Development, Calibration, Evaluation And Application Of a Spatially Explicit, Individual-Tree, Growth And Yield Model

Tree And Stand Simulator TASS

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Outline

- Introduction
- TASS Structure and Operation
  - TASS II
  - TASS III
- Calibration
  - Individual-Tree Measurements
  - Plot Measurements
- Adaptation to New Silviculture Treatments and Issues
- Model Evaluations
- Applications

Outline

Introduction

History and Overview

-beginnings 1963 - Ken Mitchell

-historically - spatially explicit models

- Canadian role

- Canadian Forest Service, Yale Univ.

- 1980 - BC Forest Service

- TIPSY

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Classification

Individual Tree – geometric model of the crown and bole of individual trees

Spatial – recognizes location of trees in 3D space

Raster Model – 3D growing space

Crown Model
- organ of competition
- metric of growing space
- crowns search the growing space without calculating inter-tree distances.

Classification (cont'd)

Growth and Yield Model

– measure of success is repeating the patterns of tree dimensions observed in historic yield experiments and plots.

– intended for application to management issues.

Hierarchy of Measurement Detail

Growth & Yield PSPs
- inventory
- monitoring

G &Y Experiments
- plot-level statistics
- tree-level statistics

- crown measurements
- branch measurements
- upper stem diameters
  (taper & form)

Hierarchy of Measurement Detail (cont'd)

Individual Tree – destructive analysis

Crowns

Branch extension

- 1st Order
- Higher order

Branch diameters

Foliar Biomass

- Distribution
- Leaf Area & SLA
- leaf anatomy
- leaf morphology
- leaf physiology

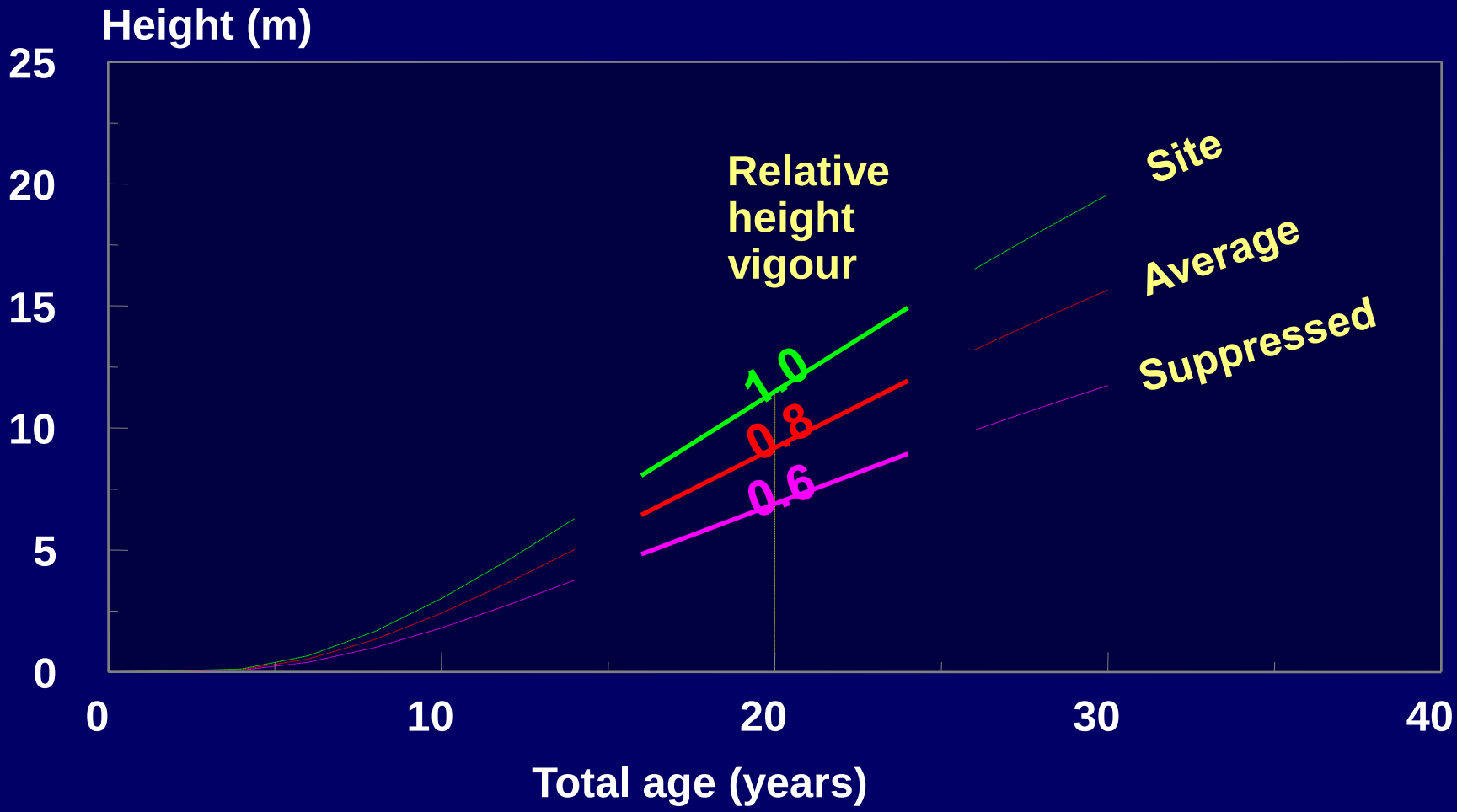
Hierarchy of Measurement Detail (cont'd)

- Individual Tree – destructive analysis
  - Boles (stems)
    - Height increment
    - Ring width and area
    - Sapwood area
    - Earlywood – Latewood
    - Ring density profiles
    - Cell characteristics
      - (microfibril angle)

TASS Components

- **Height Growth**
- **Branch Growth & Crown Expansion**
- **Crown Competition**
- **Tree Mortality**
- **Crown Volume**
- **Bole Increment**
- **Increment Distribution**

Potential height growth of individual trees (may be altered by competition)



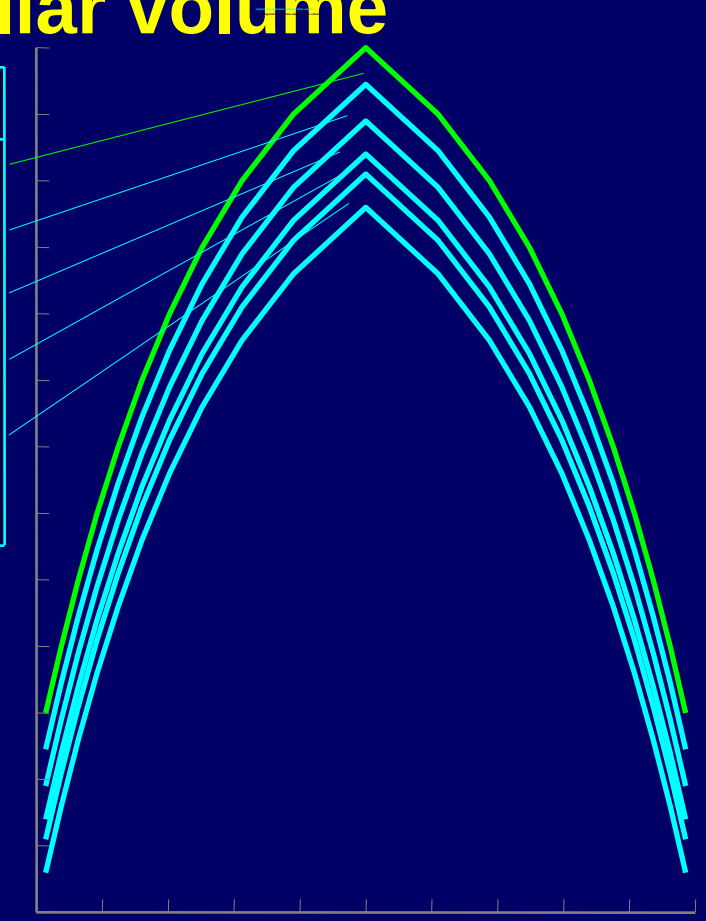
Measurements of branch length and branch growth …

… described by distance from the apex

Crown Volume

Shells of productive crown, integrated as weighted foliar volume

i	Hgi	Wi	WiHgi
1	0.55	1	0.55
2	0.55	0.86	0.47
3	0.5	0.75	0.38
4	0.3	0.63	0.19
5	0.5	0.4	0.2
		Sum:	1.59



$FV = CA * \Sigma\ WiHgi$

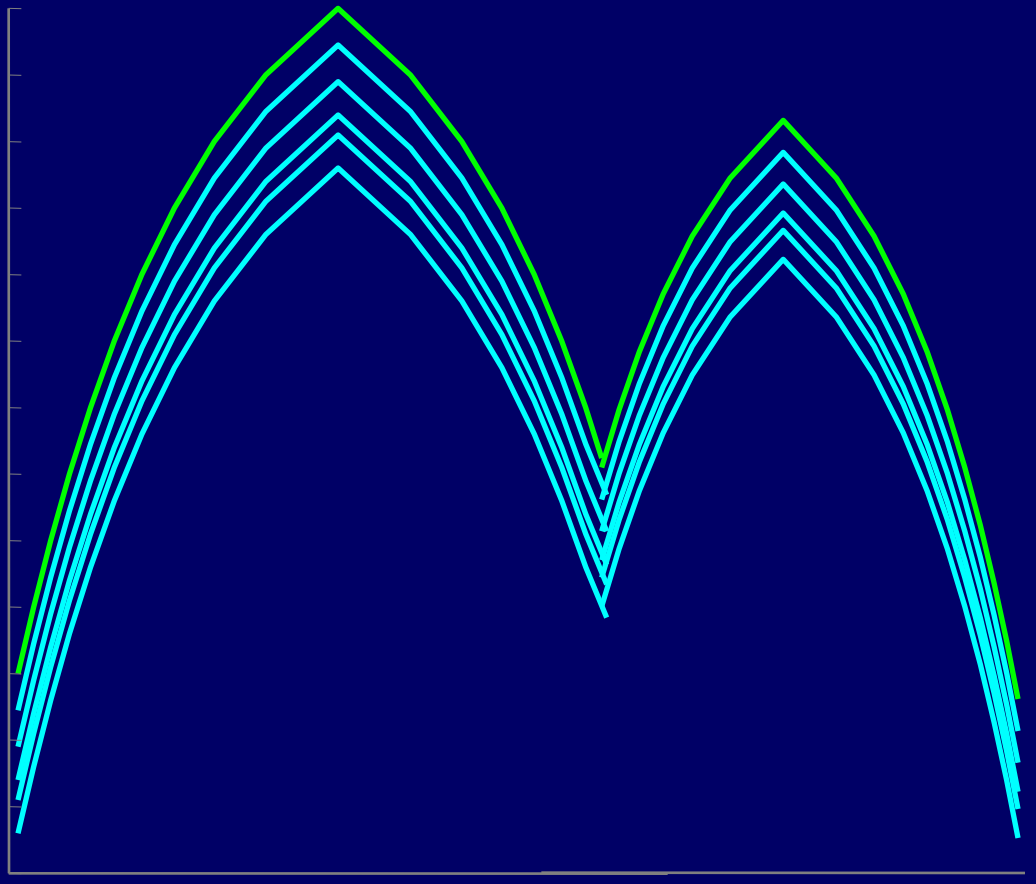
$= 31.4 * 1.59$

$= 50$ cu.m.

