Genetic Worth in Timber Supply Analysis

Ian R. Cameron
Azura Formetrics Ltd

Role of growth and yield models in forest-level analyses

Modelling genetic gain in TIPSY and TASS

What's new?

- Context for growth and yield in forest-level analysis
- Changes in how yield curves are developed
- Implications for modelling genetic gain

Forest-Level Analyses

Timber Supply Analysis and Integrated Silviculture Strategies

- Landscape-level analyses for TSAs and TFLs
- Use whole-forest models to simulate how landscapes and fibre supply change through time

Timber Supply Analysis

- Strategic perspective, setting of allowable annual cut
- Emphasis on fibre flow
- Landscape divided into Analysis Units for modelling
- Yield predictions for analysis units: managed stands use TIPSY or TASS predictions; natural stands use VDYP predictions
- Genetic worth of planted stock is used in yield predictions for regenerated stands

Modelling Genetic Gain in TIPSY and TASS

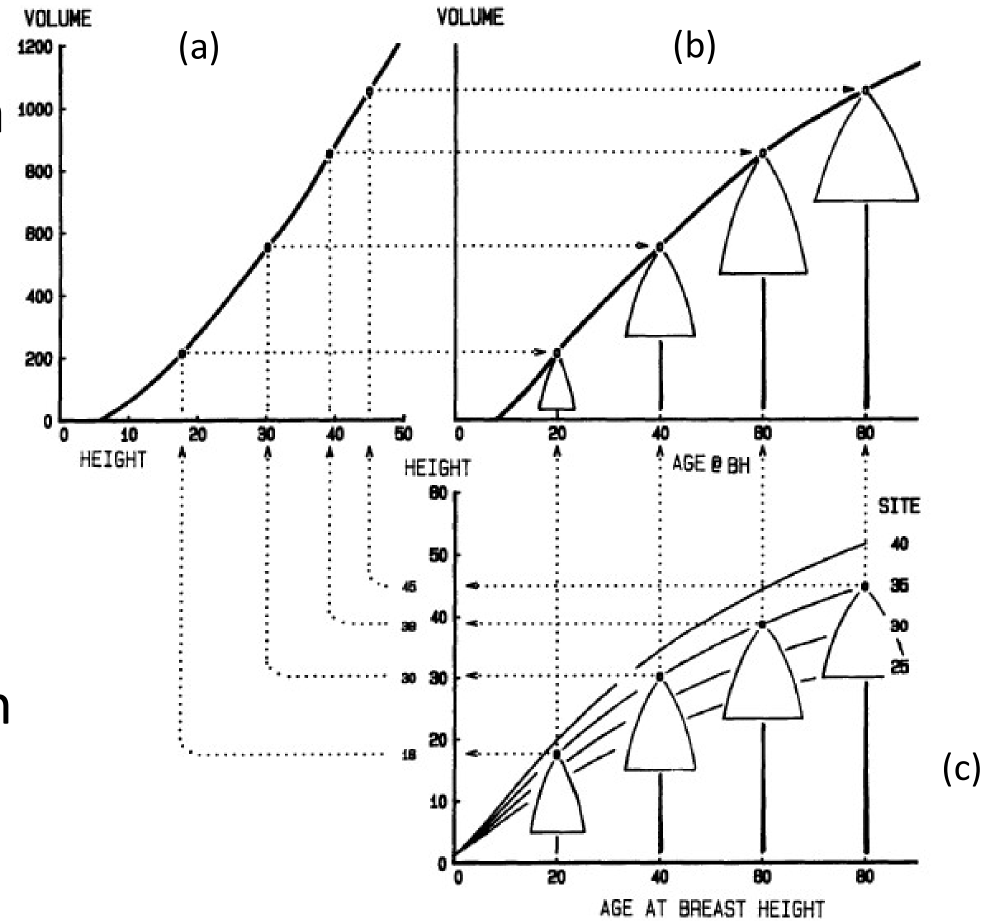
Routines built for TIPSY ~2000 and documented in Xie and Yanchuk (2003)

Involves modifying existing functions based on methods developed by forest geneticists

Genetic gain in yield is achieved by modifying the trend in Top Height

The role of Top Height in TIPSY

TIPSY tables use Top Height as the independent variable (See Volume-Height in Fig a). Transforming that to a volume-age graph for some specific site index involves using site index curves (Fig c) to predict the Top Height for some specific age. Then that predicted height is used to find the predicted Volume (Fig a), allowing the us to produce the volume-age relationship (Fig b). The GW routines in TIPSY and TASS modify the height-age curve, thereby translating height gains to volume gains.



Lambeth (1980)

