The Tree and Stand Simulator (TASS)

Seeing the light of complex stands

Stand Development Modelling Group
Forest Analysis and Inventory Branch
British Columbia Ministry of Forests

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Acknowledgment

We acknowledge with respect that the BC Public Service operates throughout B.C. on the traditional lands of Indigenous Peoples. The BC Public Service is deeply committed to true and lasting reconciliation with Indigenous Peoples in B.C.

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Background

Models are simplifications useful for understanding

Introduction

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- Vision
- Software
- History
- Brief overview of TASS and its growth engine structure
- Recent challenges

Background

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The Vision for TASS

"The model represents an initial step in the evolution of a precise analytical tool for use in the development of optimum forest management regimes. Further, application as a teaching device and instrument of research is expected"

Mitchell, K. 1969. Simulation of the growth of even-aged stands of white spruce. Yale School of Forestry & Environmental Studies Bulletin Series. 62.

"TASS is a biologically oriented model designed to assess the effects of cultural practices and environmental factors on the growth and yield of Douglas-fir .. and other species."

Mitchell, K. 1988. SYLVER: Modelling the impact of silviculture on yield, lumber value, and economic return. The Forestry Chronicle. April 1988. 127-131.

TASS Software

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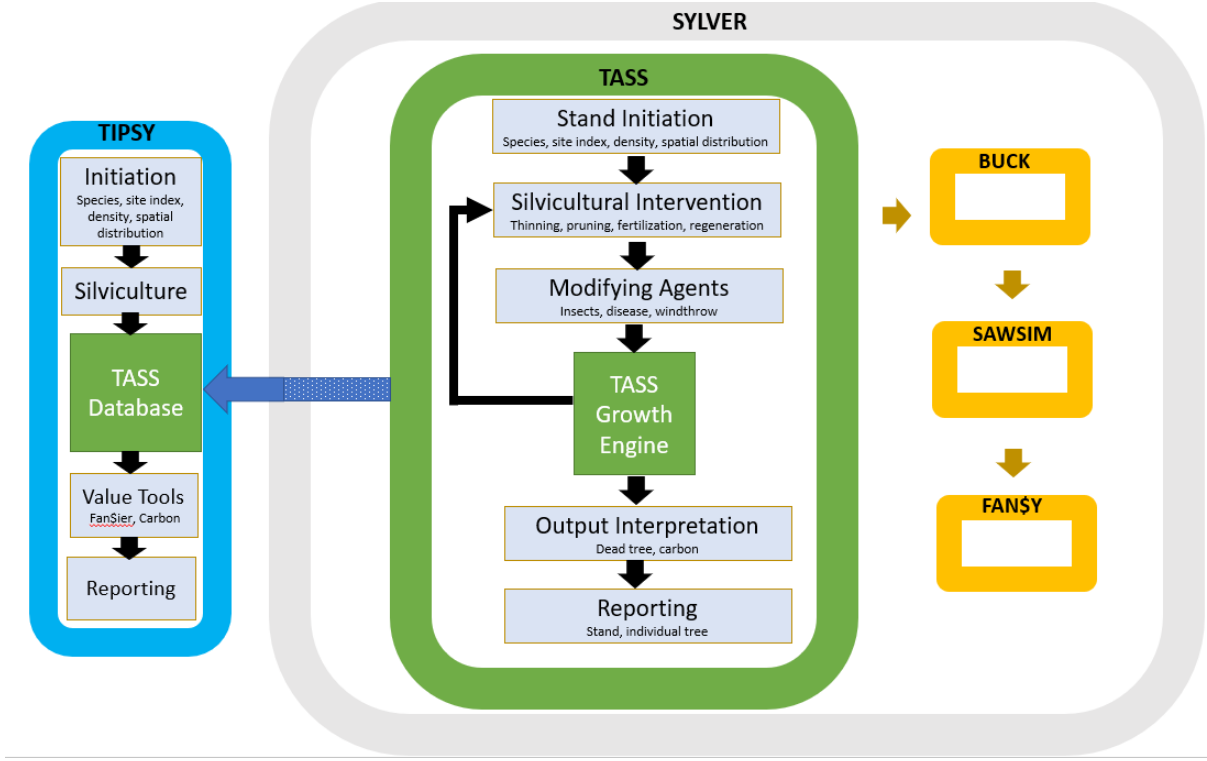
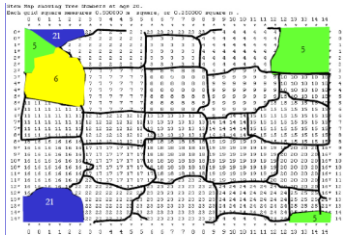
TASS Ecosystem



https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/tree-and-stand-simulator-tass

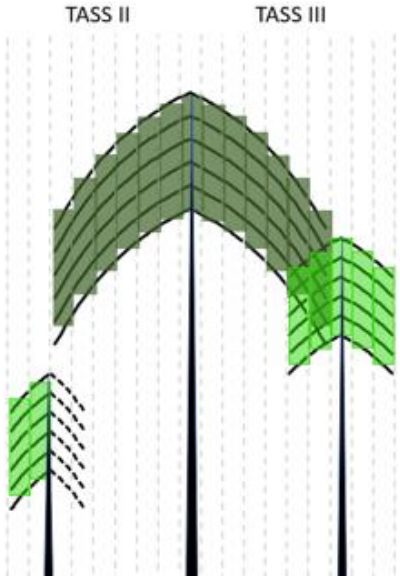
TASS History

History



TASS 1 - 2-D crown non-overlapping, white spruce

- 1963 ideas for TASS developed
- Ken Mitchell PhD work
- 1969 Yale Bulletin describing model