Crown area = 31.4 sq.m

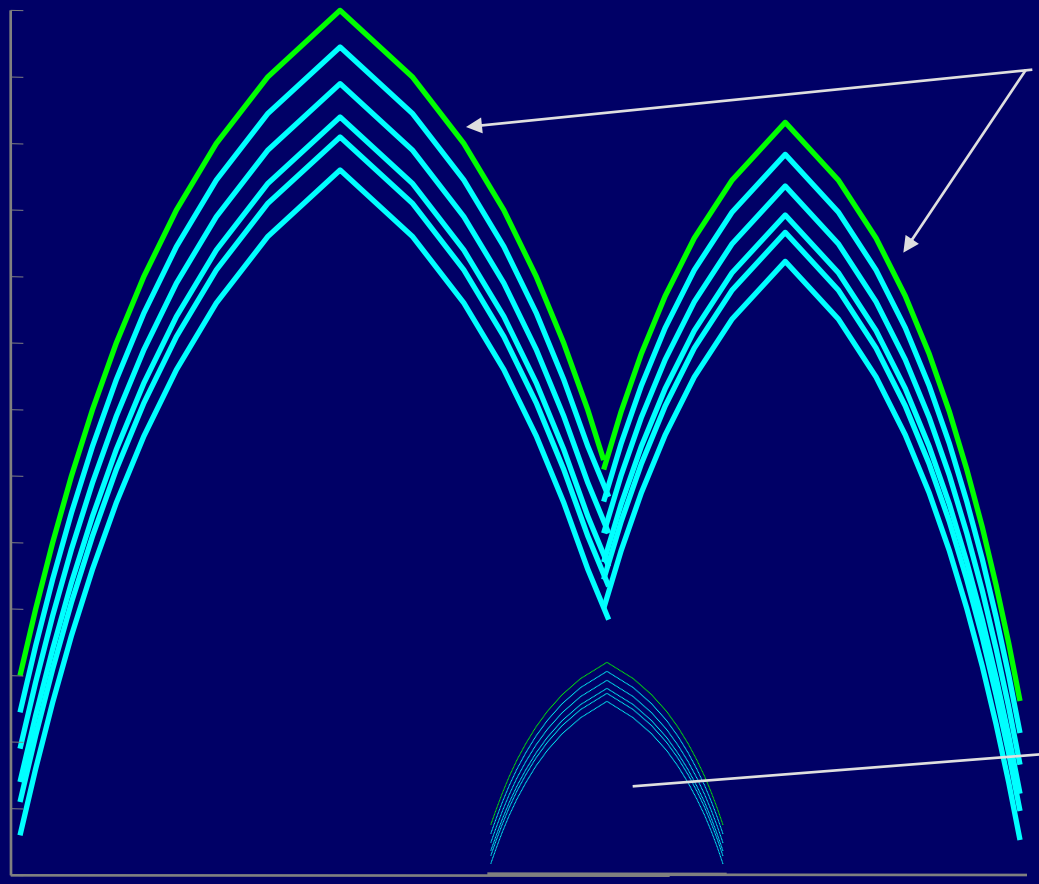
Crown Competition

space is occupied, "branches" die, and crowns lift

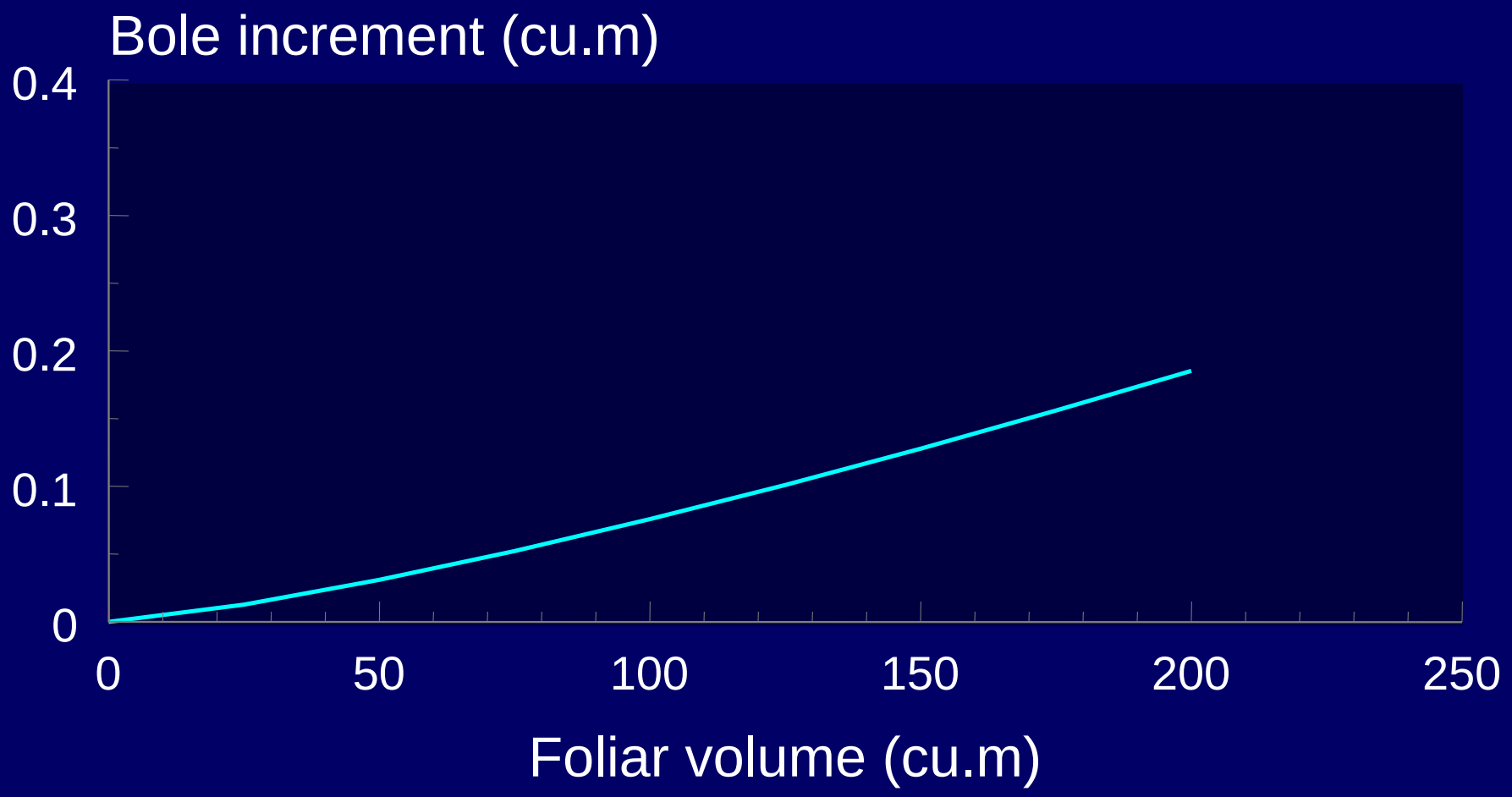


Mortality based on

- degree of overtopping
- size of crown relative to size of tree

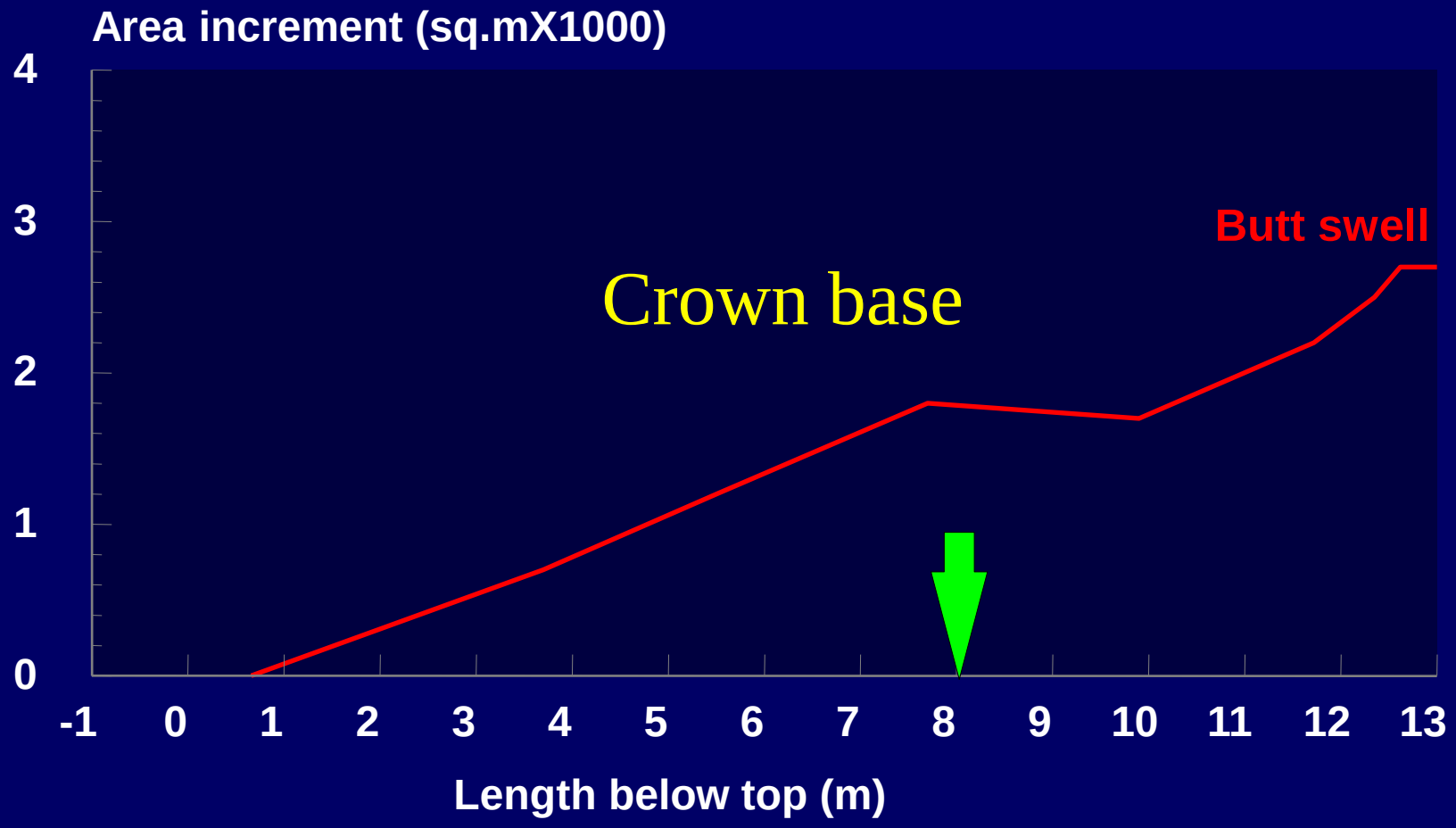


Bole increment

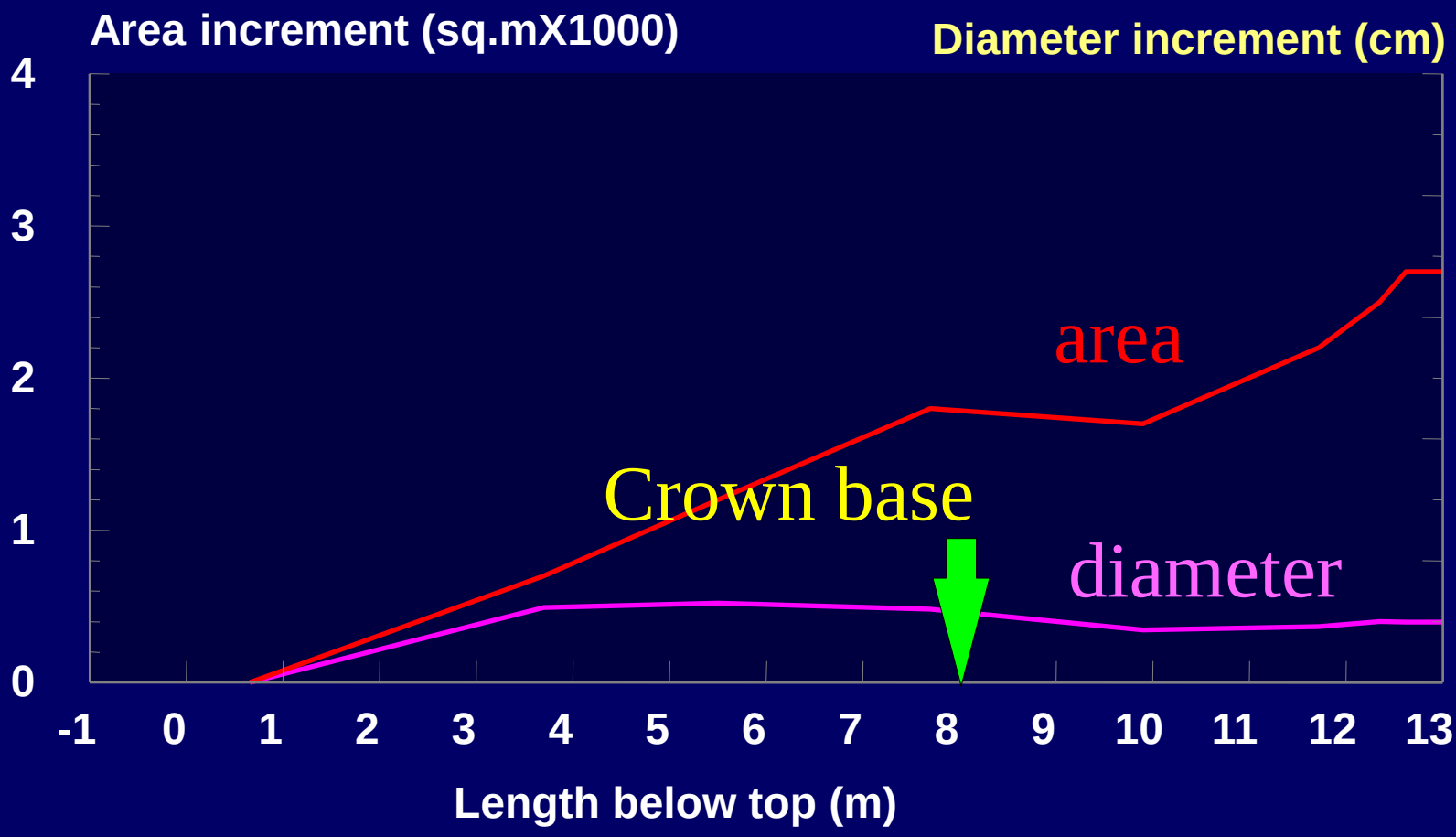


With other modifiers for competition effects

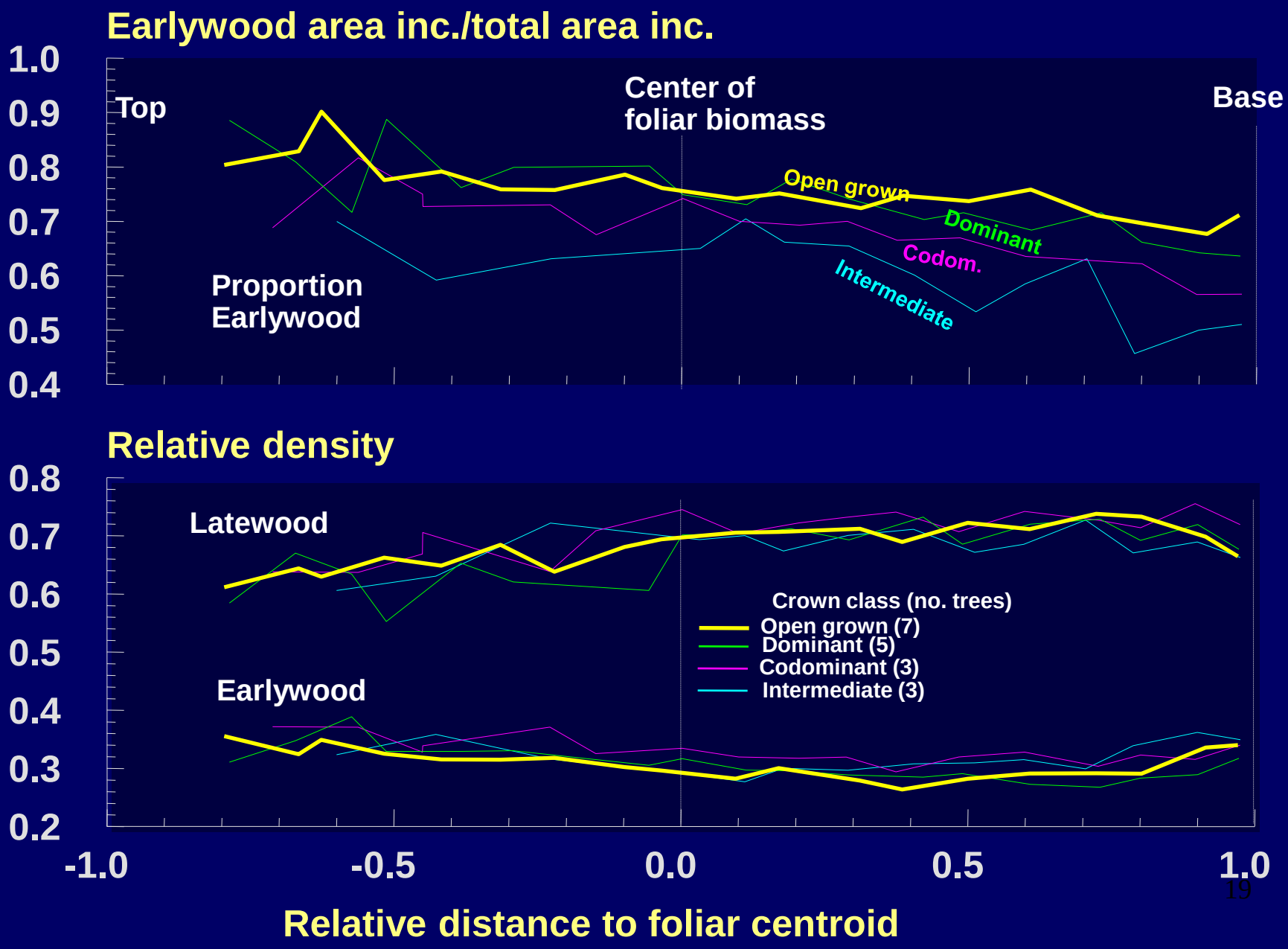
Area Increment from Tree Measurements