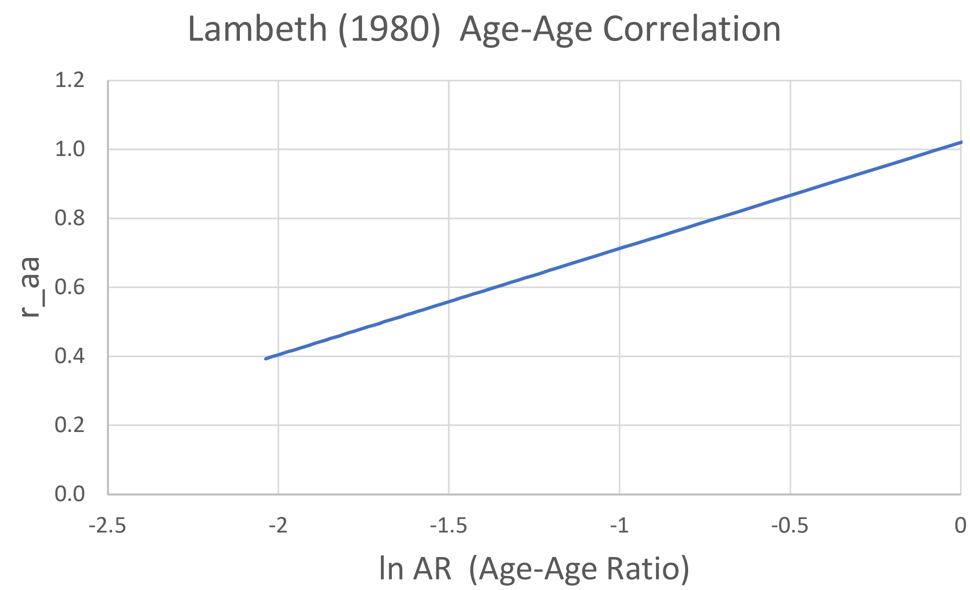
r_aa = 1.02 + 0.308 * ln AR

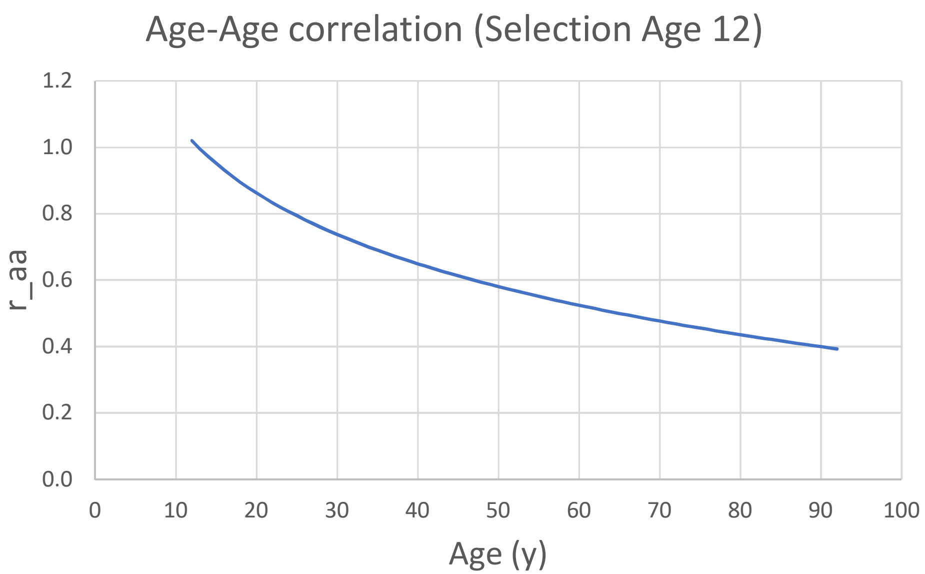
r_aa = age-age correlation

AR = As / Af

As = selection age

Af = some future age





Fixing selection age = 12 creates a relationship that's easier to understand

Lambeth's function is used to modify the height-age relationship, and TIPSY's internal routines transform that into volume gains relative to age.

Xie and Yanchuk(2003) noted that:

- GW = percent volume gain at a designated rotation or index age (Ad)
- That the relationship between height gains (GHd) and volume gains (GW) at rotation is approximately

  GHd = GW / 2

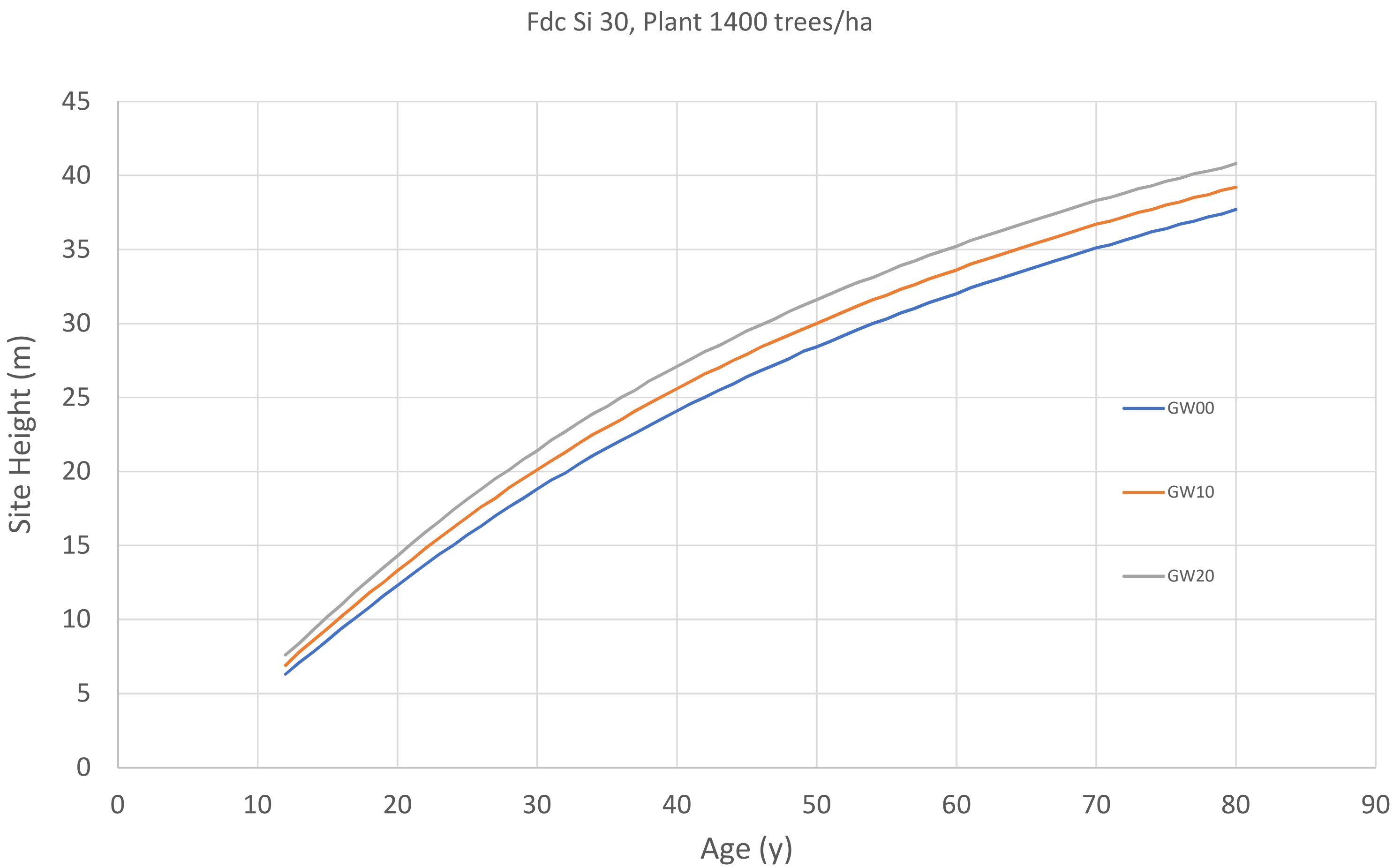
Then we can use the Lambeth function to predict the percent height gain (GHs) at selection age (As):

$$GHs = (GW/2) / [1.02 + 0.308 * \ln(As / Ad)]$$

And with that value of GHs we can predict the height gains (GHf) at any future date.