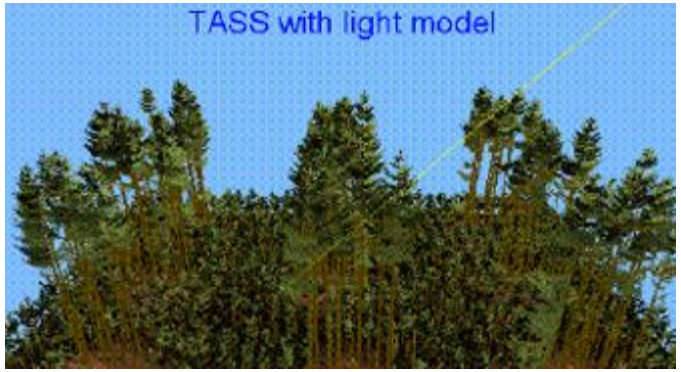


TASS 2 - 3-D crown non-overlapping, 10 BC commercial species

- 1967 - Douglas-fir 3-D development begins
- 1975 - Forest Science monograph describing model
- 1980 - Ken Mitchell hired by BC Forest Service to advance TASS
- 1980-1990's - expanded species; linked to sawmill, financial, and forest health tools;
  - meta-model TIPSY developed for provincial strategic applications and wider access

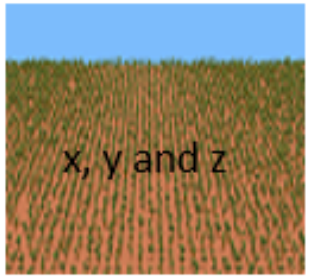
TASS 3 - 3-D crown overlapping, light model, currently limited BC commercial species

- 2003 – development begins for inclusion of a light model
- 2017 – Release of TASS III GUI for lodgepole pine and white spruce
- 2023? – Technical document describing current structure of TASS III



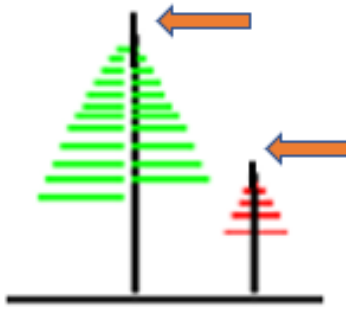
TASS Overview

TASS is a spatially explicit individual tree model that is driven by height growth and crown dynamics

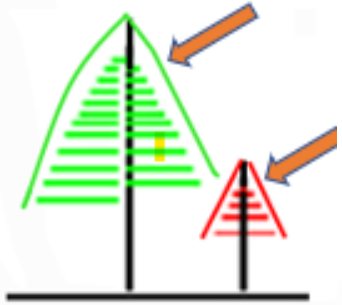


spatially explicit

individual tree



height driven



crown growth

crown competition

bole increment

mortality

TASS Engine

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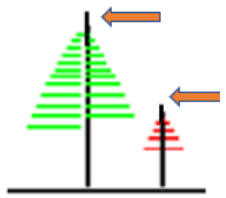
Height Growth

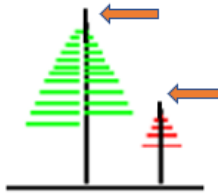


$$\Delta h_{jy} = \Delta H_{Sy} \cdot v_{hj} \cdot m_{hj}$$

Δh_{jy} is the annual height increment of an individual tree

TASS Engine

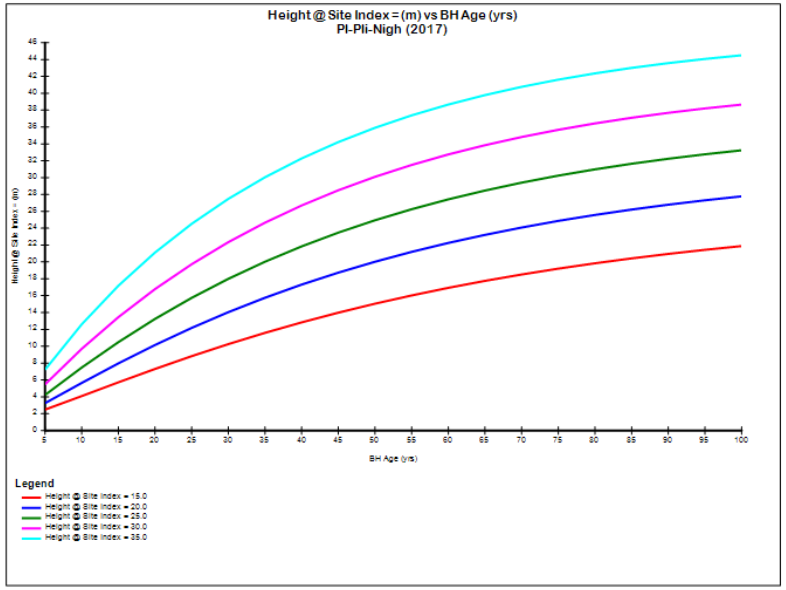
Height Growth



$$\Delta h_{jy} = \Delta H_{Sy} \cdot v_{hj} \cdot m_{hj}$$

Δh_{jy} is the annual height increment of an individual tree

ΔH_{Sy} is the annual change in site height, H_S, which is usually derived from a site index function



- Over 25 different published "site index functions" are available for selection in TASS II and TASS III
- Most site index functions originate from research in British Columbia since 1990
- Potential site index by species is a key TASS input

TASS Engine

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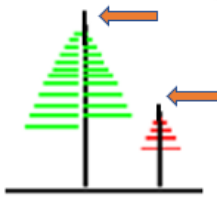
Height Growth

