

Analysis of growth patterns in Conifer stands present in Gothic town

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Abstract

Forest ecology research is being revolutionized with the advent of remote sensing. Remote sensing is more accurate and reliable than previous methods for assessing forest dynamics, so it is important to generate workflows for assessing them. The forests of the Gothic townsite are an underutilized subject of study within the Rocky Mountain Biological Laboratory and the aim of this project is to answer questions of how forests grow and why and create workflows for doing this in other localities using remote sensing data. The conifers present in the Gothic Townsite appear to be decreasing in volume and have had negative height changes. There are environmental factors at play but more work needs to be done to understand the mechanisms behind the decrease in total conifer volume.

Introduction

Forests provide a vast number of services to both people and the ecosystems that they are a part of. They help maintain many important systems including the water cycle, carbon cycle and soil health (Lindquist et al., 2012). Of most relevance to people is the ability of forests to store carbon and with over 3 trillion trees present on the planet, forests are one of the most significant carbon sinks (Crowther et al., 2015). Given the importance of trees, understanding certain aspects of forests is necessary to future management. In the past forest ecology has relied on measures of trees taken at ground level such as diameter at breast height (DBH) to gauge the health and demography of forest stands (Contreras et al., 2011). This measure is often used as a proxy for many aspects of individuals but is not overall representative of anything other than the diameter of the trunk. The use of DBH is generally unreliable when used to describe things such as the leaf area, crown volume, and ecological processes such as competitive interactions and population dynamics (Molto et al., 2013).

One of the most promising solutions to these issues is developments in remote sensing (Lines et al., 2022). With remote sensing three dimensional reconstructions of tree size and shape can be used to measure features of tree canopies. Methods for this previously were often destructive and required intense work. Instead, new techniques developed with the help of large data sets containing point clouds and analyzed with machine learning are now providing more accurate data on the features of trees considered the most important to forest ecosystems such as above ground biomass, carbon sequestration and canopy microclimates. One of the most

effective tools for measuring some of the traits previously mentioned is tree segmentation which is used to identify individual trees in the forest from point clouds made by high resolution imagery (Zhang et al., 2022).

The focus of the research being undertaken was to use remote sensing techniques to analyze aspects of forest ecology on the Gothic townsite with the use of high-resolution imagery taken by a drone platform. The main topics of interest were in relation to the conifers present in the townsite and how different microclimates impact their growth and development. In addition, questions of how the conifers interact with the environment are important as well as how trees can influence snow melt patterns and other climatic variables. The comparison relies on extracting species level data on the spruce and fir trees across different terrain in the townsite.

Methods

The site selected was the Gothic Townsite where over 6,500 individual conifer trees are present and visible to remote sensing methods. The Gothic Townsite was mostly clear cut in the late 1800s before being obtained by the Johnsons and turned into the Rocky Mountain Biological Laboratory. The tree stands here are relatively young and understudied which made them an interesting choice for an observational study of their forest growth. The data was collected over the course of three years using a drone platform flown over the Gothic townsite every week. The photogrammetry data was then taken to construct the digital surface model of the townsite and extrapolate information from this (Cho et al., 2015).

The main methods of the research that was undertaken involved using digital surface models of the townsite taken across three years around the same phenological time for the conifers of the townsite. The dataset had to be filtered for conifers using a vegetation class model developed using a machine learning algorithm (Xie et al., 2008). These digital surface models were then used to calculate aspects of tree growth such as growth change and total volume for the conifers of the townsite. After tree growth was calculated, climatic information was extracted from the RMBL Spatial Data Platform on snowpack duration, freezing degree days, and topographic wetness. These datasets were in raster form and zonal functions from QGIS were used to calculate average values within the polygons of conifer trees. Each polygon was then grouped together based on watershed and proximity to other groups of trees to form four stands named after approximate geographic location: East River, Rocky Meadows, Above Research

Meadow and Below Research Meadow. Each stand was classified respectively in rising numerical order. The values of these were then filtered to eliminate extraneous values caused by collection error or tree fall so only values greater than -2 meters and less than 2 meters were kept. These were then analyzed using the variables aforementioned for patterns of growth. The data acquired from analysis in RStudio and QGIS were run through a multiple linear regression to analyze which variables had an effect on the response variable and which variables were significant. A random forest model was also done to analyze which variables were most important.

