Looking ahead: Will Free-growing stands produce the volumes we expect?

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December, 2009

Planning for the future

- What do we want our forests to look like?
- After harvesting a stand or group of stands, we usually reforest them so that we can get . . . ??
- What is our target/goal?

- We must make decisions **now** hoping that they will have the right long-term effect.

From here to there?

- How do we assess how recently reforested areas are doing? Whether we are likely to get the desired volume from that stand(s)?
- This means that we want a way to measure how a stand is doing NOW in order to predict whether we are likely to get the desired outcome at rotation.
- I am going to talk about which measure of density sampled NOW will do the trick.
- This is more of a “methods” talk.

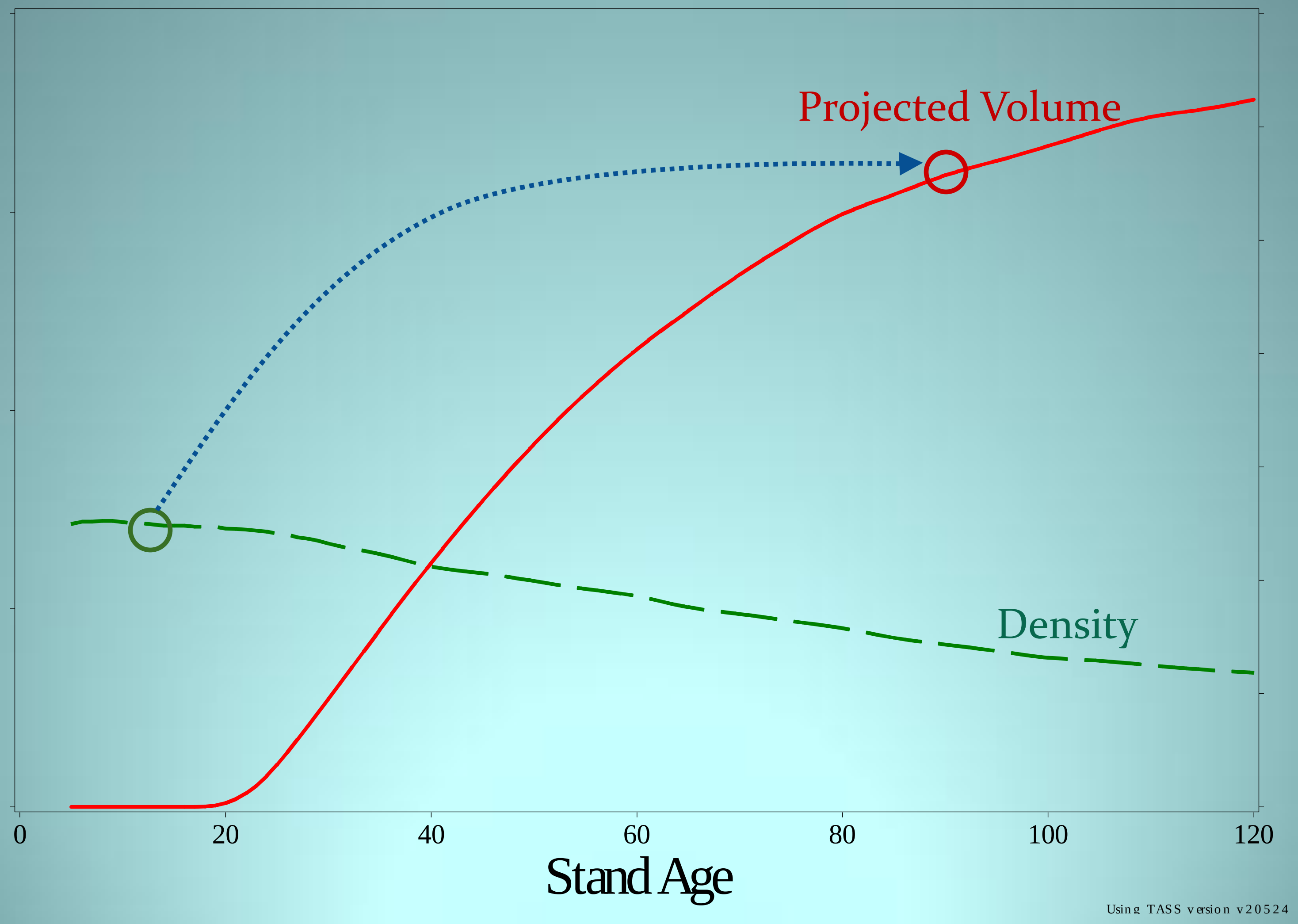
Key Messages

- TASS and TIPSY now have well-spaced density, free-growing density, and mean stocked quadrants as **output** variables.
  - Can use to project volume at rotation
  - Modeling young stands still hampered by lack of information on:
    - Ingress
    - Forest Health
    - Vegetation Competition
    - Mixed species and uneven aged stands

Key Messages

- **Spatial distribution** is very important when projecting volumes at rotation for current densities.
- So is **Site Index**.
- Under optimum conditions, well-spaced density 10 to 20 years after FG declaration should be about the same. The free-growing density might actually increase.
- Modeling stand dynamics with TASS and TIPSY require a **good understanding of the assumptions** that must be made.

Density & Volume with Stand Age



Factors affecting the prediction of projected merchantable volume as a function of density include:

- Species
- Site Index
- Spatial Distribution
- Growth Model used
- Health Effects
- Competition
- Unexpected events (e.g. MPB)
- Other factors?

Discussion Assumptions

- Spatially homogeneous, even-aged stands.
- No brush or competition issues
- No forest health issues or unexpected events
- No OAFs
- Minimum inter-tree distance (MITD) is 2.0 m
- Minimum height to be free-growing is 2.0 m
- Well-spaced and free-growing density are all "uncapped" estimates.

Discussion Assumptions

- Preliminary results
  – **I reserve the right to correct**, if necessary

- Look at the TRENDS, not the specific numbers

- The TRENDS are more likely to remain the same under a different set of assumptions than would the specific numbers presented.

LAND MANAGEMENT HANDBOOK

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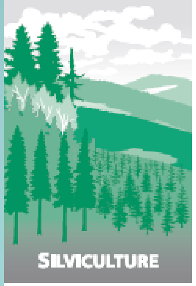
The Effect of the Silviculture Survey Parameters on the Free-Growing Decision Probabilities and Projected Volume at Rotation



2002

BRITISH COLUMBIA

Ministry of Forests
Forest Science Program

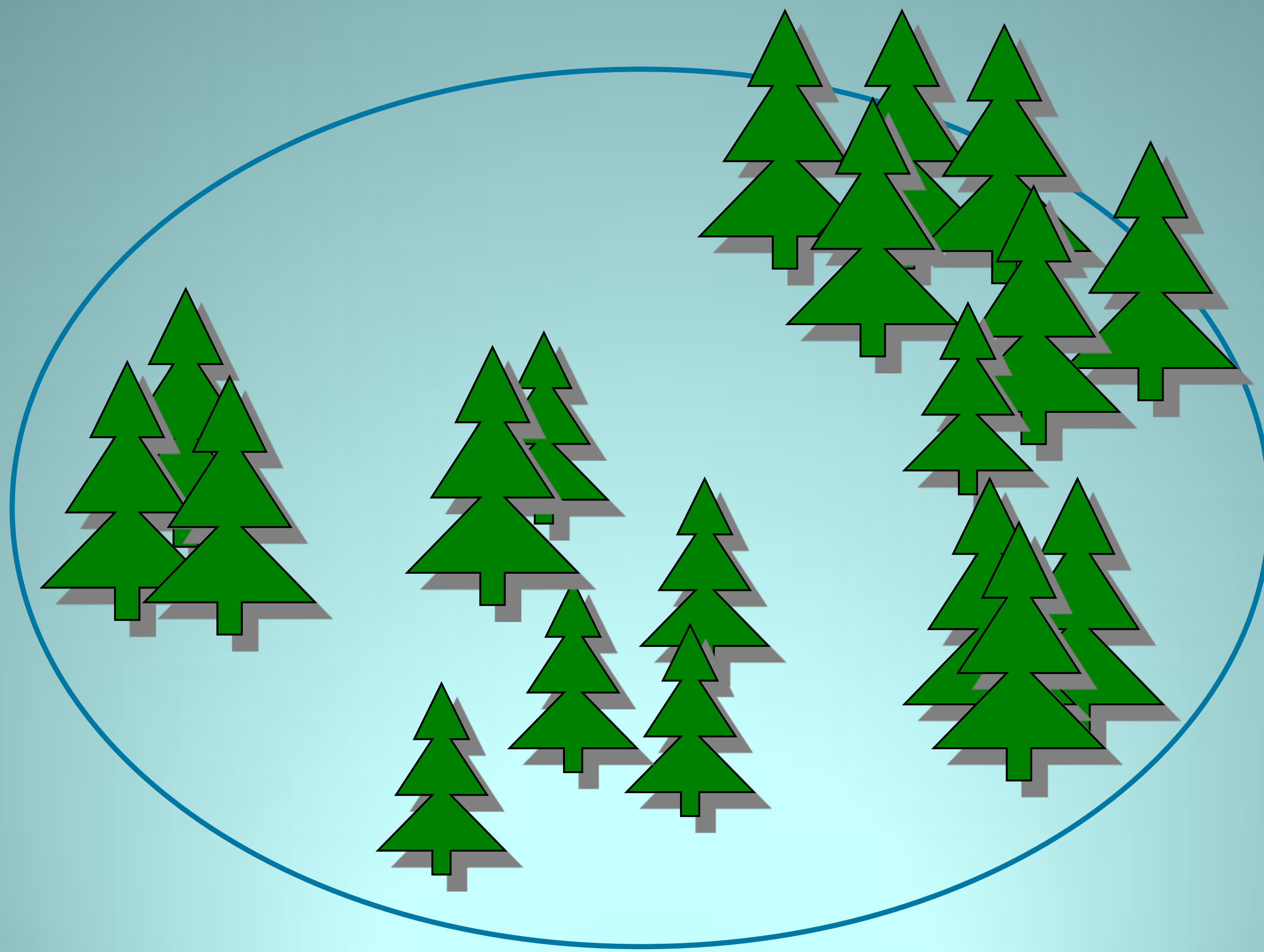
Different Types of Density

- Nominal - TASS input (often called Initial density)
- Total - All trees (regardless of spacing)
- Well-spaced - depends on choice of MITD
- FG - Well-spaced with height restriction
- MSQ – Mean stocked quadrant

(All count only acceptable trees)