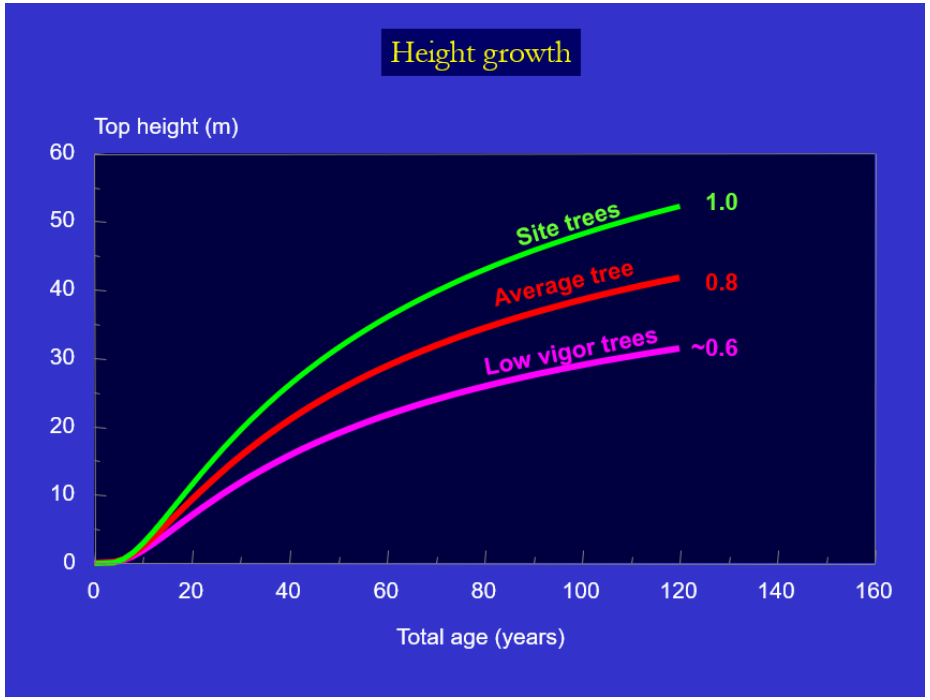


$$\Delta h_{jy} = \Delta H_{Sy} \cdot v_{hj} \cdot m_{hj}$$

Δh_{jy} is the annual height increment of an individual tree

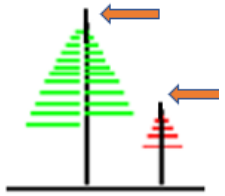
ΔH_{Sy} is the annual change in site height, H_S, which is usually derived from a site index function

v_{hj} is a height vigour coefficient that emulates the role of genetics and other factors that contribute to tree-to-tree variation in potential height growth rate



TASS Engine

Height Growth



$$\Delta h_{jy} = \Delta H_{Sy} \cdot v_{hj} \cdot m_{hj}$$

Δh_{jy} is the annual height increment of an individual tree

ΔH_{Sy} is the annual change in site height, H_S, which is usually derived from a site index function

v_{hj} is a height vigour coefficient that emulates the role of genetics and other factors that contribute to tree-to-tree variation in potential height growth rate

m_{hj} a multiplicative height growth factor ($0 \leq m_{hj} \leq 1$) that mimics the reduction in height growth rates through tree-to-tree interactions

Height growth is reduced where:

- TASS II: the ratio of the foliar volume of an individual tree to the foliar volume of an open grown tree falls below a critical level
- TASS III: the PACL at the leader of a tree falls below a species specific $PACL_{max}$ value derived where a relative height index is maximized.

TASS Engine

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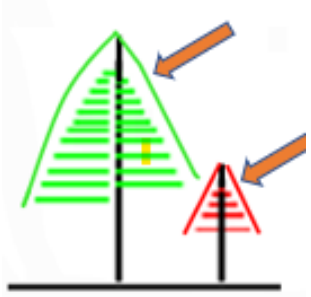
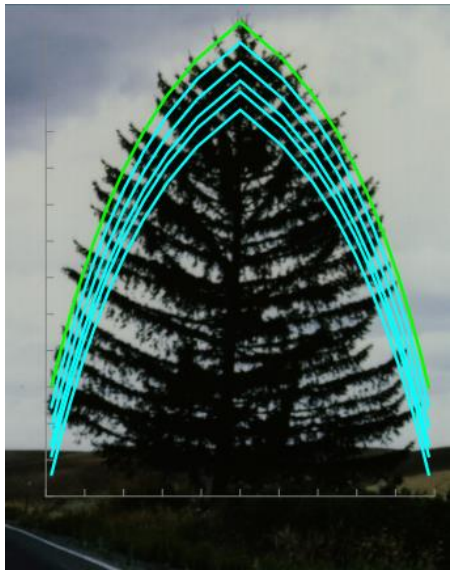
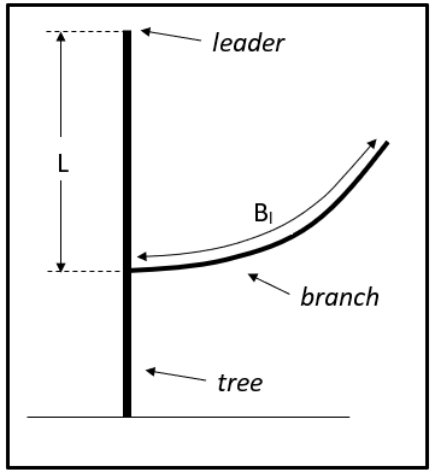
Crown Dynamics