Preliminary work was done on building a species level identifier between the Subalpine fir and the Engelman's Spruce with an RTK GPS system to ground truth at a species level then use drone orthomosaic imagery and polygons constructed from the RTK GPS tracks to train a machine learning algorithm to differentiate the two. This would be something to further work on as the training dataset is complete but the machine learning algorithm needs to be trained.

Results

According to the random forest model, the most significant factor in tree growth in the Gothic townsite is in relation to the topographic wetness index. However, the multiple linear regression suggests otherwise with the only significant factor being snowpack duration for the entire townsite. Results are in Table 1. When split into the four stands however, the multiple linear regressions suggest that certain factors affect the stands at different rates. Wetness had a significant effect on mean height difference for stands one, two and four. Snowpack duration had a significant effect on stands two and four. Freezing degree days had a significant effect on stands two, three and four. Overall, the volume of conifers in the townsite has decreased by -15,925 cubic meters between 2021 and 2022 and -32,001 cubic meters between 2021 and 2023. The trees on average had a mean height change of -0.302951 meters over the course of two years.

Discussion

There are many factors that go into patterns of forest growth and disentangling them can be difficult. From this study it appears that overall conifer forest health of the Gothic townsite is getting worse as there is a general decrease in total crown volume of the conifer trees. The four

stands each have varying responses to different environmental factors which can be useful in discerning what factors affect certain areas. For instance, topographic wetness is negatively correlated with growth in the East River and Rocky Meadows but positively correlated Below Meadow stand. For Snowpack, it appears as if the Rocky Meadows and Below Meadow stands are negatively correlated with the duration of snow on the ground. However, overall according to the multiple linear regression model snowpack duration is positively correlated with mean height difference. Freezing Degree Days was also correlated positively with each stand individually but not the entire population. These relationships all need to be further investigated with ground truthing techniques and more statistical analyses as according to the Random Forest analysis topographic wetness was the most important factor to tree growth which was not reflected in the multiple linear regression.

Topographic wetness index had an impact on three of the four stands in a way contrary to what would be conventionally understood (Song et al., 2007). Two of the stands saw negative relationships with topographic wetness and one with a positive. This could suggest that wetness could be causing some negative impact on the forest such as some type of root rot causing declines in certain stands.

Snowpack duration was expected to have an important role in growth as conifers drive snowpack by shading the understory and providing water through the dry period before the monsoon season (LaMalfa & Ryle, 2008). However, once again the inverse relationship is seen for the individual stands but for the total population there is a positive correlation between growth and snowpack duration.

Freezing Degree Days was the only variable with the expected outcome for each stand (Girardin et al., 2022). Freezing degree days are important to conifer growth and as the climate warms it is expected to have a negative impact on the forest dynamics. Long term climate data can be used to analyze if these past years have had less freezing degree days than the average for the townsite.

The total forest volume decreasing is of importance to note as there is not a clear mechanism for this is happening. The most likely culprit is some type of pathogen such as spruce budworm that is targeting new growth of the conifers in the townsite (Fellin, 1982). Forest dynamics are complex and there are a multitude of factors to consider when analyzing a forest. Recent research has identified that scale of analyses needs to be taken into account when doing

forest ecology and that it may impact the relationships greatly depending on the resolution (Fricker et al., 2019). In the future, more environmental factors would be chosen and long term climatic data would be taken into account. Additionally, ground truthing would help ensure that the remote sensing data acquired is accurate as there is room for error when the Digital Surface Model is generated in the form of holes in the model.

Table 1.

Forest Stand	Sample	Mean Height Change	St dev	Topographic Wetness	Snowpack Duration	Freezing Degree Days
Stand One- East River	3556	-0.242588	0.684226	9.56E-06	0.196	0.762
Stand Two- Rocky Meadows	641	-0.523036	0.667397	0.002172	8.41E-10	0.000205
Stand Three- Above Meadow	823	-0.481633	0.622458	0.889351	0.716748	0.000106
Stand Four- Below Meadow	475	-0.302209	0.637885	3.77E-07	1.92E-09	0.042727
Population	5736	-0.302951	0.667408	0.717737	0.000211	0.072628