Total Density

All trees or all healthy trees



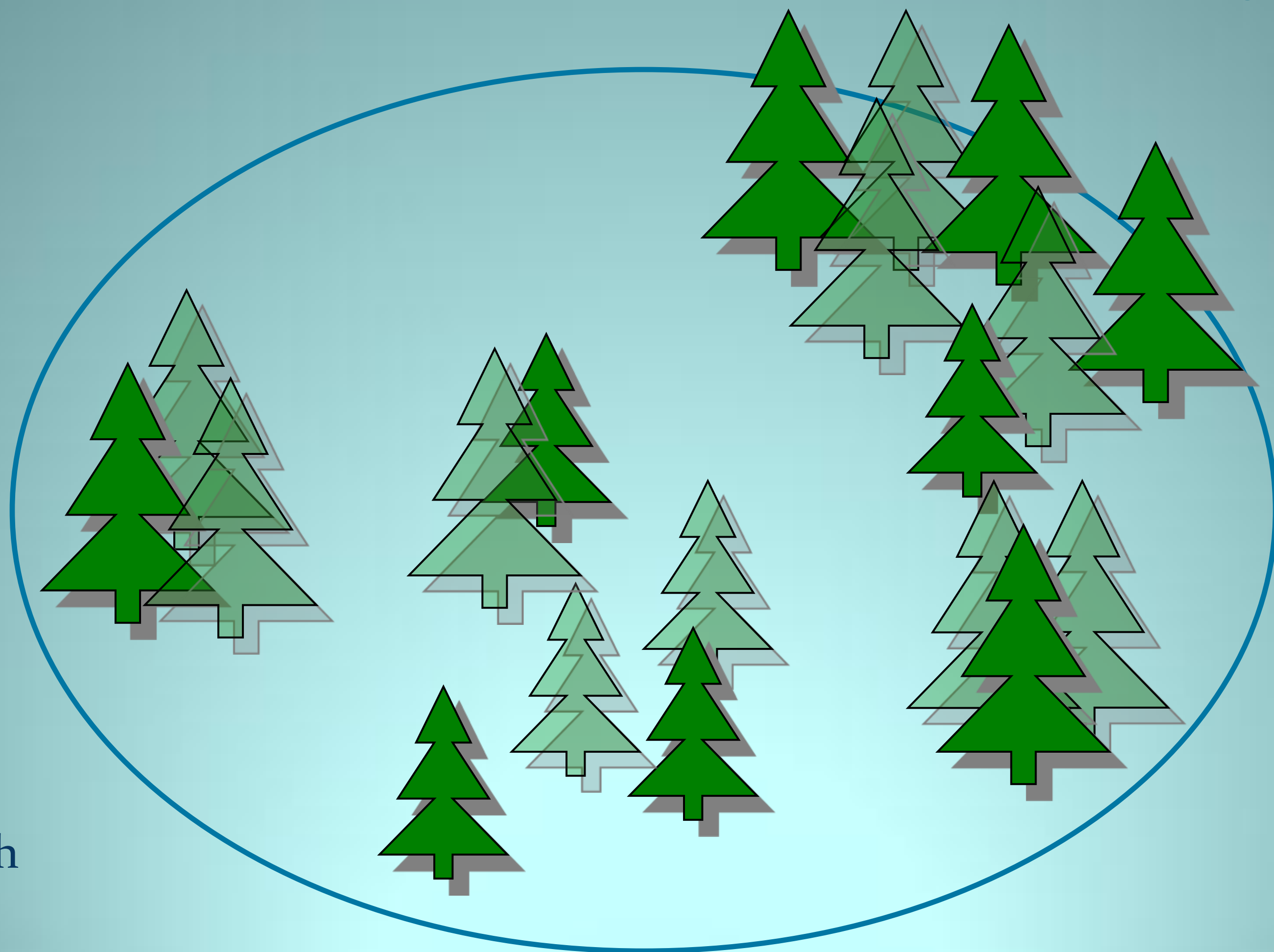
Total:
19 trees
3800 sph

50 m^2 plot

2 m

Well-spaced Density

All trees a Minimum Inter-tree Distance (MITD) apart



WSP:
9 trees
1800 wsph

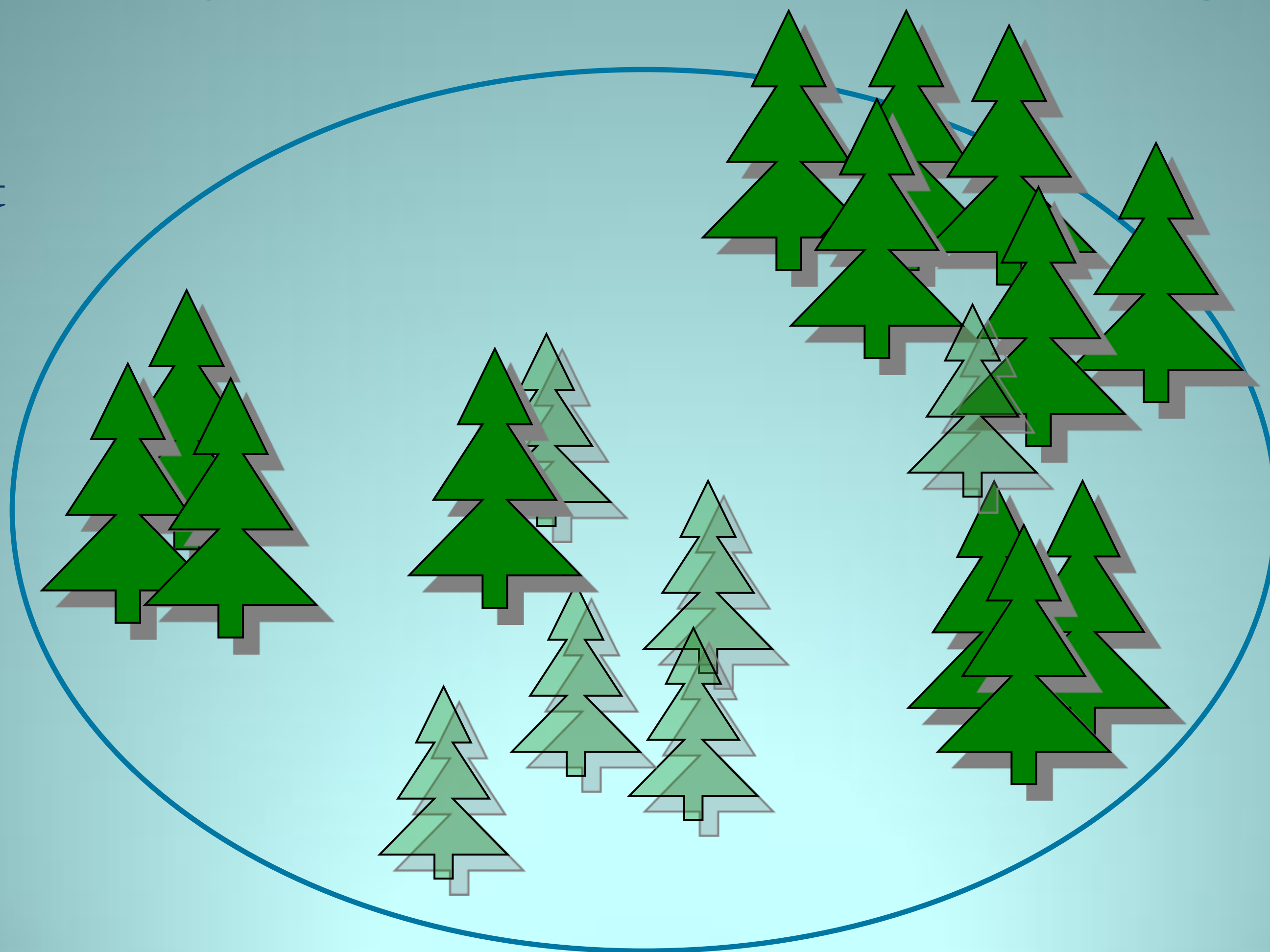
50 m^2 plot

2 m

Free-growing Density

Well-spaced trees taller than a minimum height

Remove
Short
Trees First



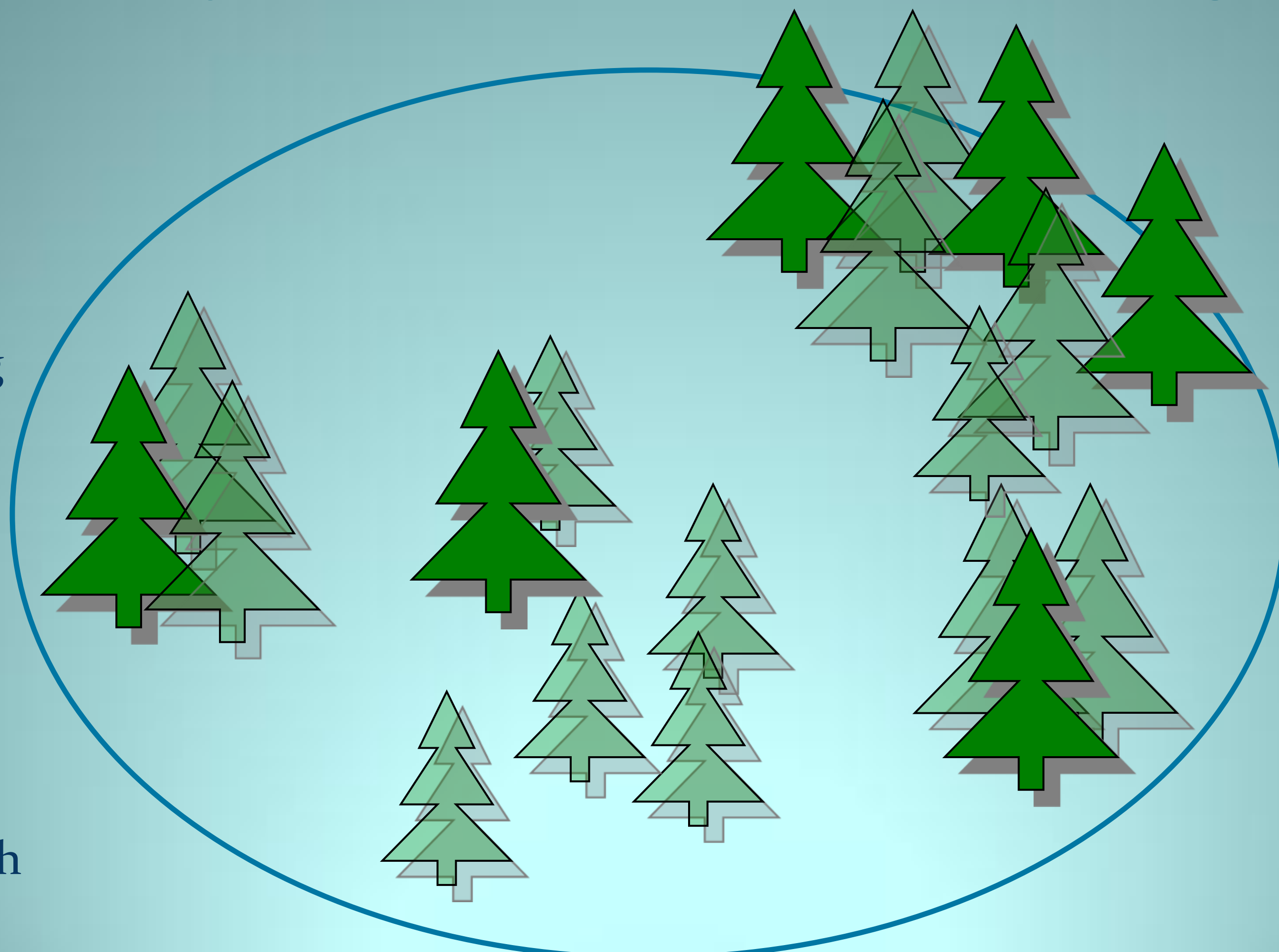
50 m² plot

2 m

Free-growing Density

Well-spaced trees taller than a minimum height

Now look at the well-spaced trees remaining



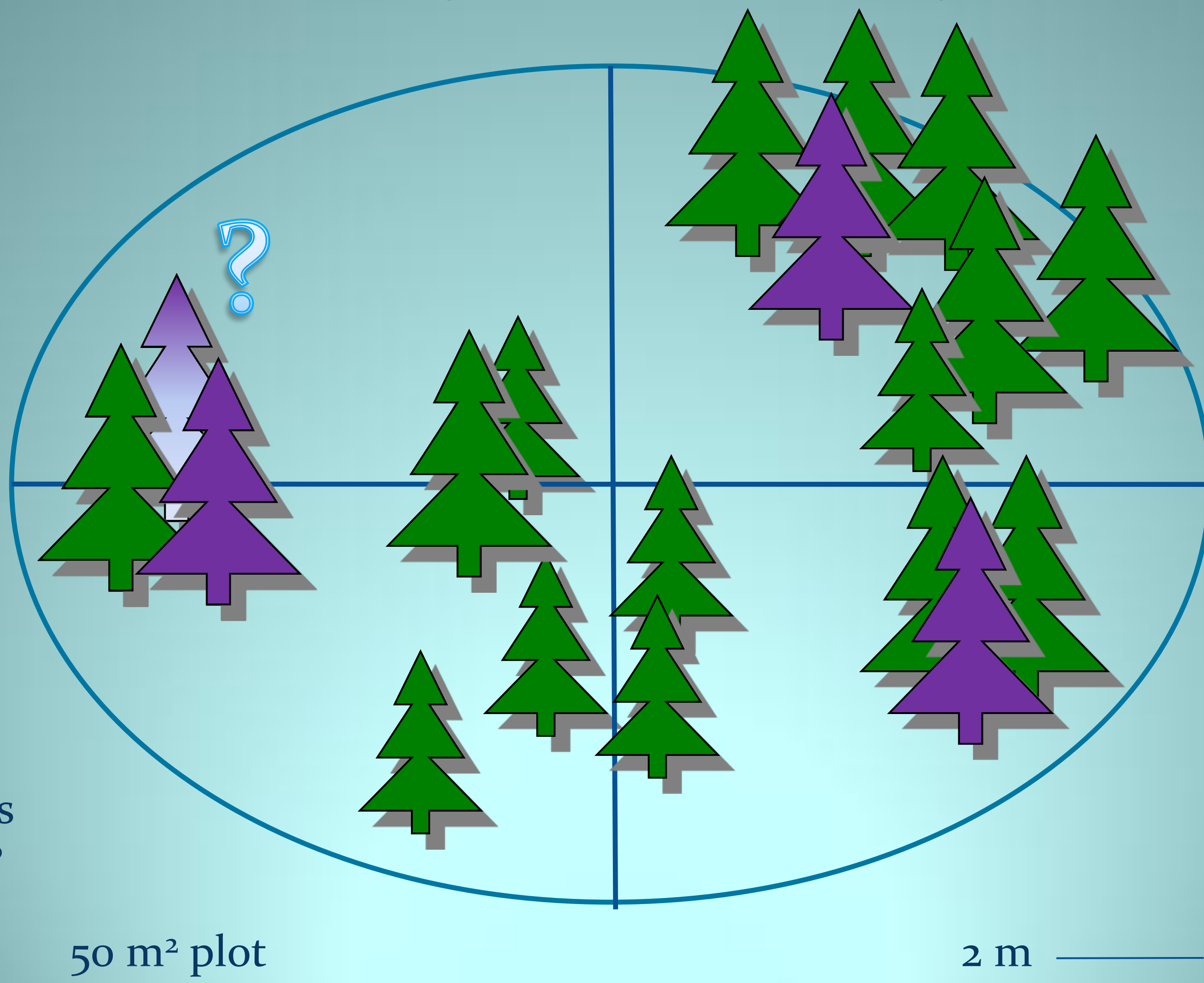
FG:
6 trees
1200 fgsph

50 m² plot

2 m

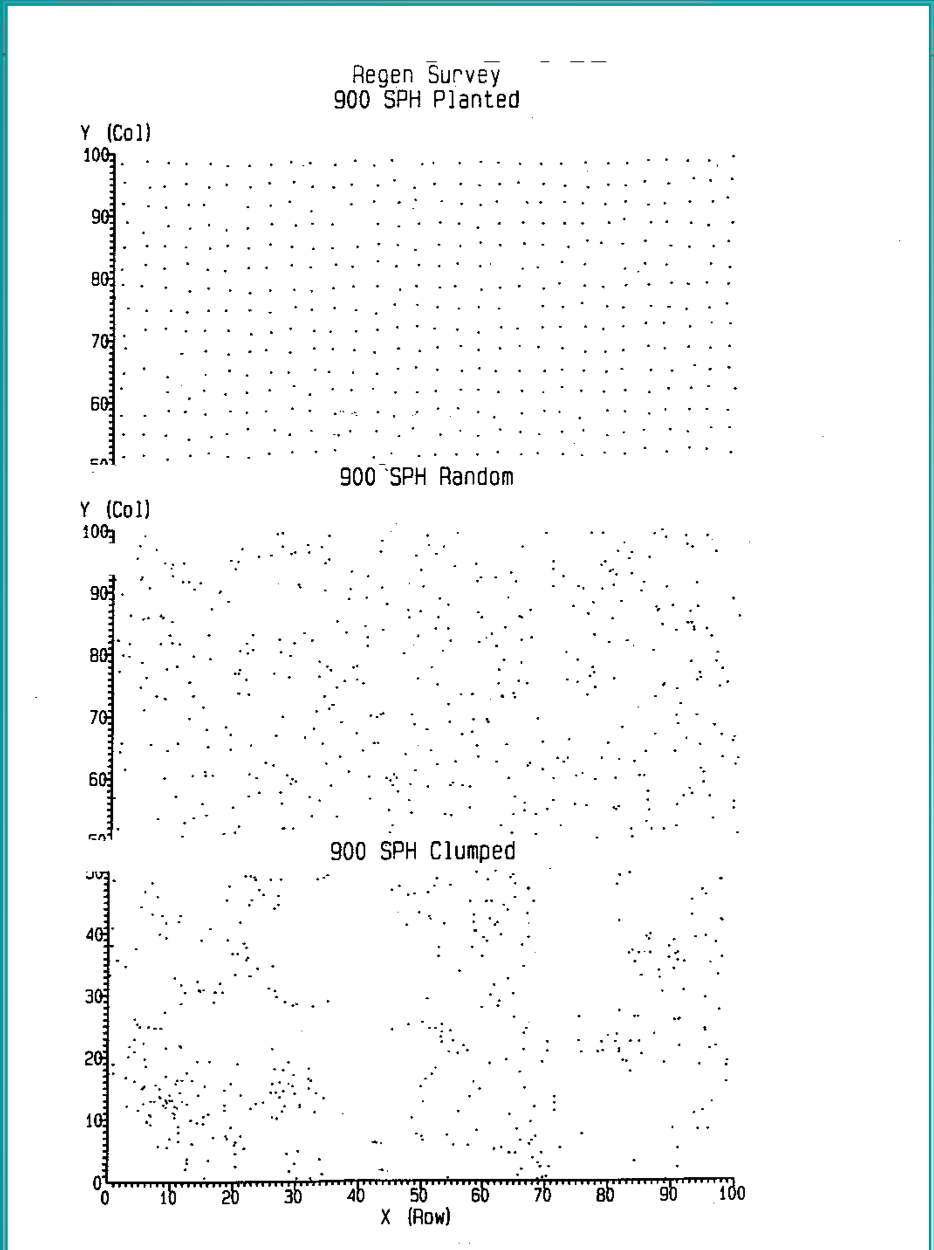
Mean Stocked Quadrant (MSQ)

Count of acceptable tree in each quadrant



MSQ:
3 filled
quadrants
or, is it 4?

50 m² plot



Example Density Map showing spatial distributions

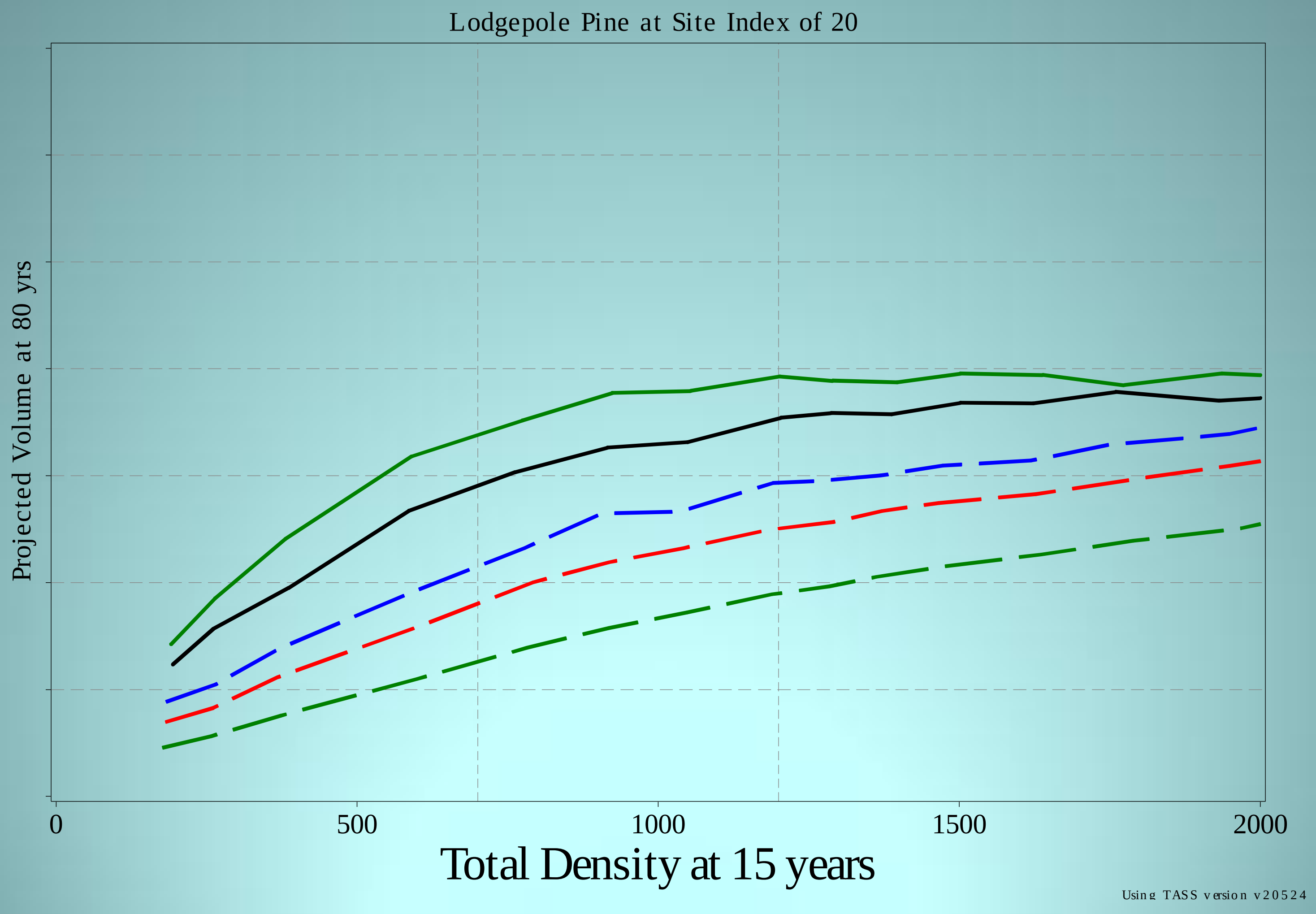
900 sph (nominal density)

Which type of Density to use?

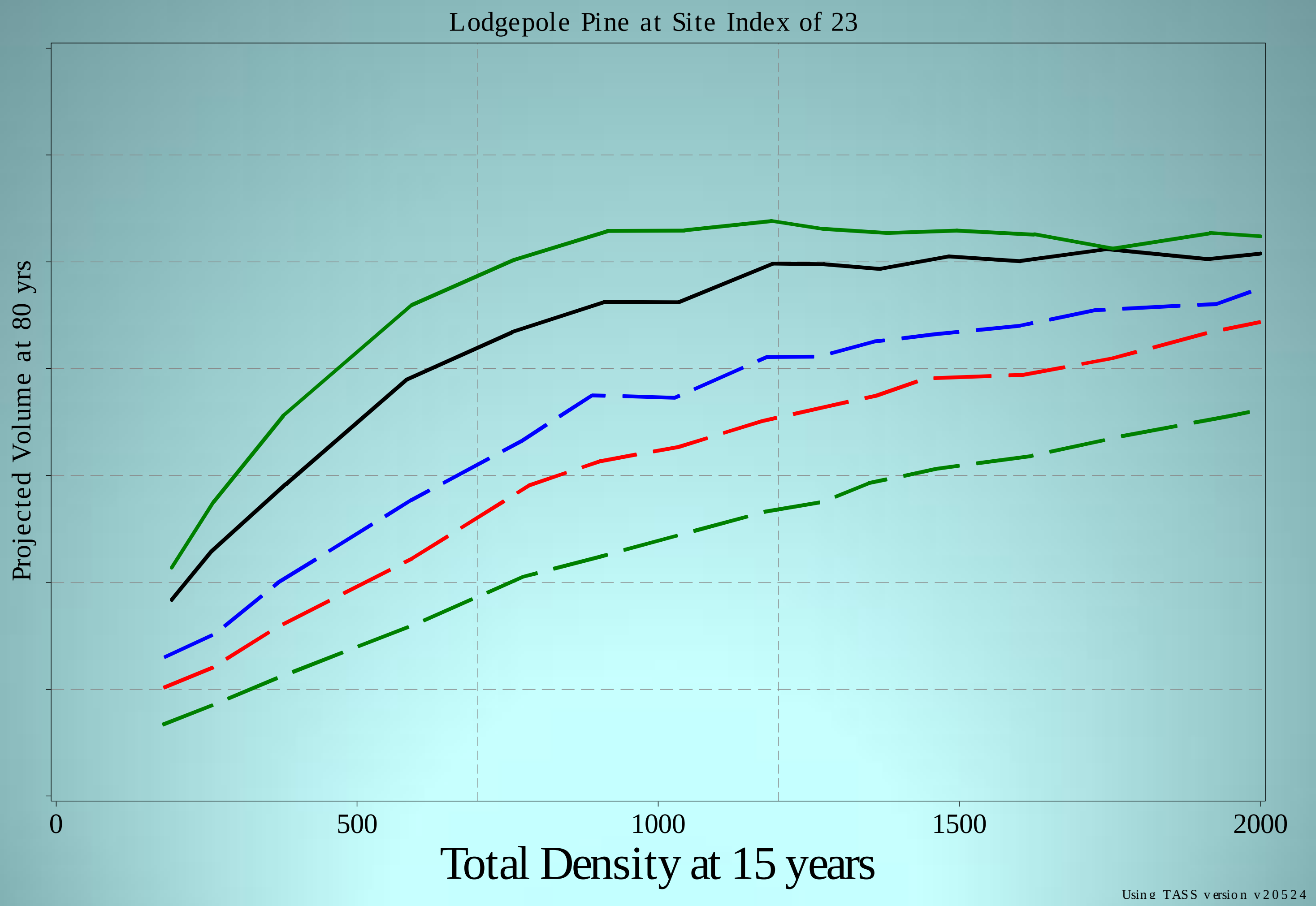
(assuming even-aged stands)

- Total - All trees (regardless of spacing)
  - Easy to measure
  - Projected Merchantable Volume (PMV) is sensitive to site index misspecification
  - PMV very sensitive to spatial distribution misspecification

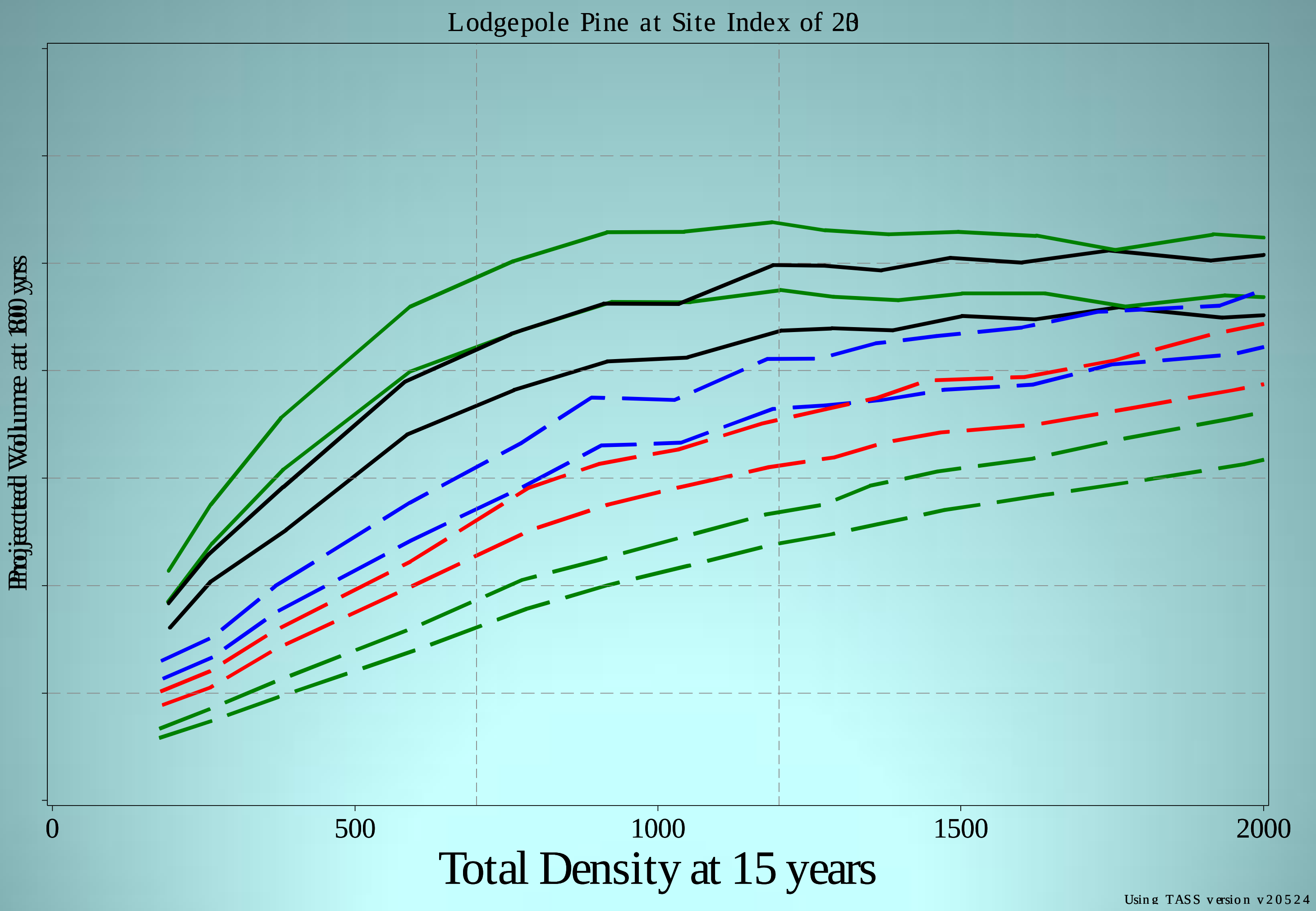
PMV (80 yrs) vs Total at 15 years (SI = 20)



PMV (80 yrs) vs Total at 15 years (SI = 23)



PMV vs Total: Bigger SI > Waiting 20 yrs

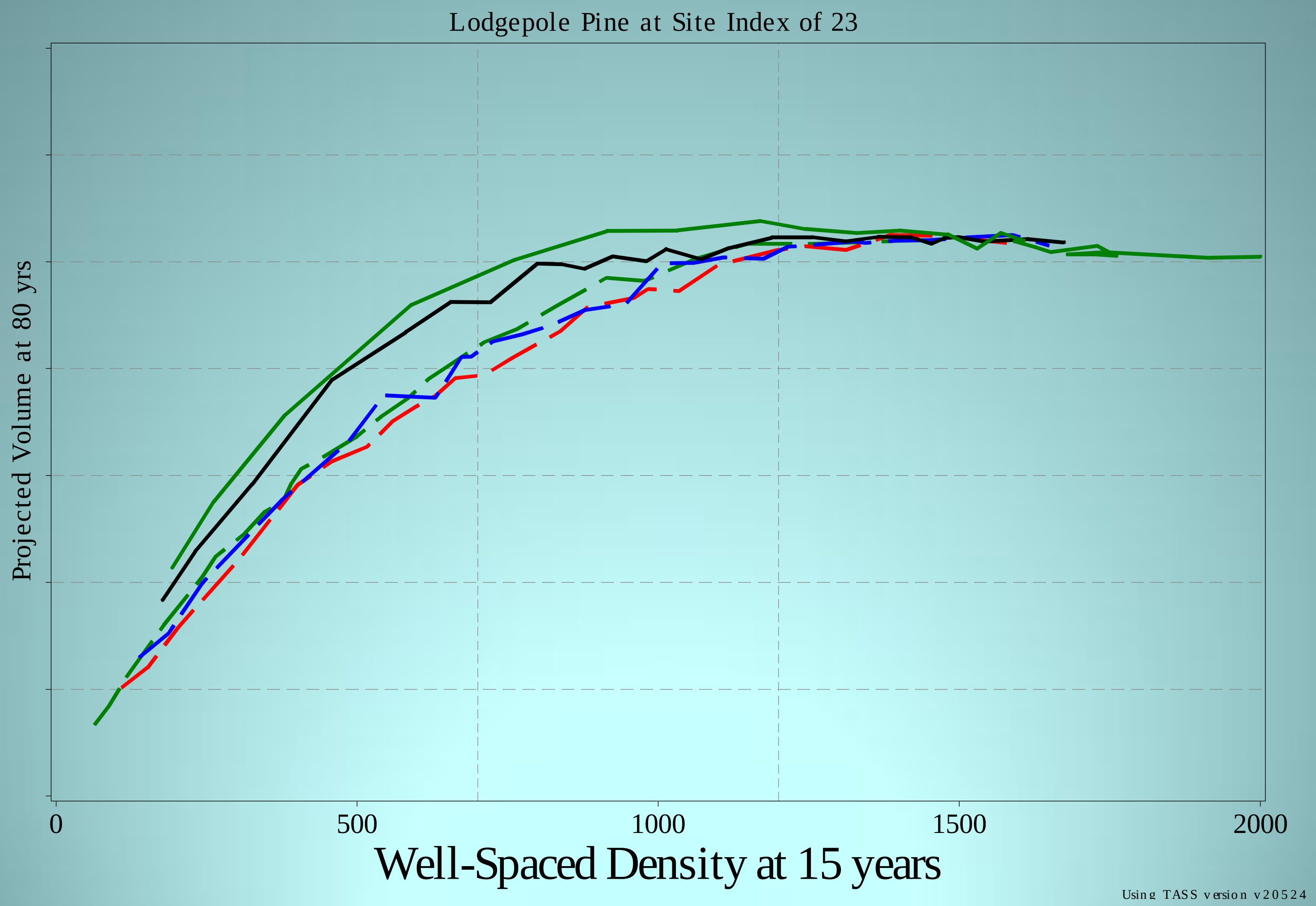


Which type of Density to use?

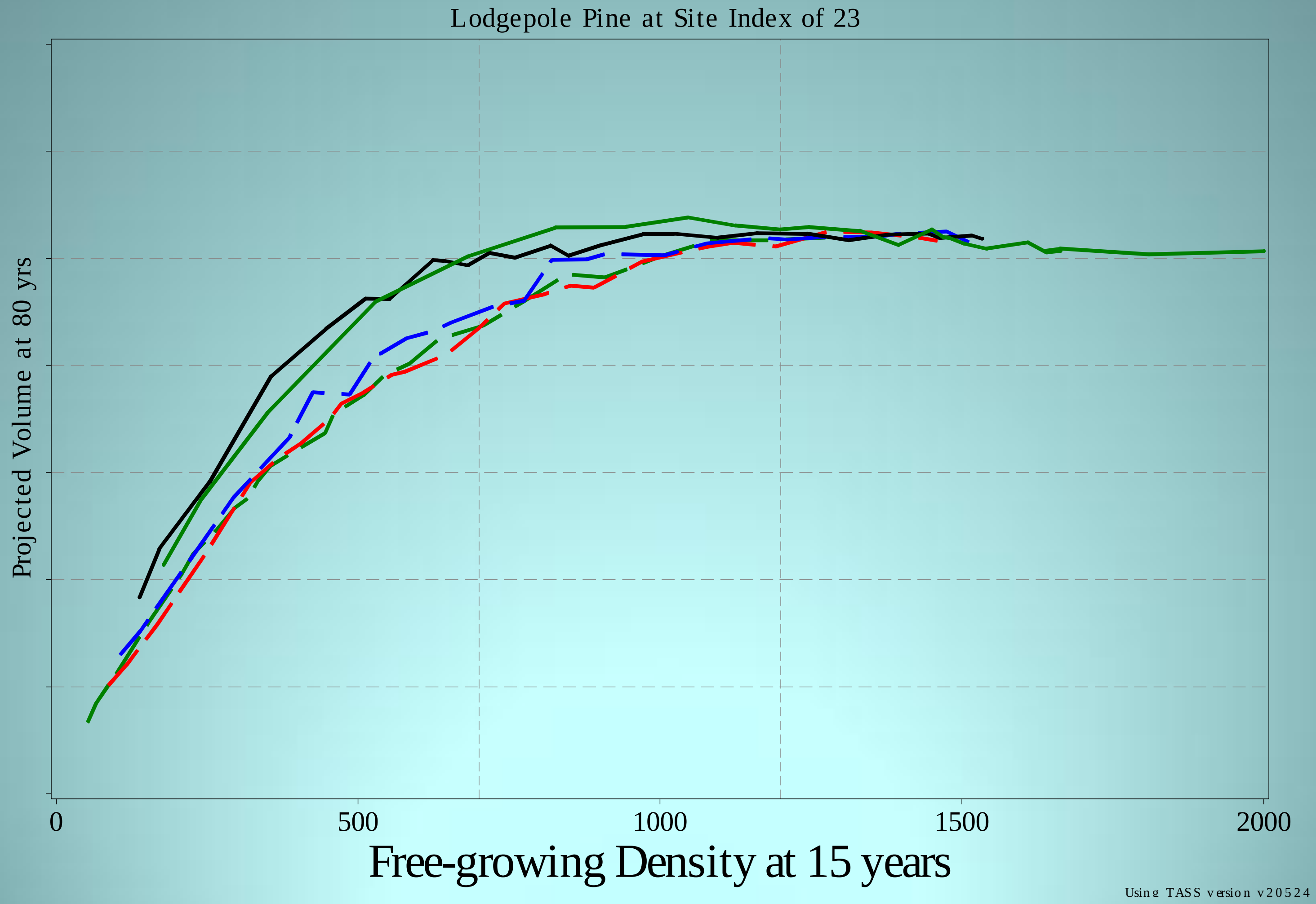
(assuming even-aged stands)

- Well-spaced - depends on choice of MITD.
  - Not so easy to measure but
  - PMV less sensitive to spatial distribution misspecification
- FG - Well-spaced with height restriction
  - More sensitive to site index and to
  - Stand age for ages less than 30 years or so
  - (and in the field, more sensitive to brush and competition)

PMV vs WS at 15 years



PMV vs FG at 15 years

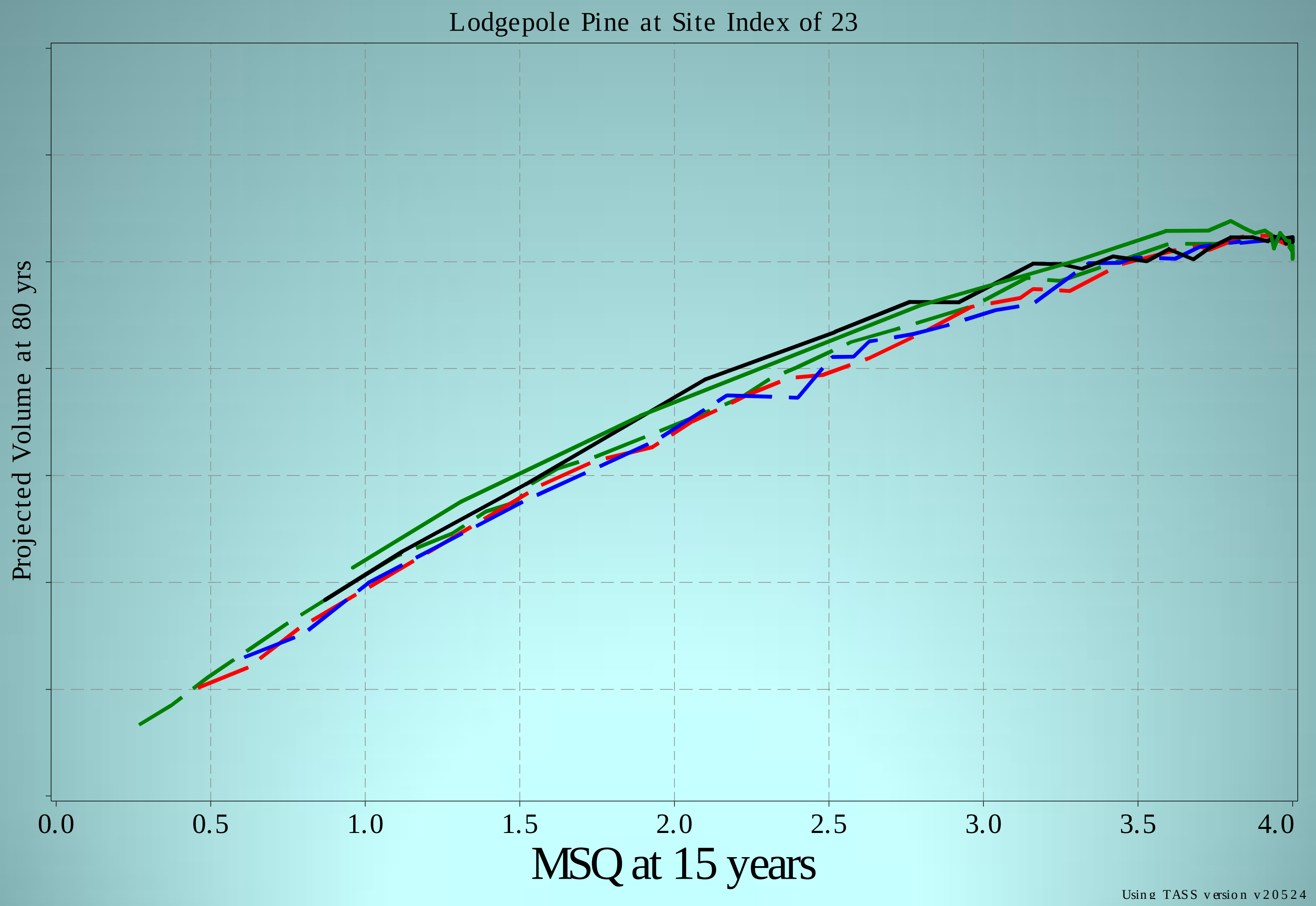


Which type of Density to use?

