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Canadian Forest Service

CANADIAN WOOD FIBRE CENTRE

Fibre Facts nº 28

Realizing the full growth potential of a forest: TreeCG, a forest compensatory growth model.

An important attribute to understand when managing a forest is its productivity. Productivity allows forest managers to assess the health of a forest. It also allows managers to determine important ecological and economic attributes, such as carbon sequestration, sustainability, and the production of wood-based products. Forest managers use growth and yield models to identify current growth rates, predict future development, and determine optimal approaches to maximize the growth of a forest. When used as a silviculture planning tool, growth and yield models allow foresters to understand how a silviculture treatment can improve a forest's growth rate and meet desired outcomes. Forest researchers from the Canadian Forest Service's Canadian Wood Fibre Centre, Simon Fraser University, University of British Columbia, and the Alberta government are trying to improve forest productivity modelling by gaining a better understanding of long-term forest responses to changes in growing conditions. To achieve this goal, they have developed a new growth and yield model, TreeCG, which utilizes a well know biological phenomenon, compensatory growth (CG).

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TreeCG (Compensatory Growth) Model

Compensatory growth can be defined as a change in growth rate, usually positive, following a disturbance that reduces biomass and/or individuals from a population. This increase in growth is beyond the traditional expectations of current forest growth and yield models. This concept is difficult to study within the field of forestry due to the slow growth rate of trees and their long-life span. However, by utilizing long-term forestry research data from across Canada, researchers were able to detect a compensatory growth signal (Figure 1). To further investigate their findings, the TreeCG model was developed as a state-dependent individual tree-based forest growth model. The model simulates the compensatory growth of trees after experiencing a partial mortality within a forest stand. It redistributes resources released from dying trees to surviving trees and simulates the growth of trees over a long period of stand development.

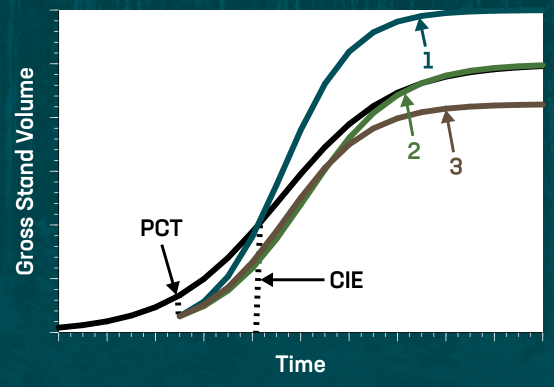

Figure 1. The three main possible patterns of a forest stand's compensatory growth response after a precommercial thinning (PCT), 1: over-compensation, 2: exact compensation, and 3: under-compensation. The solid line represents a natural stand's growth pattern, and CIE indicates the point of compensatory induced-equality.

Model Validation

Results from the model were validated using long-term experimental research data. One of these data sets was from a 40-year trial of a precommercial thinning (0%, 33% and 66% removal) and fertilization (three intensities) experiment on coastal Douglas fir near Shawnigan Lake, British Columbia. The TreeCG model simulated growth and yield results were similar (Figure 2a) to the actual measurements (Figure 2b). Partial mortality in the stand initially reduced the gross stand volume. However, it gradually caught up to the control (0% removal) stand and eventually exceeded it, equating to an over-compensation in volume. These results suggest that the compensatory growth occurred in these stands and the TreeCG model was able to emulate this result. It also indicates that due to the slow growing nature of trees, the growth impacts after a thinning will be observed over a long period of time.

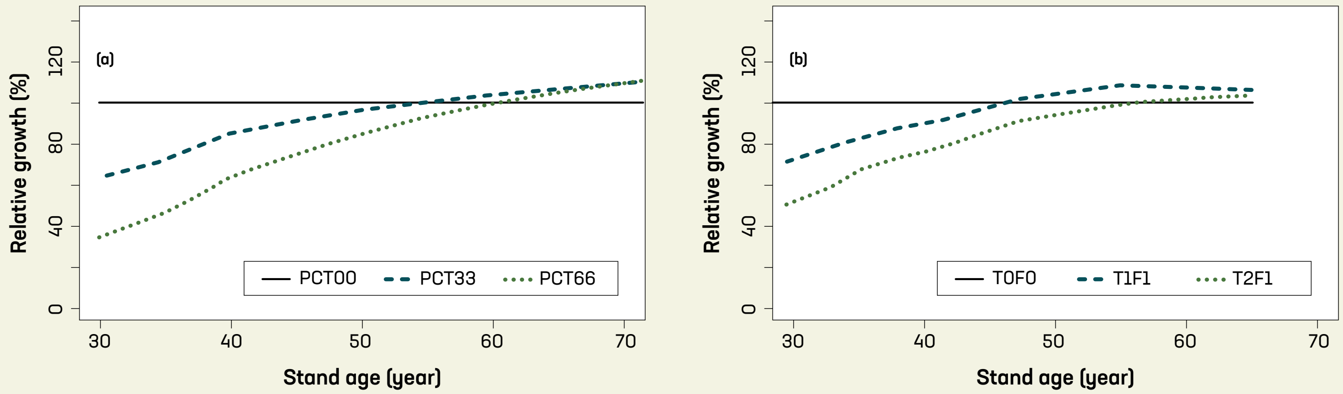

Figure 2. The stand growth trajectories after a thinning operation within a Douglas Fir forest at the Shawnigan Lake trial, British Columbia, Canada: (a) simulated growth trajectories after experiencing a precommercial thinning (PCT), 33% removal and 66% removal at age 30, and (b) observed growth trajectories after PCT at age 24 based on the PCT and fertilization (T1F1 = PCT 33% removal and 224 kg N/ha, T2F1 = PCT 66% removal and 224 kg N/ha) treatments.

