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Estimated Decrease in Productivity for Pacific Silver Fir as Elevation Increases

Introduction

When making decisions on which areas to harvest in a sustained yield, even-flow manner in mountainous areas such those in coastal British Columbia, it is important to know how timber productivity changes with elevation. This information allows foresters to decide at what elevation to start increasing the rotation age and to decide at what elevation sustainable harvesting becomes infeasible due to low productivity. Since Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) has an elevation range that extends from sea level nearly to the tree line (0 m to approximately 1,650 m; from the Coastal Western Hemlock zone, through the Mountain Hemlock zone; to the lower limits of the Alpine Tundra zone), productivity-elevation relationships are especially important.

To acquire quantitative measures of productivity decrease with increasing elevation a regression equation relating site index (the height of the dominant trees at a base age of breast height age of 50 years) to elevation in southern coastal BC was developed. In turn, we used this regression as an input into the height driven yield model named the Variable Density Yield Prediction model (VDYP). The use of the VDYP model allows the site index values to be translated into actual productivity measures (e.g., volume per hectare, mean annual increment at culmination age).

Methods

A regression equation relating site index to elevation was developed from 44 stands growing on sites identified by site characteristics (e.g., slope position, soil depth, soil texture) as zonal (sites with well drained soils and moderate nutrient availability; the vegetation on zonal sites are believed to be primarily affected by climate) located on Vancouver Island and the adjacent mainland. The latitude of the area sampled ranged from 49°10'N to 50°50'N, the longitude from 121°15'W to 127°20'W, and the elevation from 220 m to 1670 m (Splechtna *et al.*, in preparation). Stands were chosen which had Pacific silver fir as a major species, and were located in naturally established, unmanaged, even-aged stands without evidence of a history of suppression or damage. In each stand a 0.04 ha plot was established and three of the largest diameter trees felled for stem analysis. The site index for each plot was determined from the resulting height growth curves. A regression equation relating site index to elevation was developed (Figure 1) and used as input into the VDYP model.

The VDYP model was developed from a combination of temporary forest inventory sample plots and permanent growth sample plots in natural second-growth stands. The model is an empirical yield prediction system for even-aged, naturally established stands, and uses height, age, and density (estimated from crown closure) as input to predict stand heights, diameters, volumes, and mean annual increments at different utilization levels and ages. Yield dynamics over time are driven by height growth. We supplied the site index values directly (instead of height and age) and used the default values for crown closure (57%) and stocking class 1 up to 1250 m. For 1250 m in elevation we used a crown closure of 20%; for 1600 m in elevation we used a stocking class of 2 (which is approximately half the volume of stocking class 1). The reductions at the higher elevations were done to reflect the increasing patchiness as timberline is approached. We chose the net merchantable volume utilization level of 17.5 cm diameter.

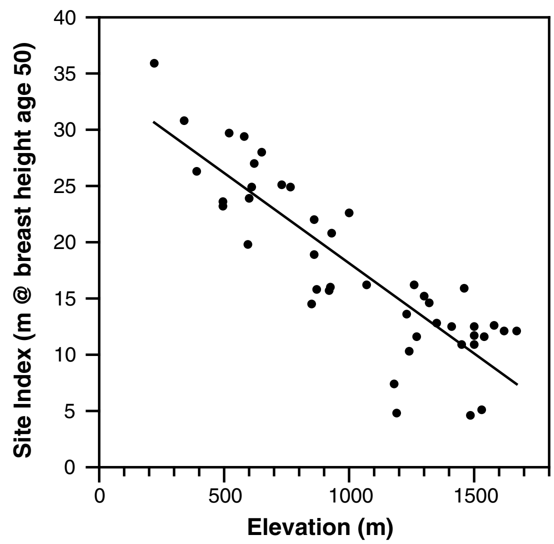


Figure 1. Site index-elevation regression model for Pacific silver fir (Splechtna et al. in preparation). The regression is: site index = $34.17 - 0.016 \times$ elevation (m) ($R^2 = 0.75$; root MSE = 3.80 m; $P < 0.001$; $n = 44$).

Results

Site index on zonal sites ranged from 34.2 m at sea level to 8.5 m at 1600 m in the Alpine Tundra-Mountain Hemlock zone boundary (Table 1). The predicted productivity (merchantable volume, culmination age, mean annual increment at culmination age, and the merchantable volume at culmination age) by the VDYP model showed a corresponding decrease.