(assuming even-aged stands)

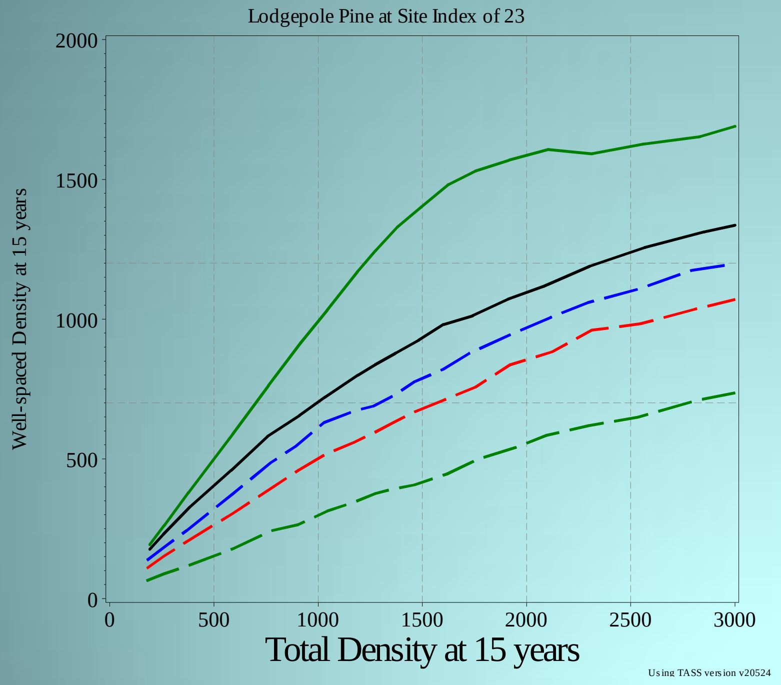
- MSQ – Mean stocked quadrant
  - Easier to measure
  - PMV less sensitive to spatial distribution misspecification
  - Not as familiar to foresters
  - Capped at 4 which occurs at all higher densities even extremely high densities

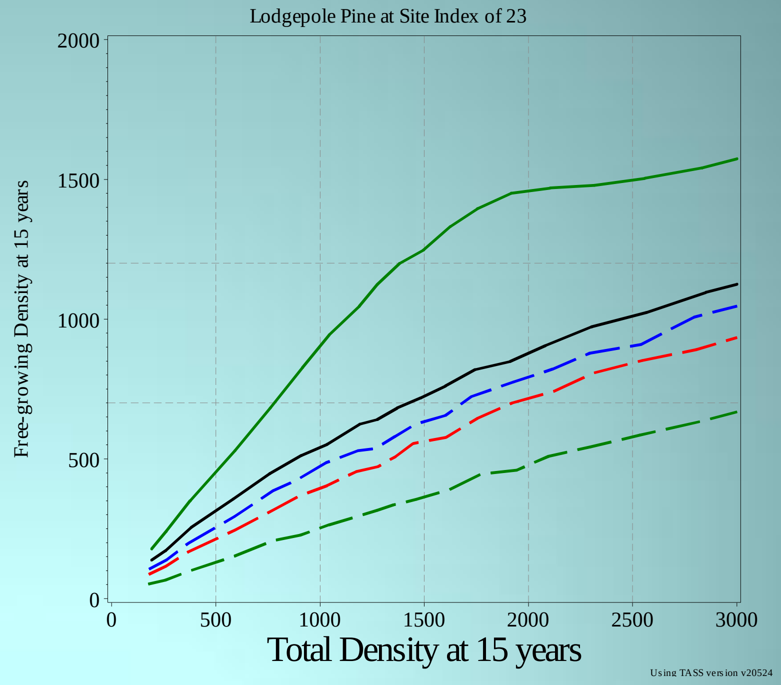
PMV vs MSQ at 15 years



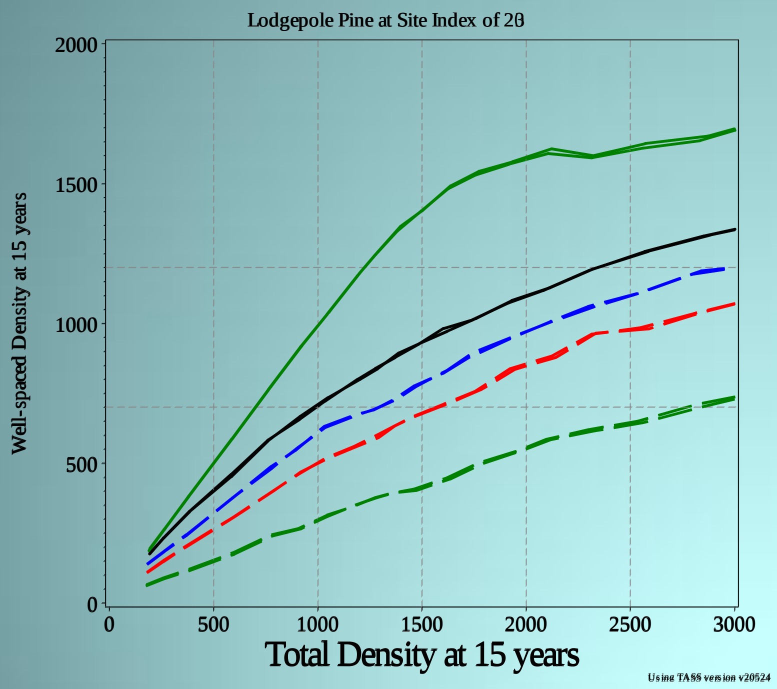
Relationships between Density Measures

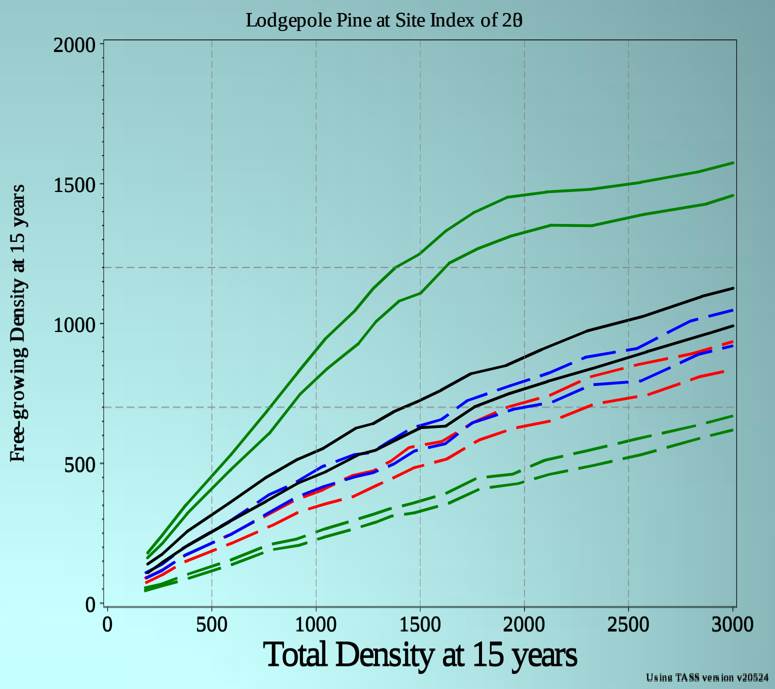
WS and FG vs Total Density at 15 years



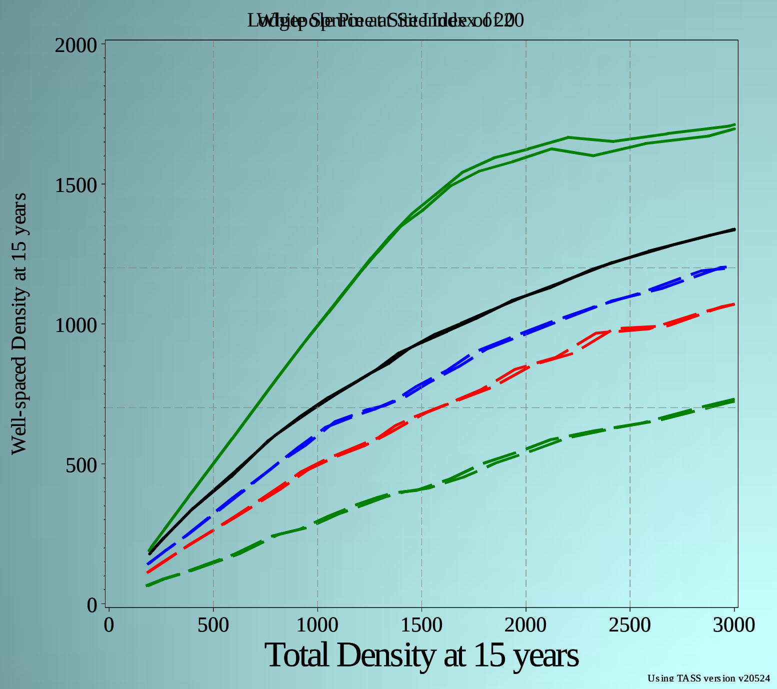


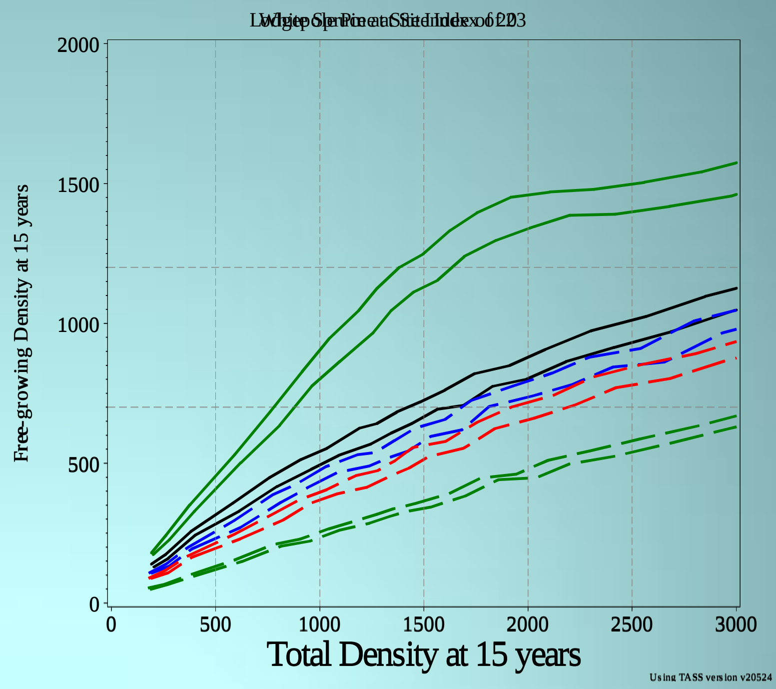
WS and FG vs Total Density effect of Site Index



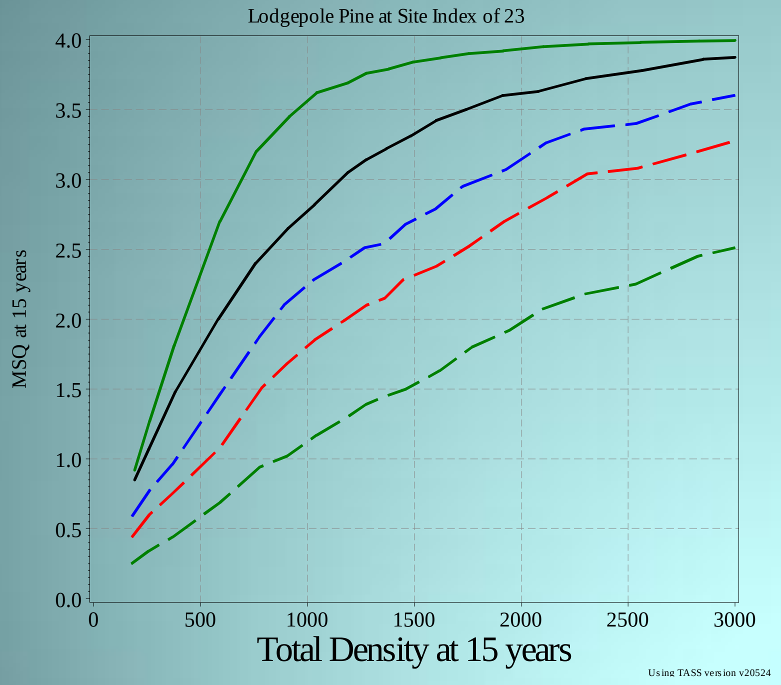


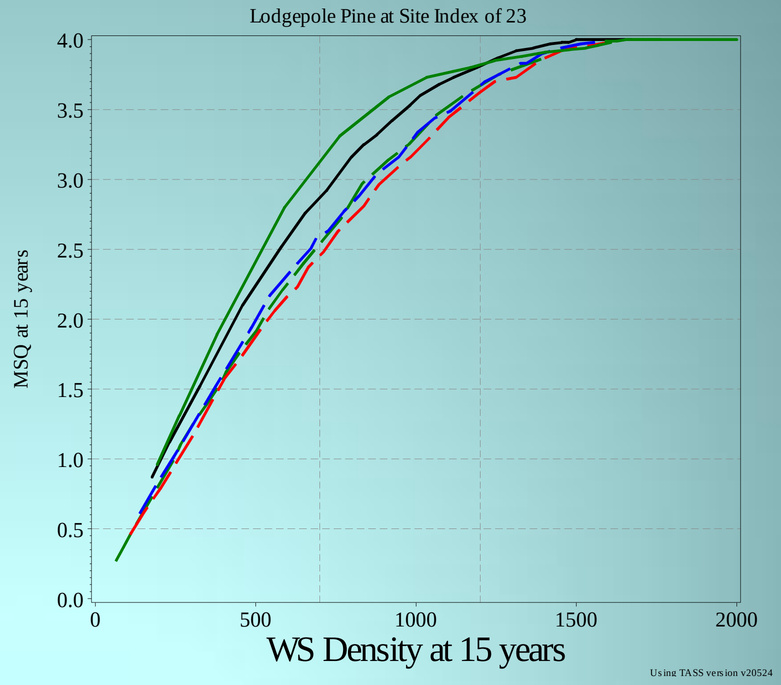
WS and FG vs Total Density effect of Species (SI = 20)





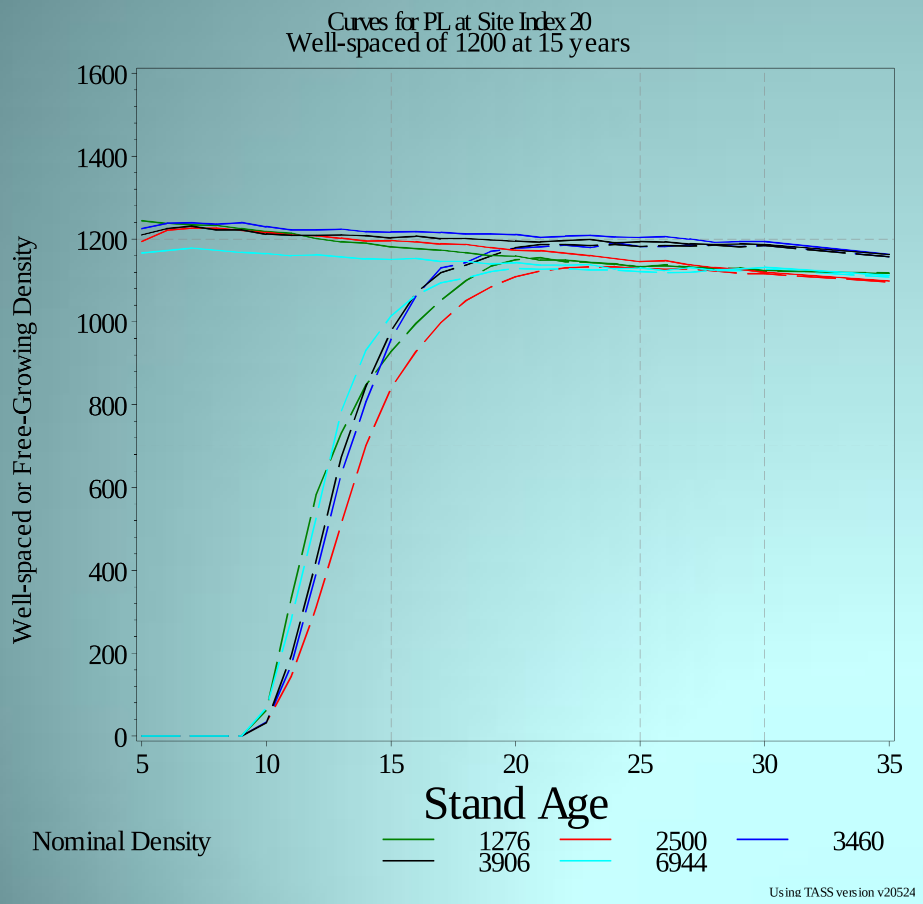
MSQ vs Total and WS Density at 15 years





But,
what about all those trees?

Stands with the same WS density produce about the same Volume

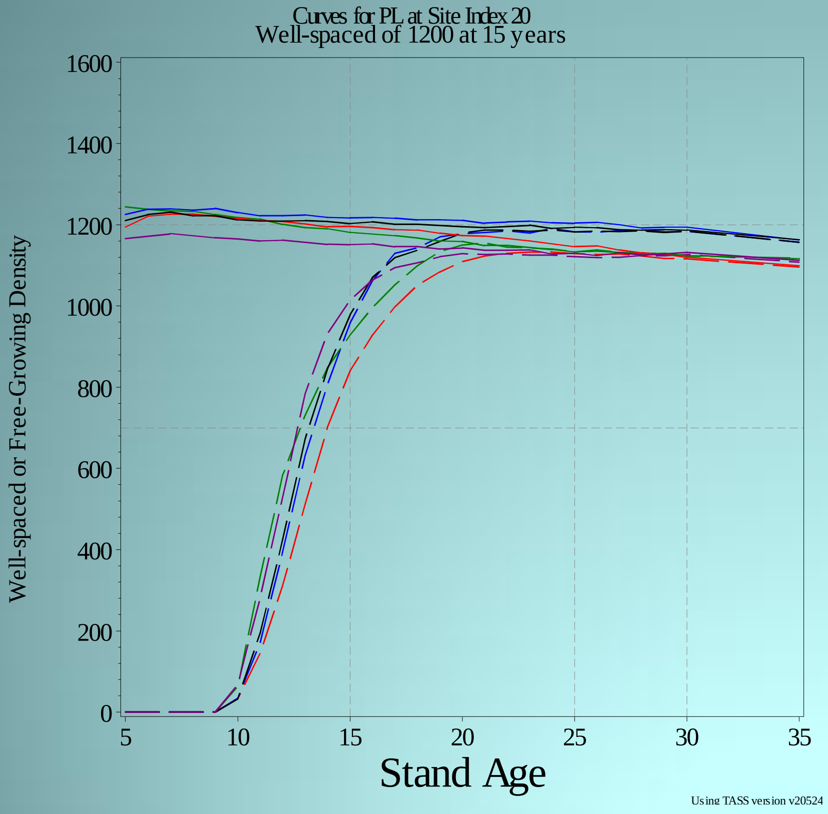


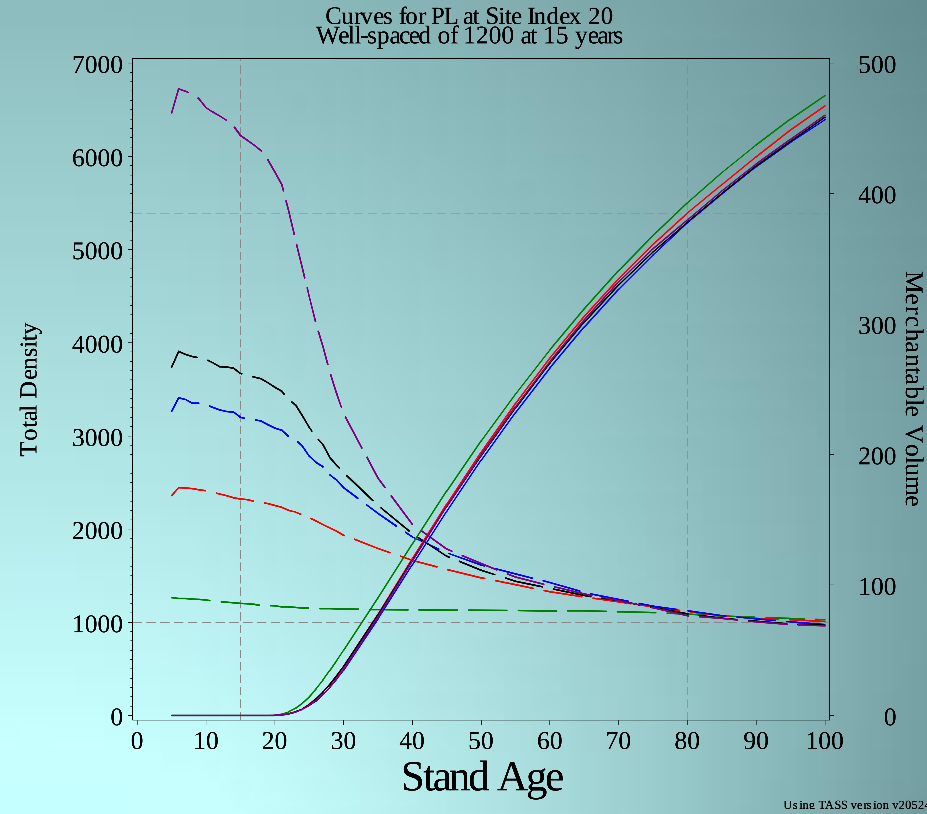
Spatial Distribution	Total Trees at 15 years	Volume at 80 yrs
Regular	1202	393
Natural	2336	385
Clump (3)	3199	378
Clump (2)	3669	378
Clump (1)	6224	380

Density values at 15 years (about 1200 wsph)

Spatial Distribution	Nominal	Total	Well-spaced	Free-growing	Total at 80 yrs	Volume at 80 yrs
Regular	1276	1202	1181	928	1087	393
Natural	2500	2336	1196	840	1114	385
Clump (3)	3460	3199	1217	958	1123	378
Clump (2)	3906	3669	1203	978	1092	378
Clump (1)	6944	6224	1151	1014	1070	380

But, what about all those trees?