Area Increment and Diameter Increment From Tree Measurements



Average values by source and crown class



Stem Profile

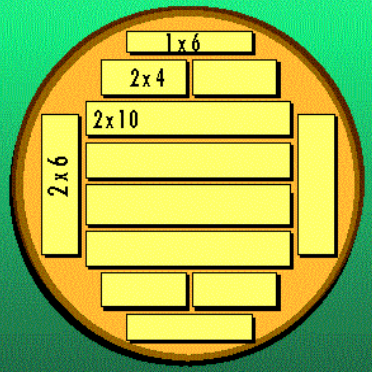
Juvenile Wood

Mature Wood

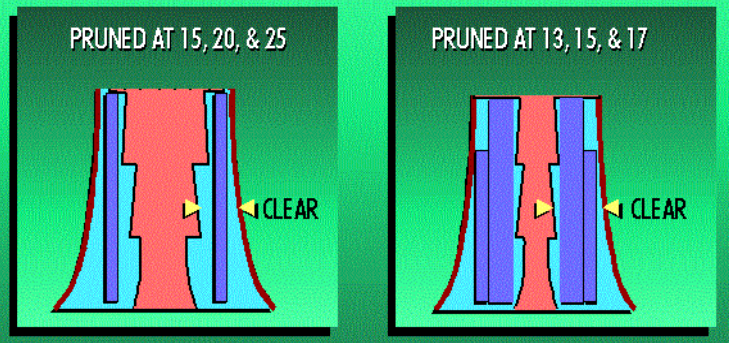
Clear Wood

SAWSIM:

SAWS LOGS INTO LUMBER



Clear Wood



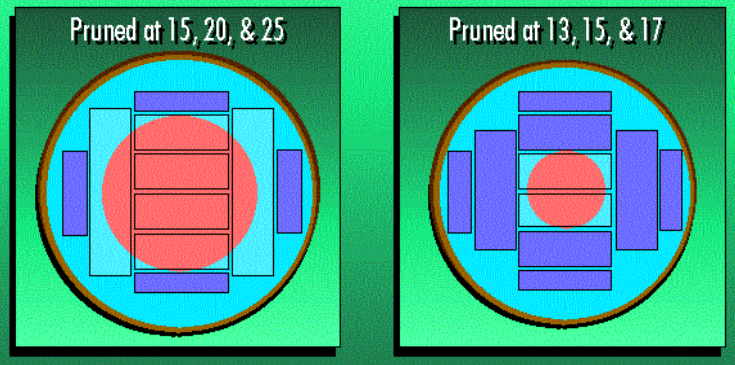
24 Board feet
20%

80 Board feet
75%

Benefits of Pruning Early

Pruning Ages	Harvest Age (yrs.)	Clear Lumber (M bd ft)	NPV ($)
---- ---- ----	60	0	570
15 20 25	60	26	250
14 17 20	60	43	1050
13 15 17	60	63	2300