1. Crown (profile) growth

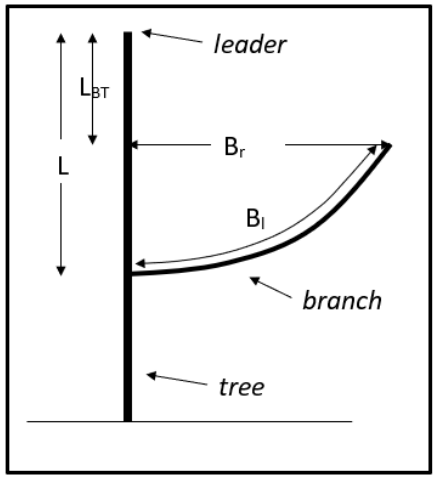


TASS II



$$B_l = v_{bj} \cdot d_{Bl} \cdot ln\left[\frac{L}{c} + 1\right]$$

TASS III



$$B_{rj} = \left(b_0 R^{b_2} + u_{0j}\right) \cdot ln\left(\frac{L_{BT}}{b_1} + 1\right)$$

where

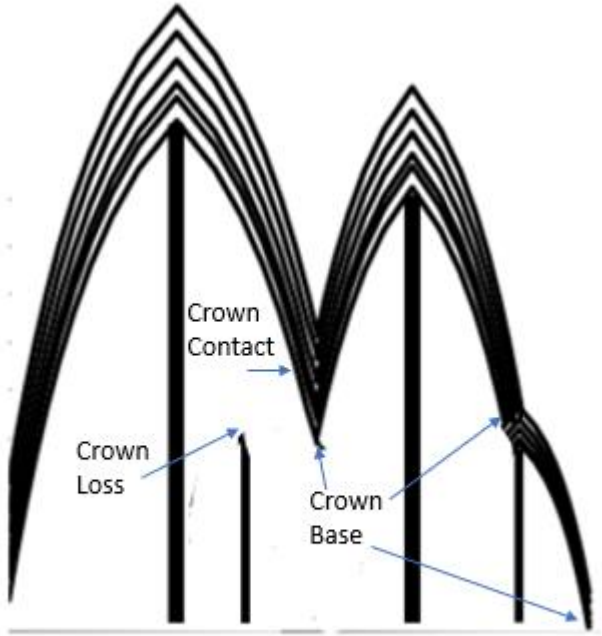
v_{bj} is a branch vigour coefficient
d_{Bl} is a scalar for branch angle and growth irregularities
c is a regression coefficients defining shape

u_{oj} is $N(o,s^2_u)$
b_o, b_1, b_2 are coefficients
R is the ratio of sample branch length to the longest branch in sampled internode

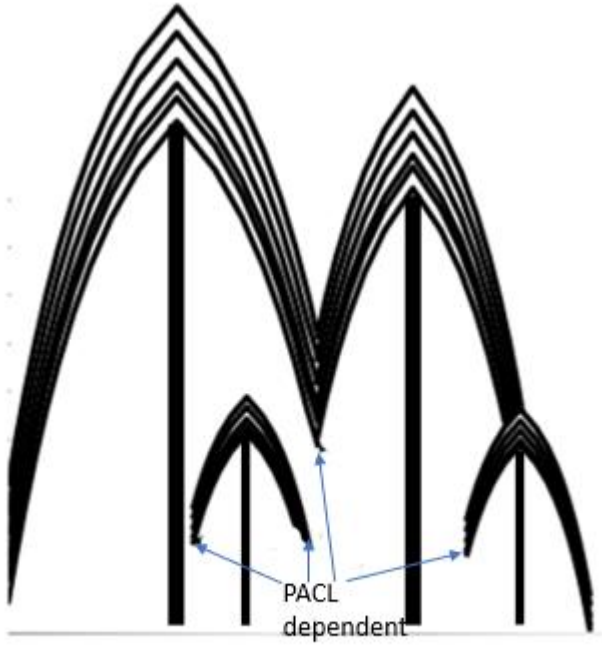
TASS Engine

Crown Dynamics

1. Crown (profile) growth
2. Crown (expansion) competition



TASS II



TASS III

TASS Engine

Bole Increment

TASS II

Tree annual total bole increment i_{vj} is modelled as a function of an individual tree's foliar volume (F_{vj}) and the foliar volume of an open grown tree (F_{vmax})

$$i_{vj} = b_1 * F_{vj}^{\ b_2} * \left[1 - \left(F_{vj}/F_{vmaxj}\right)\right]^{b_3}$$

TASS III

Tree annual total bole increment i_{vj} was modelled as a function of an individual tree's foliar volume (F_{vj}), the tree crown area ratio (c_{aR}), and tree height (h) through a step-wise regression process.

$$i_V = b1 \cdot F_V^{b2} \cdot c_{aR}^{b3} \cdot h^{b4}$$

where b1, b2, b3, and b4 are regression coefficients

TASS Engine

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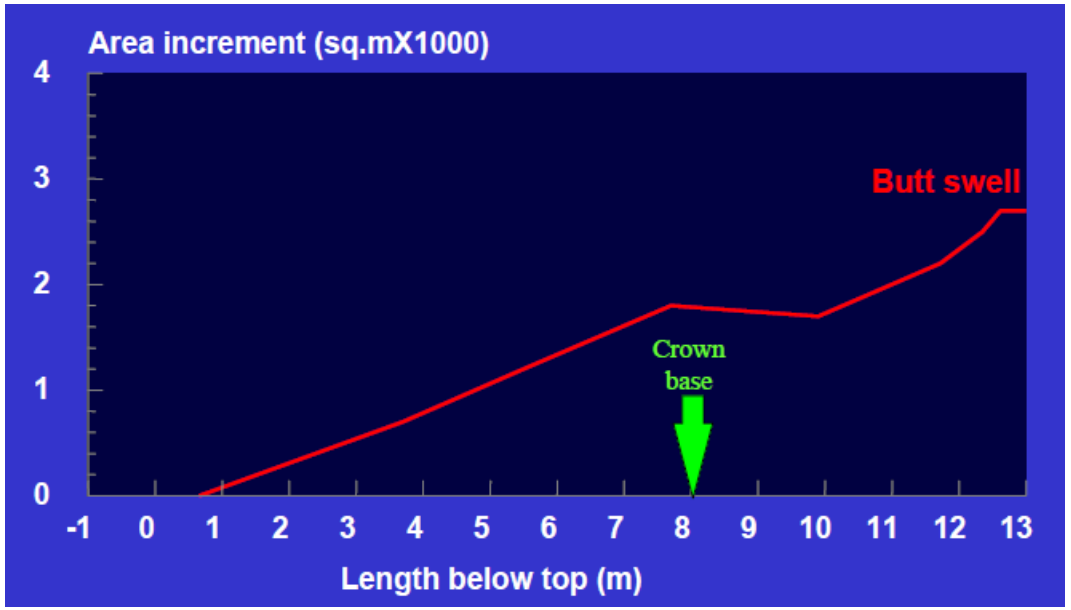
Bole Increment Distributi