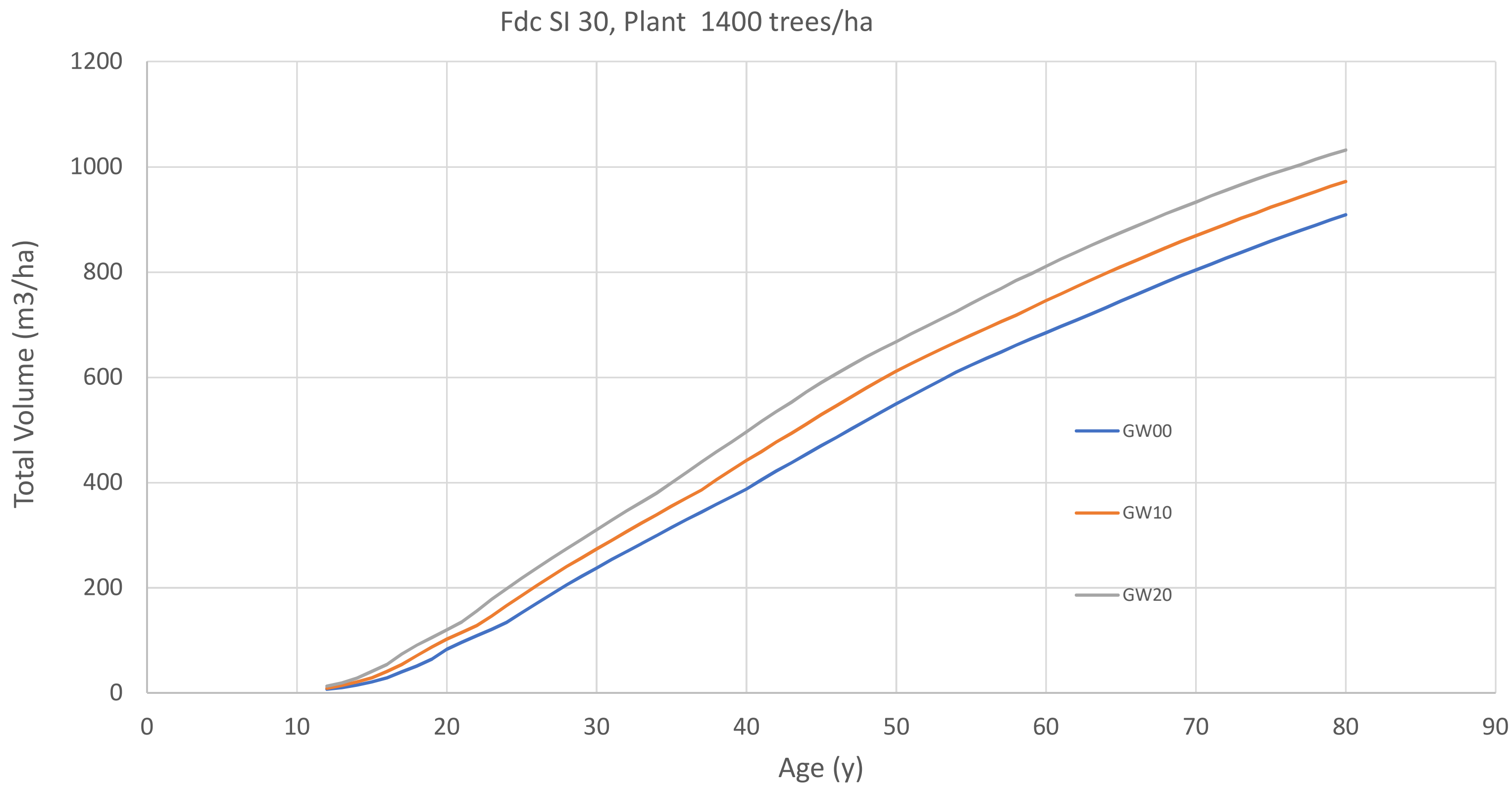
$$GHf = GHs * [1.02 + 0.308 * \ln(As / Af)]$$

Adjusted Height-Age Curves for Fdc Derived from Lambeth's function



GW = 0, 10 and 20

Yield curves for Fdc Constructed from adjusted ht-age curves GW = 0, 10 and 20



Context

Wildfires, MPB, Climate Change and their various interactions have had a large effect on forest management

For all forms of analysis, the yield predictions for regenerated stands are now more important to predictions of fibre flow than at any time in the past.

They are also under more scrutiny than at any time in the past

- data used to initiate the growth predictions
- accuracy and credibility of the models and their predictions
- data used to build and test the growth models
- Interpretation of the outputs

FAIB is implementing changes to how yield curves are constructed for Timber Supply Analysis

This includes:

- making more use of TASS rather than TIPSY

- Revisiting how the information in RESULTS is used for model inputs

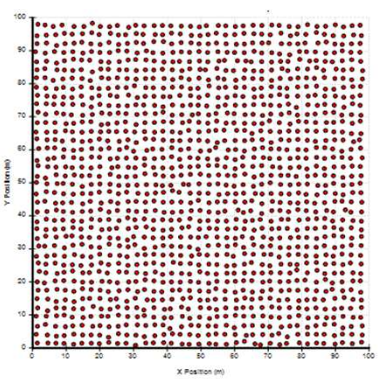
In the next section, I will show you some analysis that Eleanor McWilliams and I did to show what might be done. Genetic Worth plays a role in this.

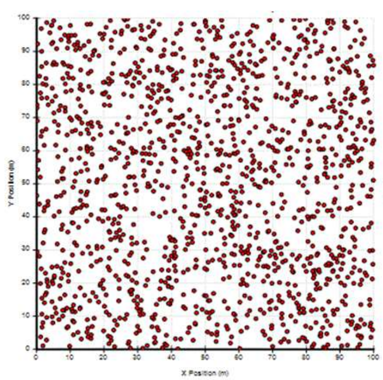
Some of our recommendations are being implemented by FAIB. One of those is that Timber Supply Analysts should use TASS rather than TIPSY to predict the future yields of stands composed of a combination of planted trees and natural ingress.

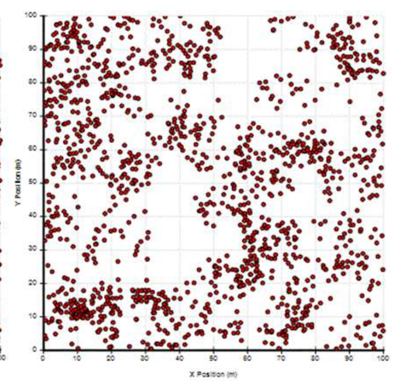
TIPSY Regeneration Methods

- TIPSY is limited to 3 regeneration methods
  - Planted
  - Natural
  - Clumped
- Each method was designed by specifying the spatial arrangement and temporal ingress pattern of the trees at establishment.

Planted	Natural	Clumped







Spatial distribution

Planted - trees are simulated on a regular (square) distribution with some random variation about the intended locations

.

Natural - trees are randomly located.

Clumped – tree locations are generated by randomly generating clump centers and then generating about 10 trees randomly around each clump.

Temporal distribution

Planted trees are all established at the same time as seedlings, and the default age for seedlings is one.

Trees in the Natural and Clumped methods come in over time, approximating a Poisson distribution with lambda = 3.18

Predicting the Yields of Stands with Both Planted Trees and Natural Regeneration

Many of the regenerated stands in BC have some combination of planted trees and natural regeneration. None of the TIPSY regeneration methods address that situation directly.