Clear Wood



24 board feet
20%

80 board feet
75%

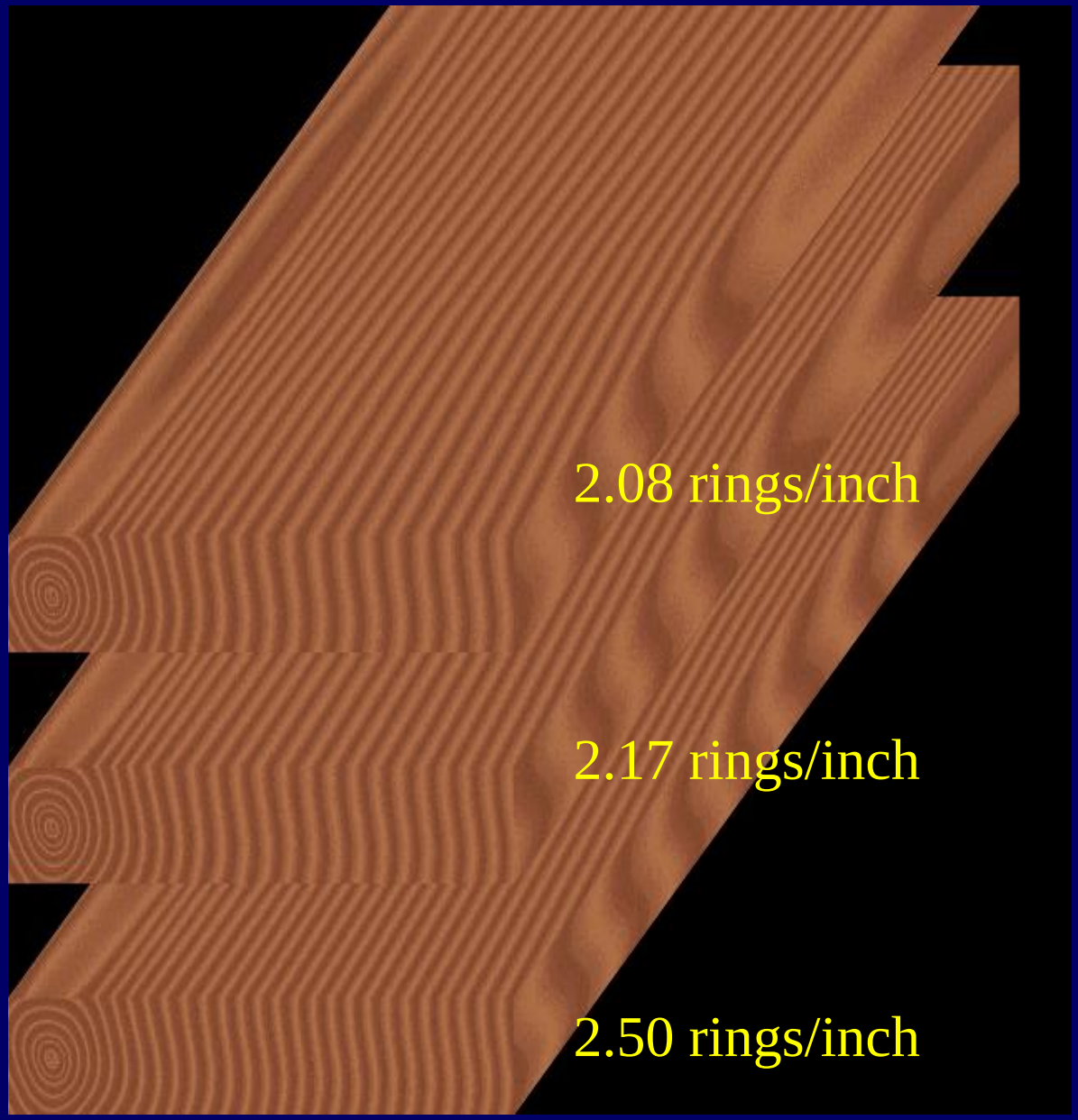
Simulated Lumber

Planting Density

330/ha

820/ha

2500/ha



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TASS III

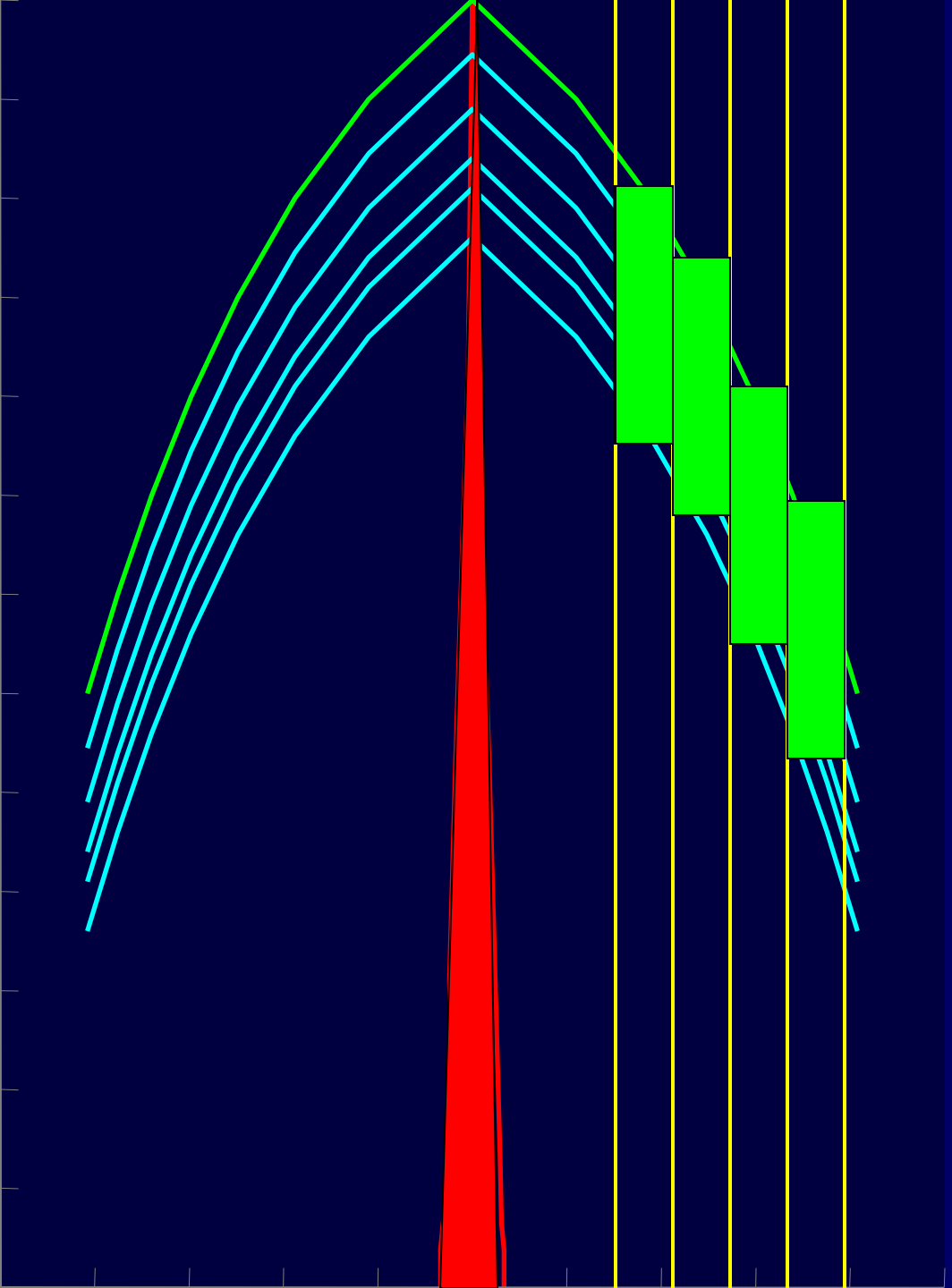
3-year Project (2005/06 to 2007/08)

Integration of Components Previously Developed
- Redesigned Raster Grid
- VISTAS visualization
- tRAYci light model (Brunner 1998)