Green: Regular at 1276 Red: Natural at 2500

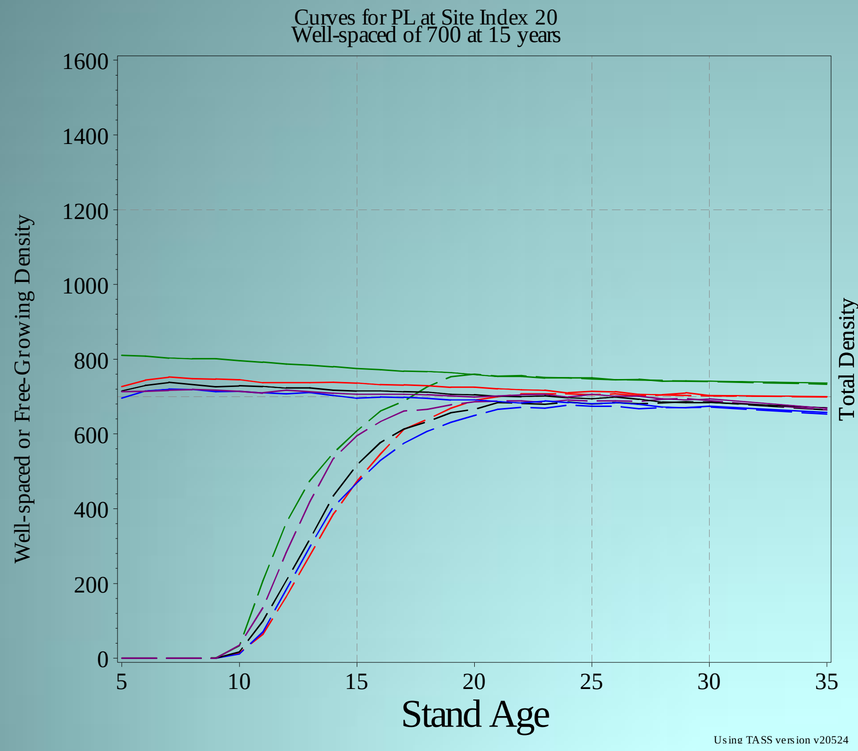
Blue: Clumpy(3) at 3460 Black: Clumpy(2) at 3906 Purple: Clumpy(1) at 6944

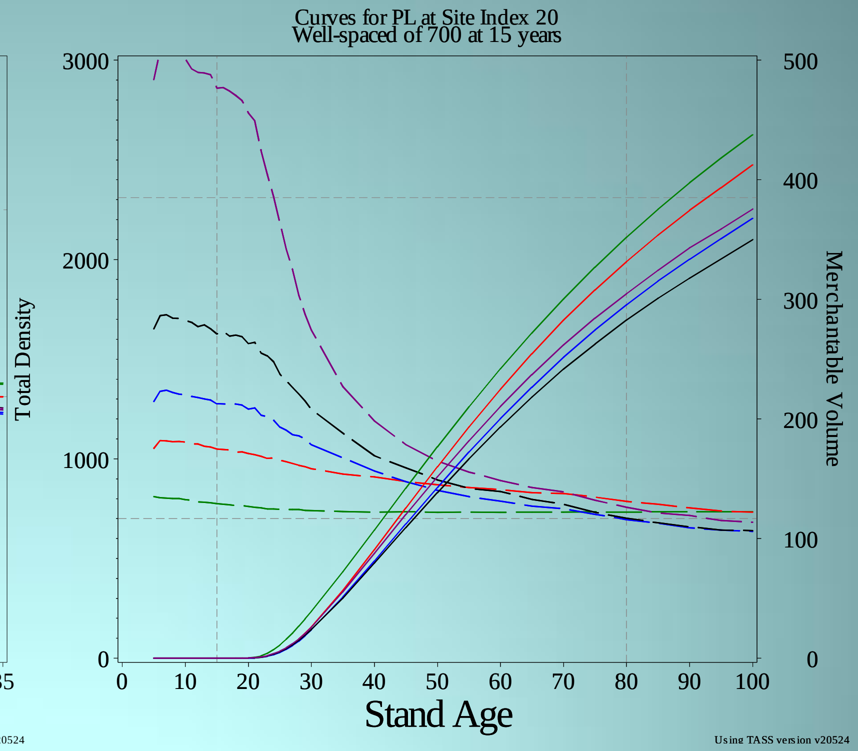
Density values at 15 years (about 700 wsph)

Spatial Distribution	Nominal	Total	Well-spaced	Free-growing	Total at 80 yrs	Volume at 80 yrs
Regular	816	775	775	608	733	352
Natural	1111	1049	736	473	786	332
Clump (3)	1372	1276	696	469	695	295
Clump (2)	1736	1627	715	517	702	283
Clump (1)	3086	2860	706	595	757	305

Projected volumes not as close for lower well-spaced densities

But, what about all those trees?





Green: Regular at 816 Red: Natural at 1111

Blue: Clumpy(3) at 1372 Black: Clumpy(2) at 1736 Purple: Clumpy(1) at 3086

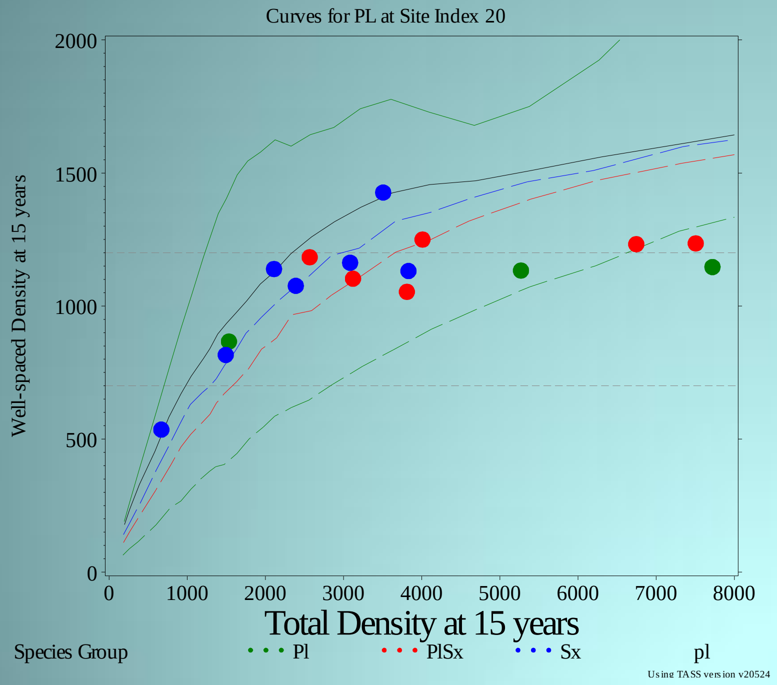
What spatial distribution to use?

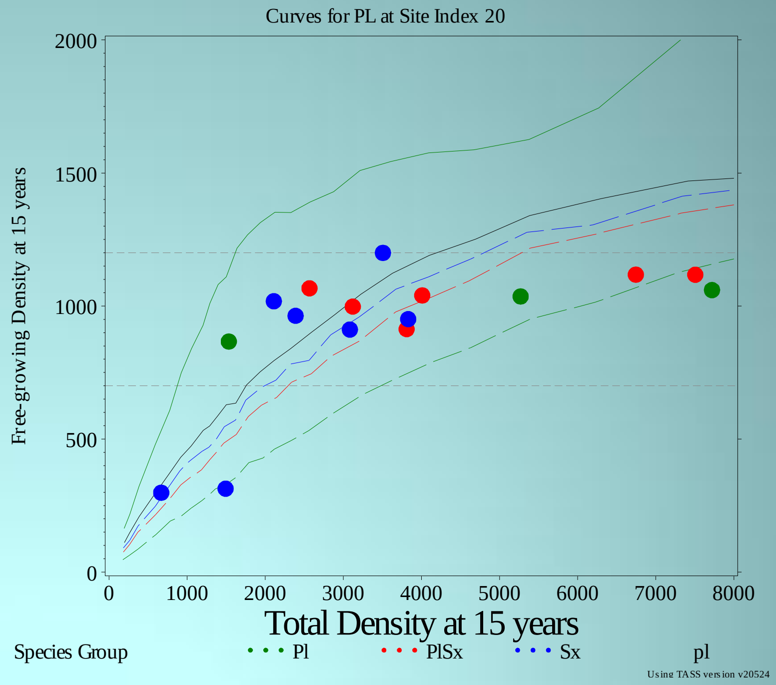
- How can we tell from field data which spatial distribution best matches the stand?
- There are several indices in the literature, e.g. Pielou's index of dispersion or Morisita's index.
- We could also consider the ratio of the total trees to the well-spaced trees, both readily available from survey data. Preliminary work shows that this ratio is a simple function of the total trees.
  - I've been thinking about this for years, but haven't been able to pull anything together yet.

Fort St John District Data

- District collected 895 standard silviculture survey plots in many but not all of the Multi-block strata of the Fort St John Pilot Project (15 year old cutblocks)
- Also collected MSQ data – plots divided into quadrants and presence of an acceptable tree determined for each quadrant – values 0 to 4.
- Plots placed into 18 strata, regardless of cutblocks
- Three species groups: Pl, Pl/Sx, Sx
- Wide range of site index observed

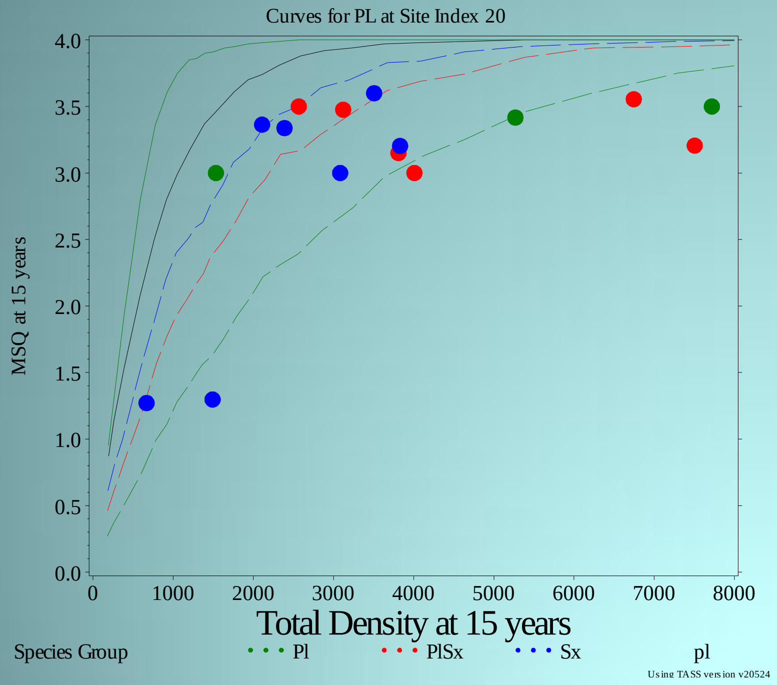
WS and FG vs Total Density Fort St John District Data

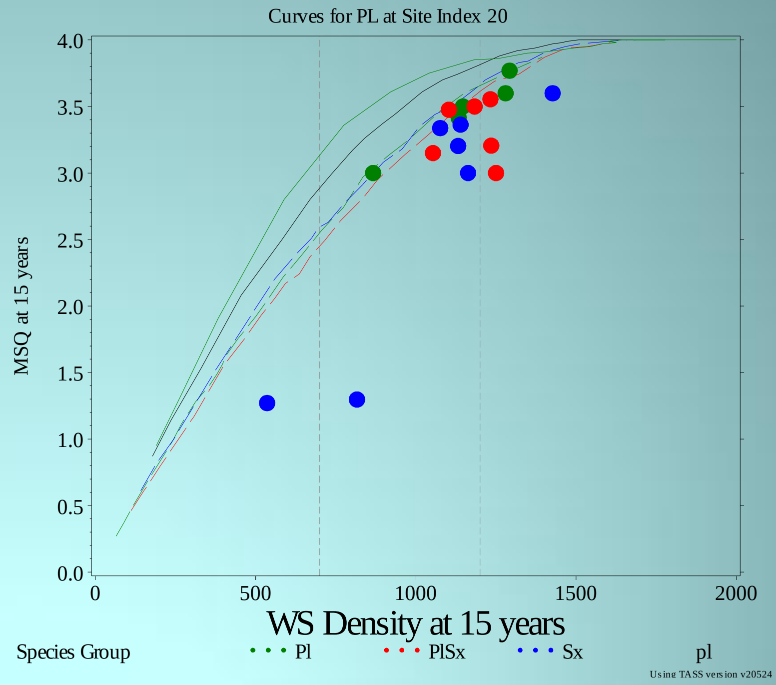




Data plotted without regard to estimated site index of the data

MSQ vs Total & WS Density Fort St John District Data





Data plotted without regard to estimated site index of the data

Post-free growing Survey Study

- FREP project with Alex Woods in Smithers
- Sixty stands in two areas declared free-growing between 1987 and 2001 were randomly selected using RESULTS
- Stands re-surveyed in 2005 (Lakes) and 2006 (Okanagan) using standard silviculture survey methodology and current forest health standards.
- FREP is now piloting a Stand Development Monitoring (SDM) program based on this work.

Purpose of Free-Growing Policy:

- "free-growing requirements ensure that reforested stands remain successfully reforested." Forest Practices Board Special Report No. 16 (2003),
- The licensee obligation to create free-growing stands is one of the few measurable results under the *Forest and Range Practices Act*.

Features of the Silviculture Survey

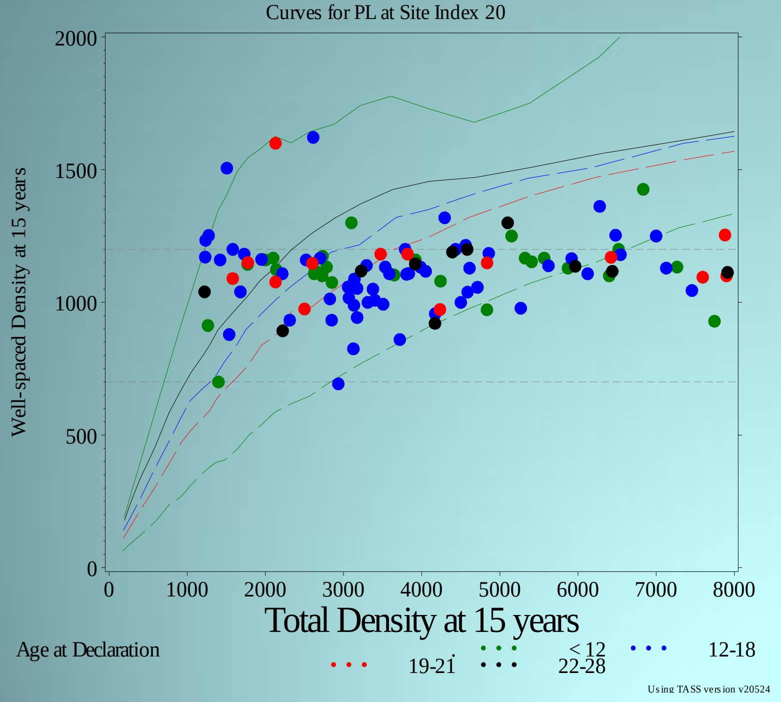
- Uses 50 m^2 plots (3.99 m radius -- 1/200th ha)
- Usually 1 plot per hectare placed in survey area
- Count number of acceptable, well-spaced trees
- Trees must be a minimum tree height to be counted in Free-growing surveys
- Well-spaced is <u>defined</u> by the Minimum Inter-tree Distance (MITD)
- Count is capped by the M-value (this is the equivalent plot count for the Target Stocking Standard, TSS, i.e., M = TSS/200)

Post-FG Surveys – Stand Ages

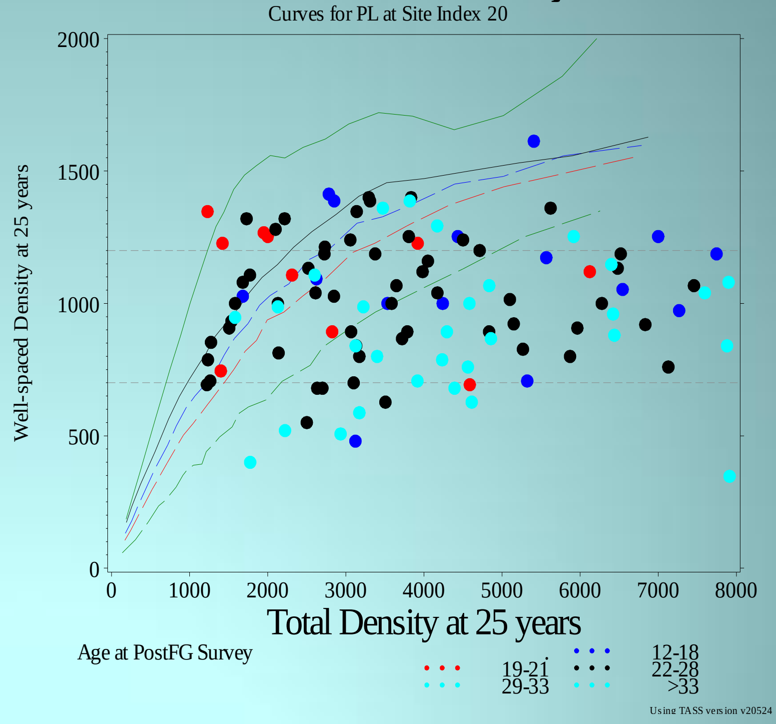
	Declaration		Post Free-Growing	
Age Range	Lakes	Okanagan	Lakes	Okanagan
< 12 years	19	13	--	--
12 - 18 years	35	26	9	8
19 - 21 years	4	11	9	2
22 - 28 years	2	10	34	23
29 - 33 years	--	--	6	22
> 33 years	--	--	2	5
Average Age:	14 yrs	16 yrs	24 yrs	27 yrs

WS Density vs Total Density Lakes & Okanagan Data

At Declaration



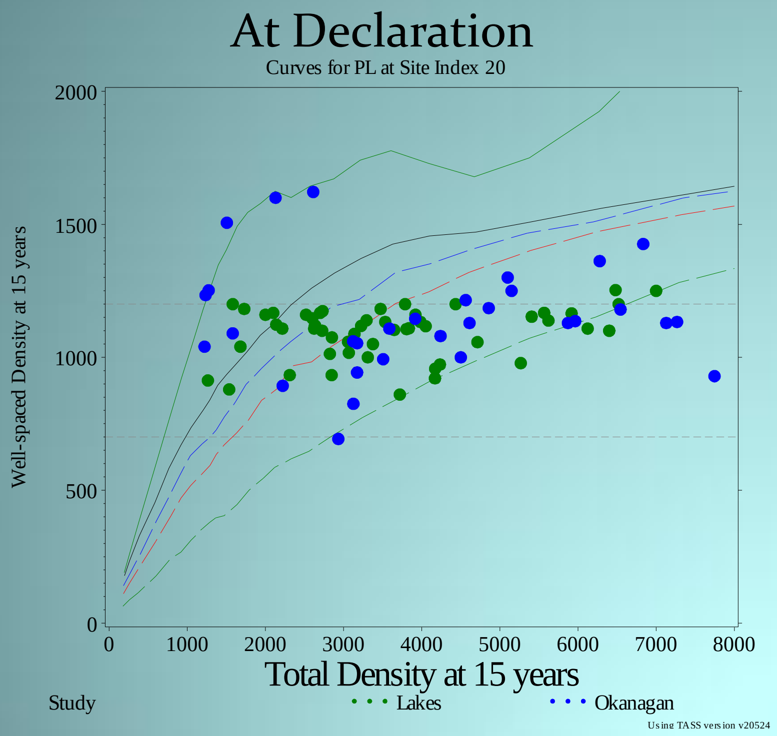
At Post FG Survey

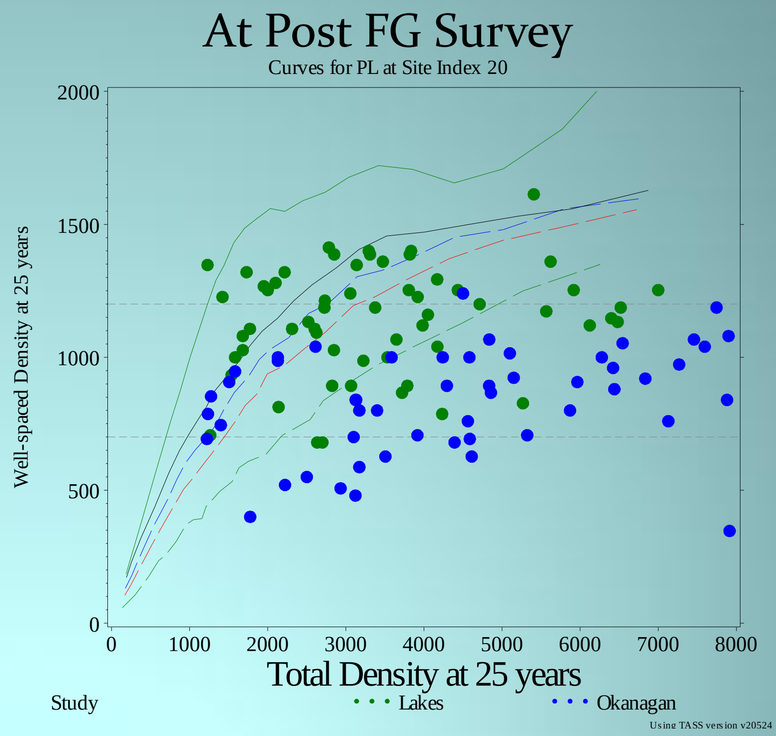


Dot colours show different age range of the cutblocks

Curves use stand age of 15 or 25 years

WS Density vs Total Density Lakes & Okanagan Data

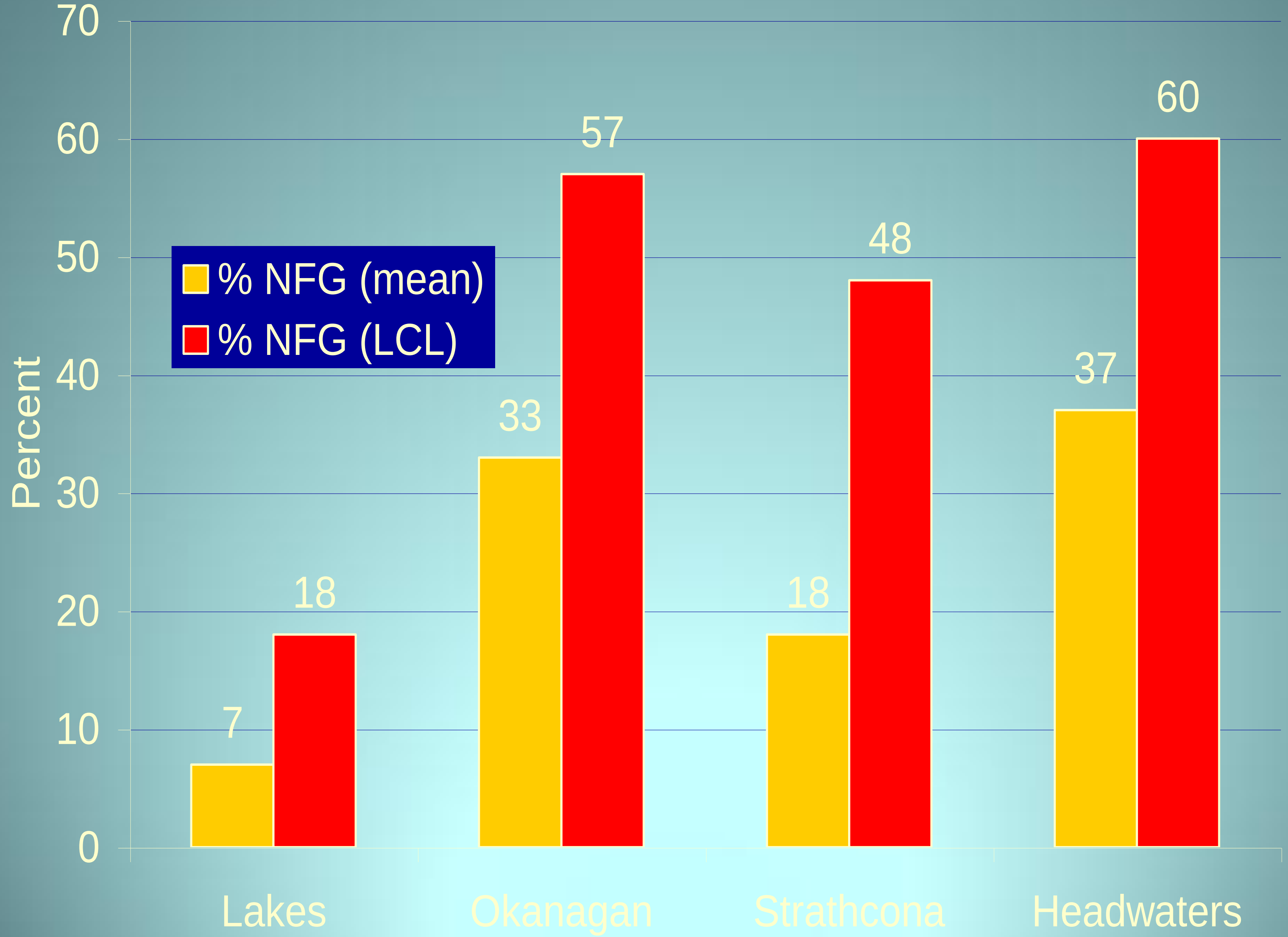




Dot colours show cutblocks from different areas

Curves use stand age of 15 or 25 years

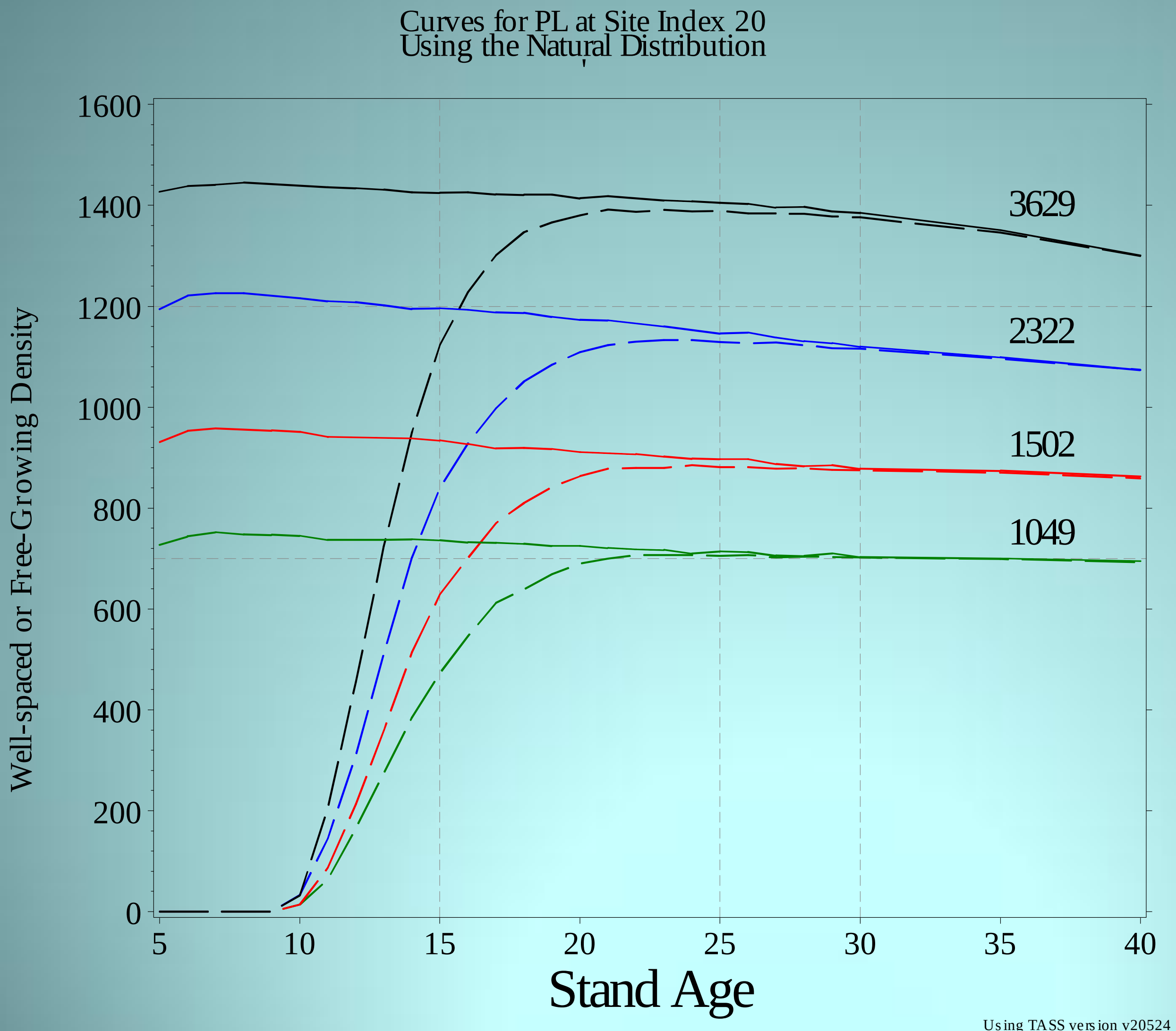
Percent of stands falling below minimum stocking thresholds based on mean and LCL decision rules



Post FG Question:

- Should stands at 25 years of age (or older) have about the same well-spaced and free-growing densities as at declaration?
- Or should these values have decreased, and if so, by how much?
- Used TASS and TIPSY with the new output density variables to assess this.