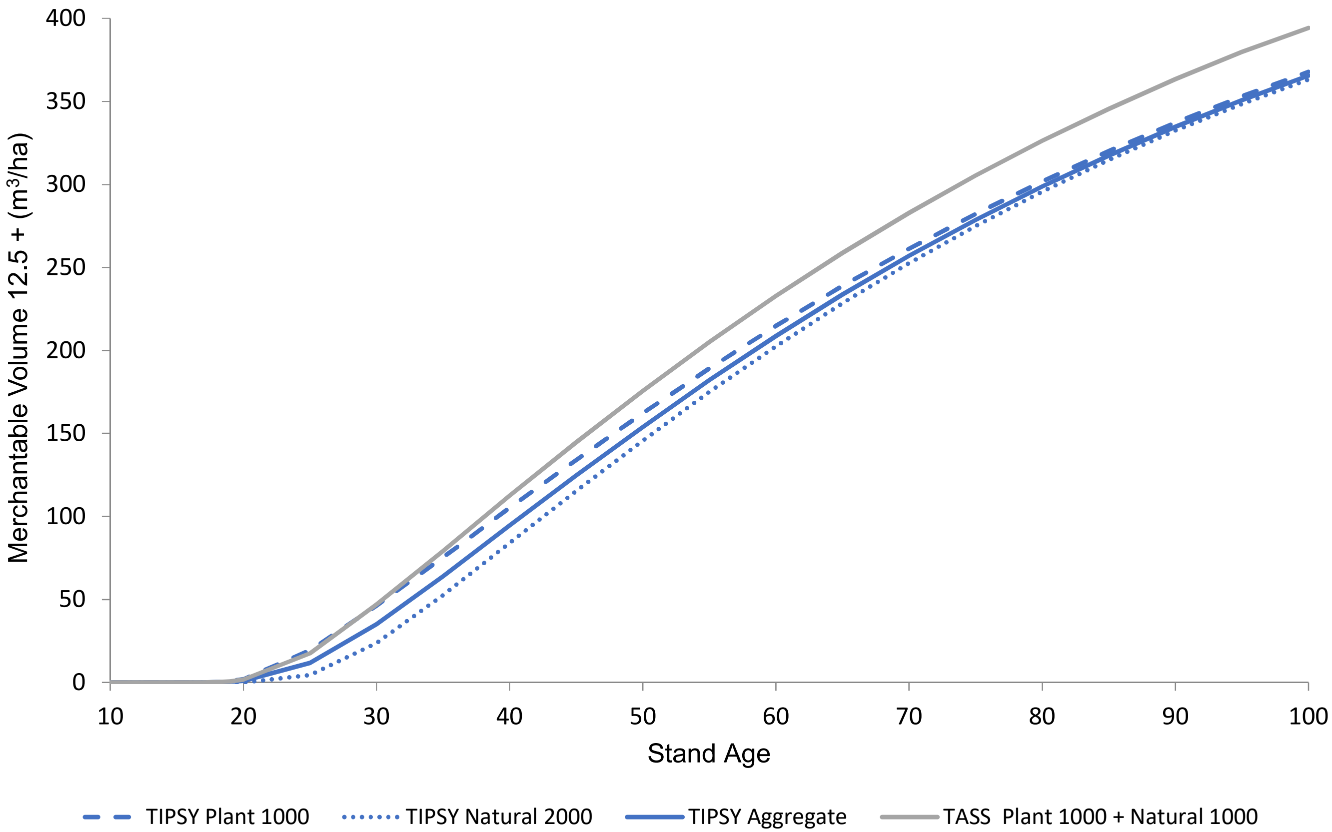
Some TIPSY users have been attempting to model the combination of planted trees and natural ingress by creating a weighted aggregate of separate TIPSY curves for natural and planted stands.

We know of a few different weighting schemes. A common one for a stand composed of P planted trees and N natural trees can be described as follows:

- Make a TIPSY prediction, (Y1), for P trees per ha with the Planted Method
- Make a TIPSY prediction, (Y2), for (P + N) trees per ha with the Natural Method.
- Make an aggregate prediction, (Y3), by combing Y1 and Y2 with the following weights
    - Y1 with weight P/(P+N)
    - Y2 with weight N/(P+N)

Such combinations of planted and natural trees can be simulated directly in TASS, with planted and natural trees growing together and competing for growing space. It is informative to compare the yield results of a simulation like this with predictions created via the TIPSY weighting method.

Predicting the Yields of Stands with Both Planted Trees and Natural Regeneration



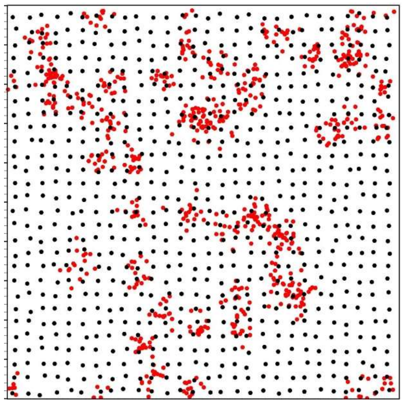
The blue lines show the two TIPSY components and the weighted combination.

Y1: TIPSY Planted (blue dashed)
Y2: TIPSY Natural (blue dotted)
Y3: Aggregate (blue solid)

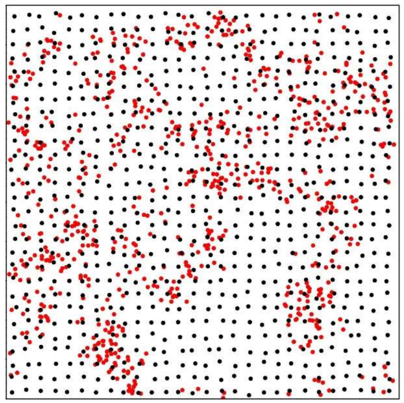
The aggregate curve is intermediate between the two components.
The more realistic prediction from TASS (black solid) is above them all. Logically, adding more trees to a planted stand your increase yield, not reduce it.

