Modeling Diameter Growth in Response to Varying Silvicultural Treatments

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Location

- Coastal Western Hemlock (CWH) BEC zone
- Temperatures - 5.2 to 10.5°C
- Latitude - 48.37 to 53.53°N
- Longitude - 132.59 to 122.35°W
- Second growth uneven- and even-aged multi-species stands regenerated naturally and from plantings.
- Western hemlock, Douglas-fir, western redcedar, red alder, Sitka spruce and yellow cedar
Database

• Permanent Sample Plot (PSP) data
• 1,895 plots
• 0.008 to 0.806 ha
• 1932 to 2003
• Varying intervals - 1 to 17 years, average of 4.8 years
• 19 to 11,750 live trees per hectare
• Site Index values from 6.2 to 52.8 m
• Basal area per hectare values from 0.09 to 185.0 m³/ha
Box-Lucas Model

\[ D_{\text{incq}} = k \frac{g_1}{g_1 - g_2} \left\{ \exp \left( -g_2 \text{dbh} \right) - \exp \left( -g_1 \text{dbh} \right) \right\} \]

- \( g_1 \) – models anabolic metabolism
- \( g_2 \) – models catabolic metabolism
- \( k \) - asymptote
- \( \text{dbh} \) – diameter at breast height (1.3m)

both parameters working in conjunction to describe tree metabolism
Box-Lucas Model
Parameter Prediction Approach

- Data was subset to obtain estimates for $\mathcal{I}_1$ and $\mathcal{I}_2$ for a species.
- Subset defined from untreated data containing at least 4 measurement periods.
- Different combinations of predictor variables were used.
- Linear, log-linear, and nonlinear equations.
- Residual and actual versus predicted value plots were used to evaluate.
- Box-Lucas model was refit using the resultant parameter estimates as starting values.
Variable Selection

Tree size and stage of development, site productivity, and inter-tree competition were considered:

• Dbh, height, and diameter increment
• Site index and growth effective age
• Curtis’ relative density and basal area per hectare
• Basal area of larger, stems per hectare, relative dbh, crown competition factor of larger
Selected Model

\[ D_{incq} = k \frac{\mathcal{G}_1}{\mathcal{G}_1 - \mathcal{G}_2} \exp(\mathcal{G}_2 \text{dbh} - \mathcal{G}_1 \text{dbh}) \]

\[ \mathcal{G}_1 = \exp(b_1 + b_2 \log(dinc_{prev}) + b_3 G^{0.5} + b_4 \log(GEA) + b_5 SpH) \]

\[ \mathcal{G}_2 = \exp(c_1 + c_2 \log(dinc_{prev}) + c_3 \log(BAL) + c_4 \log(RDBH)) \]
Model Accuracy
Douglas Fir
Model Accuracy
Western Hemlock
Model Accuracy
Western Redcedar
Fertilization Effects

• 150 plots received fertilization
• Majority received one application of nitrogen ranging in concentration from 50 to 400 kg/ha
• A few plots additionally received ammonium phosphate.
Fertilization Effects

\[ D_{incq} = k \frac{g_1}{g_1 - g_2} \exp \left( -g_2 \cdot dbh \right) - \exp \left( -g_1 \cdot dbh \right) \]

• All three parameters were modified individually
• Each possible combination of the three parameters were modified
• Akaike’s Information Criteria (AIC) values used to select final model
Fertilization Effects

\[ D_{incq} = k \frac{g_1}{g_1 - g_2} \exp (-g_2 \text{dbh}) - \exp (-g_1 \text{dbh}) \]

- All three parameters were modified individually
- Each possible combination of the three parameters were modified
- Akaike’s Information Criteria (AIC) values used to select final model
Asymptote

\[ k_F = k + a_1 \times F \frac{1}{\text{time}_F} \]

- \( k \) – original asymptote from unthinned plots
- \( F \) - categorical variable defined as 1 for fertilized plots and 0 for unfertilized plots
- \( \text{time}_F \) - time since fertilization
\( \mathcal{g}_1 = \exp(b_1 + b_2 \log(dinc_{prev}) + b_3 G^{0.5} + b_4 \log(GEA) + b_5 SpH) \)

\( \mathcal{g}_2 = \exp(c_1 + c_2 \log(dinc_{prev}) + c_3 \log(BAL) + c_4 \log(RDBH) + c_5 F \frac{1}{time_F}) \)

- F - categorical variable defined as 1 for fertilized plots and 0 for unfertilized plots
- \( time_F \) - time since fertilization
Fertilization Effects
Douglas Fir

![Graph showing the effect of fertilization on Douglas Fir growth over time. The x-axis represents time in years, and the y-axis represents the change in growth rate (lDinc). The graph shows a decrease in lDinc over time.]
Fertilization Effects

Western Hemlock

![Graph showing fertilization effects on Western Hemlock species.](graph.png)
Fertilization Effects

Western Redcedar

![Graph showing fertilization effects on Western Redcedar growth over time. The x-axis represents time in months, ranging from -22.5 to 22.5. The y-axis represents Average Annual Dinc, ranging from 0.0 to 0.8. The graph illustrates fluctuations in growth with peaks and troughs.]
Thinning Effects

• Original model was fit using parameter estimates found from untreated data to assess changes in variables directly
• 78 plots receiving a single thinning event
• Basal area cut varied from 0.02 to 28.9, for an average of 9.2 m³/ha
• Average of 940 trees per hectare was removed
Thinning Effects
Douglas Fir

Average Annual Inc

\begin{array}{c|c|c|c|c|c|c|c}
\hline
\text{time} & -22.5 & -17.5 & -12.5 & -7.5 & -2.5 & 2.5 & 7.5 & 12.5 & 17.5 & 22.5 \\
\hline
\text{IDinc} & 0.0 & 0.2 & 0.4 & 0.6 & 0.8 \\
\hline
\end{array}
Thinning Effects

Western Hemlock
Thinning Effects
Western Redcedar

![Graph showing Thinning Effects of Western Redcedar]

The graph illustrates the trend of annual change in density (Dinc) over time for Western Redcedar species. The x-axis represents time in increments of 22.5 units, while the y-axis represents the density change ranging from 0.0 to 0.8. The data points and their trend lines indicate a peak in density change around the middle time points, followed by a decline.
Next Steps

• Evaluate plots which received multiple treatments
• Continue with height increment growth
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