Post FG Question:



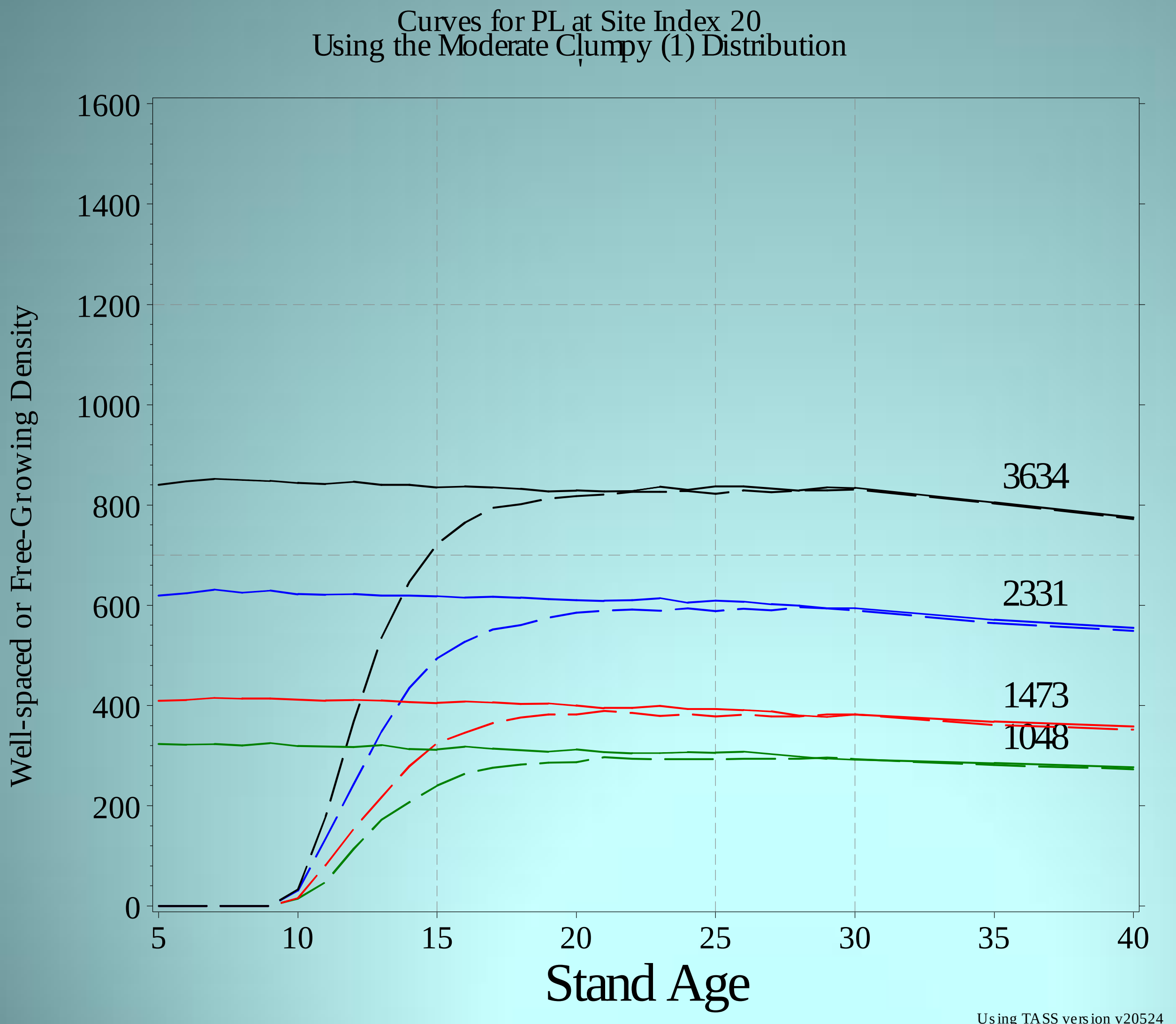
Total density at age 15 are shown above each curve

Nominal Densities were 3906, 2500, 1600, and 1111

Solid lines show Well-spaced Densities

Dashed lines are Free-growing Densities

Post FG Question:



Total density at age 15 are shown above each curve

Nominal Densities were 3906, 2500, 1600, and 1111

Solid lines show Well-spaced Densities

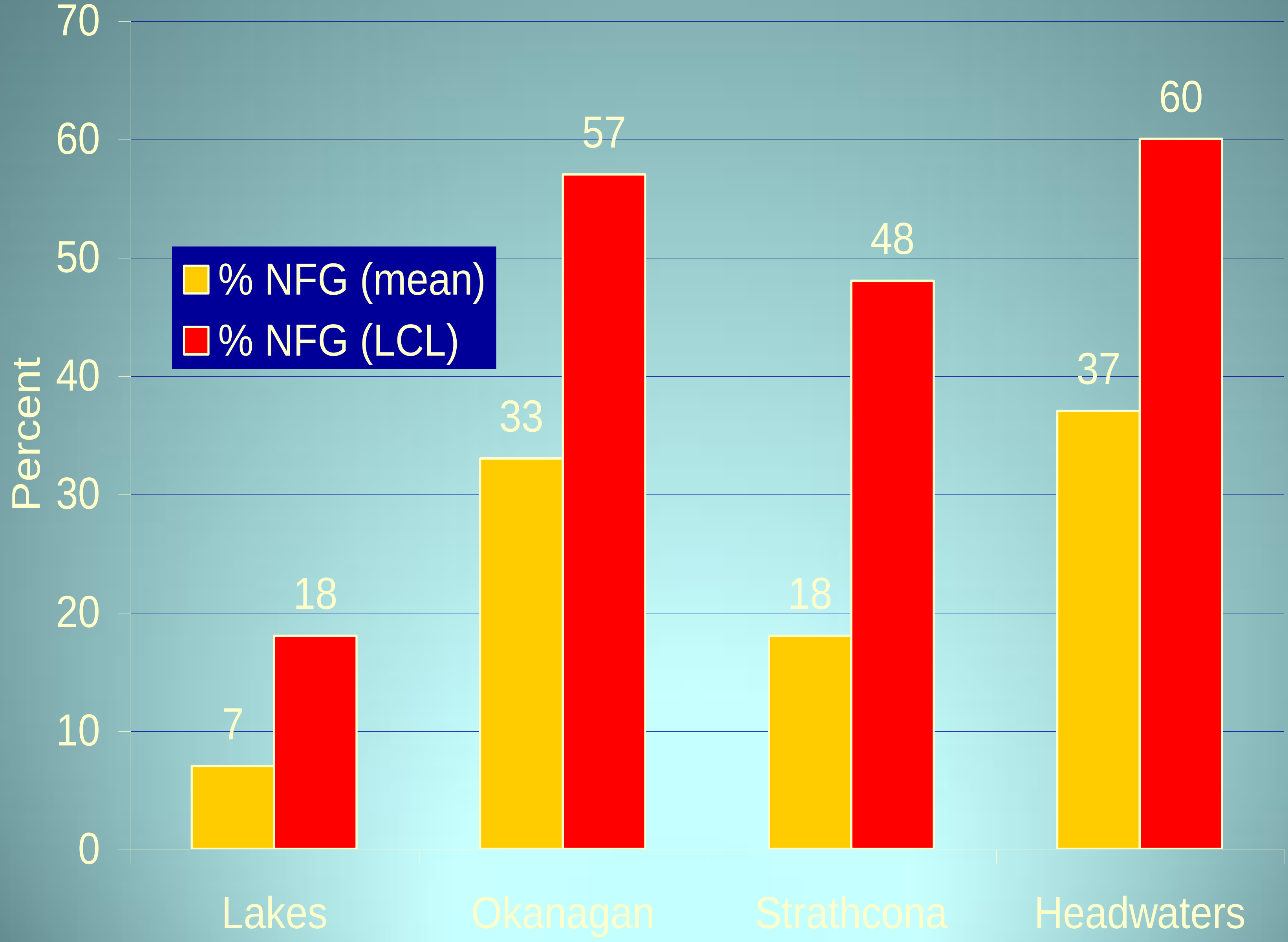
Dashed lines are Free-growing Densities

Answer to Post FG Question:

- Well-spaced Densities should decline a “little” from declaration to 25 or 30 years
- Free-growing Densities should either increase or hardly change depending upon the site index and tree age at declaration.

- That is, the MSS at 25 or 30 years should probably not be different from that at declaration.
- Under optimum conditions, stands at 25 or 30 years should still pass the same numerical FG tests as at declaration.

Percent of stands falling below minimum stocking thresholds based on mean and LCL decision rules



Conclusions

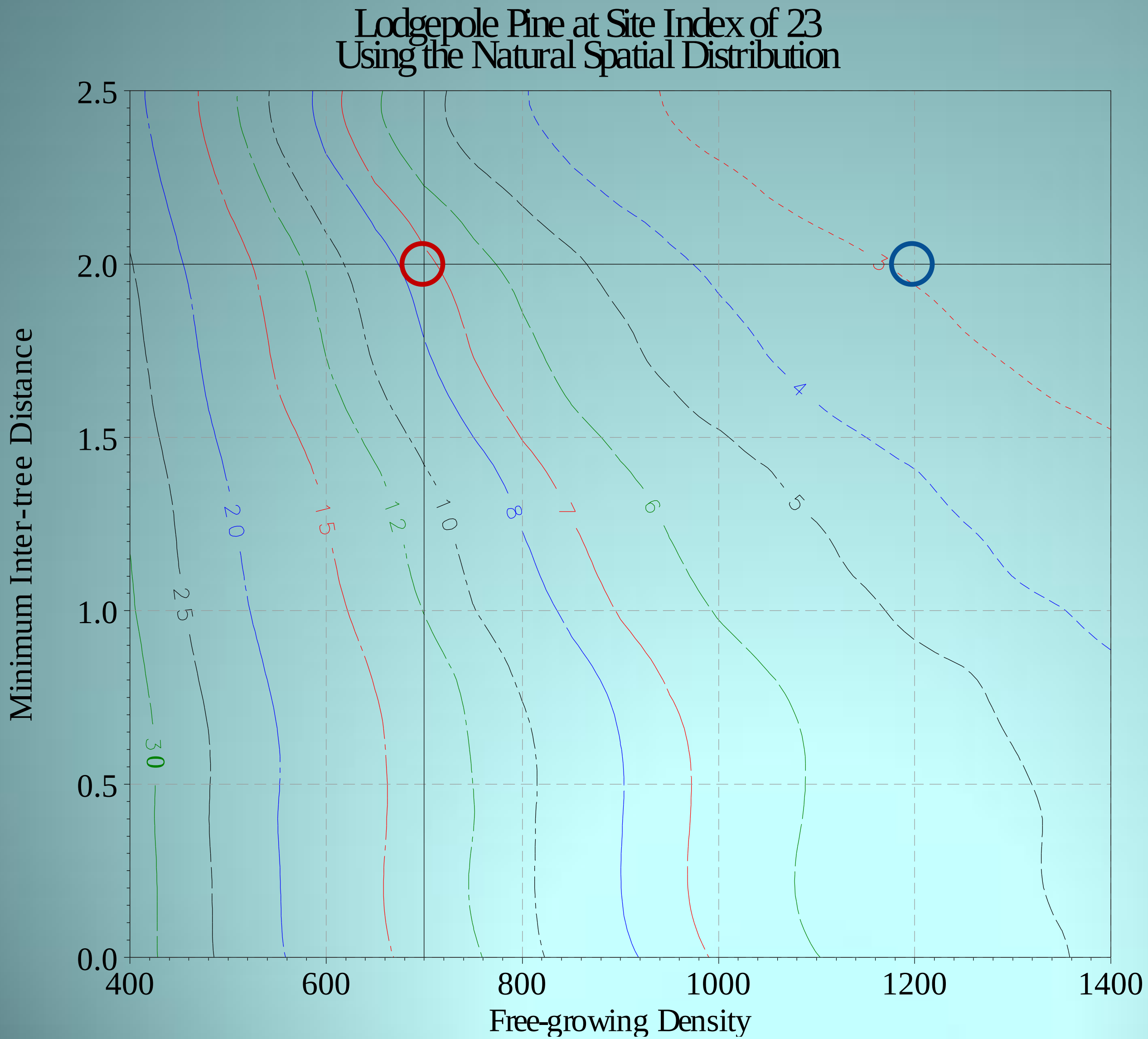
- Spatial distribution and site index have a significant impact on PMV – it is important to have good estimates for effective modeling.
- Well-spaced density minimizes these impacts, especially near target densities.
- Under optimum conditions, stands passing the FG tests at declaration should still pass them 10 to 20 years later.

The MITD reduces the effect of gaps in the spatial distribution It defines WS and FG density AND it helps maintain the Ministry’s risk at a reasonable level

MITD and Projected Volume Losses

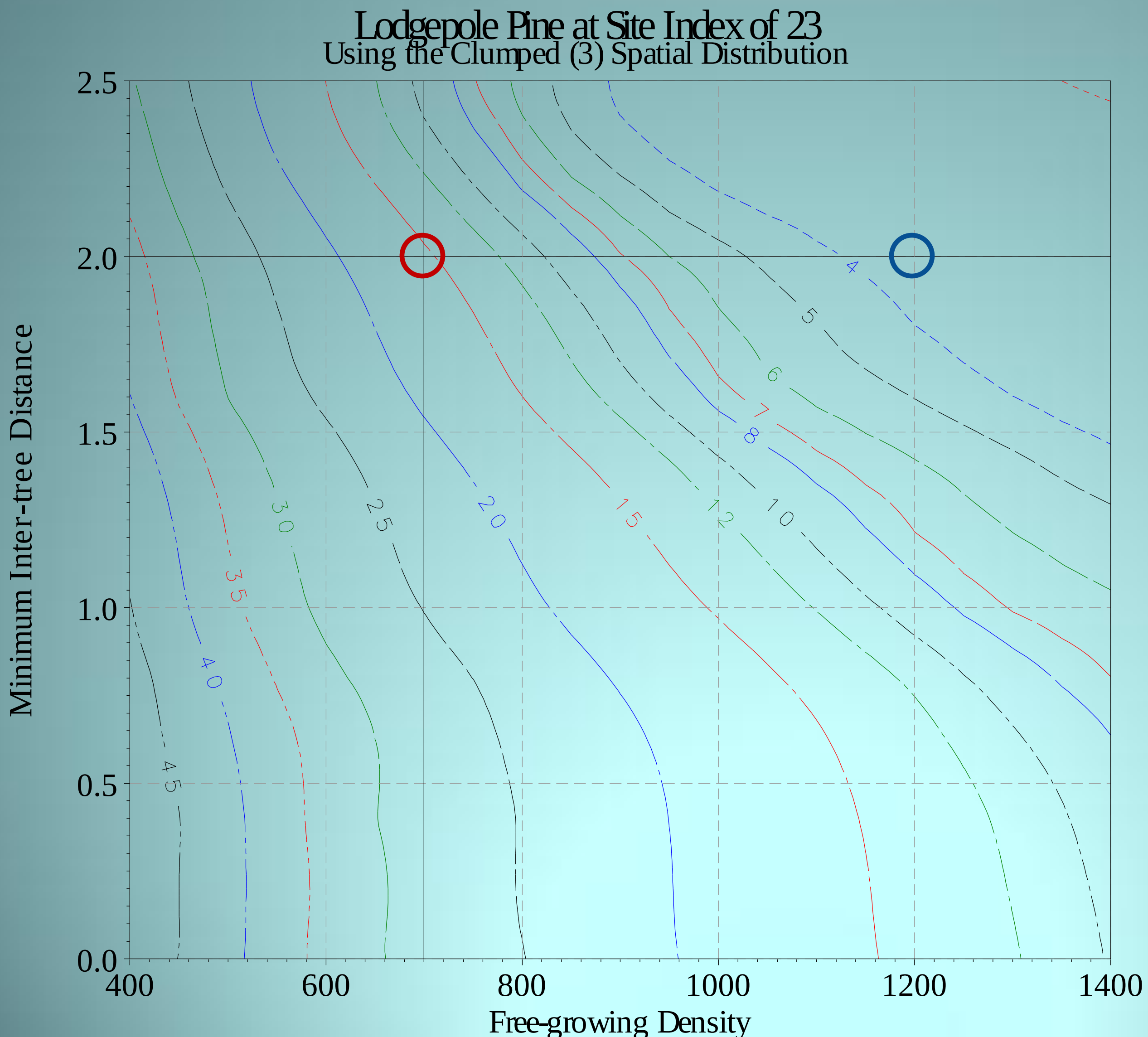
- Remember that there are many assumptions in all of the graphs in this presentation.
- Remember to look more at the TRENDS or patterns than the specific values – these are more likely to remain the same under a different set of assumptions than would the specific values presented.

MITD and Projected Volume Losses



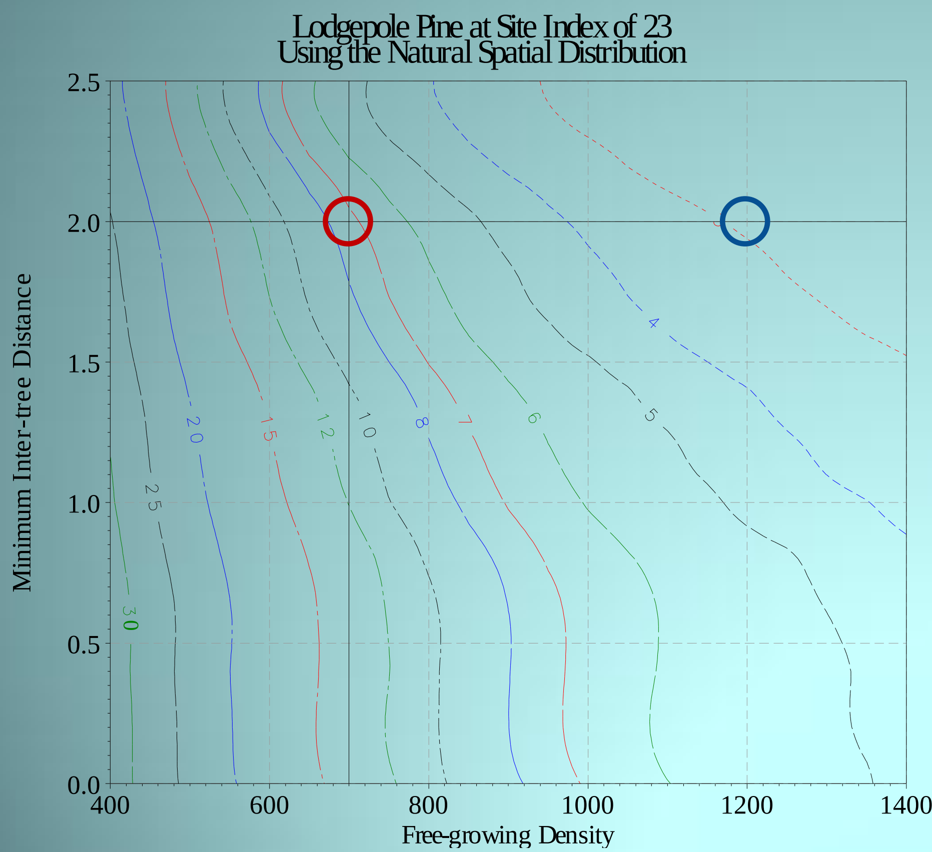
- At MITD of 2 .0 m we see ~ 3% volume loss at 1200 fpgh
- But at 700 we have >7% volume loss

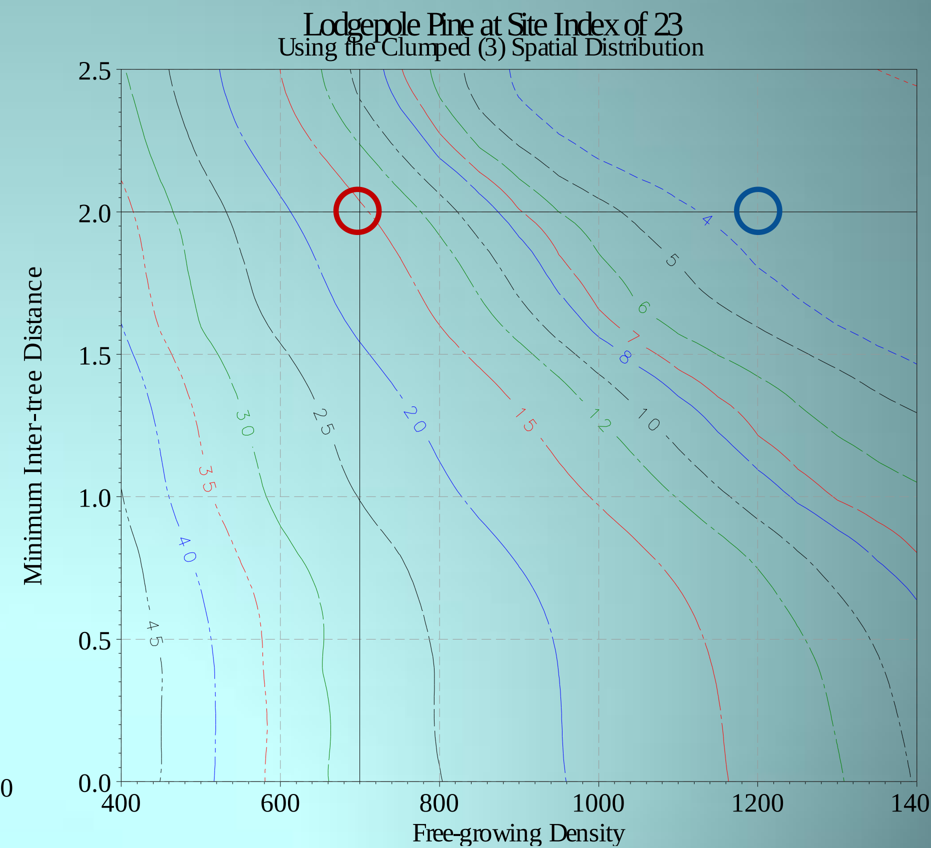
MITD and Projected Volume Losses



- At MITD of 2 .0 m we see 3 - 4% volume loss at 1200 fpgh
- But at 700 we have 15-16 % volume loss