New Components
- Graphical User Interface
- Carbon-Balance structure

Updates
- Crown shyness

General Release

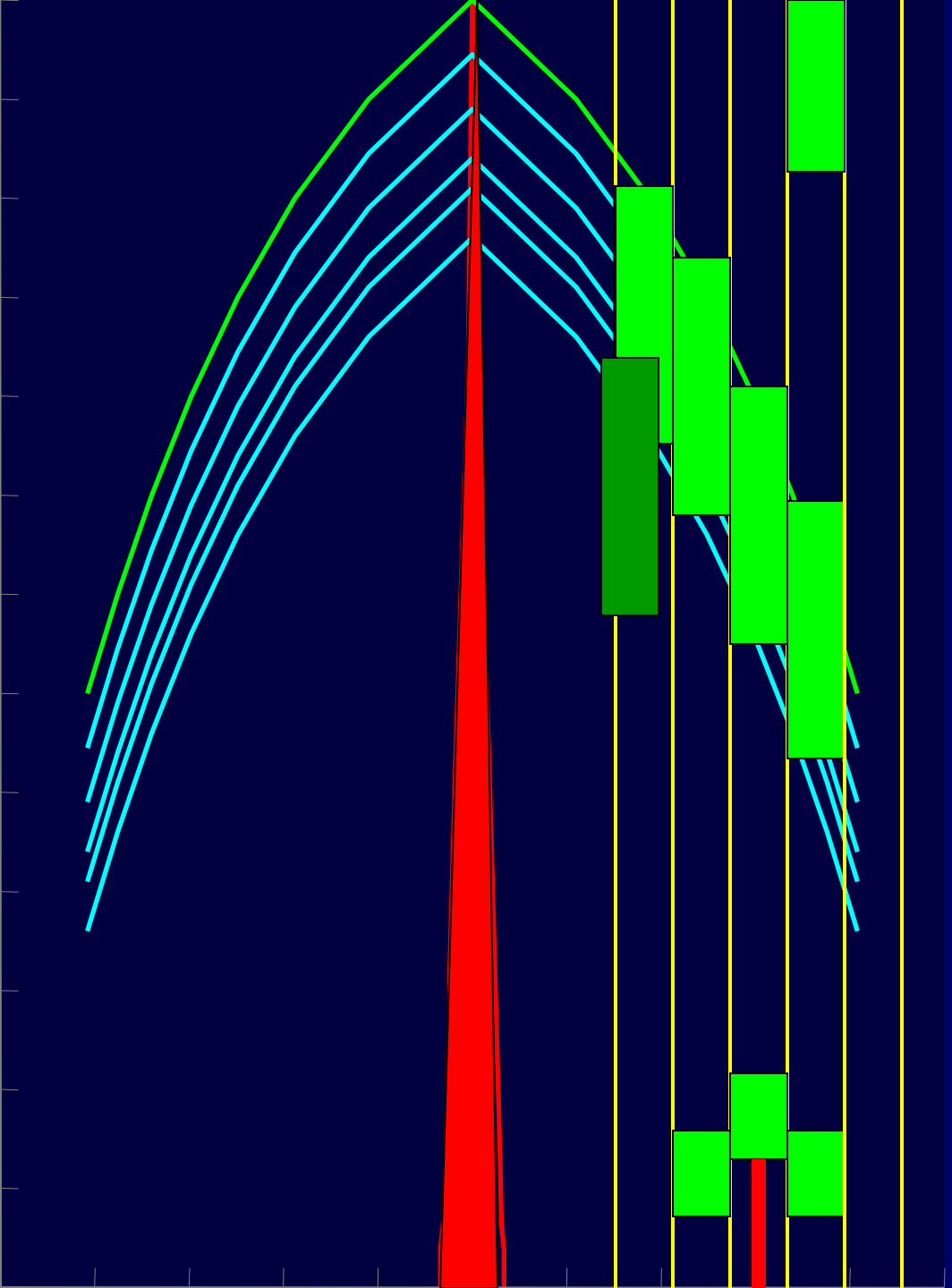


TASS Grid

Square columns

Typically
20 cm x 20 cm

<u>TASS II</u>
One canopy layer
Per grid column

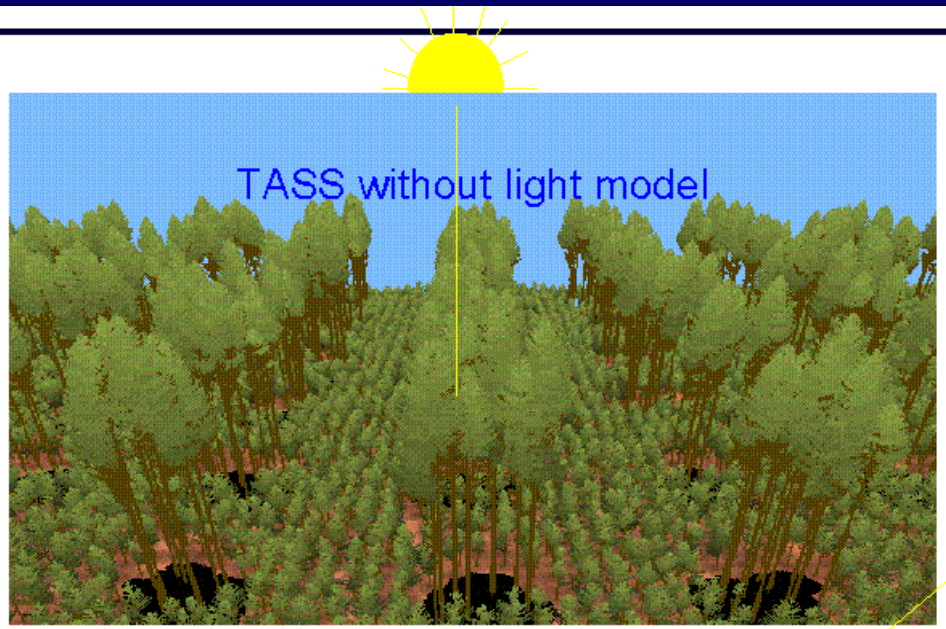


TASS III Grid

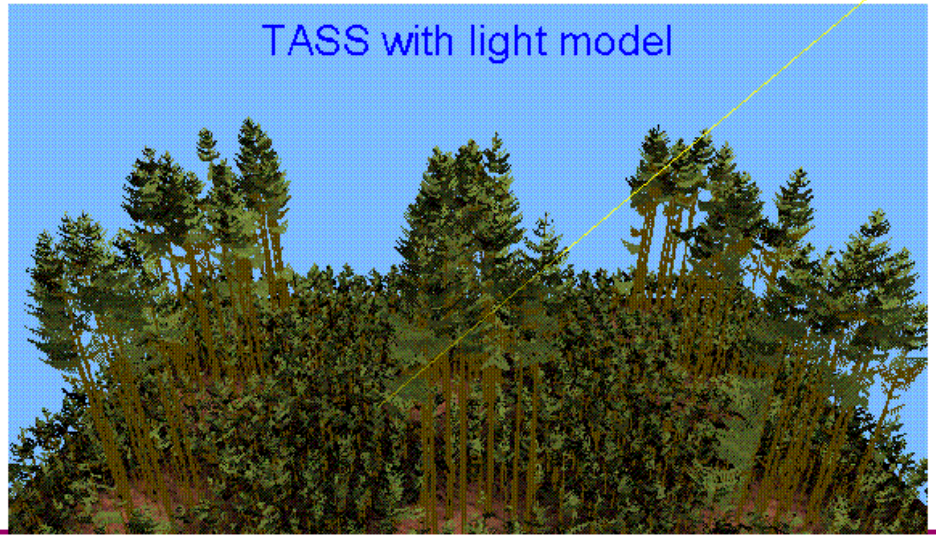
TASS III
- multiple layers
  per grid column
-overlaps permitted
  (interlocking crowns)

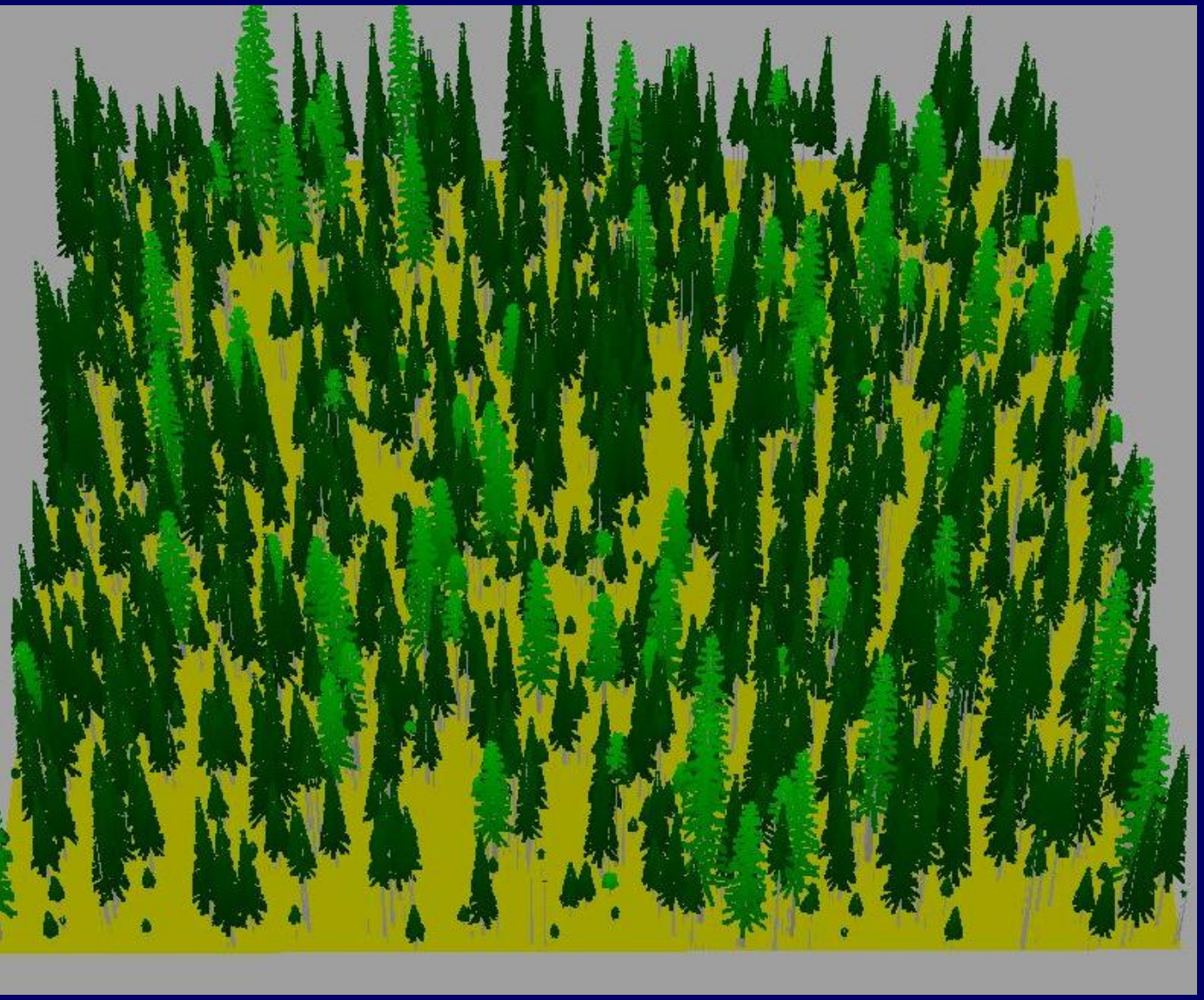
TASS with and without tRAYci light model

