Evaluating effect of DBH and distance of neighboring trees on individual tree height for *N.pumilio* and *N.antarctica*

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Abstract

In this research study, we hypothesized that lenga (*N.* pumilio) and ñirre (*N. antarctica*) trees would have significant growth effects correlating to the presence of nearby neighbors of the same tree species. A statistical comparison was done to assess the effects of proximal neighboring trees' DBH and distance from a central tree on the height of the central tree. The DBH of the central tree was similarly compared to its height to assess the strength of all measurable factors. There was no strong correlation of growth impacts of neighboring trees.

Introduction

The region of Patagonia is the southernmost latitudes of South America specifically including the southern and western shores and the land in between. In Patagonia, tree diversity is made up almost entirely of lenga (*Nothofagus pumilio*), ñirre (*N. antarctica*), and coigue (*N. dombeyi*). Often, lenga and ñirre are found in close proximity, with ñirre occupying more extreme habitat conditions; the evergreen coigue tends to be found at higher elevations in the area. These trees often form mono-specific forest stands, but the effects of proximity on tree growth have not been studied for these species. For this study, the goal is to identify which tree stand factors affect the growth of individual trees. It is understood that plant growth is dependent on multiple factors, such as soil quality and nutrient abundance, which speak to environmental factors. However, canopy cover, which relates to neighboring tree proximity, also has a noted influence on tree growth. Proximity between trees and their individual growth structures are what define the nutrient usage from the soil and the canopy cover.

Between lenga and ñirre, ñirre are often split from one main trunk into two or three trunks ranging from splits near the soil to eight feet up. Some young trees were observed to be thin, straight, and relatively tall while their adjacent neighbor was short, wide, and had a considerably nonlinear trunk. This makes it difficult to specify the most accurate idea of what a "typical ñirre" should look like. Lenga on the other hand take what some would consider a more traditional tree shape. These trees do occasionally have divergent trunks but are more often singularly trunked and considerably taller on average.

Tree Proximity effects growth through the form of competition. This competition can take place through the canopies and competitive shading, or nutrient resource allocation through the roots which is done by individual trees obtaining all the useful nutrients in the soil leaving it barren for other trees close to it. This form of competition happens on a very long time scale, therefore only long term effects of this competition can be seen and analyzed. Typically where there is a very large tree both in below and above ground biomass there is a lack of trees directly around it. If there is a lack of large trees then small trees may exist in these gaps as they are not being out competed. However, these are the two extremes. The pure existence or lack thereof trees has a very stark contrast but more often it is seen that a very large tree can impose difficulty on the surrounding tree, not causing them to die but forcing them to grow differently to accommodate this less than ideal growing environment. This general concept is what drove the hypothesis for this study which was that trees with larger and/or closer neighboring trees will have measurable variations between its own height and trunk diameter compared to individuals without influential neighbors.

Methods

Site description: Patagonia Bagual. A private estancia located adjacently east of Parque National Torres del Paine. The estancia has been grazed by sheep and cattle for many years and stopped being grazed in 2018. Currently, there are domestic and wild horses on the land, as well as guanaco. The lenga forest was located on a hillside with an east-southeast aspect, while the ñirre forest occupies a particularly flat landscape with no significant shading from nearby hills or mountains.

Field collection method: DBH (Diameter at Breast Height) was measured on randomly selected trees with no splits in their trunks. These trees served as the "central" tree. Heights were also calculated using an electronic clinometer to measure the height of the tree and a tape to measure the distance to the point of measurement; a modified tangent method was used to evaluate tree height. For particularly short ñirre trees, direct height measurements were done. Proximity measurements were also conducted. First, the single closest tree to the central tree determined, and its distance to the central tree was measured, along with its DBH. Then, at 45° increments, seven more measurements of distance and DBH were taken from the closets trees found in those directions. This left eight total measurements of proximity to the central tree. Twenty-two ñirre, and eighteen lenga central trees – and proximity measurements – were recorded in these stands.