TASS Spatial Patterns

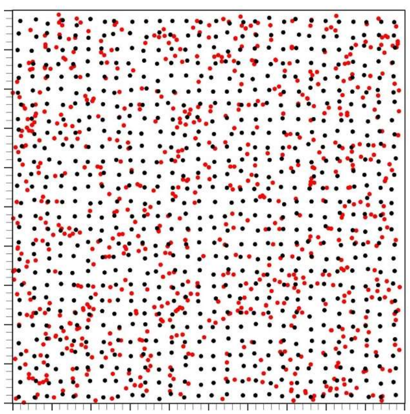
Planting + Heavily Clumped Regen



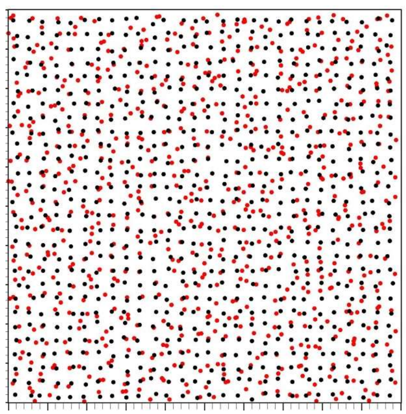
Planting +Clumped Regen



Planting + Random Regen

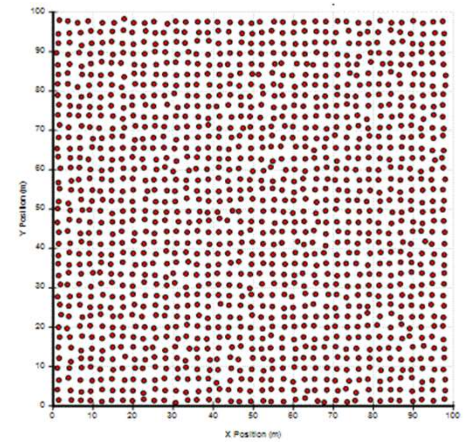


Planting + Uniform Regen

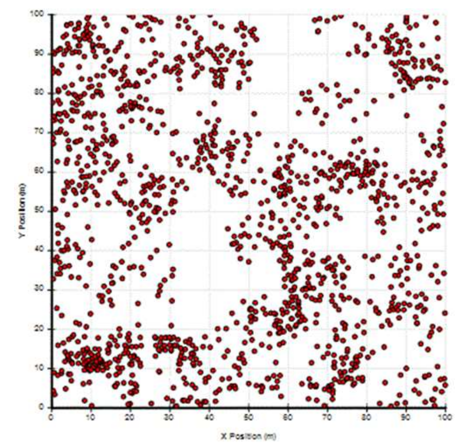


TIPSY Regeneration Methods

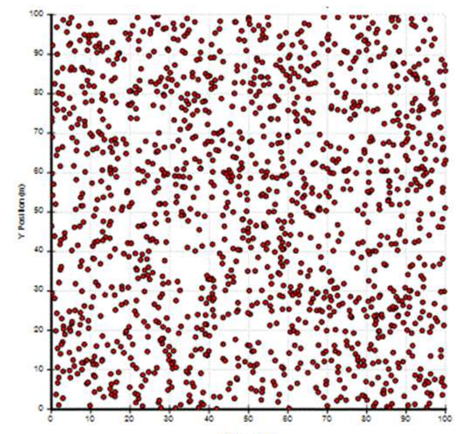
Planted



Clumped

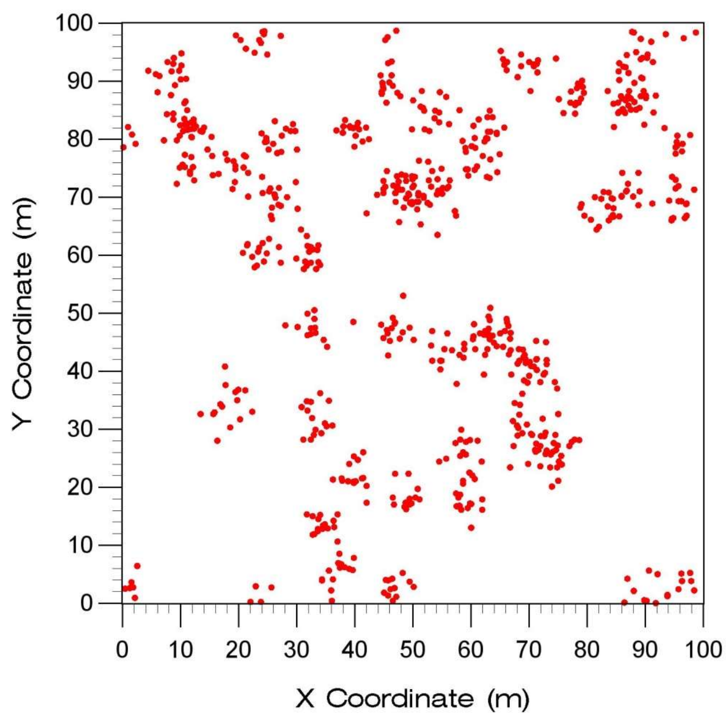


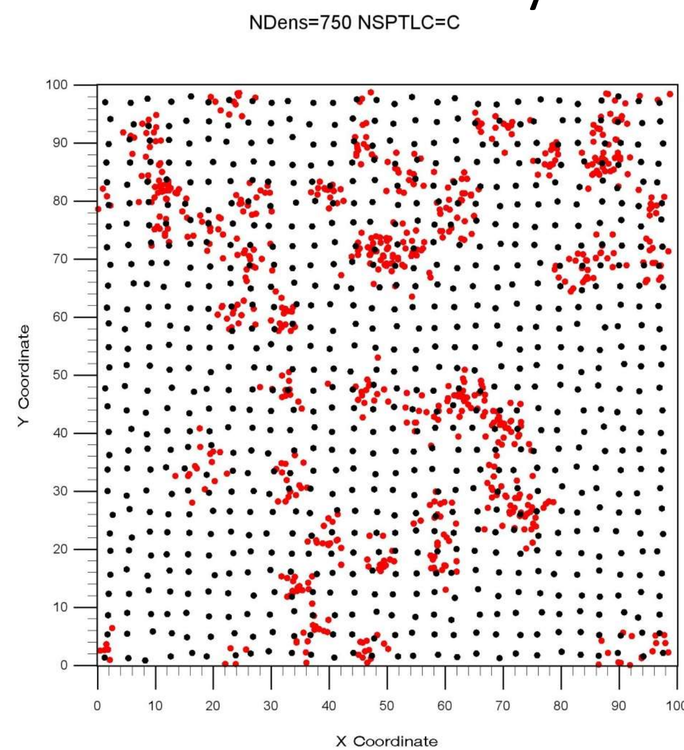
Natural



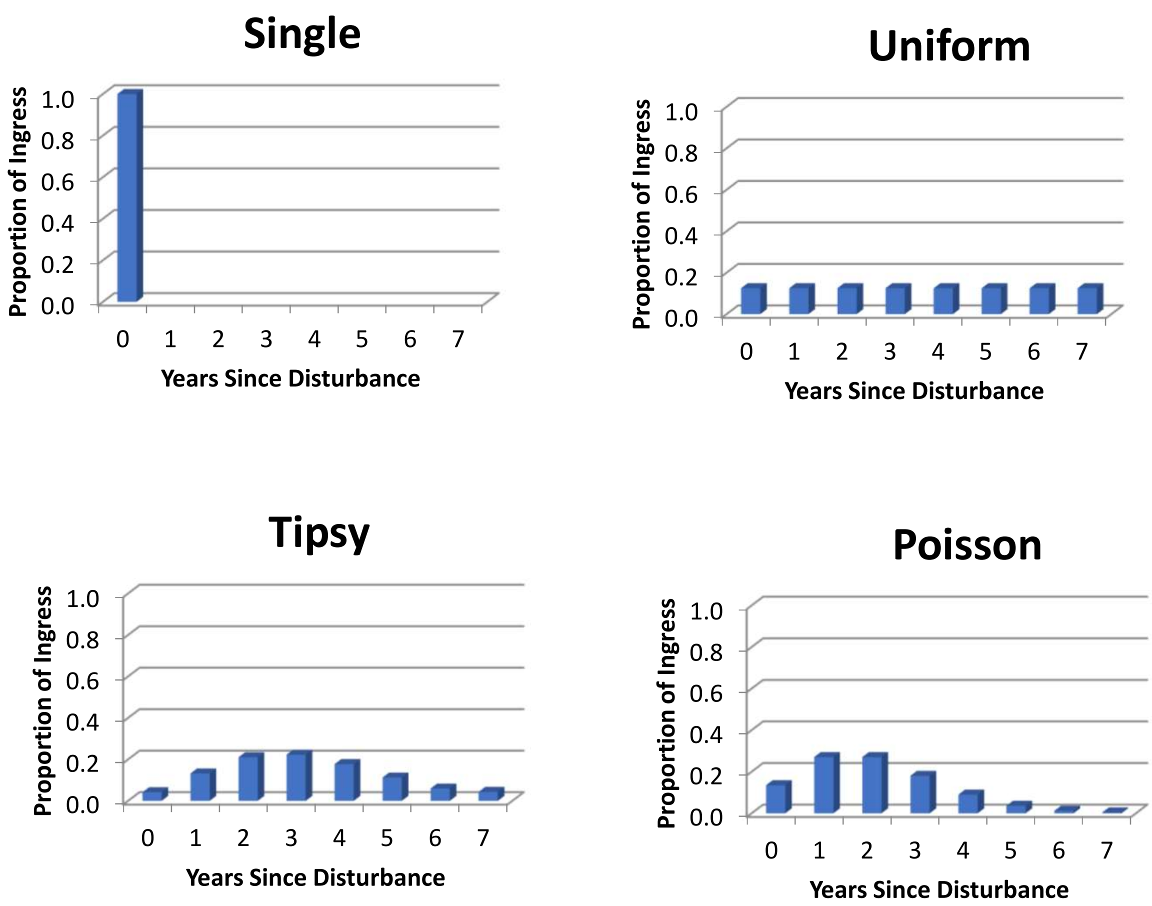
Clumped ingress (red dots) without and with planted trees (black dots)

The major difference is the large areas of unoccupied space on the left.
The yield predictions for these two scenarios are dramatically different.



