1. Introduction

Ecotones occur where distinct forest types meet across a climatic gradient and form transition zones. In the mountains, ecotones are compressed over steep vertical gradients. As the climate warms in New England, USA, high elevation forests dominated by spruce and fir are expected to recede upslope, with deciduous species like sugar maple moving up behind them (Bockage et al. 2008, Iverson et al. 2008). The rate of this elevational range shift remains in question, as forest turnover can take decades or longer.

2. Objectives

1. Systematically model and map the boreal-hardwood forest ecotone from leaf-off LIstndat imagery across the entire elevational zone (650 and 1000 m A.S.L) for the Green and White Mountains (Figure 2 and 3) including named peaks and valleys from prior publications: Mt. Abraham, Mt. Boles and Camel’s Hump (Siccama 1974, Bockage et al. 2008), Hubbard Brook, Crawford Notch, “The Bowl”, etc.

2. Calculate the distribution of elevational changes in the montane ecotone at local and regional scales, accounting for model uncertainty, from 1984 to 2011.

3. Model the dependence of ecotone elevation on Latitude, slope, and aspect (not reported here).

3. Methods

3.1 Comparing LandSat TM Images

Acmeotic detection of montane forest ecotone change requires differences between images to be minimized. Landsat reference needs to be collinear and consistent between mountain slopes. We carefully matched Landsat surface reflectance images phonologically and corrected them for topographic vicissitudes using 3rd-order (Stallard et al. 1982). Spring leaf-off images show the full-color of both canopy and understory continuous tree canopies, while fall imagery represents mostly canopy traces. We show analyses for both seasons (Table 1).

3.2 Deriving Sample Areas – Confliguous Mountain Slopes

We subdivided the elevation range by aspect to create topographic subsets of NE or SW exposure at least 500 pixels (45 ha). Subsets ranged from 45 to 5387 ha (median 152 ha). For each subset, we extracted surface reflectance for forested Landsat pixels that were cloud and snow free in all five dates and balanced data across the elevation range. We used vegetation indices (VI) as our proxies for montane boreal species abundance (Normalized Difference Vegetation Index (NDVI), and Normalized Difference Moisture Index (NDMI)).

3.3 Fitting Models & Deriving Ecotone Edge Elevations

We fit 4-parameter logistic models to predict NDMI as a function of elevation with the package “rlme” in R. Models account for spatially autoloaded error. We defined 0.5% inflection points (max and min of the 2nd derivatives) of the fitted curves as the upper and lower ecotone boundaries (Figure 5). We show trends from these of the parameter distribution of ecotone edge, based on parameter means and SD and computed posterior distribution of ecotone elevations among years using Juulia’s HSD.

3.4 Validation with Forest Inventory Data from Hubbard Brook

We compared LandSat reference locations of forest inventory plots from Hubbard Brook Experimental Forest (Figure 6a) (Clark et al. 2005). Relative basal area (RBA) of boreal species measured in 400 m² plots (1955-1994) agreed well with spring leaf-off of the boreal vegetation index (NDMI) for 20 plots missed from 1991 (Figure 6b). This confirms that NDVI is a suitable proxy for boreal species abundance from which to model ecotone boundaries.

5. Conclusions

Landsat change detection showed that coniferous boreal species have moved downwards over the past 20-30 years in the Green and White Mountains of the northeastern US, in contrast to smaller scale studies that found the opposite trend (upward movement of the ecotone). Most of this change represents spread of spruce and fir for the unbderstory layer, as shown by larger changes in spring imagery in comparison to fall. At the scale of individual mountain slopes (45-1000’s ha), montane forest ecotones have moved both up and down, but the overall average is down. As this is opposite to the response predicted by increasing climate stress in these species, other factors must be having a stronger effect on recent forest dynamics than climate change. We hypothesize that the observed process represents recovery of spruce and fir forests to historically upper montane elevations, following spruce dieback and decline in the 70’s and 80’s, and human resource extraction over the prior century. These results highlight the importance of analyzing forest processes at appropriate spatial scales and considering competing drivers of forest change.

References