TASS II



TASS III





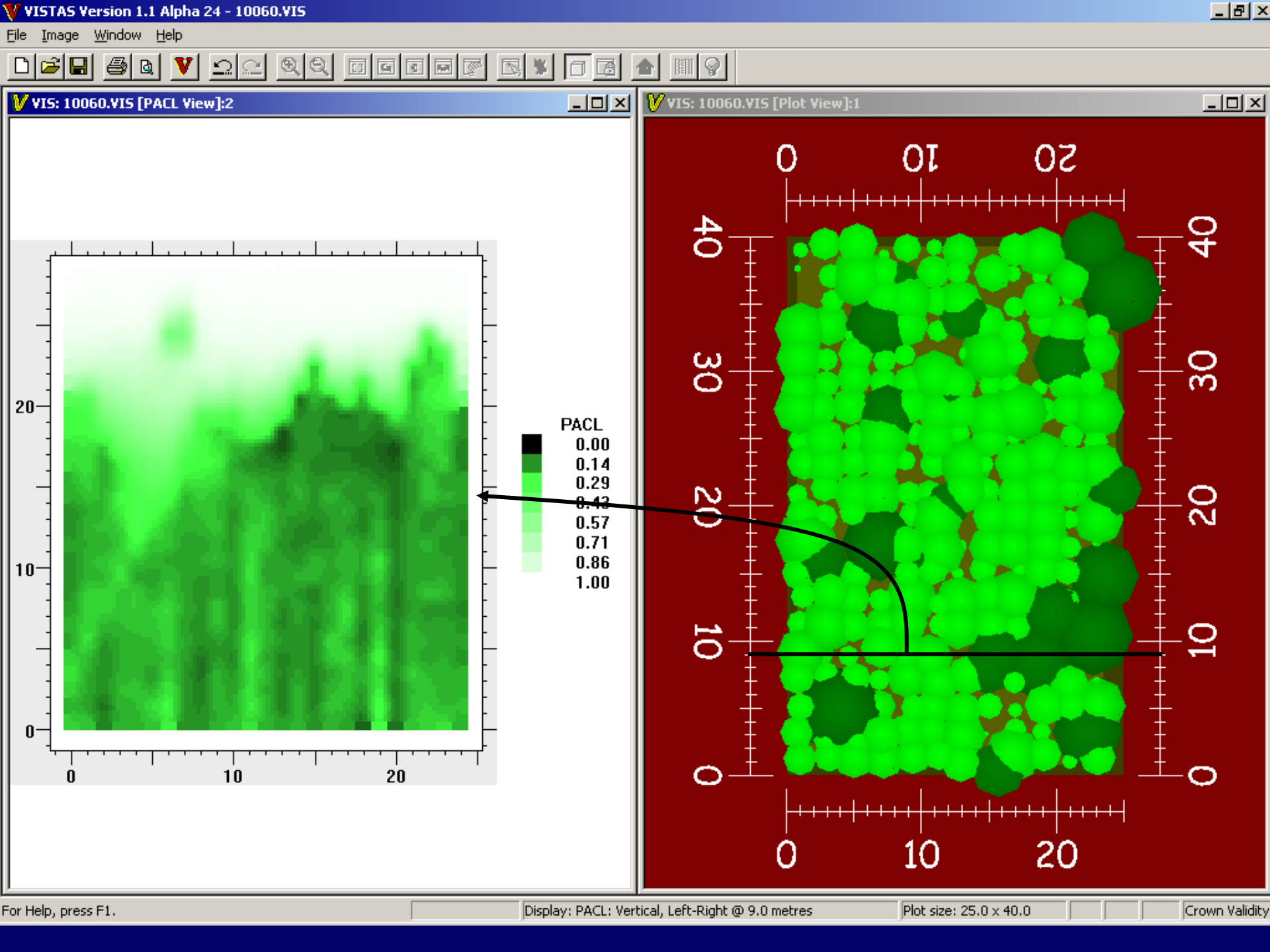
VISTAS

3D Visualization

OpenGL Graphics

Integrated graphic and text reporting

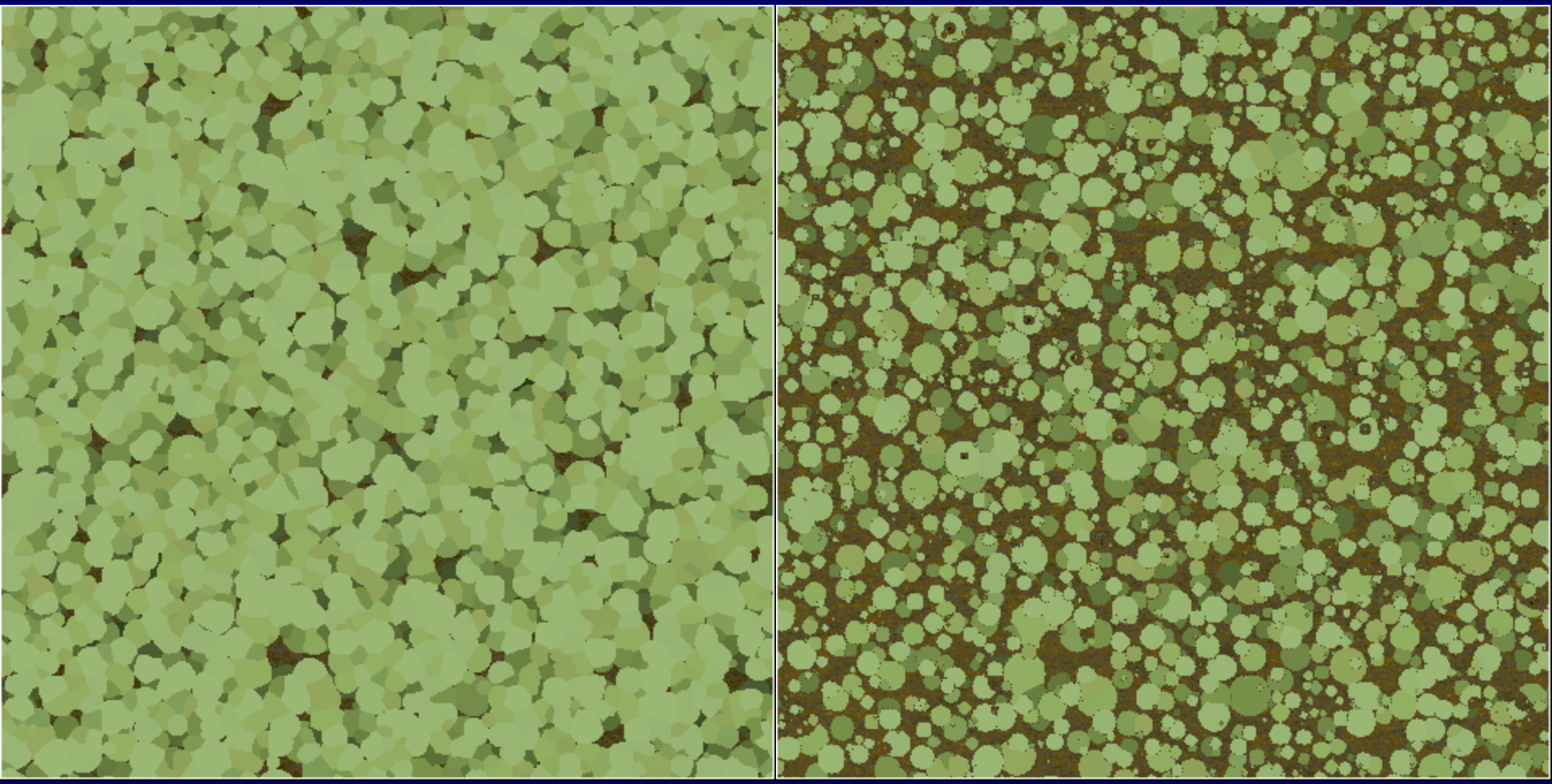
Analysis of Stand Structures


VISTAS Version 1.1 Alpha 24 - 10060.VIS
File
Image
Window
Help
VIS: 10060.VIS [PACL View]:2
VIS: 10060.VIS [Plot View]:1
PACL
0.00
0.14
0.29
0.43
0.57
0.71
0.86
1.00
0
10
20
30
40
For Help, press F1.
Display: PACL: Vertical, Left-Right @ 9.0 metres
Plot size: 25.0 x 40.0
Crown Validity

Crown Shyness

Without crown shyness

With crown shyness



Adapting to New Treatments, Pests and Issues

How are tree components affected?

- Height Growth
- Branch Growth & Crown Expansion
- Crown Volume
- Bole Increment
- Increment Distribution
- Crown Competition
- Tree Mortality

Adapting to New Treatments, Pests and Issues

Example: Genetic Gain

How are tree components affected?

- **Height Growth**
- **Branch Growth & Crown Expansion**
- **Crown Volume**
- **Bole Increment**
- **Increment Distribution**
- **Crown Competition**
- **Tree Mortality**

Adapting to New Treatments, Pests and Issues

Example: Armillaria Root Disease

How are tree components affected?

- X **- Height Growth**
- X **- Branch Growth & Crown Expansion**
- X **- Crown Volume**
- → **- Foliar Biomass**
- → **- Bole Increment**
- → **- Increment Distribution**
- **- Crown Competition**
- **- Disease spread – root systems**
- **- Tree Mortality**

Special Version of TASS

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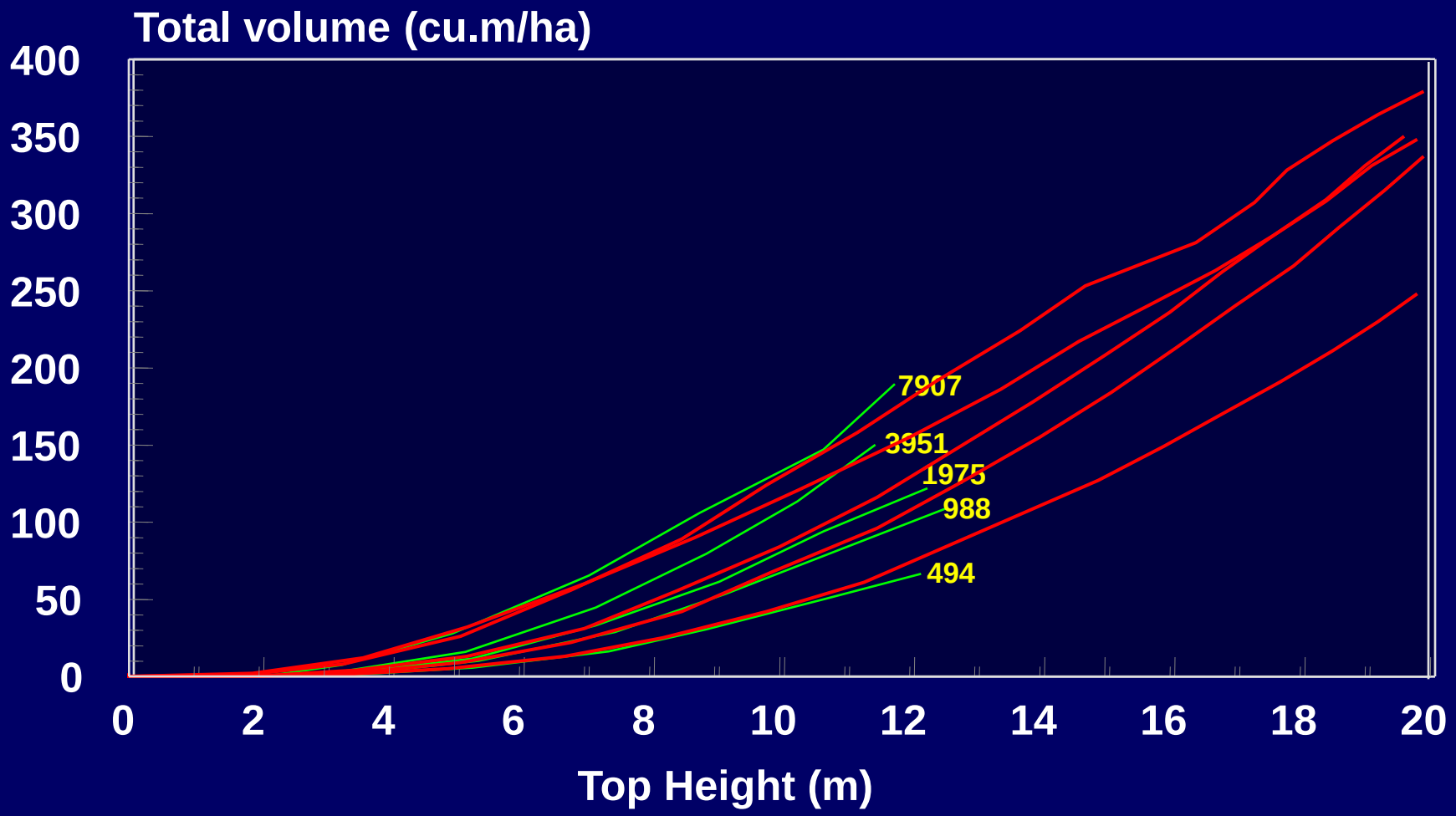
Total volume/ha vs height