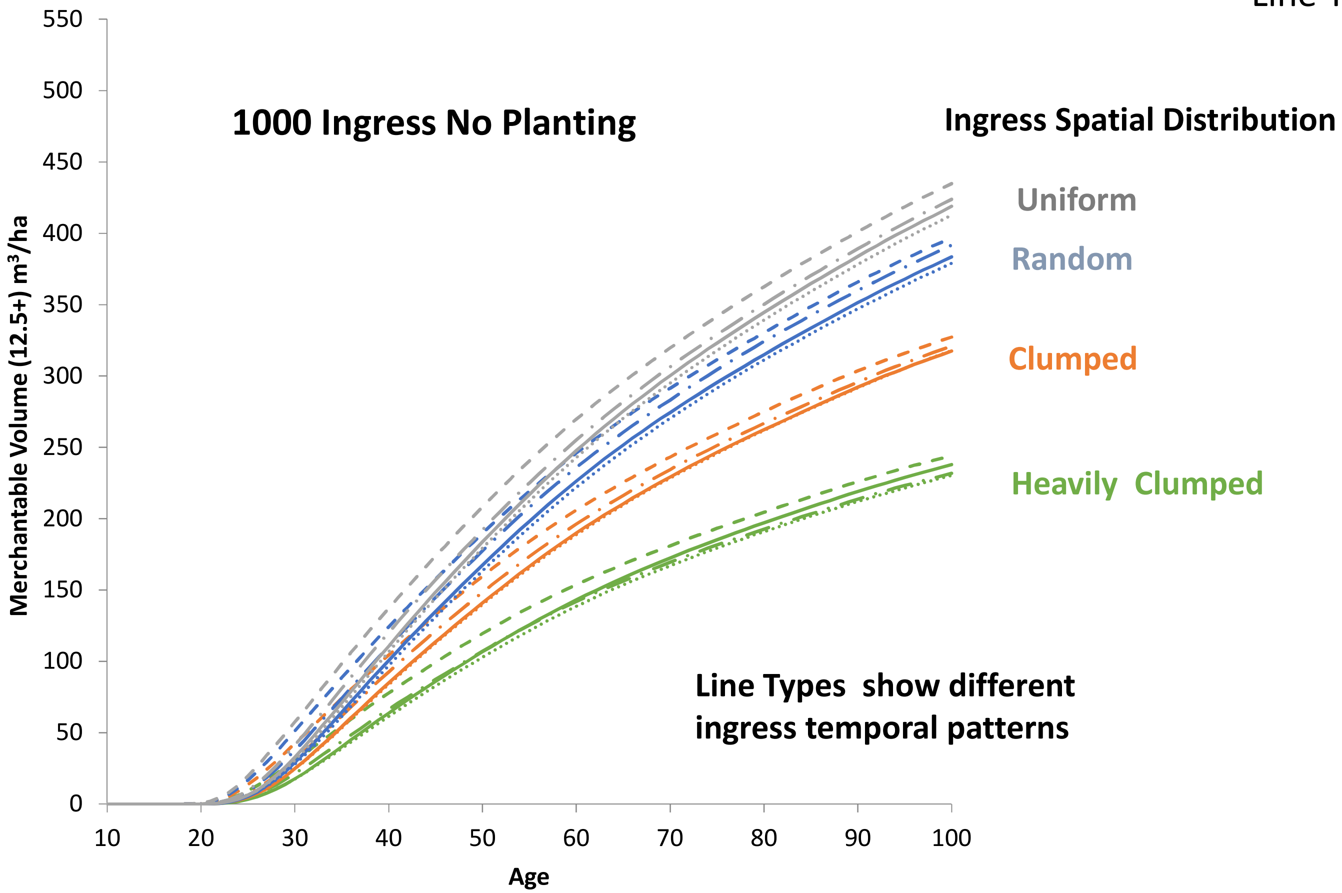


Examples of Temporal Patterns for Ingress



Effects of Spatial and Temporal Patterns on Yield

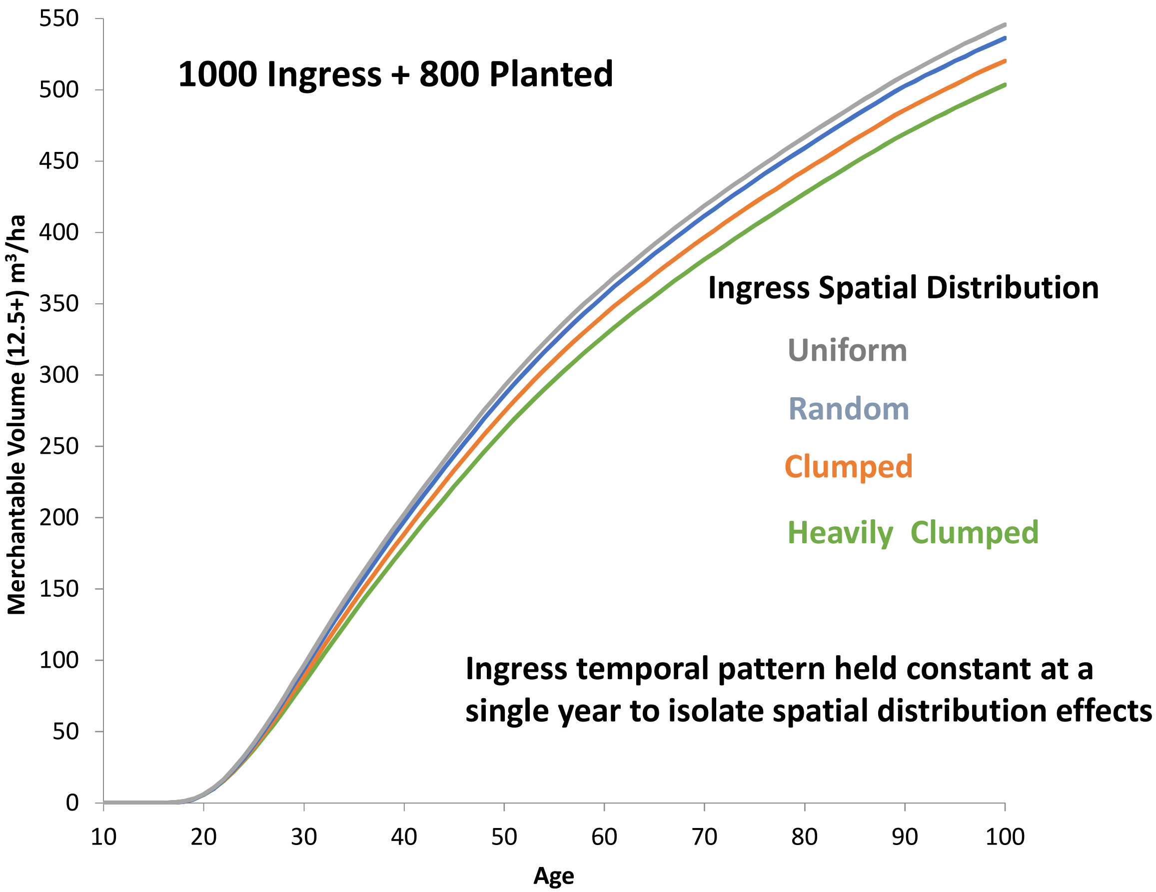
Colours denote different spatial patterns.
Line Types indicate different temporal patterns



We have very little information about the real patterns of spatial and temporal variation in our regenerated stands. When using TASS to produce yield curves for Timber Supply Analysis, users need some guidance about spatial and temporal distributions.