The annual bole increment is distributed over the simulated bole in approximate accordance with Pressler's 1864 hypothesis where *cross-sectional area increment increases linearly from the leader to the base of the crown and is constant below*



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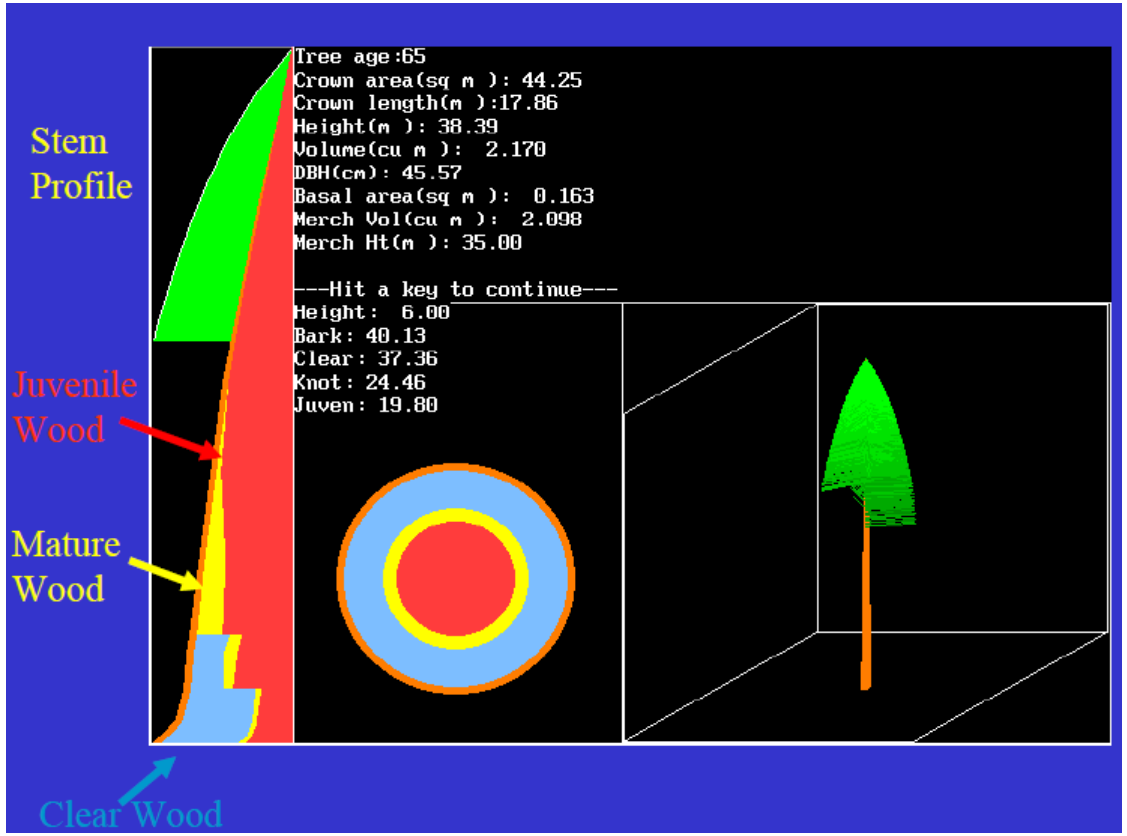
Bole Wood Quality

In addition to wood volume, TASS identifies wood quality characteristics such as juvenile versus mature wood



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Individual Tree Mortality

1. Initial mortality
2. Juvenile mortality
3. Mature Tree Mortality
   a. Overtopping mortality- TASS II only
   b. Small crown mortality – TASS II and TASS III
4. Specified treatment or disturbance

TASS III Development

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TASS III Design Objectives

- More realistic simulation of understory tree development
- Better depiction of changing species dominance observed in some mixed-species stands

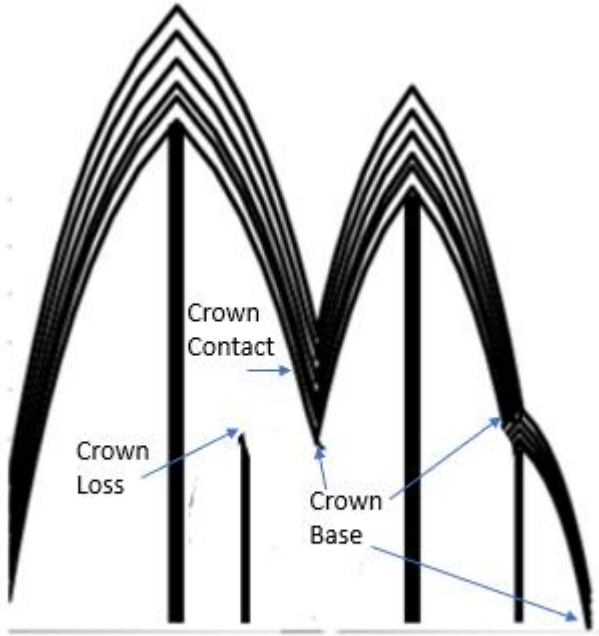
Major Changes

- Change crown data structure to enable overlap of multiple crowns
- Light model use
- Different light-based methods for controlling competition-related height growth, crown expansion, and mortality