Data methods : Multiple linear regression models were produced (R Core Team 2019) directly comparing two or more measurements from the data. The primary dependent variable assigned for the central tree was tree height. For the linear regressions, the height of the central tree was compared to the values for central tree DBH, the distance between the central tree and each of the eight closest trees, and the DBH of the eight closest trees. Multiple equations were tested by combining the different independent variables, and each were tested for their statistical significance (F-value), trends (R^2 value), and model parsimony (AIC). The final model showing the influence of proximity on tree height was selected by choosing the model that had the lowest AIC value and whose independent variables were all statistically significant. The cutoff for significance in this analysis was considered to be P = 0.05.

Results

The equations in Tables 1 and 2 show the comparative linear regressions for individual and combined influential factors. Considering the F-Statistic, AIC value, and R-squared value, the most effective correlation equation was chosen for each species. This equation for ñirre had a positive relationship with the DBH of the central tree and a negative relationship with the distance to the proximal tree. For lenga the best equation was that one that correlated height with the DBH of the central tree itself.

Discussion

For ñirre, the strongest predictive model used the center tree DBH, along with the distance component when compared to central tree height, had the most significance. Overall none of the measurement comparisons showed a strong correlative trend, with the best model having an R^2 of only 0.1211. This is likely due to the unique nature of ñirres, which have the tendency to lose branches, leaving only the highest canopy branches creating a singular plane of sunlight absorption above the tree. (Connors Unpublished). Ñirres tend to allocate more biomass to aboveground space in locations with better soil and more biomass to belowground space in conditions where soil is poor. (Veronica 2010) This study implies that root growth is secondary to canopy growth and if canopy growth is not that large of an issue due to the loss of branches then the root growth definitely isn't a competition factor for neighboring trees. However, this branch loss process removes the ability for the trees to have many leaves, which in return limits its growth rate. This would help explain why ñirres are typically shorter than lenga's of the same age, along with the ñirre's ability to resist high winds and poorer soils. Overall we reject the original hypothesis on the basis that when considering both the lenga and ñirre tree species there was no consistent correlation between tree diameter/height and the proximity to other trees.

Although a weak correlation, the negative association between central tree height and distance to the proximal tree implies that proximity to other ñirre has a negative effect on the height of the central tree. This implies that denser stands of ñirre will grow more slowly than less-dense stands. However, increasing proximity may be positively associated with other factors that would be positive to growth, such as protection from wind. However, the site locations in Patagonia Bagual were well shielded from most of the winds; a comparative study between this stand and nearby stands with differing levels of wind exposure could help shed light on whether distance to proximal tree (i.e., stand density) has positive effects on tree height under different conditions.

For the lenga, the only statistically significant relationship with the height of the central tree was its own DBH. While unsurprising that the tree's own DBH would be correlated with its height, what is surprising is that no other comparison was statistically significant on their own, save for distance, which had a very large AIC value. Also surprising is that all combinations of more than one explanatory variable all had at least one variable that was not statistically significant.

The tree shape, i.e. canopy structure and tree size, did have a visual representation that may not be correlated noticeably in the data. Trees when considering competitive shading grow taller faster to capitalize on the unshaded neighborhood above the neighboring canopies (Tucić, 2006). Lengas that grew far from the presence of any other tree would take a more conical shape with wide spreading branches from low on the tree up to the top. Trees that were large and had close proximity neighbors obtained a top-heavy canopy dispersion where the tree was considerable taller than those around it and had most or all of its branches towards the top. This comparison is seen in Figure 1. This makes sense as trees have been understood to emphasize shade avoidance as one of the most competitive competition strategies (Smith & Whitelam 1997).