Figure 1. Scatter plot of Freezing Degree Days

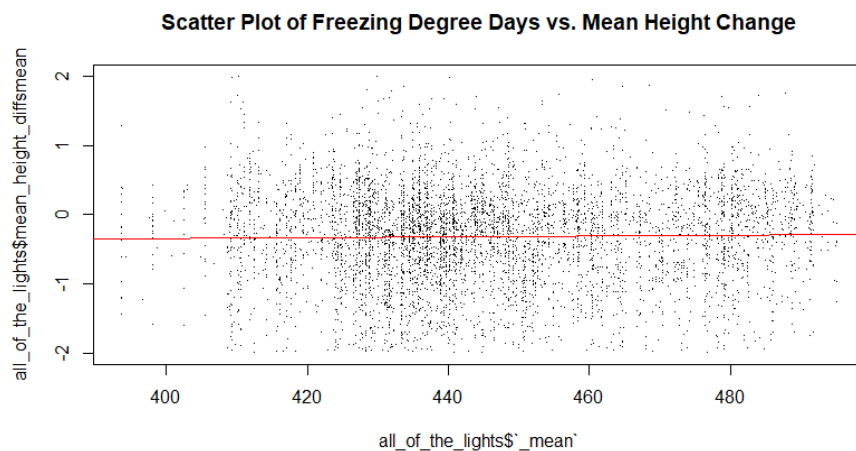


Figure 2. Scatter plot of Snowpack

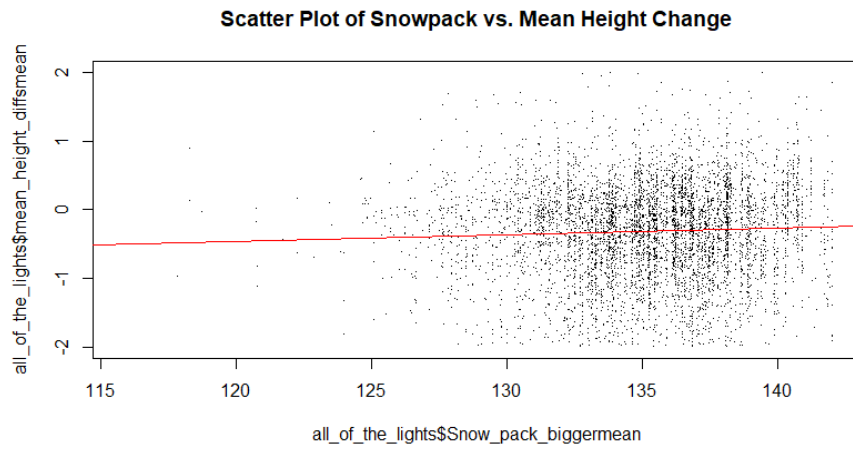


Figure 3. Scatter Plot of Topographic Wetness Index

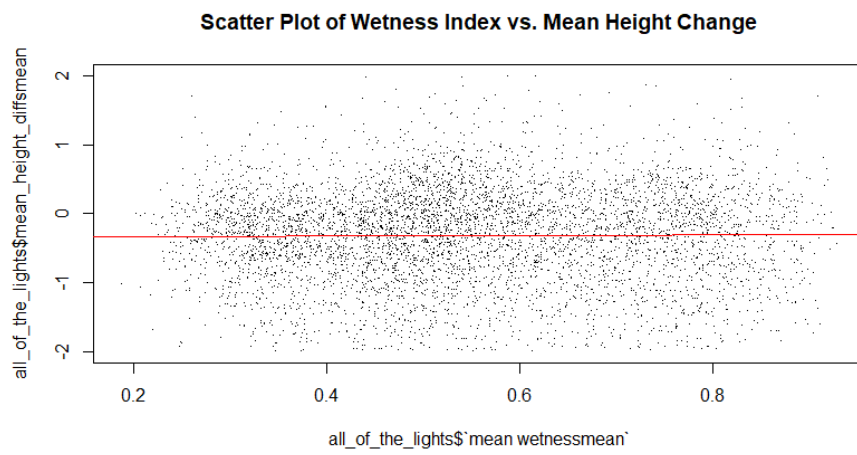


Figure 4. Map of mean height change per conifer crown



Figure 5. Map of Topographic wetness per conifer crown



Figure 6. Map of mean Freezing Degree Days per conifer crown



Figure 7. Map of Snowpack duration per conifer crown



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