decades. Issues with climate related regeneration failures are more likely to show up on hotter, drier sites than the ones we sampled. Our research suggests regeneration is occurring in these high elevation stands regardless of drought conditions. Our results suggest partial cutting is a reliable way to secure natural regeneration in high elevation Engelmann spruce stand in Southern Colorado.

Works Cited

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