At TSS and MITD = 2 m, volume losses similar regardless of spatial distribution

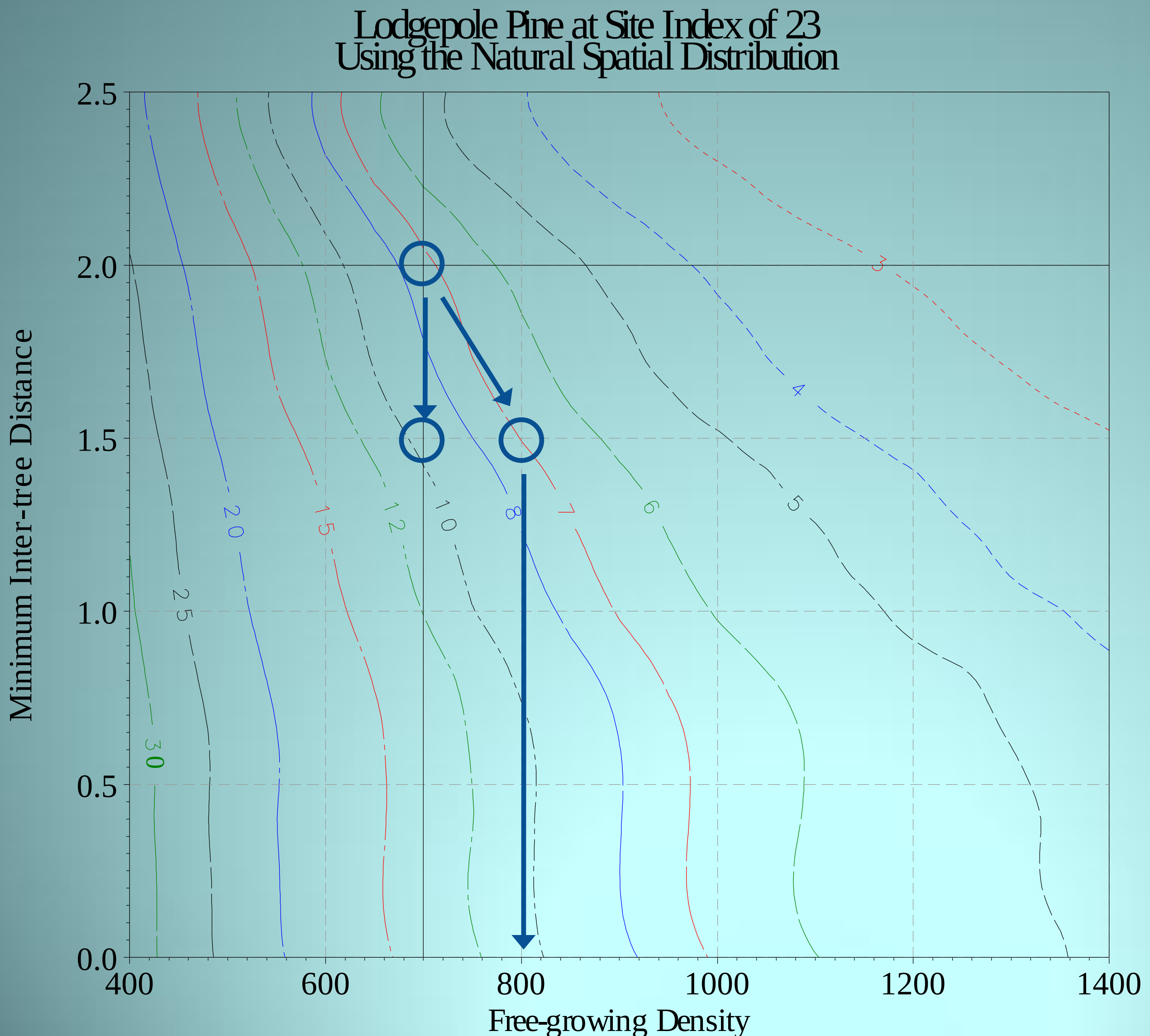




MITD and Projected Volume Losses

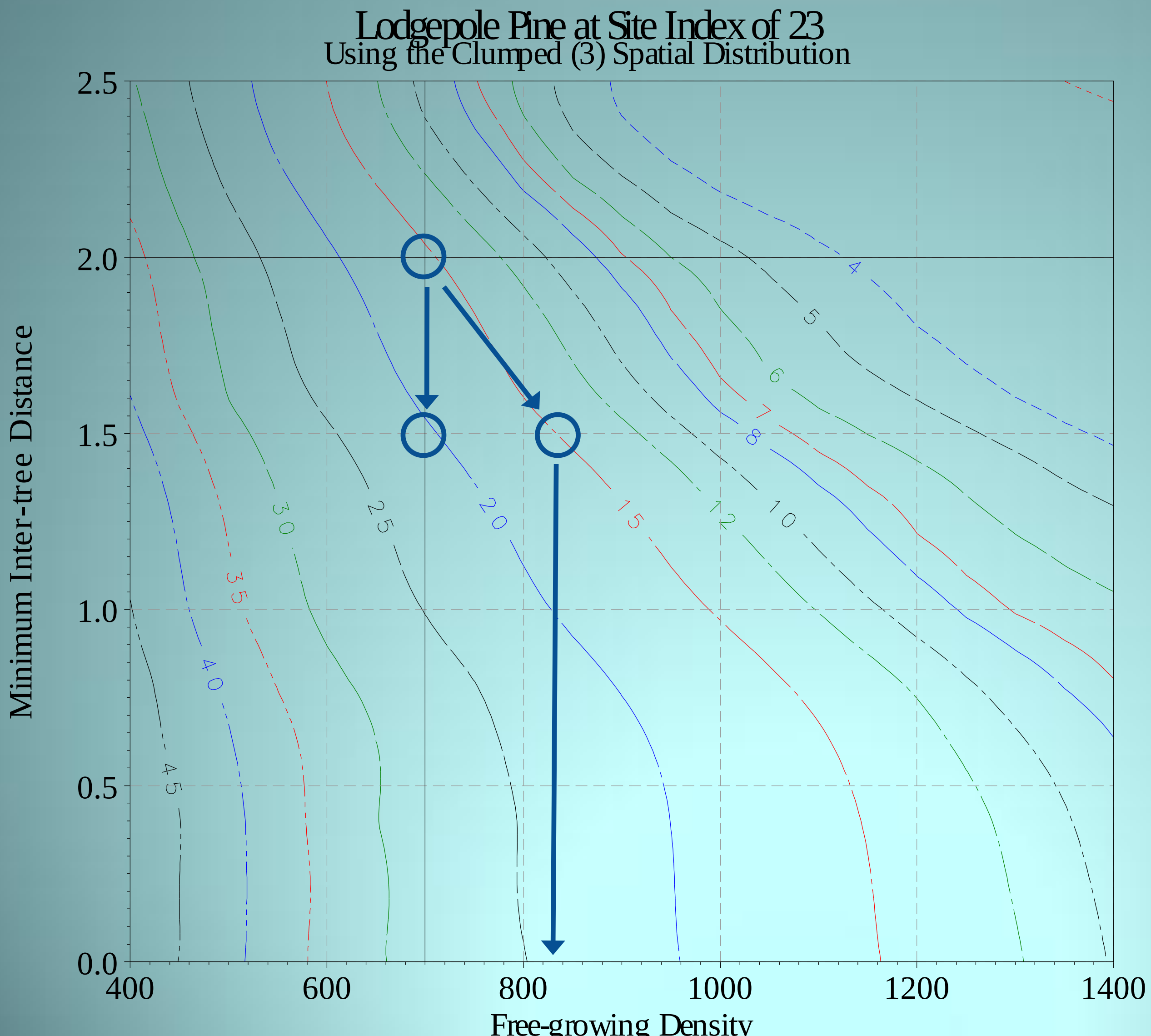
- At the target stocking of 1200 fgph with an MITD of 2.0 m, we see a similar volume loss regardless of spatial distribution.
- BUT at the minimum stocking of 700 fgph, the volume loss increases from ~7% for the "natural" distribution to ~15% for the standard clumped distribution in TIPSY.
- For the more clumpy distributions, the volume loss at 1200 remains about the same, but at the minimum the losses rise to about 20%.

What if we reduce the MITD?



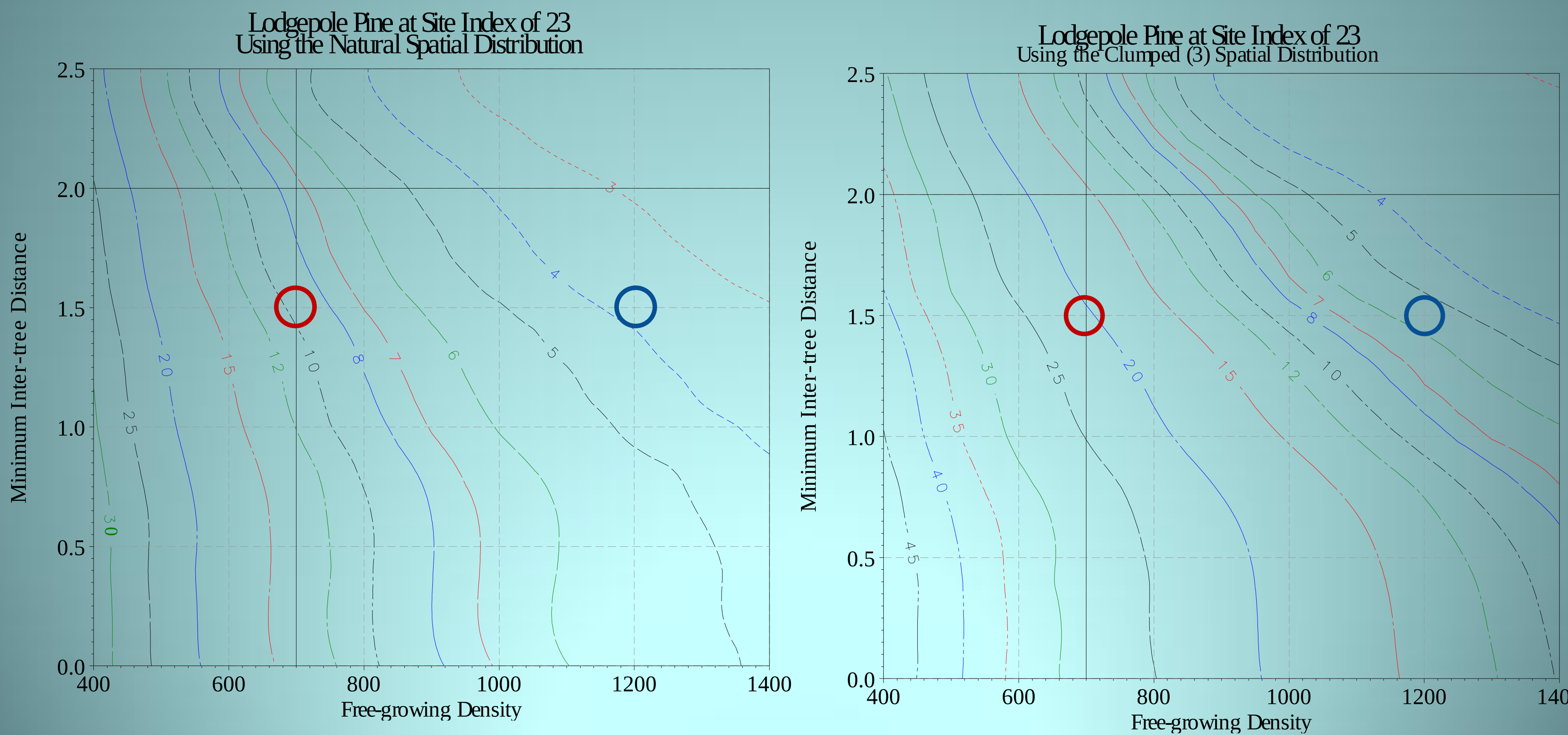
- Reducing the MITD increases the volume loss.
- Increasing the MSS from 700 to 800 compensates for this.

What if we reduce the MITD?



- Reducing the MITD increases the volume loss.
- Increasing the MSS from 700 to 830 compensates for this.

At TSS and MITD = 1.5 m, volume losses differ more wrt spatial distribution



Changing the MITD

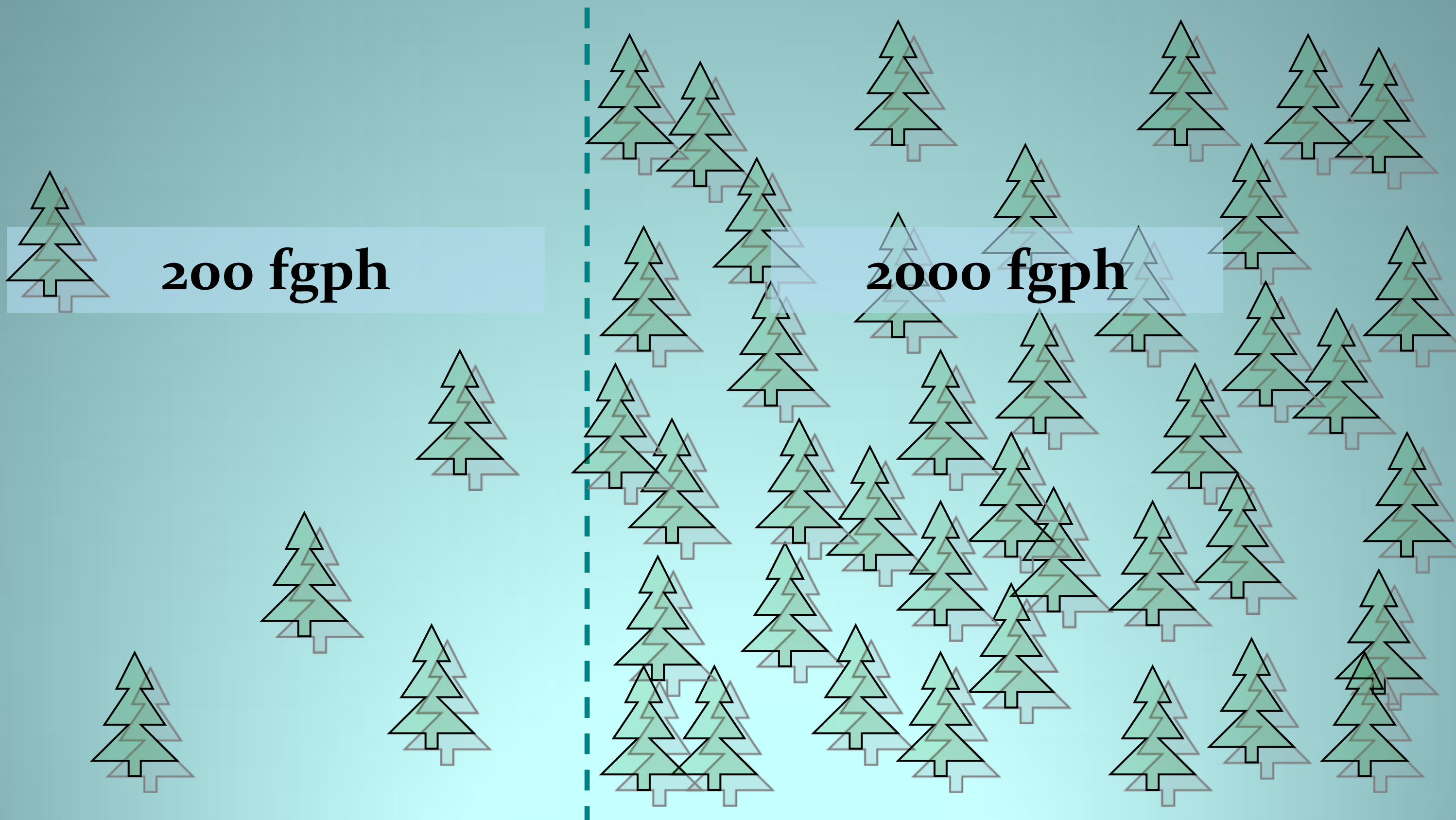
- Changing the MITD from 2.0 m to 1.5 m without any other compensating changes can substantially increase the projected volume losses and the Ministry's risk.

- Projected volume losses at the TSS of 1200 fgsph are less sensitive to spatial distribution misspecification than at the MSS of 700 fgsph when an MITD of 2.0 m is used.

The M-value keeps poor stratification and/or heterogeneous strata from increasing the Ministry's risk too greatly

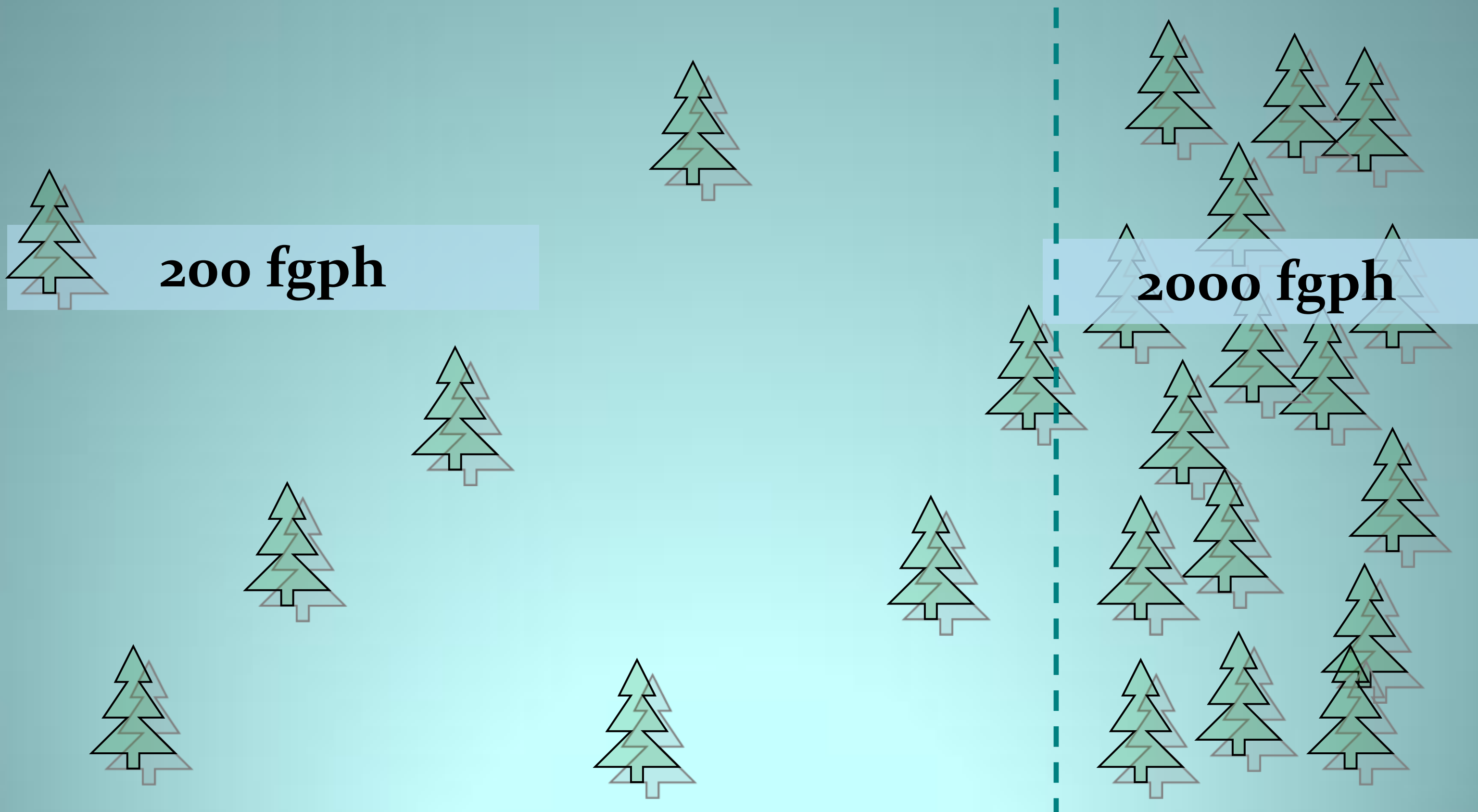
What if we don’t stratify?

(And average density is at MSS=700)



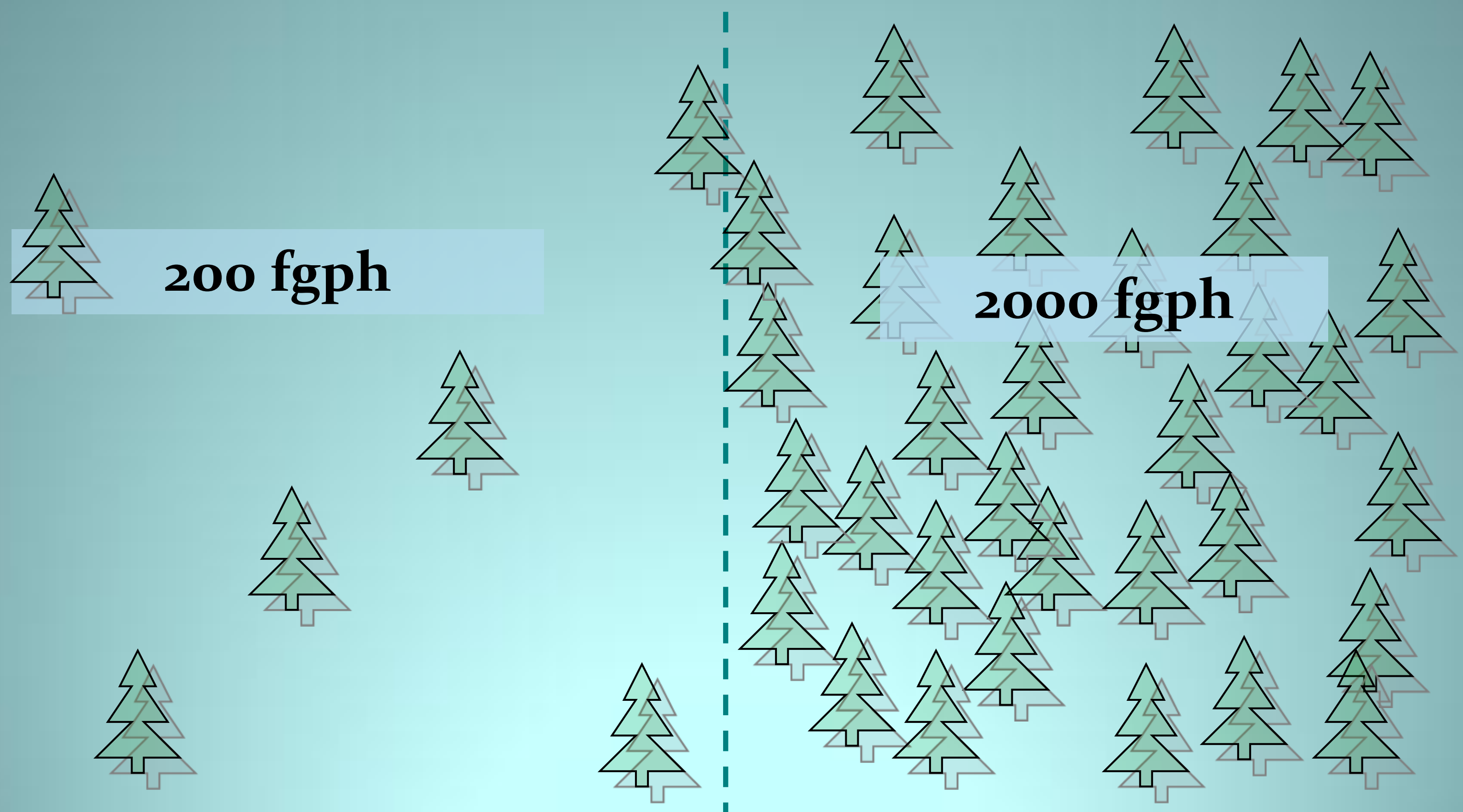
What proportion of area can be understocked?

What if we don't stratify?
(And average density is at MSS=700)



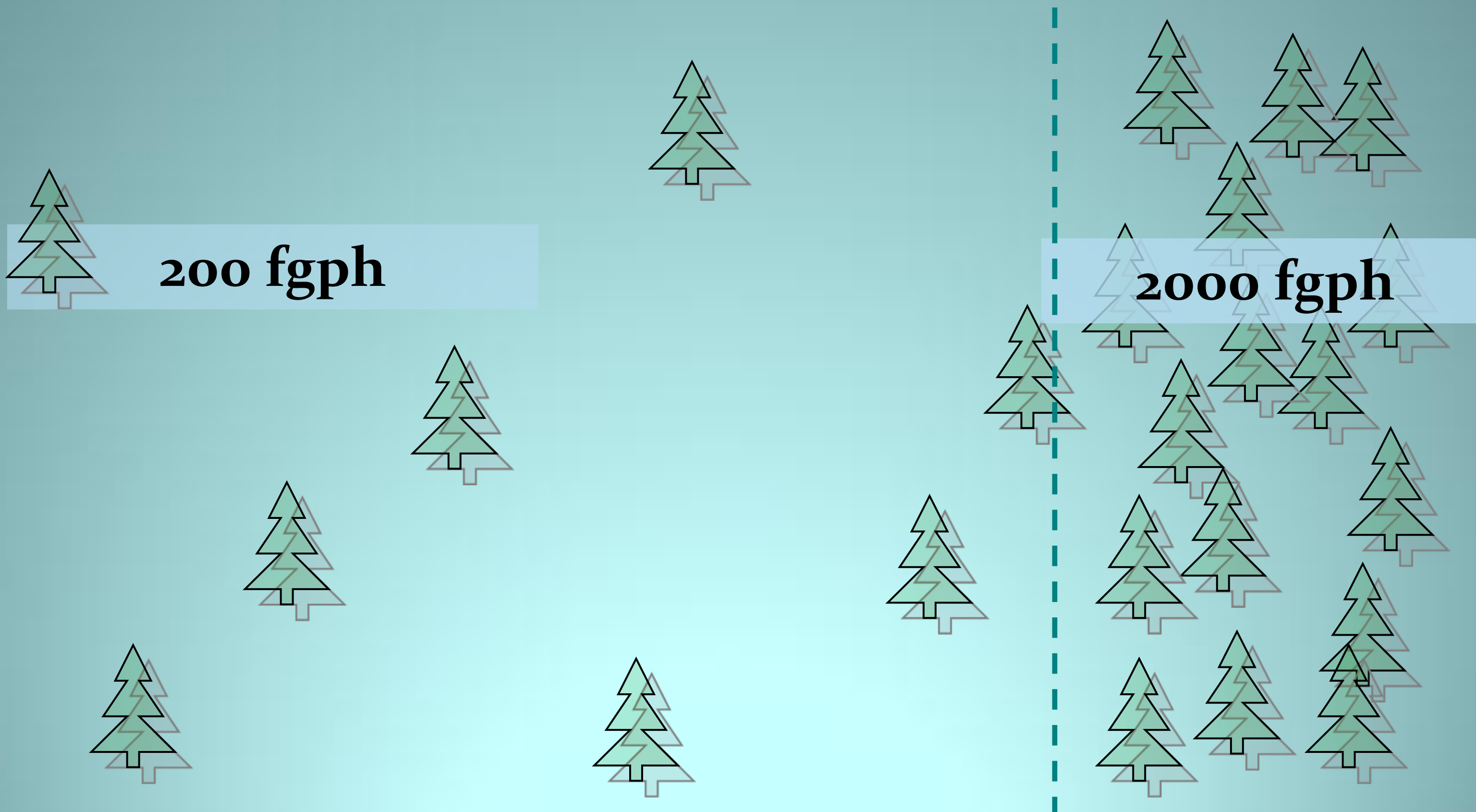
The proportion of area that can be understocked ➔ 72% !!