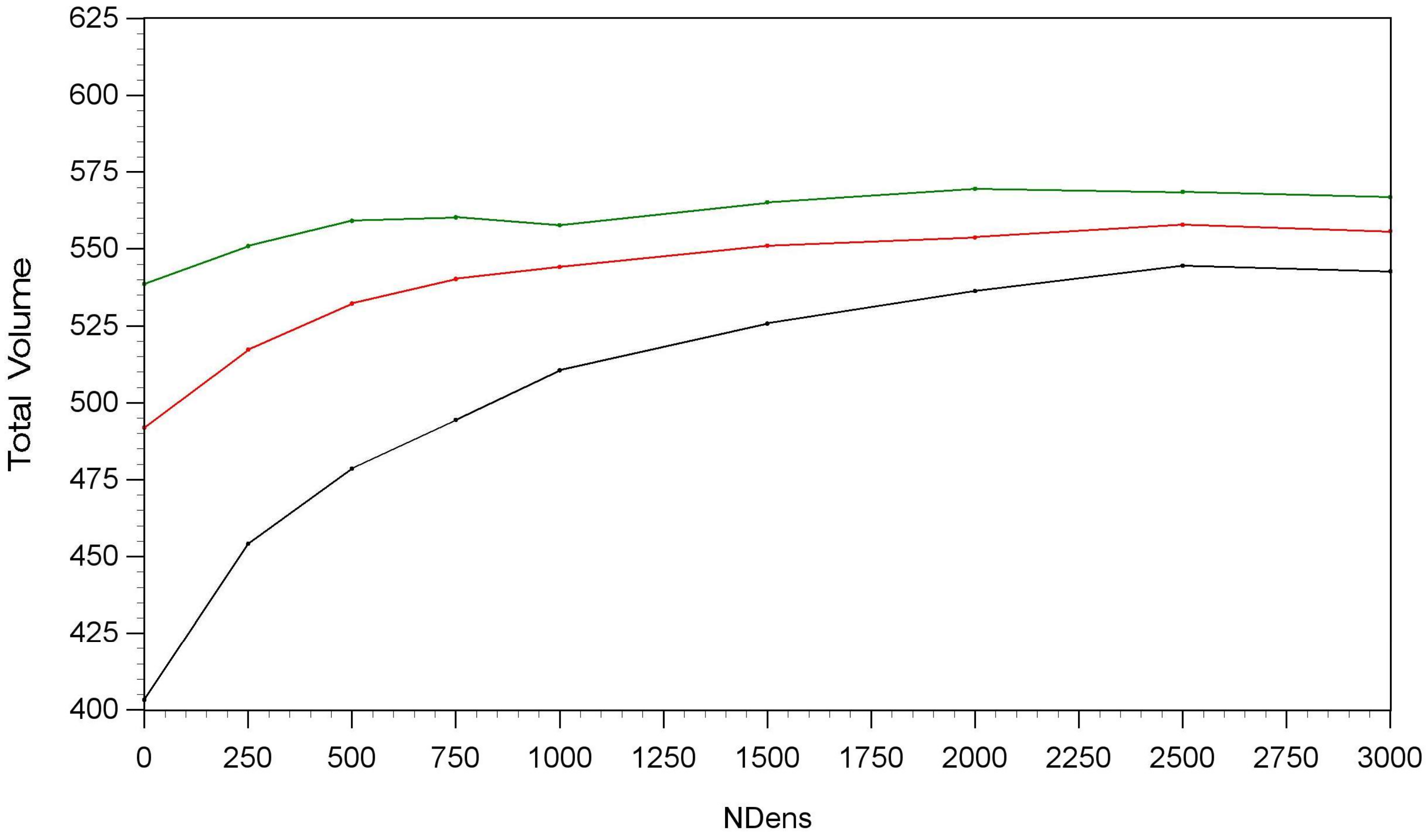
Simulations like this suggest that yields are more sensitive to the assumptions about spatial distribution of regeneration than assumptions about the temporal distribution of ingress.

Effects of Spatial and Temporal Patterns on Yield



For planted stands, yields are much less sensitive to the spatial distribution of regeneration – even when the planting density is as low as 800 tree per ha.