Simulations

To explore compensatory growth even further, the TreeCG model was used to simulate forest growth over a long-term stand growth trajectory of 100 years (Figure 3). Stand densities decreased at the early stand development stage, following the natural mortality function, and again at years 30 and 60 from the prescribed thinning operations. The results also showed that the final merchantable volume of the forest that was thinned early on in its development exceeded those of a non-thinned forest, equating to an over-compensation scenario. Additionally, a heavier thinning treatment can result in a higher merchantable volume than a lighter treatment. However, this result was not always produced. When a late thinning occurred, it was followed by an under-compensation or even-compensation. This suggests that forest capability for compensatory growth could be higher at a younger age. Simulation results suggest that a thinning performed at age 60 might be too late and have no benefit from a compensatory growth perspective.

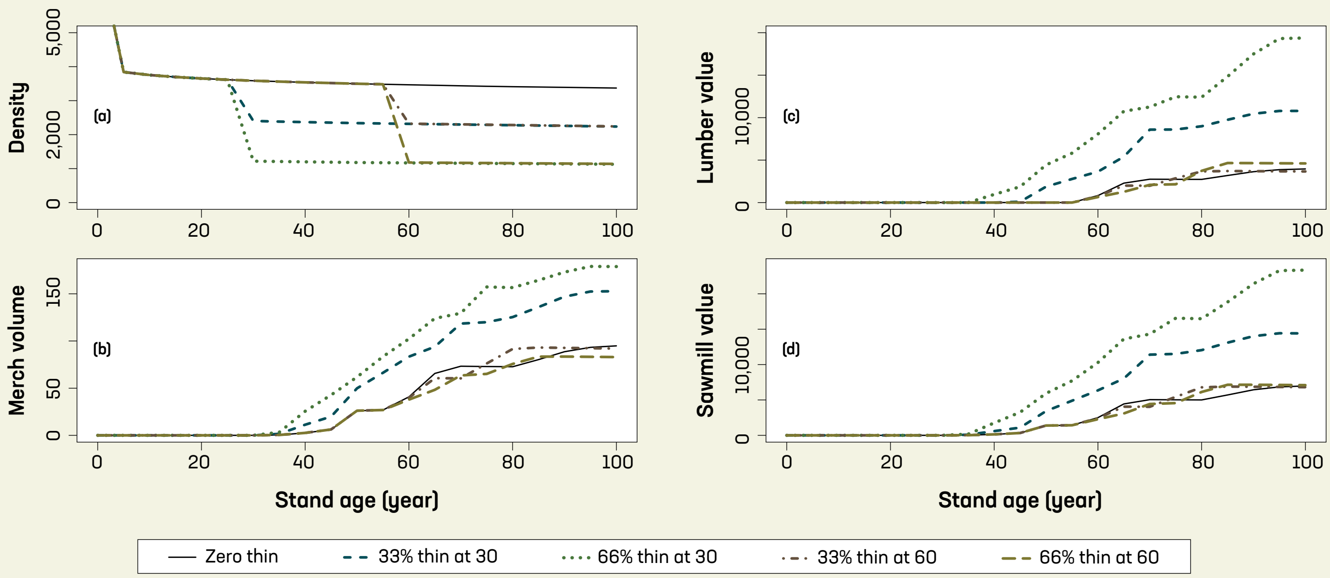

Figure 3. Simulation results of (a) stand density (stems/ha), (b) merchantable volume (m3/ha), (c) value recovery of lumber ($/ha), and (d) total value recovery of sawmill ($/ha) under different thinning intensities and timing for a hypothetical stand of lodgepole pine with an initial stand density of 7,500 stems/ha.

Management Implications

The TreeCG model allows forest managers to comprehend the mechanisms of compensatory growth within a forest. Forest managers can begin to optimize silviculture prescriptions to produce a compensatory growth response within their forest by conducting multiple simulations of various thinning intensities and timing of treatments and refining the model using local growth and yield curves. An optimized growth and yield model, such as TreeCG, can help address practical issues such as:

- estimating growth for released crop trees
- identifying optimal thinning prescriptions for maximized stand productivity
- exploring optimal spacing for plantation programs
- increasing annual allowable cut through enhanced stand productivity
- enhancing carbon capture from increased stand productivity
- reducing forest fuel accumulation through thinning operations
- supplying the bioeconomy with woody material from an increase in feedstock from thinning operations
- determining a forest's response to natural disturbances, such as fire, wind, insects, etc.

Special acknowledgement:

This study was the last multi-disciplinary project that Dr. Hugh Barclay, who has now passed, was actively involved with. He worked on the Shawnigan Lake Project since its beginning. He firmly believed that, through adapting to changing environmental conditions, proper thinning operations could enhance long-term forest stand productivity. We sincerely acknowledge his great contributions to this study.

For more information:

Li C, Barclay H, Huang S, Roitberg B, Lalonde R, Xu W, and Chen Y (2022) Modelling the stand dynamics after a thinning induced partial mortality: a compensatory growth perspective. Front. Plant Sci. 13:1044637. doi: 10.3389/fpls.2022.1044637

Web accessible at:
https://www.frontiersin.org/articles/10.3389/fpls.2022.1044637/full

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Aussi disponible en français sous le titre :
Exploiter le plein potentiel de croissance d'une forêt : TreeCG – un modèle de croissance compensatrice des forêts.

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