What if we use the M-value?
(And average density is at MSS=700)



The proportion of area that can be understocked ➔ only 50%

What if we don’t use the M-value?
(And average density is at MSS=700)



The proportion of area that can be understocked ➔ 72% !!

Percent Understocked Area

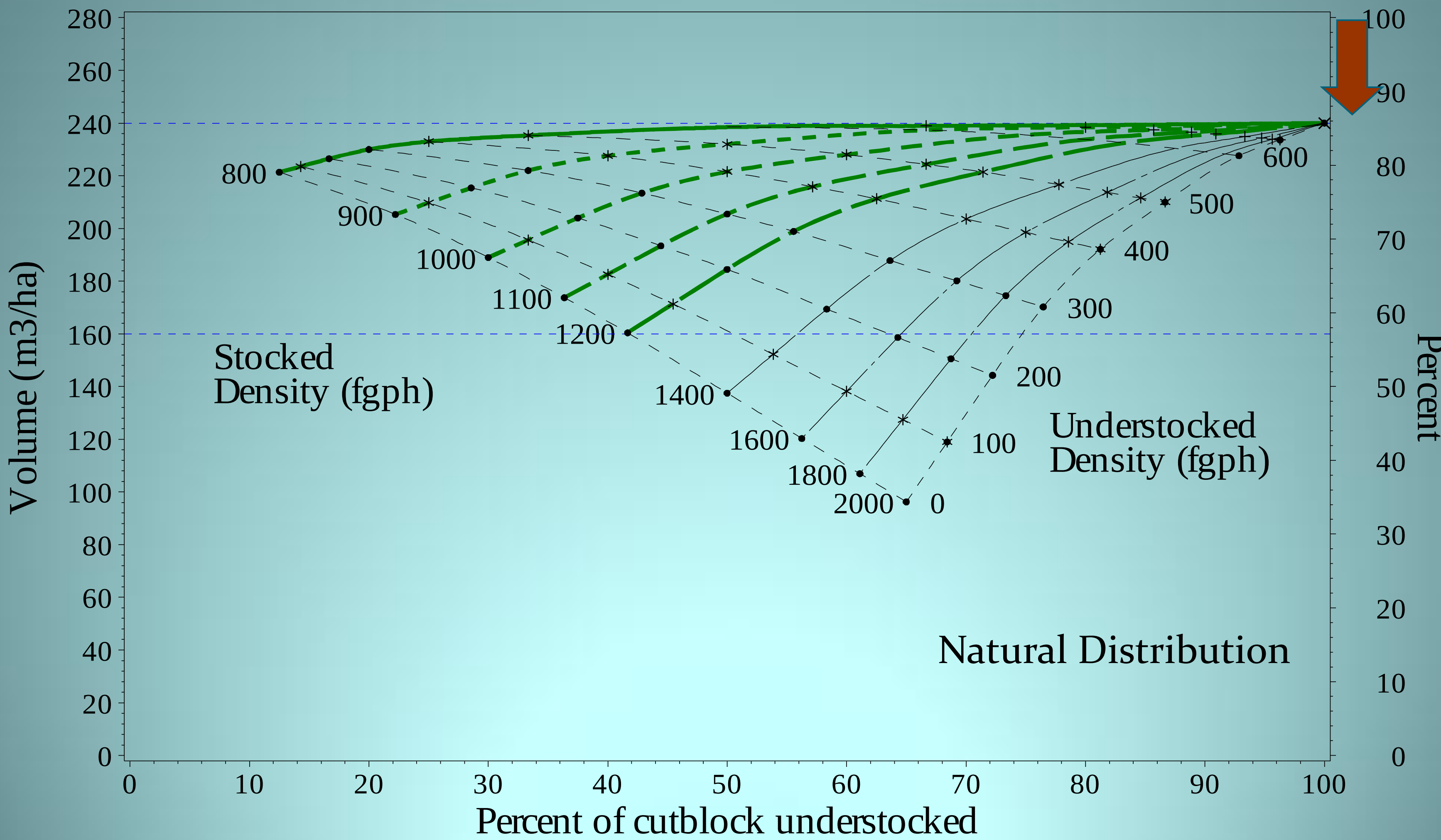
(with an overall average of 700 fpgh)

Understocked Density (fgph)	Density (fgph) in Stocked Areas				
	800	1000	1200	1600	2000
0	12.5%	30 %	42 %	56 %	65 %
200	17 %	38 %	50 %	64 %	72 %
400	25 %	50 %	62 %	75 %	81 %
600	50 %	75 %	83 %	90 %	93 %
650	67 %	86 %	91 %	95 %	96 %

How does this effect the Projected Volumes?

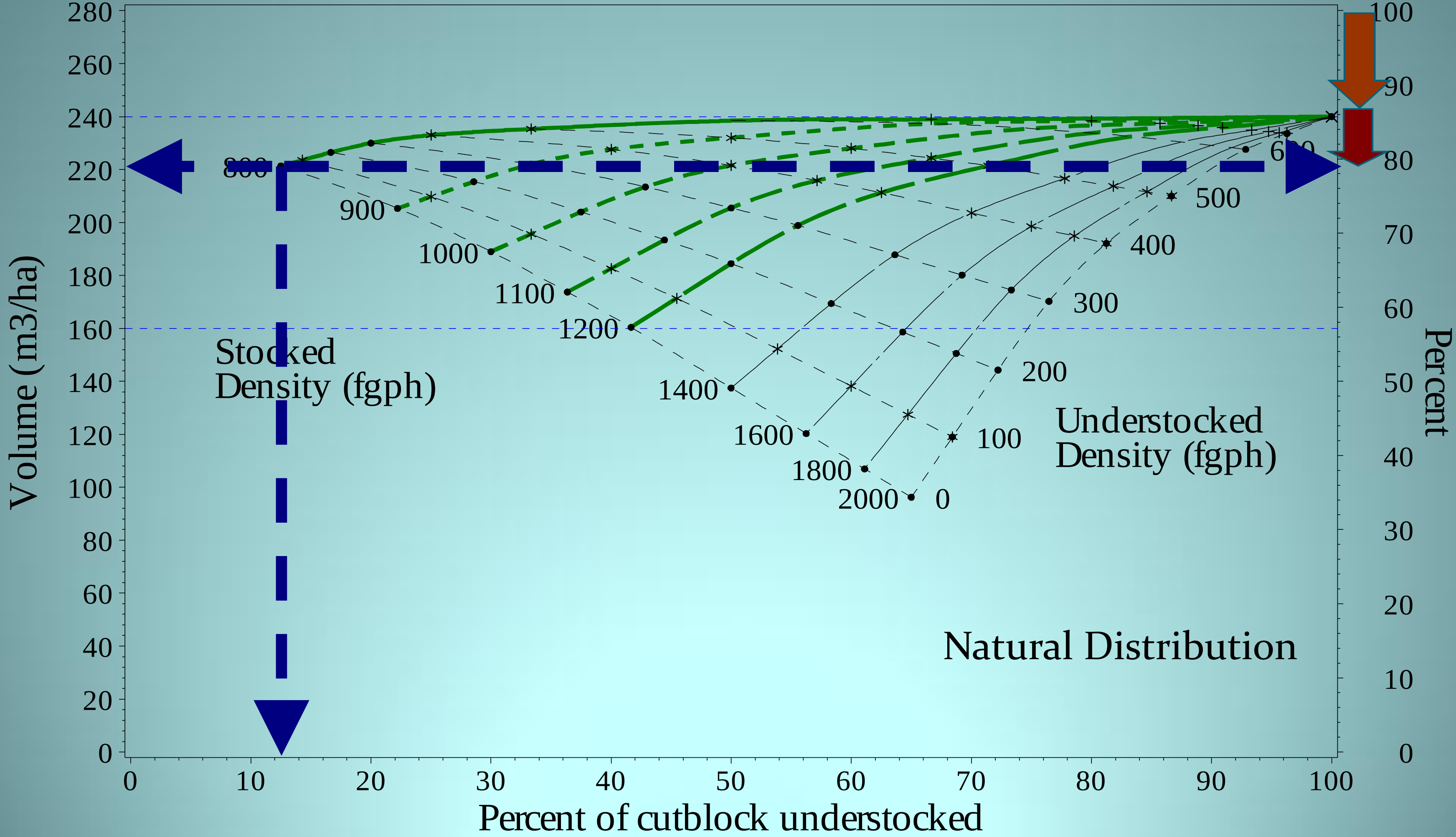
- All the points on the following graphs represent cutblocks with an average density at the MSS value of 700 fgph.
- The projected volume loss increases the greater the disparity between the understocked and stocked densities.
- The M-value limits the possible extreme projected volume loss.

Average density of 700 fgph



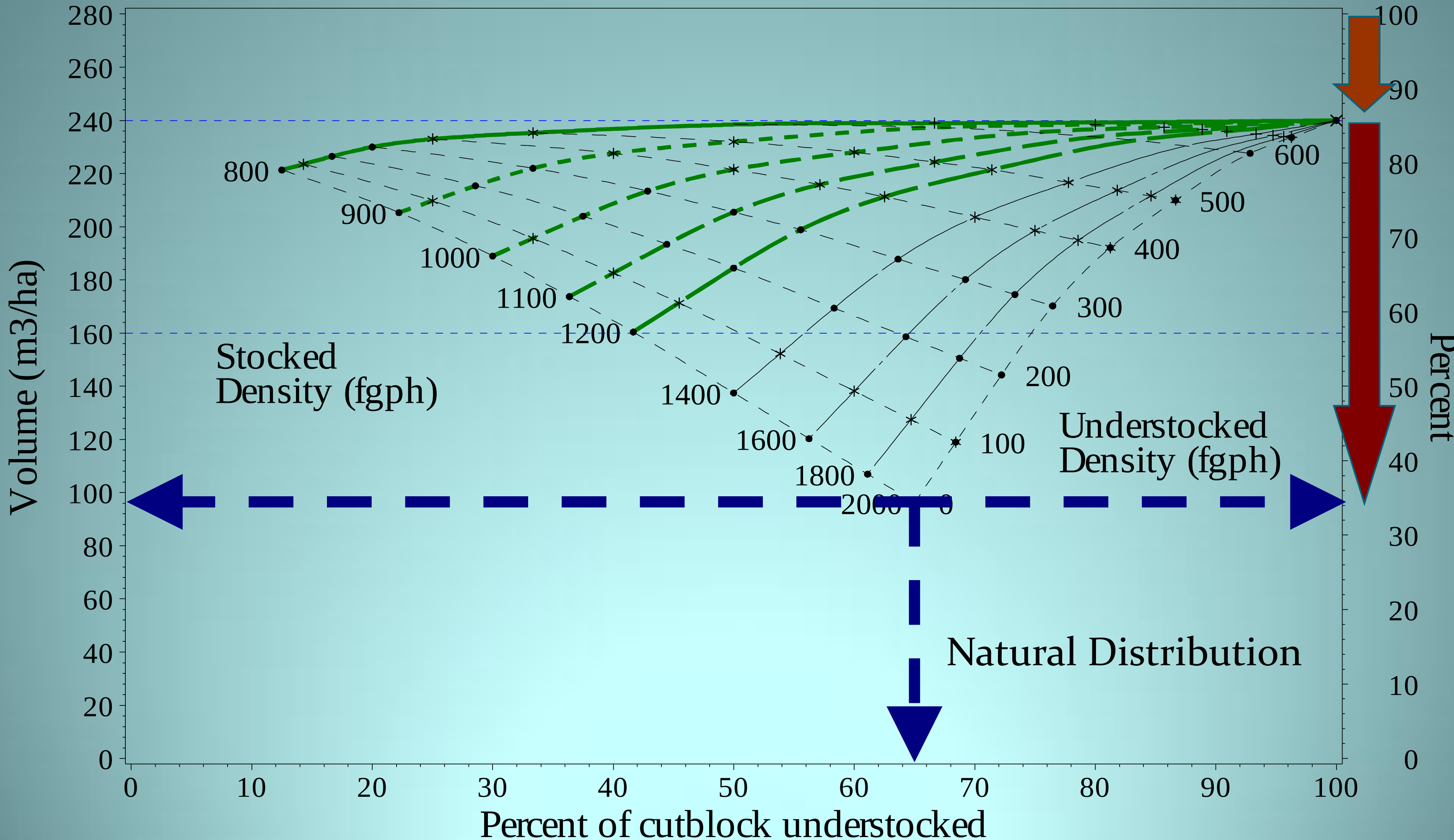
Average density of 700 fgph

(Stocked density of 800 fgph)



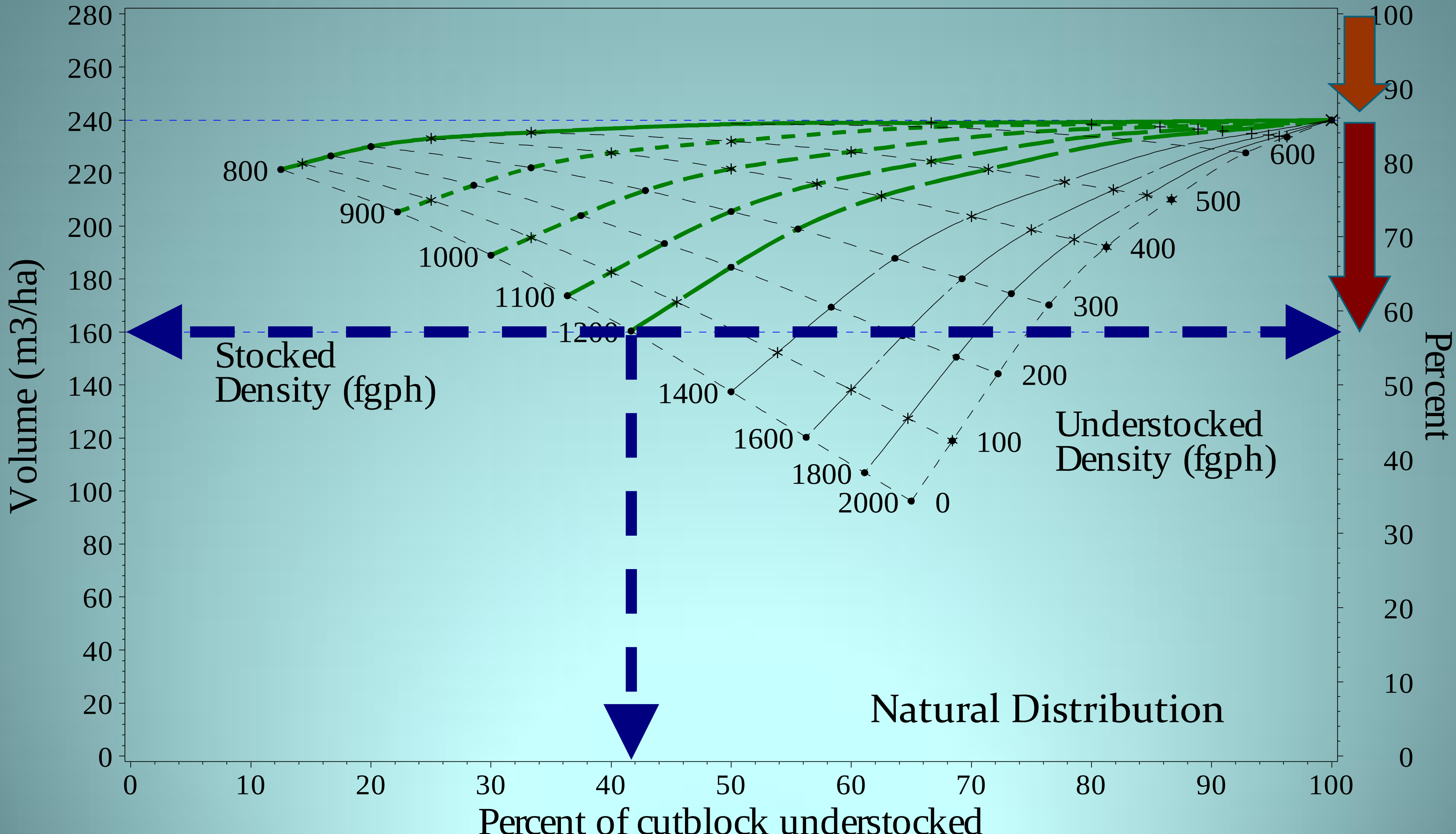
Average density of 700 fgph

(Stocked density of 2000 fgph)



Average density of 700 fgph

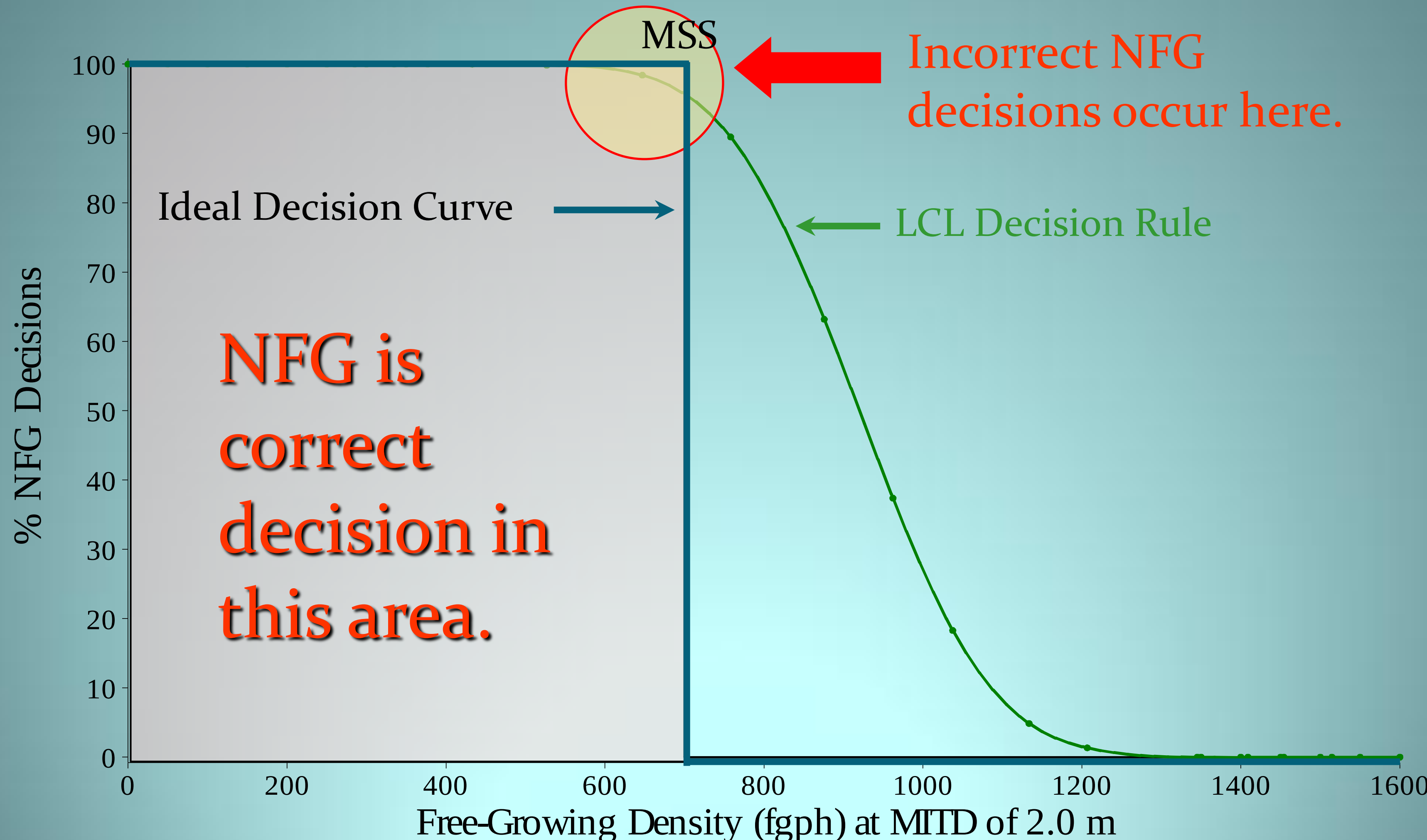
(Stocked density of 1200 fgph)



Decision Rules

LCL Decision Rule - NFG decisions

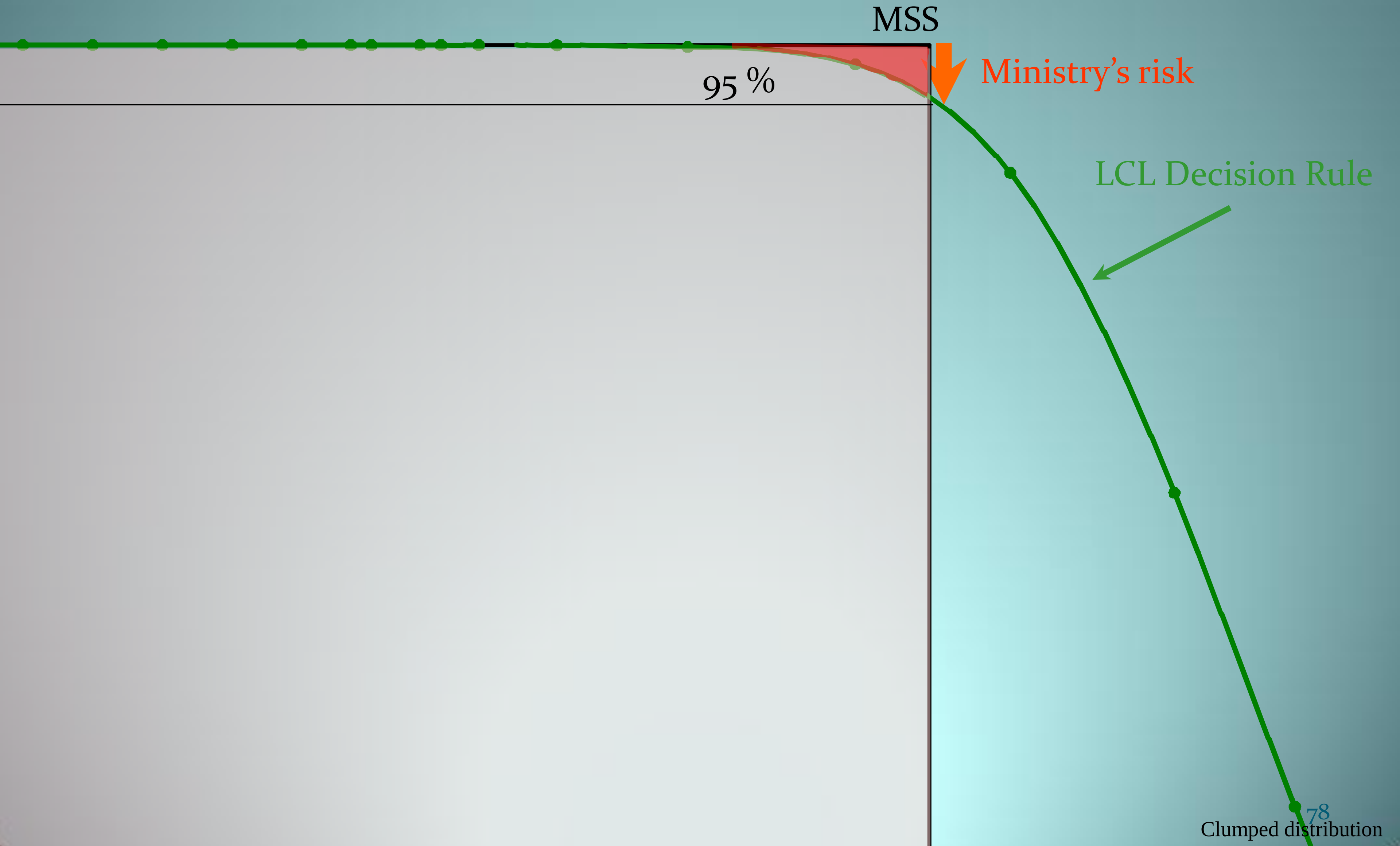
(Ministry's risk)



Clumped distribution

LCL Decision Rule - NFG decisions

(Ministry's risk)

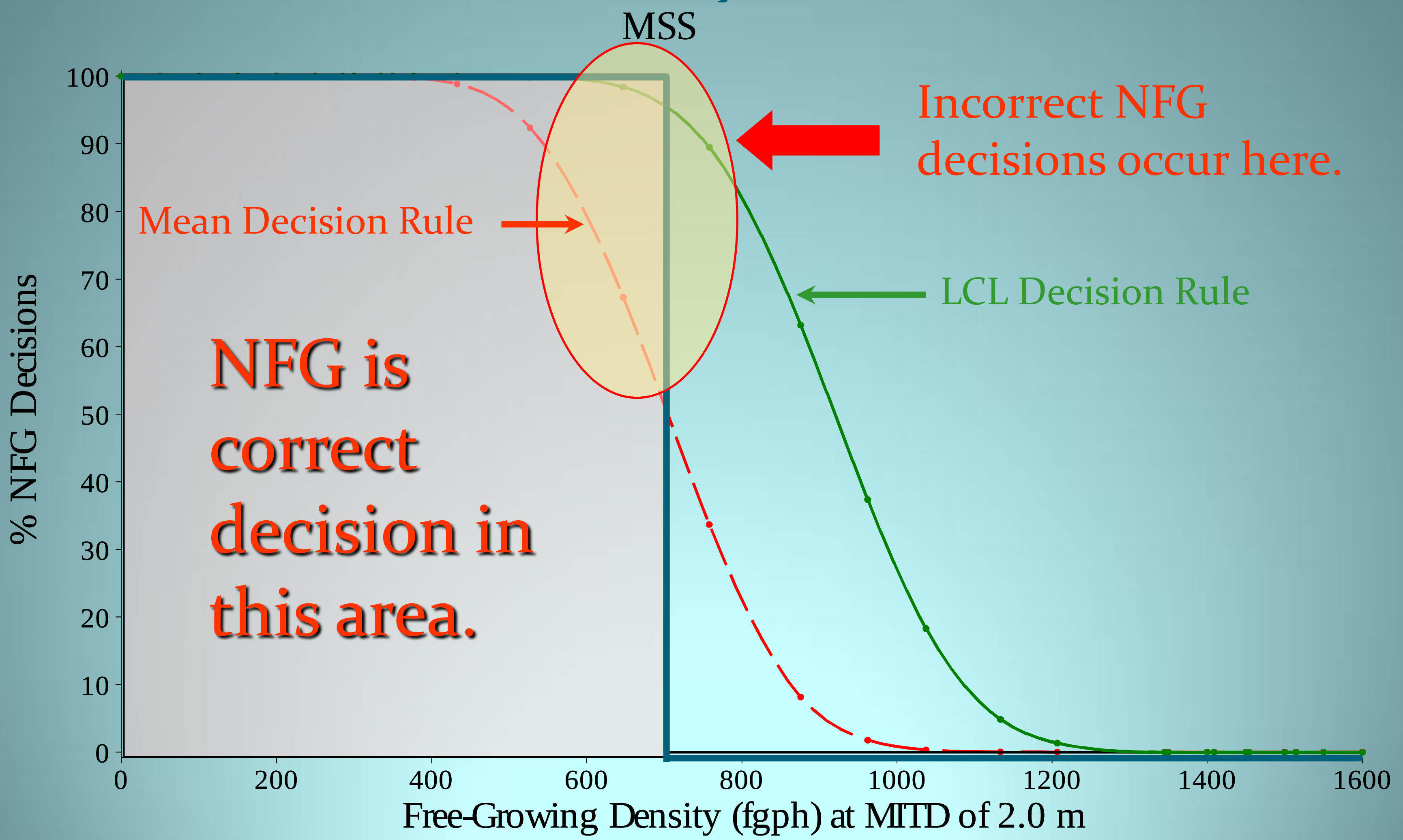


LCL Decision Rule - NFG decisions
(Ministry's risk)

- This decision rule sets 5% as the maximum risk for accepting as stocked an understocked stand.
- That is, no more than 5 out of 100 truly understocked stands would be accepted as free-growing.
- Or, we would correctly identify at least 95 out of 100 understocked stands as not free-growing.