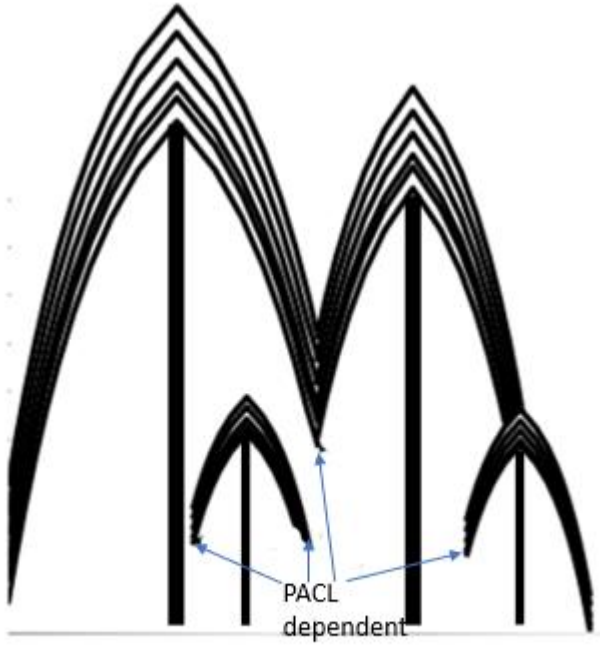
TASS III Development

Light-based Changes - Crown Expansion

- Change crown data structure to enable overlap of multiple crowns



TASS II



TASS III

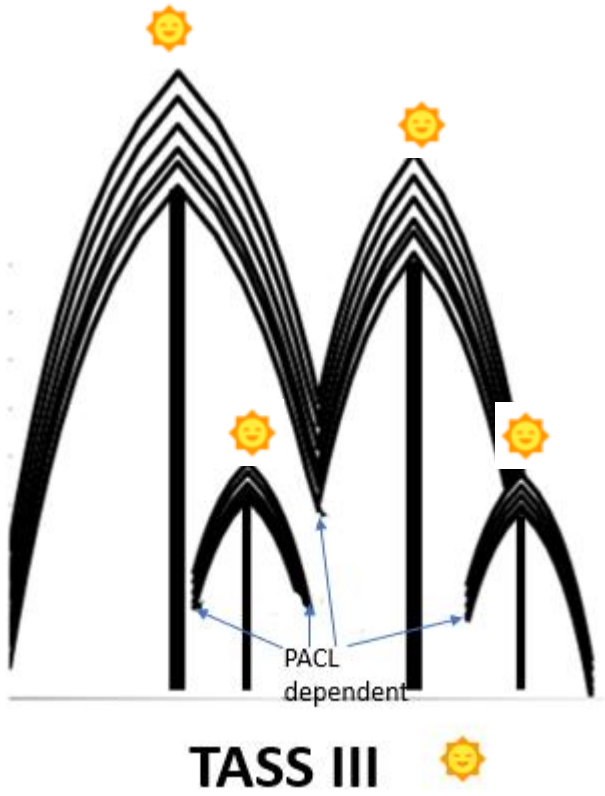
TASS III Development

Light-based Changes – Height

- Competition-related height growth multiplier (m_{hj}) considers light condition (PACL) at leader
- In TASS III, height growth of each tree stays at its potential until the PACL at the leader drops below a $PACL_{max}$ where it decreases by

$$h_R = \beta_0 \cdot PACL^{\beta_1} \cdot (1 - PACL)^{\beta_2}$$

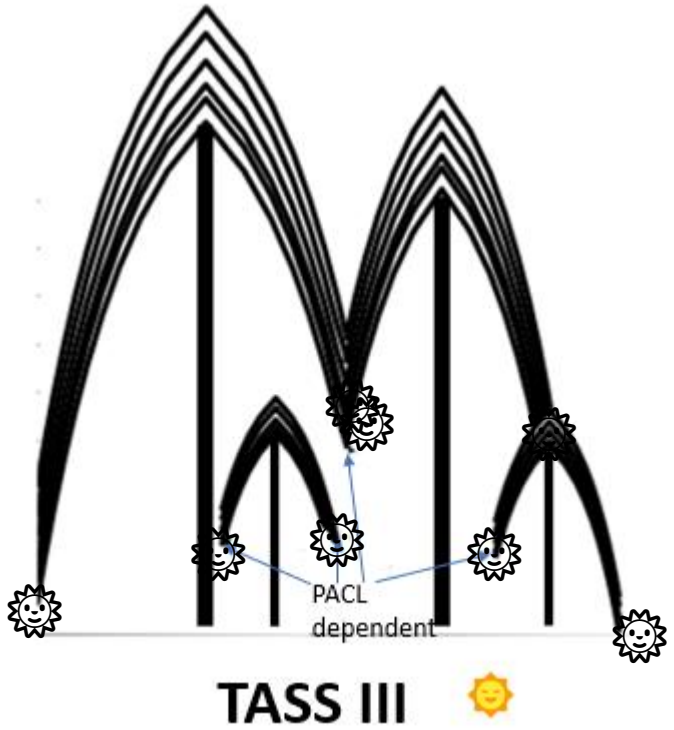
- Data primarily based on BC work of Wright et al. 1998 CJFR 28: 871-886.