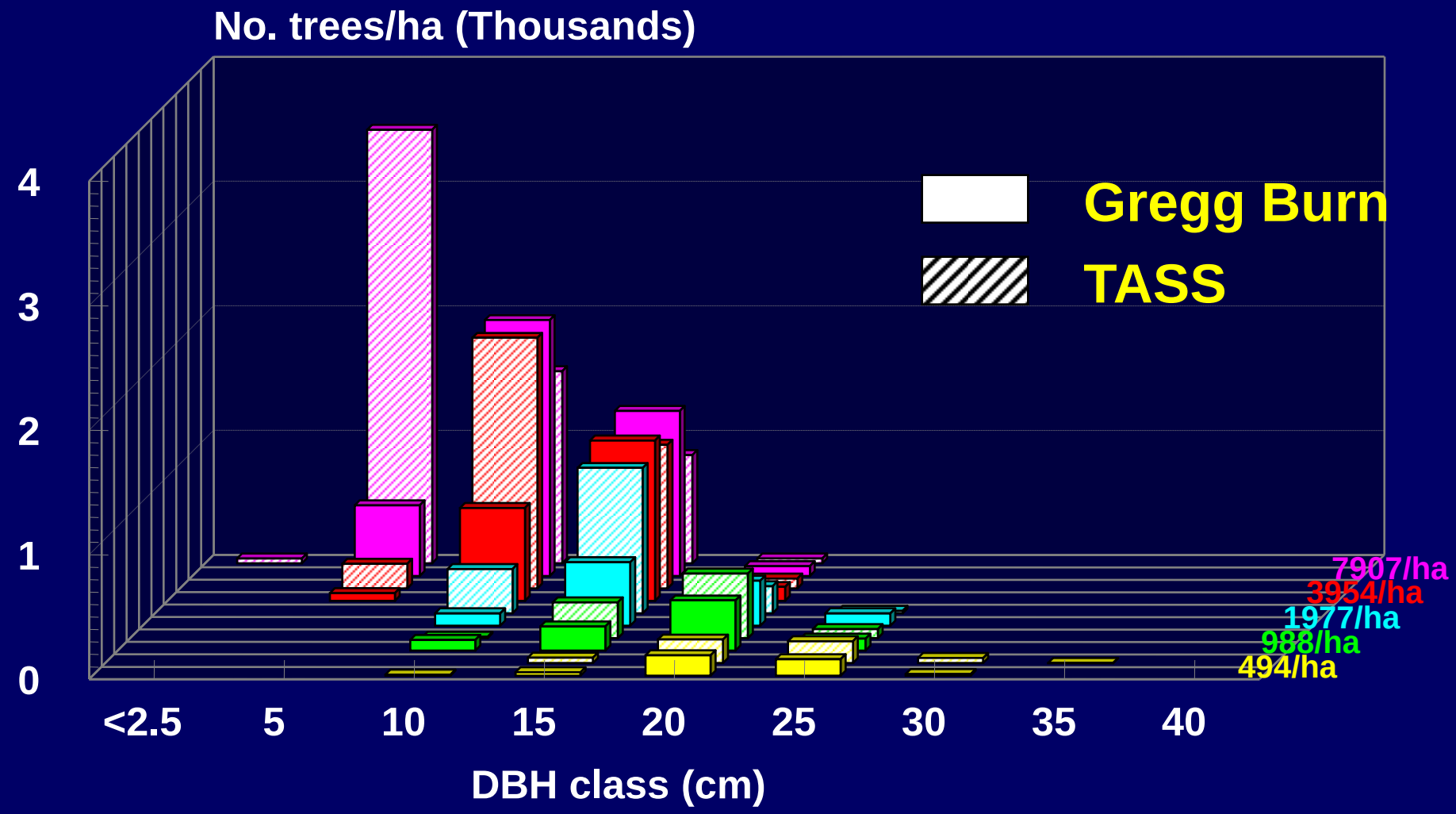
Gregg Burn - Average over all sites

TASS



Diameter distributions at age 40

Site 2 vs. TASS simulations



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Silvicultural Treatments

Planting

Pre-commercial thinning

Commercial Thinning

Fertilization

Pruning

Genetic Gain

Pests

Sitka spruce terminal weevil

Armillaria root disease

Phellinus root disease

Species

Douglas-fir

Western Hemlock

Western Redcedar

Sitka Spruce

Lodgepole Pine

White Spruce

Red Alder

Trembling Aspen

Engelmann Spruce

Subalpine Fir

Challenges in Application

Bias Associated With the Calibration Data

- experimental installations
- subjectively located plots
- mortality, increment losses and damage

TASS yields reflect the potential, even if we are accounting for density effects.

Challenges in Application

Spatial Coordinates for Trees

Stem maps are rare.

Assume distributions at stand initiation

- plantings tend to be regular
- natural regeneration can be added in a variety of spatial arrangements … but the user must choose the one they want.
- simulate wide range of alternatives to assess the sensitivity
- measure stem maps for case studies of interest.

Challenges in Application

Spatial Coordinates for Trees

Initiating mature stands is problematic

Defining the joint distributions of spatial arrangement and tree size for a mature stand is one of the most difficult problems in quantitative forestry – simply choosing random coordinates is unsatisfactory.

A partial solution -- approximate mature stand conditions by iterating over a range of initial conditions.

Stand-Level Silviculture Decisions

Best application of TASS because of close link to the type of calibration

Emphasis on response to treatment

Calibration bias less of an issue
- ranking of alternatives
- relative responses

More comfort with requisite assumptions on spatial distributions

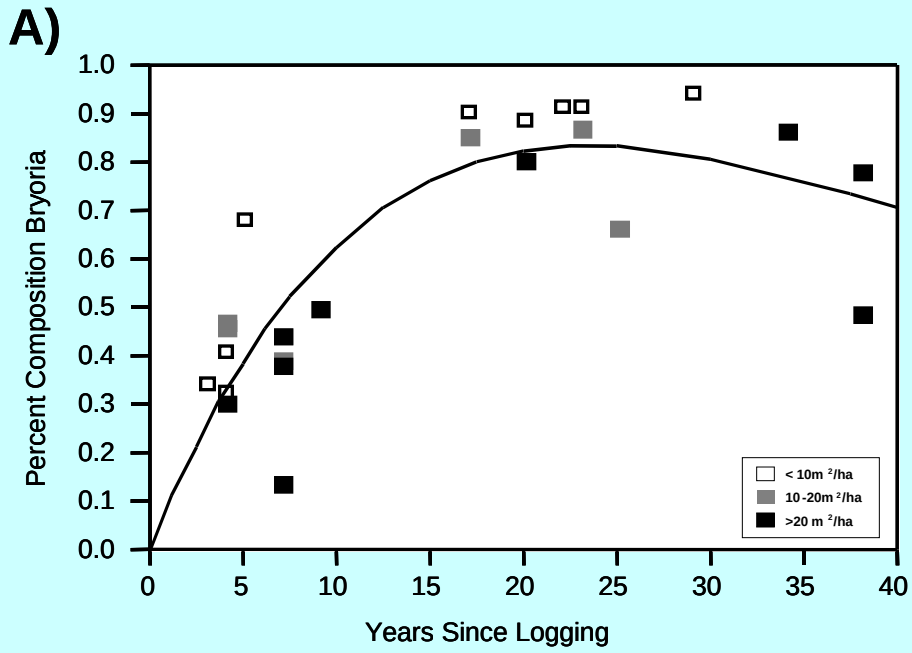
Yield Curves for Forest Management Planning

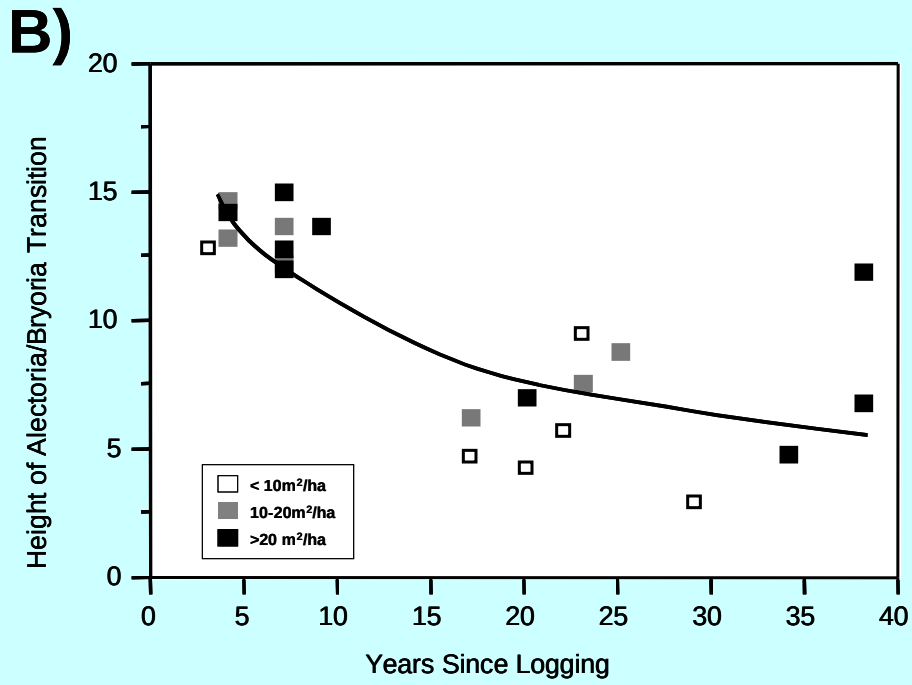
Bias issue must be addressed by:

- yield reductions (Operational Adj. Factors) when primary focus on volume.

OR

- explicit identification of factors that contribute to the bias:
  - •spatial distribution of trees, with emphasis on “holes”
  - • non-productive areas
  - • forest pests

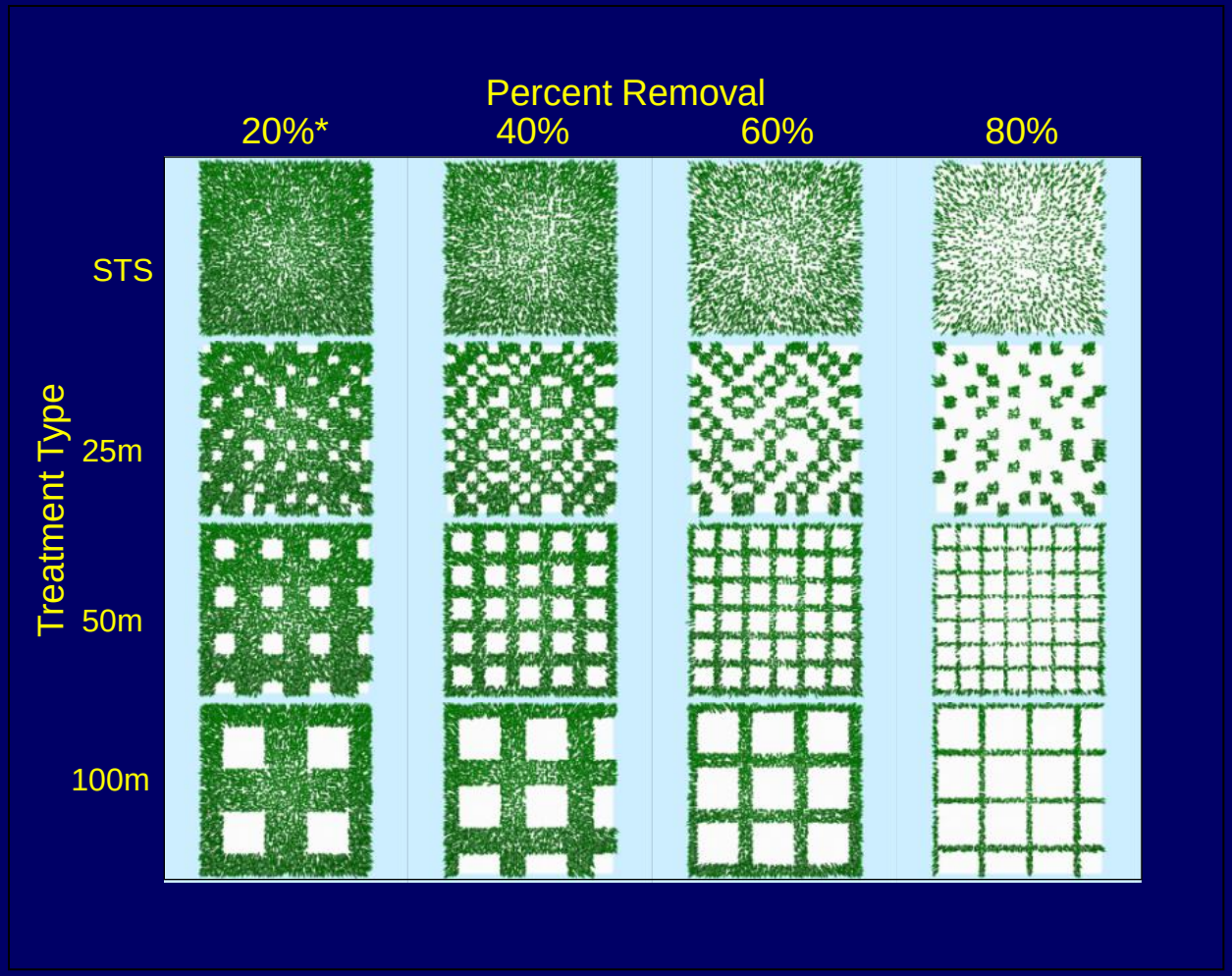




Transition from ***Bryoria*** to ***Alectoria*** **descends** in the tree after partial cutting