In a location where soil quality is low canopy competition becomes a primary influencer of tree growth. However, in Patagonia Bagual soil quality did not seem to be an issue. Unfortunately this aspect was not studied in this research but could be useful in future research projects. As soil is not a condition of concern this would provide reasoning for why these trees show little effect due to proximity as the nutrient sufficient soil provides a fallback for trees if sunlight competition exists. This analysis can be seen in figure 2 where ñirres are growing in extremely close proximity to one another but have seemingly no noticeable restriction of trunk size or height. Similarly it seems that overall stand density is a factor needing to be considered as previously studies individual-tree models have mainly failed to accurately represent the density dynamic based impacts within a stand (Fox 2000).

Overall the results of this study have shown that as far as N. Antarctica and N. pumilio are concerned tree neighbor proximity is not of large concern for individual tree growth. For lenga this is very clear, however there is some statistical evidence that distance influences individual ñirre growth but due to the extremely odd nature of ñirre structure to begin with the data provided requires additional research to be done to be considered conclusive. Larger stand areas, more stands over a larger area, and different additional research locations would prove widely useful in future studies to grasp a larger and more diverse representation of the species dynamics.

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Citations

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Tables:

(Table 1): Dynamic linear model data for Ñirre

Linear regression equations for individual and combined descriptor variables and their significance on central ñirre height. (H)= central tree height; (C)= central tree DBH; (D)= proximal tree distance; (O) = proximal tree DBH. Highlighted row is the most effective linear regression.

Equation	F-Statistic	AIC	Multiple R Squared
ln(H) = 0.213*ln(C)+1.458	17.96 ***	25.491	0.0976
ln(H) = 0.010*ln(O)+2.035 †	0.04	39.608	0.0002
ln(H)= -0.05625*ln(D)+2.116	4.965*	34.695	0.0297
ln(H) = 0.213*ln(C) -0.040*ln(O)+1.572†	8.16 ***	25.808	0.0921
ln(H)=0.205*ln(C)-0.059*ln(D)+1.542	11.09***	20.482	0.1211
ln(H)=0.035*ln(O)-0.060*ln(D)+2.027†	2.706	36.224	0.0325
ln(H)=-0.016*ln(O)-0.057*ln(D)+0.210*ln(C) †	7.836***	22.377	0.1216

†: at least one model variable was not statistically significant, *: p < 0.05, **: p < 0.01, ***: p < 0.001

(Table 2): Dynamic linear model data for Lenga

Linear regression equations for individual and combined descriptor variables and their significance on central lenga height. (H)= central tree height; (C)= central tree DBH; (D)= proximal tree distance; (O) = proximal tree DBH. Highlighted row is the most effective linear regression.

Equation	F- Statistic	AIC	Multiple R Squared
ln(H)=0.417*ln(C)+0.511	151.2***	155.44	0.5156
ln(H)=-0.006*ln(O)+1.888†	0.019	249.32	0.0001
ln(H)=0.185*ln(D)+1.557	7.689**	244.09	0.0314
ln(H)=0.045*ln(O)+0.421*ln(C)+0.378†	71.35***	151.8	0.5139
ln(H)=0.404*ln(C)+0.071*ln(D)+0.428†	71.21***	154.09	0.5115
ln(H)=-0.040*ln(O)+0.207*ln(D)+1.616†	4.561*	242.31	0.0633
ln(H)=0.410*ln(C)+0.063*ln(D)+0.033*ln(O)+0.336†	48.26***	152.24	0.5193

†: at least one model variable was not statistically significant, *: p < 0.05, **: p < 0.01, ***: p < 0.001

Figures:

(Photos by: Erik Makic)

Figure 1: Two images of Lenga trees. Left is a lenga that stands alone on the hillside far from other trees and takes a wider and rounder canopy shape. Right is a lenga in much closer proximity to young and mature trees and has taken a very tall and higher canopy shape.

(Photo by: Erik Makic)

Figure 2: Image of a tightly spaced grouping of ñirre trees that grow extremely close in proximity to one another but still have average sized trunks.