TASS III Development

Light-based Changes – Crown Expansion

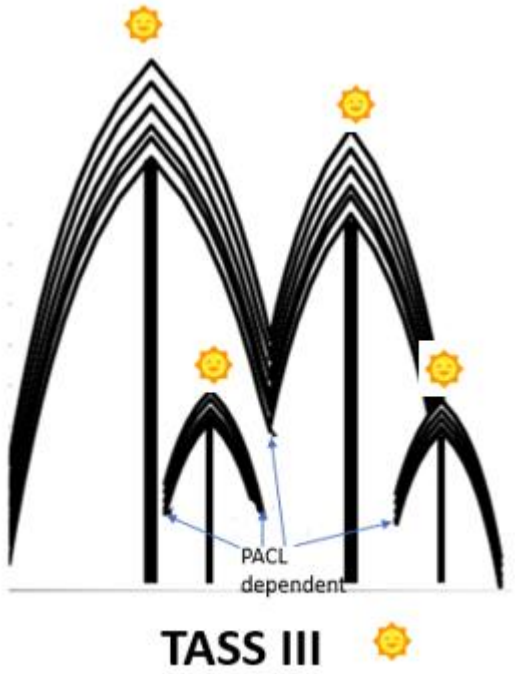
- Species specific PACL threshold values in comparison with model PACL values are used to determine expansion i.e., lift the crowns
- Threshold identified for Pl and Sw based on Alberta work of Schoonmaker et al. 2014 s. PLoS ONE 9(8): e104187. doi:10.1371/journal.pone.0104187



TASS III Development

Light-based Changes – Mortality

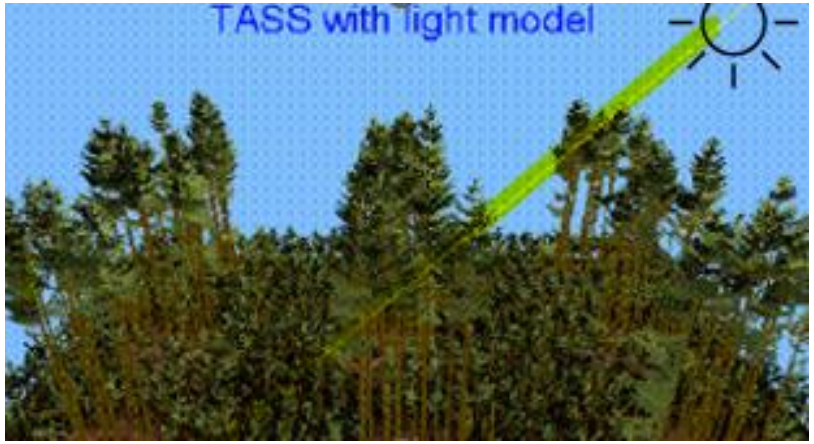
- In TASS III competition-related mortality is mostly related to crown size
- Exploring if mortality prediction relative to existing data can be improved with consideration of relative light
- Lodgepole pine competition-related mortality was improved by considering relative light at the leader



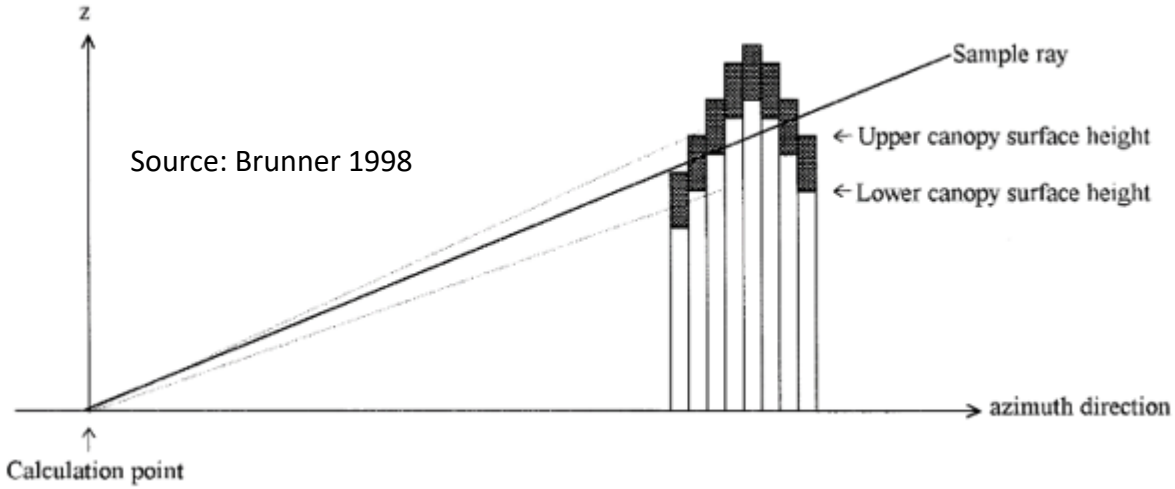
TASS III Development

Light Modelling – Initial light model

- Light model tRAYci developed by Brunner (1998) and incorporated into TASS



$$PAR = e^{(-q.LAD.PATH)}$$



Source: Brunner 1998

Challenges

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Light Modelling – Meta-model

- Meta-model created to predict light conditions within a stand in order to improve execution speed

Challenges

Light Modelling – Meta-tRAYci

- Pseudo data generated by use of tRAYci
  - a subset of light sensors (data points) to estimate PACL were positioned on upper crown surface, halfway to ground, and at crown for each grid column
  - range of stands
- A 1% sample was selected from all PACL data points with 20 associated relevant TASS variables/transformations for TASS 10 year step runs
- After a stepwise process to identify important attributes a logistic model to predict PACL was fit

$$PACL = \frac{1}{[1 + g(x) \cdot e^{f(x)}]} \qquad \text{where, for PL:} \quad g(x) = 0.2399 - 0.0365 \cdot PACL_{TTj},$$

$$f(x) = [-0.6158 \cdot ln(c_{lconTA} + 1) + 0.3857 \cdot ln(F_{lA} + 1) + 0.0053 \cdot \bar{h}_{conTA} - 0.0305 \cdot h_{cs} + 0.2312 \cdot ln(LAD_{TA} + 1) + 0.5890 \cdot h_{TA} + 1.9814 \cdot ln(\Delta h5_{TA} + 1) + 0.0035 \cdot ln(h_{PACL} + 1) + 2.7675\, ln \cdot (LA_{TA} + 1) - 0.4165 \cdot \Delta h5_{TA}],$$

- In TASS III, the full tRAYci is used to predict the PACL at the leader and the metamodel is used for PACL predictions to determine crown extent and the base by octant segments.