Yield at Age 80 with different combinations of Planted and Natural Trees



Green 1600/ha Planted

Red 1200/ha Planted

Black 800/ha Planted

Lines show the yield at age 80 that could be achieved with different amounts of natural regeneration added to some fixed planting density.

The natural regeneration has the most effect when the planting density is low (800/ha) and the least when the planting density is high (1600/ha)

BSCAF1

% Gain in Vol 12.5+ at Age 80 from 1000 Ingress – Pl SI 19

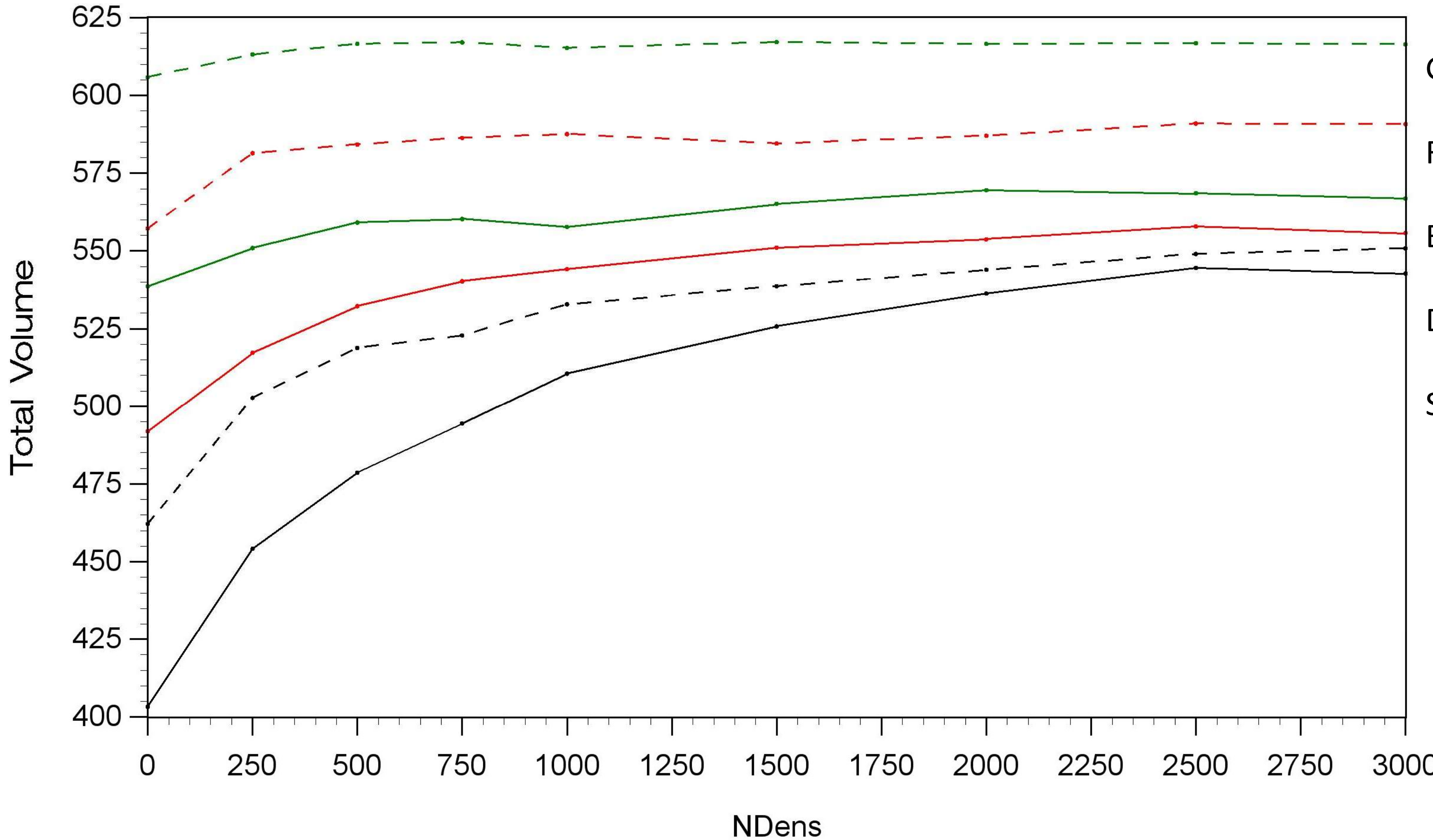
	Temporal Pattern	
Spatial Pattern	**TIPSY**	**Single**
	800 Planted No GW	
Highly Clumped	15.0	16.7
Clumped	17.2	21.1
Random	19.6	25.4
Uniform	22.0	27.5
	1600 Planted No GW	
Highly Clumped	2.4	2.8
Clumped	2.7	3.3
Random	2.8	3.3
Uniform	3.0	3.7

Slide 20

BSCAF1 Is a graph missing before this slide? i.e. the 1600 planted scenario?

Bealle Statland, Catherine A FLNR:EX, 2019-02-21

Yield at Age 80 with different combinations of Planted and Natural Trees



Green 1600/ha Planted

Red 1200/ha Planted

Black 800/ha Planted

Dashed GW=20

Solid -- wild seed

The beneficial effects of natural regeneration are diminished when the planted trees have GW=20. Planted trees with GW grow much faster than the natural regen, leading to high levels of mortality in the regen.

% Gain in Vol 12.5+ at Age 80 from 1000 Ingress – Pl SI 19

	Temporal Pattern				
Spatial Pattern	**TIPSY**	**Single**		**TIPSY**	**Single**
	800 Planted No GW			*800 Planted 18% GW*	
Highly Clumped	15.0	16.7		7.9	9.6
Clumped	17.2	21.1		9.3	11.4
Random	19.6	25.4		10.0	12.8
Uniform	22.0	27.5		10.6	15.0
	1600 Planted No GW			*1600 Planted 18% GW*	
Highly Clumped	2.4	2.8		1.1	0.9
Clumped	2.7	3.3		0.5	0.6
Random	2.8	3.3		0.9	1.0
Uniform	3.0	3.7		1.0	0.8

Summary

The mountain pine beetle and recent forest fires have dramatically reduced the stock mature timber in BC.

Yield predictions for regenerated stands now play a more important role in the predictions of future fibre supply than they did in the past. Yield predictions for genetically improved stock will be a key component.

FAIB will be relying more and more on TASS predictions for Timber Supply Analysis.

TASS predictions of genetically improved stock will show yield increases that are similar to those in TIPSY. Genetically improved stock will continue to be important for contributing enhanced volumes

Summary (cont'd)

TASS predictions of genetically improved stock will show yield gains that are similar to those found in TIPSY.

Simulations of stands with both planted trees and natural regeneration indicate that natural regeneration can augment the yield from planted stands, especially if planting densities are low.

Additional simulations with genetically improved planting stock indicate that trees with high genetic worth outcompete the natural regeneration resulting in higher mortality of the natural regeneration.

This suggests that future yields from such stands will depend more on the growth and survival of planted trees, with less contribution from natural ingress.