Discussion

We illustrated a methodology for estimating productivity trends with increasing elevation. However, caution should be used when considering the productivity values as predicted by the VDYP model.

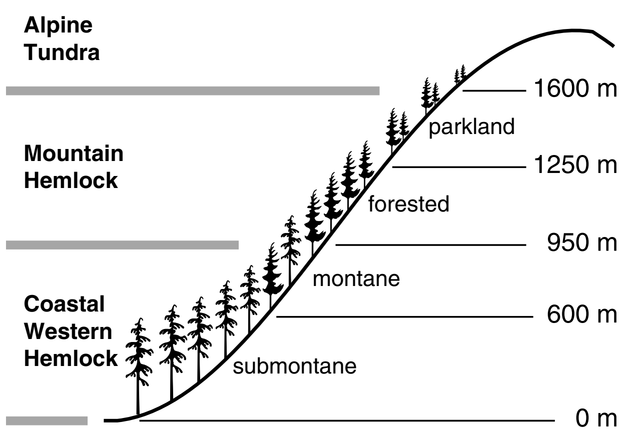
Constraints to the model when used for Pacific silver fir are:

1. The site index values we used were derived from stem analysis whereas the height curves used in the VDYP model are based on Kurucz (1982);
2. The underlying data used to develop the model are not evenly distributed across age classes and site classes. There was very little data under 50 years, while there is a disproportionately high number in ages greater than 100 years.
3. There was very little data for low crown closure conditions (less than 50%).
4. There is a lack of validation plots, again since pure even-aged Pacific silver fir stands are uncommon. There is especially a lack at the higher elevations where the logging history is more recent, but where factors such as regeneration delay may be particularly important.

Nevertheless, a technical review concluded that "in general, the VDYP volume-prediction models produce reasonable estimates of yield and average diameter over time. With the exception of low sites (site indices <10 m), the yield projections fit the data quite well." (D.R. Systems Inc., 1993:4). Considering the above constraints and the technical review, our approach should be viewed as a first approximation to changes in forest productivity with elevation. As more data becomes available, Pacific silver fir productivity estimates, relative to elevation, will be refined.

The productivity prediction reported here represents natural regeneration (without intensive silvicultural practices) on zonal sites. The productivity of the submontane CWH forest easily meets timber management objectives (Table 1). However, once in the CWH montane forest, the productivity appears to decrease enough to reconsider "traditional" 100-year rotations. Assuming we are operating on a sustained yield even-flow basis, productivity in the CWH montane forest may be low enough to require longer rotation ages. The MH forest (950-1250 m) starts to present problems in terms of low productivity, especially at the higher elevations. Even after 200 years, only 562 m^3 are realized at 1250 m elevation. Above this point in the parkland MH forest, productivity is likely too low to meet sustainable forestry objectives. One must also consider that at the higher elevations, there are fewer sites with soil nutrient regimes higher than "medium." The productivity of zonal sites at higher elevations therefore represents the high-end productivity. Ultimately, an economic analysis will be needed to determine the point where timber productivity is too low to be sustainably and economically harvested.

Table 1. Site index (m @ 50 years breast height age) and productivity (using the VDYP model) changes with increasing elevation. Values are given for the boundaries of the biogeoclimatic zones, subzones, and variants in southern coastal British Columbia. Volumes are based on a utilization level of 17.5 cm.



Elevation	Site Index (m@ 50 yrs)	Volume (m^3 ha^{-1}) 100 (yrs)	Volume (m^3 ha^{-1}) 200 (yrs)	Culmination age (yrs)	Culmination m.a.i. (m^3 ha^{-1} yr^{-1})	Culmination volume (m^3 ha^{-1})
1600 m	8.5	35	132	215	0.7	142
1250 m	14.1	292	562	134	3.3	404
950 m	18.9	489	807	101	5.2	493
600 m	24.5	693	1025	76	7.6	553
0 m	34.2	883	1208	59	10.4	594

Conclusions

The methodology developed here gives foresters a tool to evaluate cut control and harvesting options for pre-harvest decisions in high elevation sites when timber production is the primary objective.

Reference

Splechtna, B. 2000. The growth of *Abies amabilis* (Dougl. Ex Forbes) in relation to climate and soil in southwestern British Columbia. Ph.D. thesis, Forest Sciences Department, University of British Columbia, Vancouver, BC. In progress.

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