FUTURE

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The Tree and Stand Simulator (TASS)

Seeing the light of complex stands

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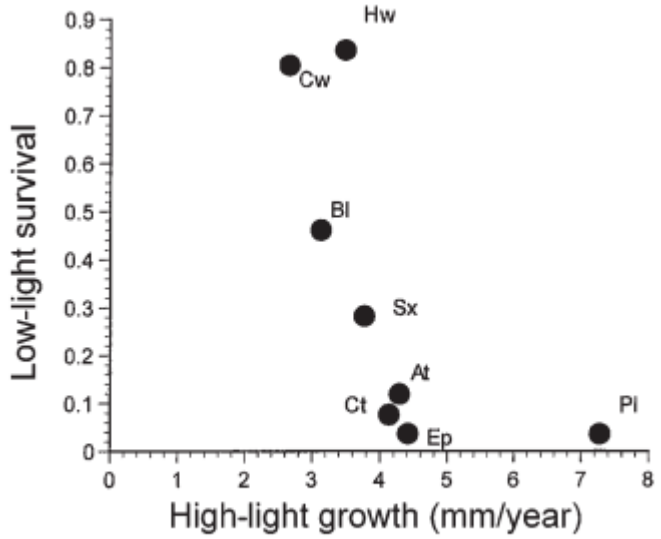
TASS Overview

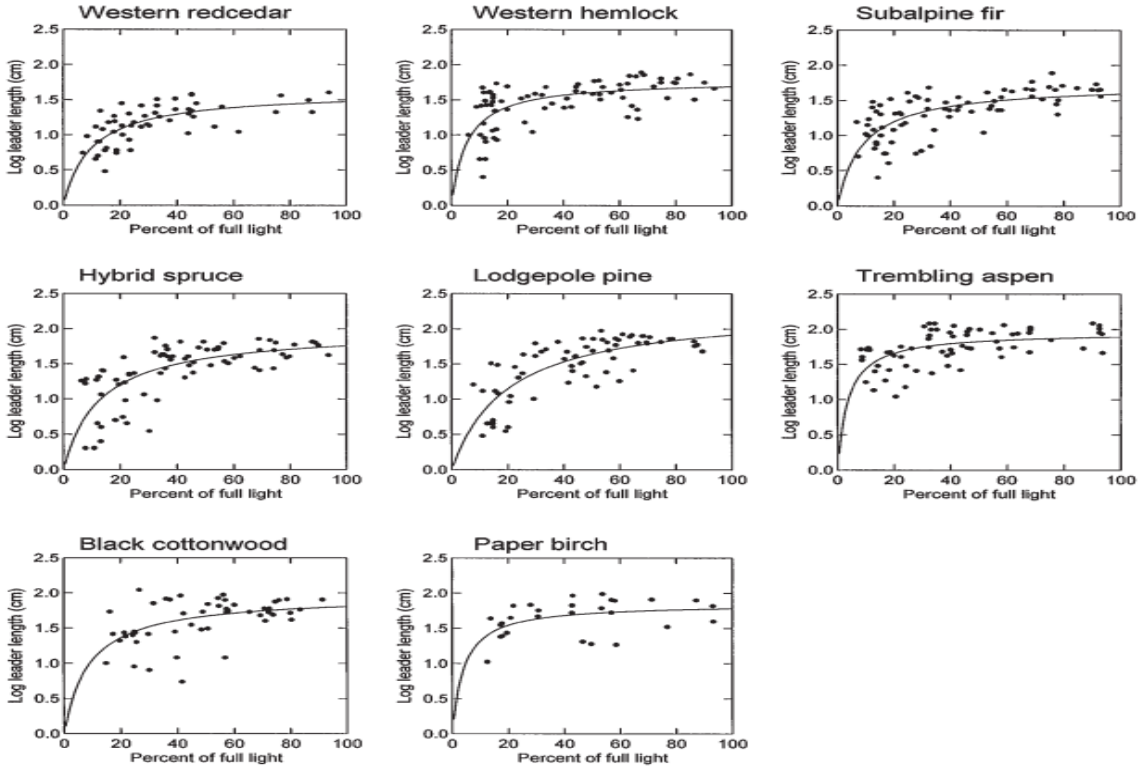
High-light Growth vs Low-light Survivorship



Source: Wright, E.F., K.D. Coates, C.D. Canham, and P. Bartemucci. 1998. Species variability in growth response to light across climatic regions in northwestern British Columbia. Can. UJ. For. Res. 28:871-886.

TASS Overview

Leader growth vs Percent full light



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Abstract

The Tree and Stand Simulator (TASS): Seeing the light of complex stands

Jeff Stone, Stand Development Modelling Research Scientist, BC Ministry of Forests, Victoria, BC

The Tree and Stand Simulator (TASS) is a forest growth model whose development began in the 1960's as the PhD dissertation work of Ken Mitchell and continues today within the British Columbia Ministry of Forests. TASS is a spatially-explicit individual tree model that is driven by height growth and crown competition. This structure reflects the original emphasis on understanding the effects of cultural practices and environmental factors on forest stand development. While the original focus of TASS was oriented to single-species and even-aged stands, current developments with the application of a light model and changed crown competition rules provide greater understanding of complex stands. In this presentation, I will provide a brief overview of TASS's distinctive structure and discuss how some of the challenges, such as the computational needs of the light model, have been addressed to advance our modelling of complex stands.