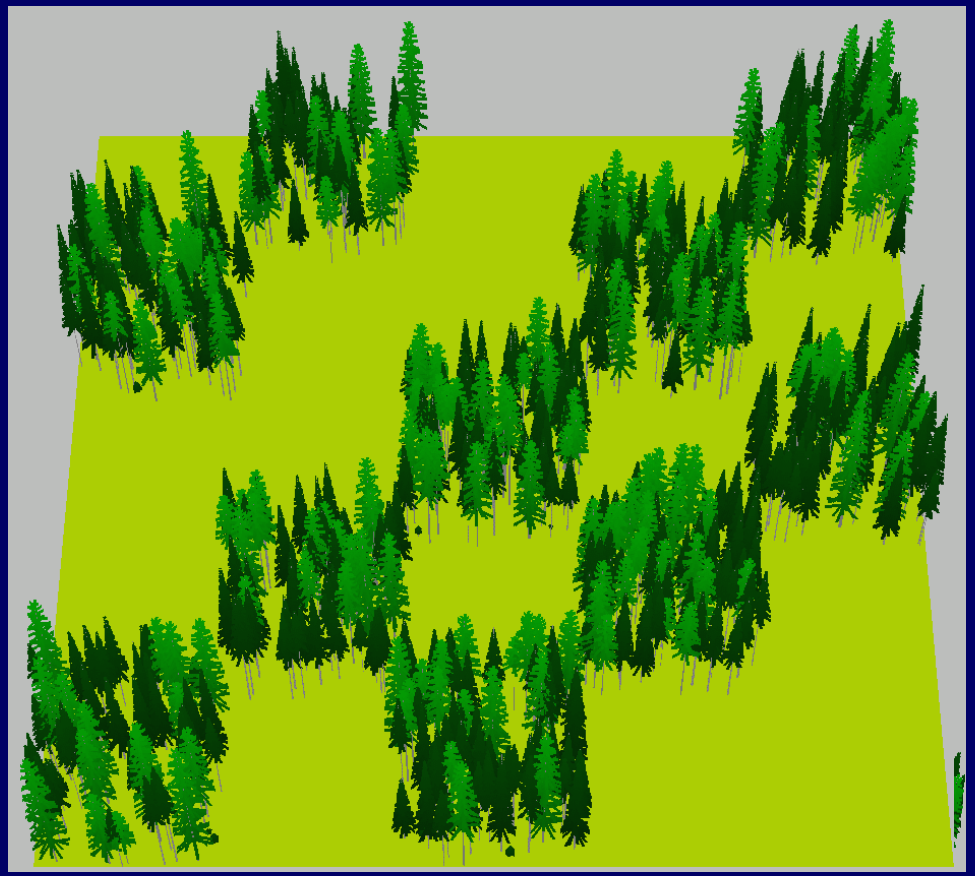
From Lewis (2004) Masters thesis, Simon Fraser U.

Factorial design of TASS simulation experiment

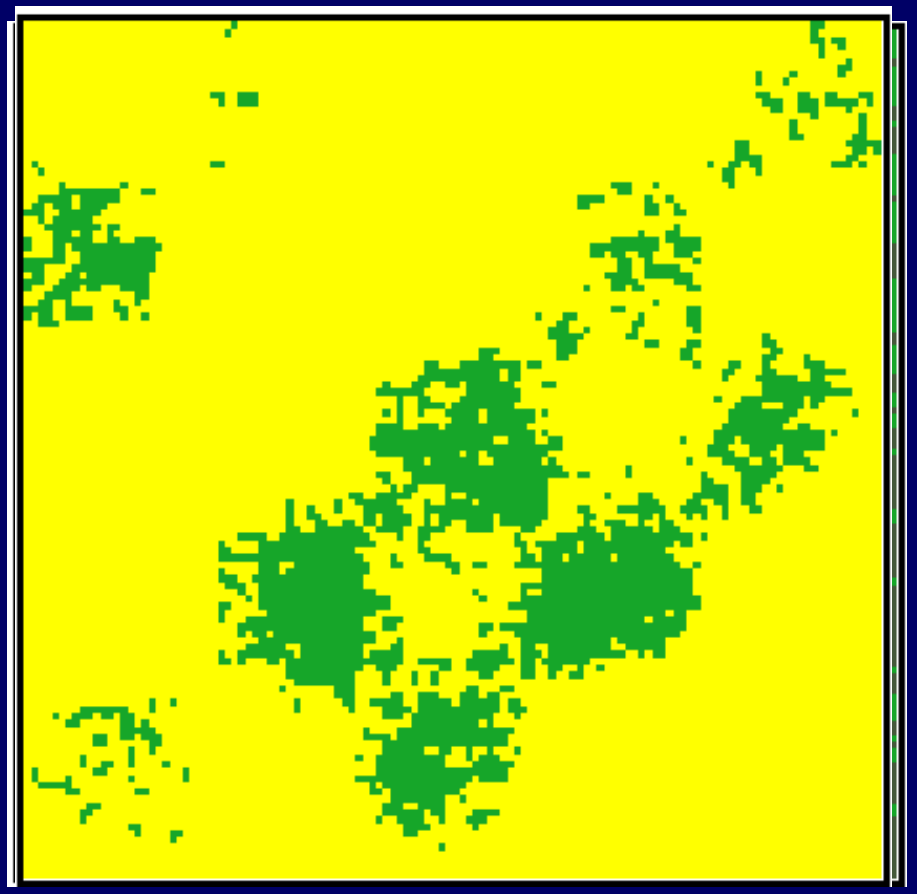


ESSF Simulations

60% removal – 25m x 25m Patches



VISTAS representation



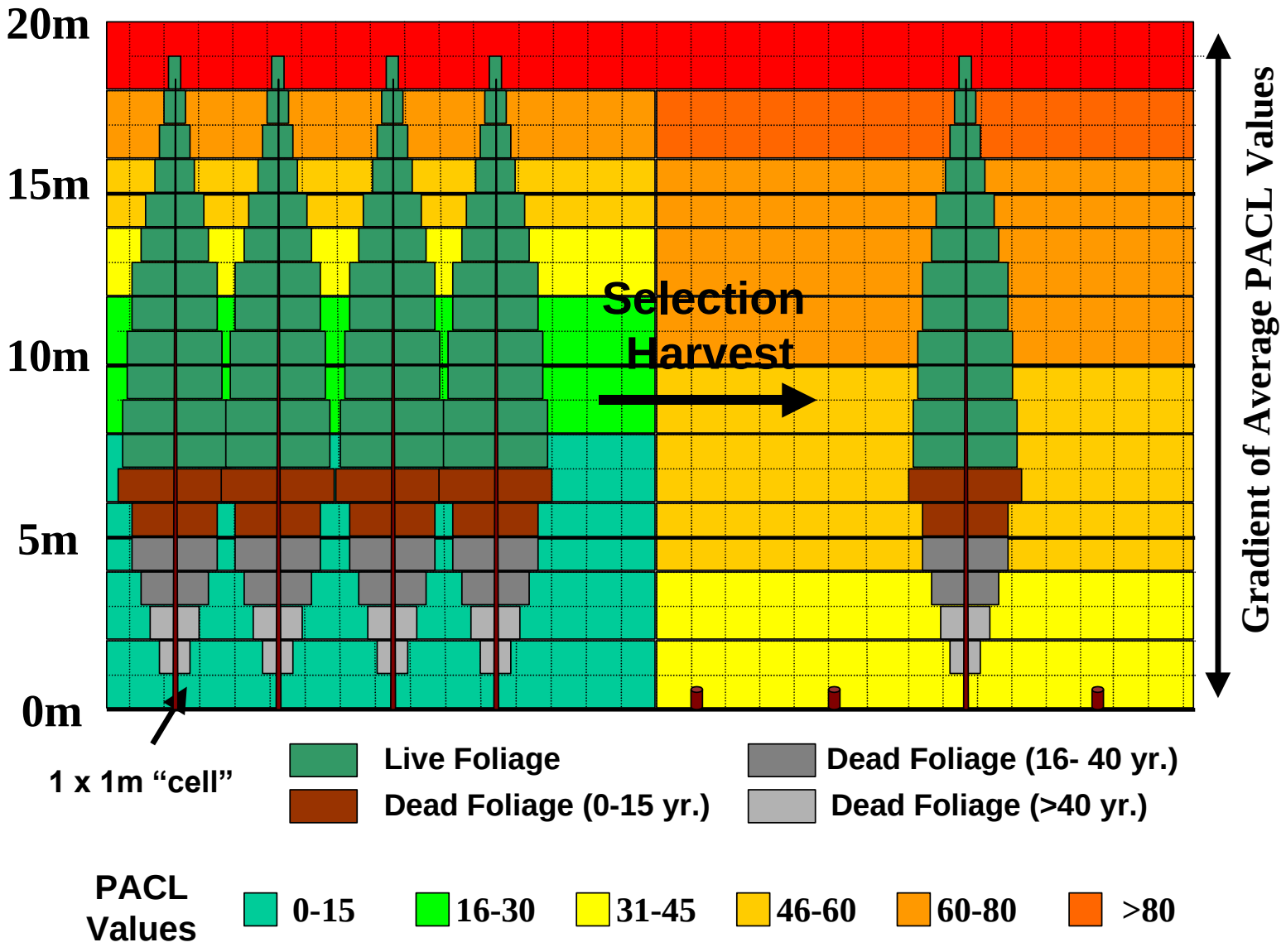
PACL at 0.5m above ground level

Engelmann Spruce

Subalpine Fir

PACL_CLASS 0.00 - 0.25 0.25 - 0.50 0.50 - 0.75 0.75 - 1.00

ESSF Simulations
Zones for live & dead branch



Concluding Remarks

There are inherent advantages and disadvantages to each of the different spatiophysical model types. Useful models can be constructed from any of these structures. The merits of the resulting model will depend on the many other decisions made about the architecture within that spatiophysical framework. Model evaluation is an essential component of the model building process and will help users differentiate the models that are useful from those that are not.