LCL Decision Rule - NFG decisions

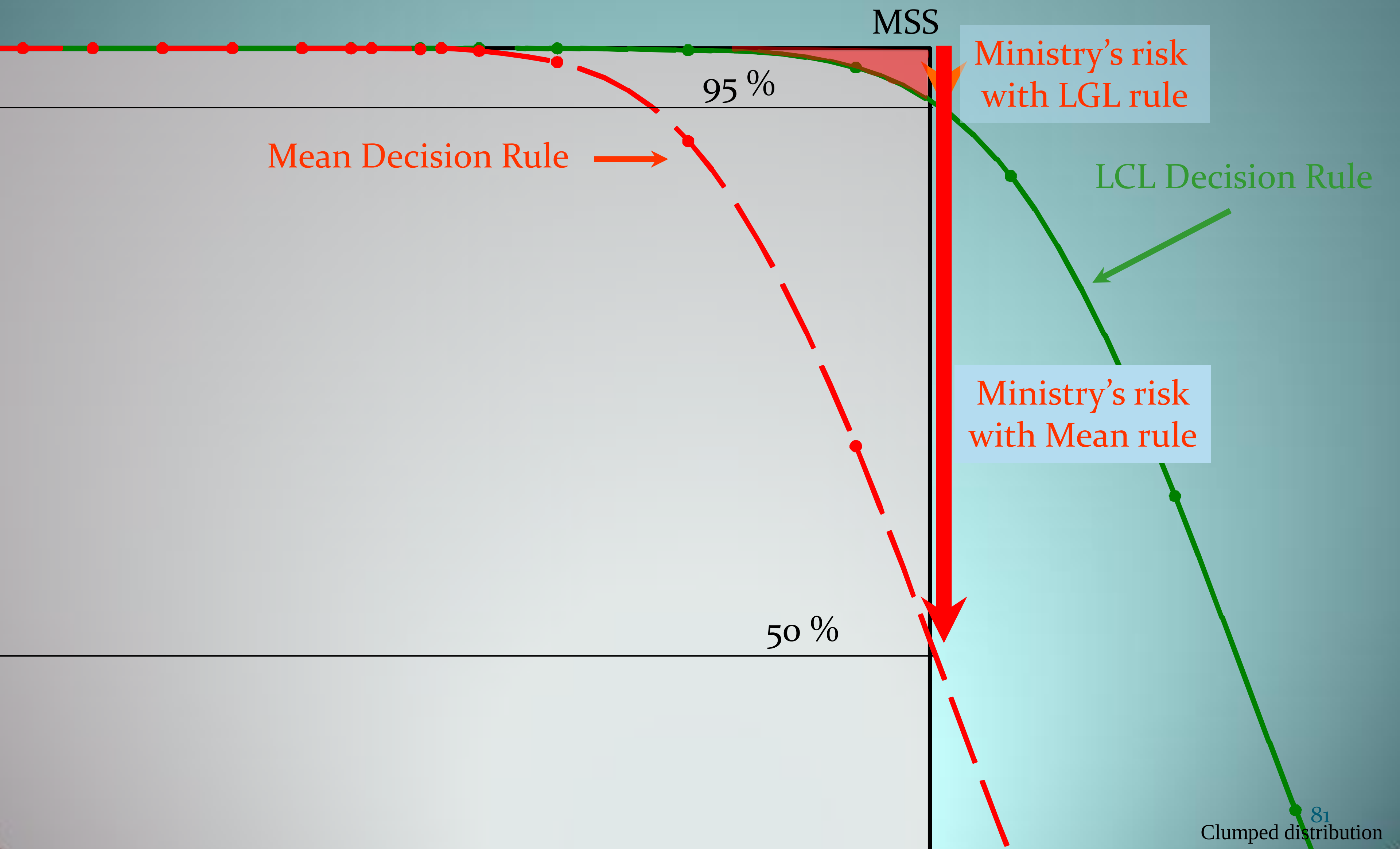
(Ministry's risk)



Clumped distribution

Mean Decision Rule - NFG decisions

(Ministry's risk)



Clumped distribution

Mean Decision Rule - NFG decisions
(Ministry's risk)

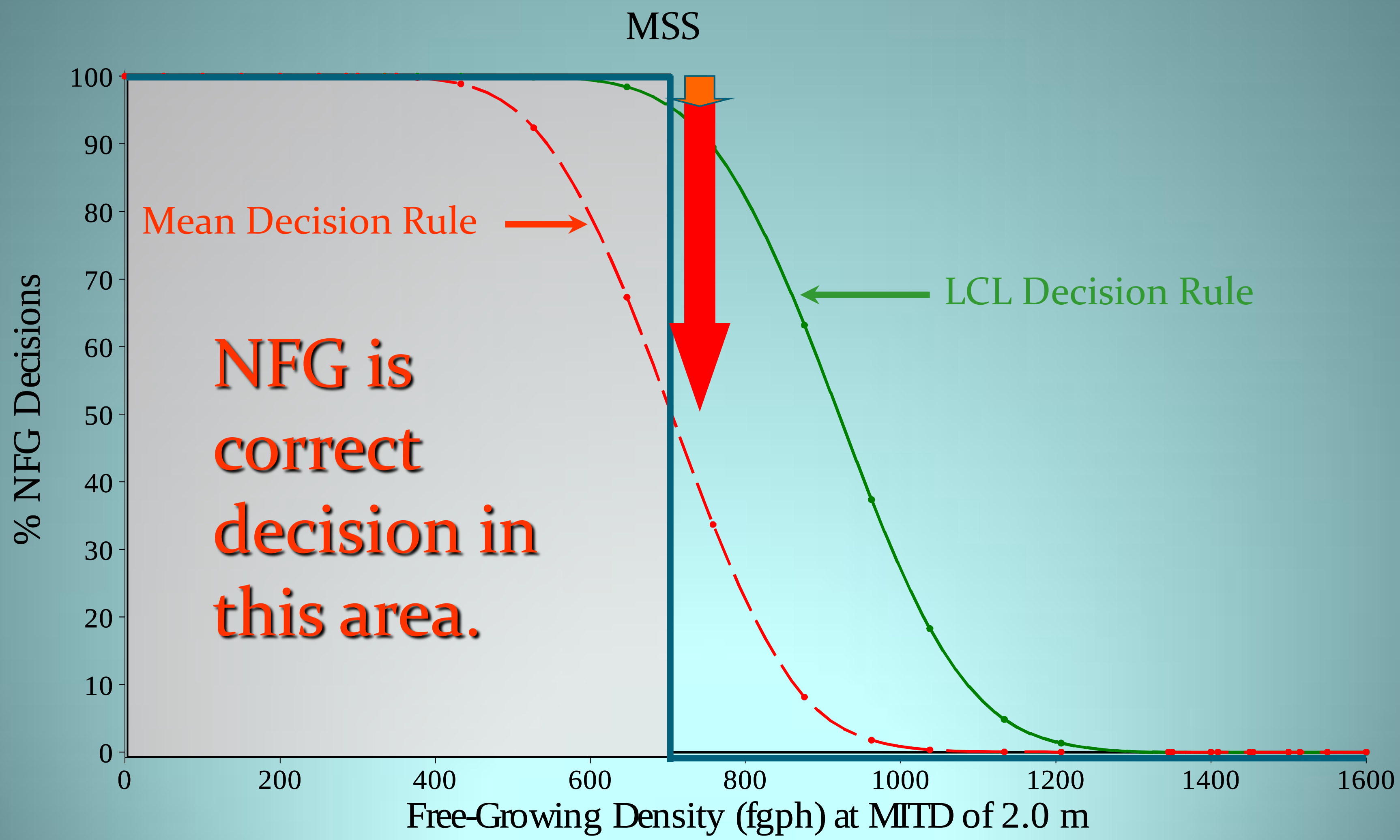
- This decision rule sets 50% as the maximum risk for accepting as stocked an understocked stand.
- That is, no more than 50 out of 100 truly understocked stands would be accepted as free-growing.
- Or, we would correctly identify at least 50 out of 100 understocked stands as not free-growing.

Comparing Decision Rules
(Ministry's risk)

Which is better:

- **LCL**: At least 95 out of 100 understocked stands correctly identified as such, *or*
- **Mean**: At least 50 out of 100 understocked stands correctly identified as such?

Mean & LCL Decision Rules



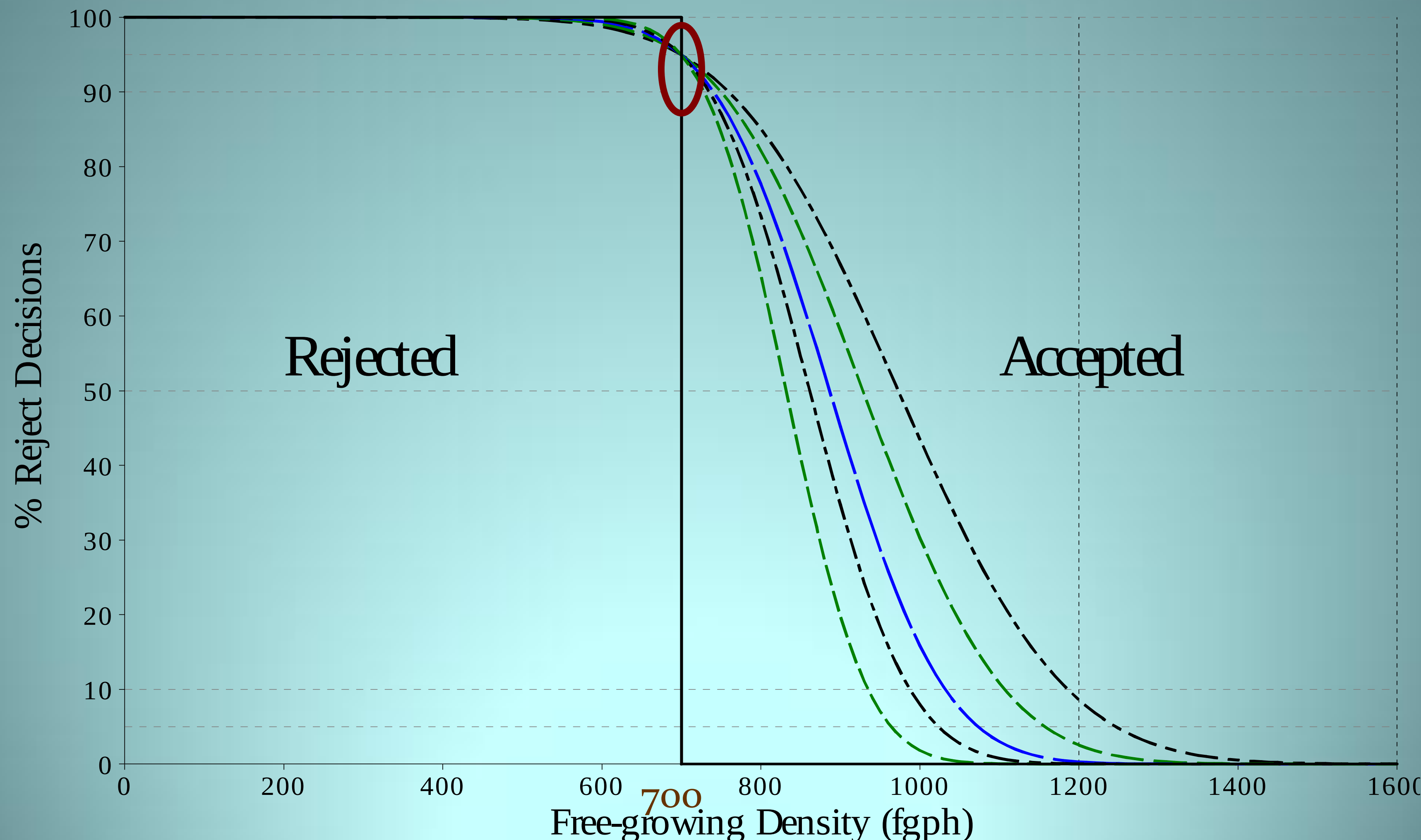
Clumped distribution

Decision Rules – Effect of Variability

(Ministry's risk)

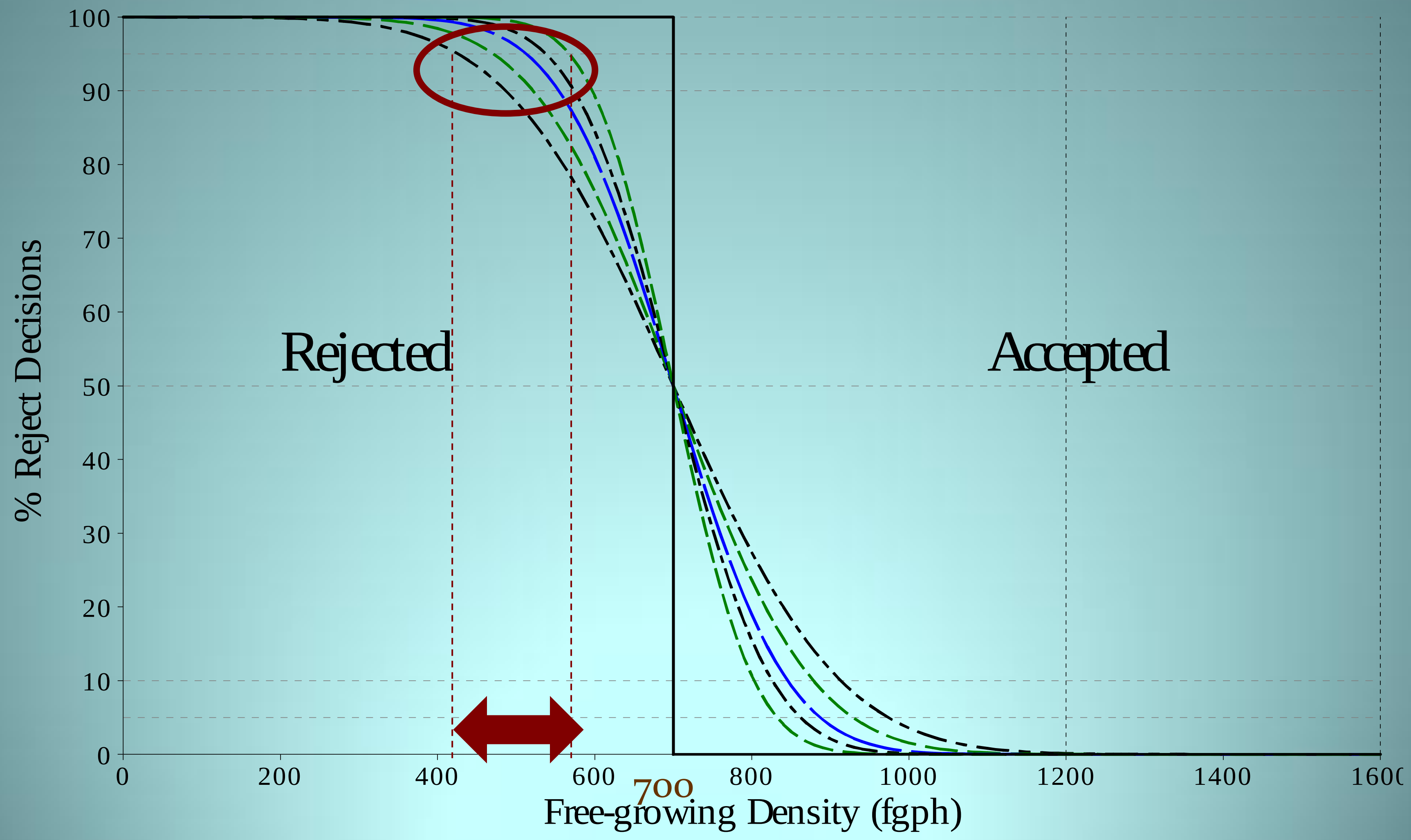
- **LCL**: Ministry's risk of 5% is <u>always</u> at the MSS.
- **Mean**: Ministry's risk of 5% changes depending upon variability but is always at a true free-growing density less than the MSS.

LCL Decision Rule – Variability
(Ministry's risk – at the MSS)



Mean Decision Rule – Variability

(Ministry’s risk – at some density < MSS)



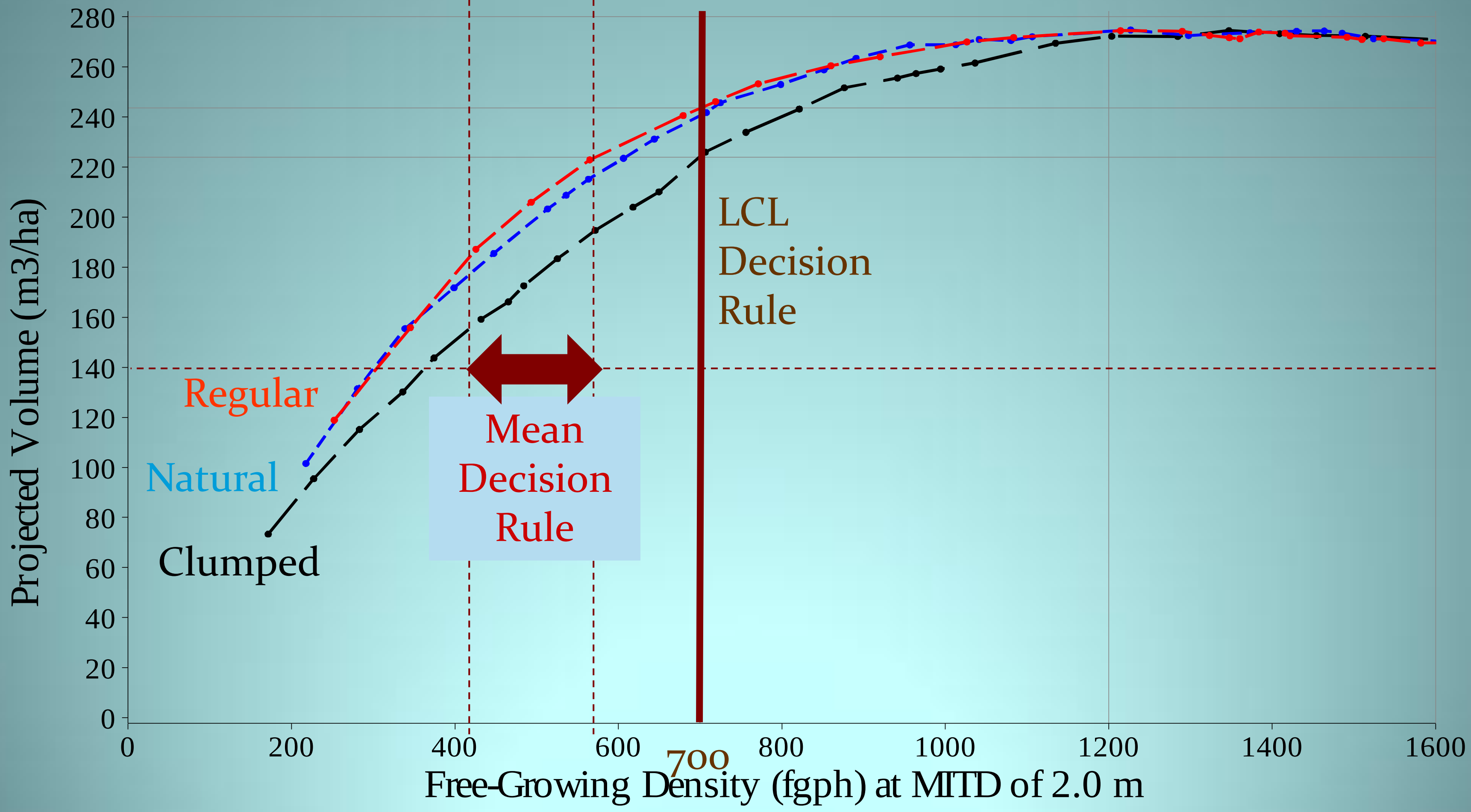
Decision Rules – Effect of Variability

(Ministry's risk)

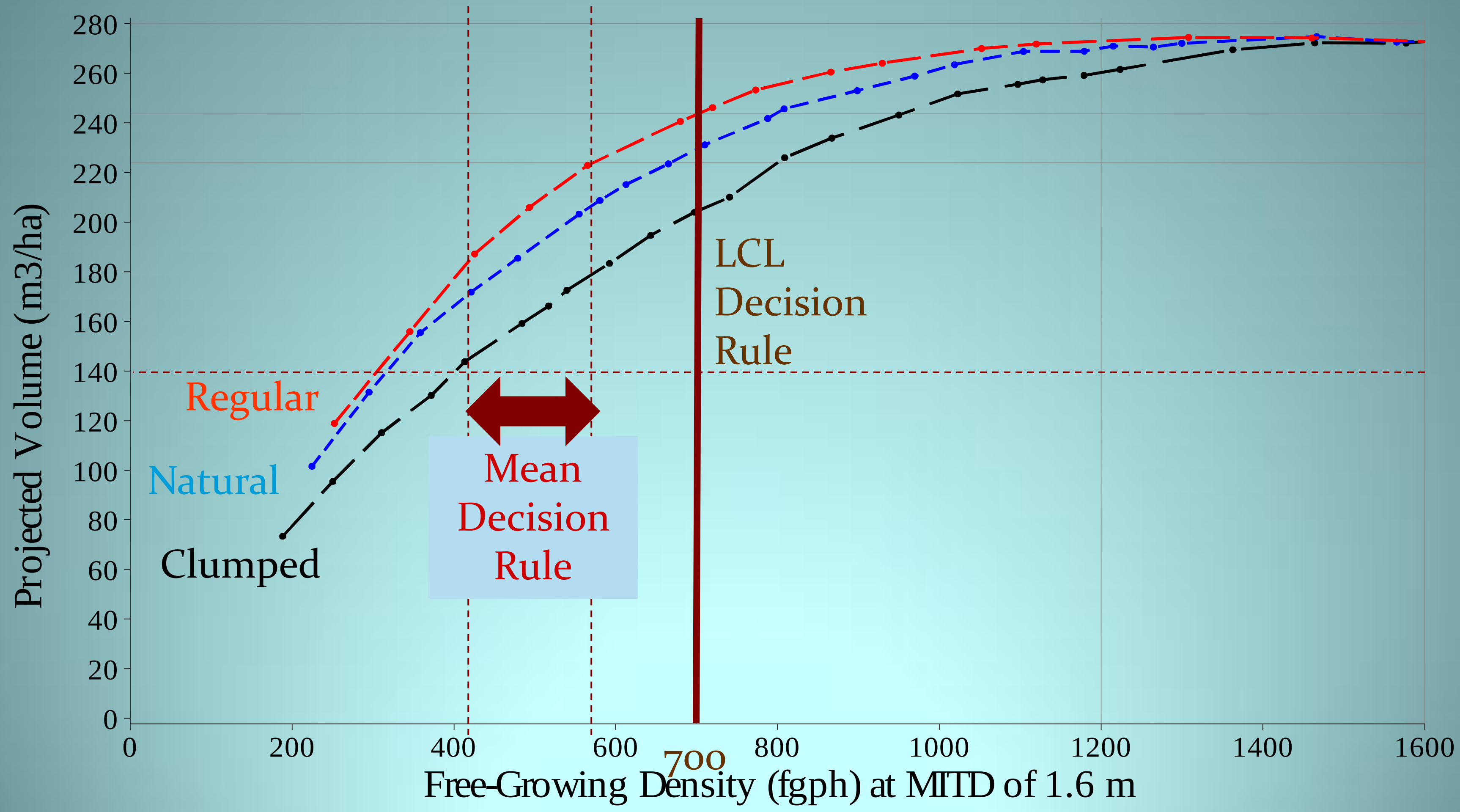
- **LCL**: Ministry's risk of 5% is always at the MSS = 700 fgph.
- **Mean**: Ministry's risk of 5% in graph ranges from 420 to 570
  -- > but is always less than 700 fgph.

- This is an example only and other ranges are possible.

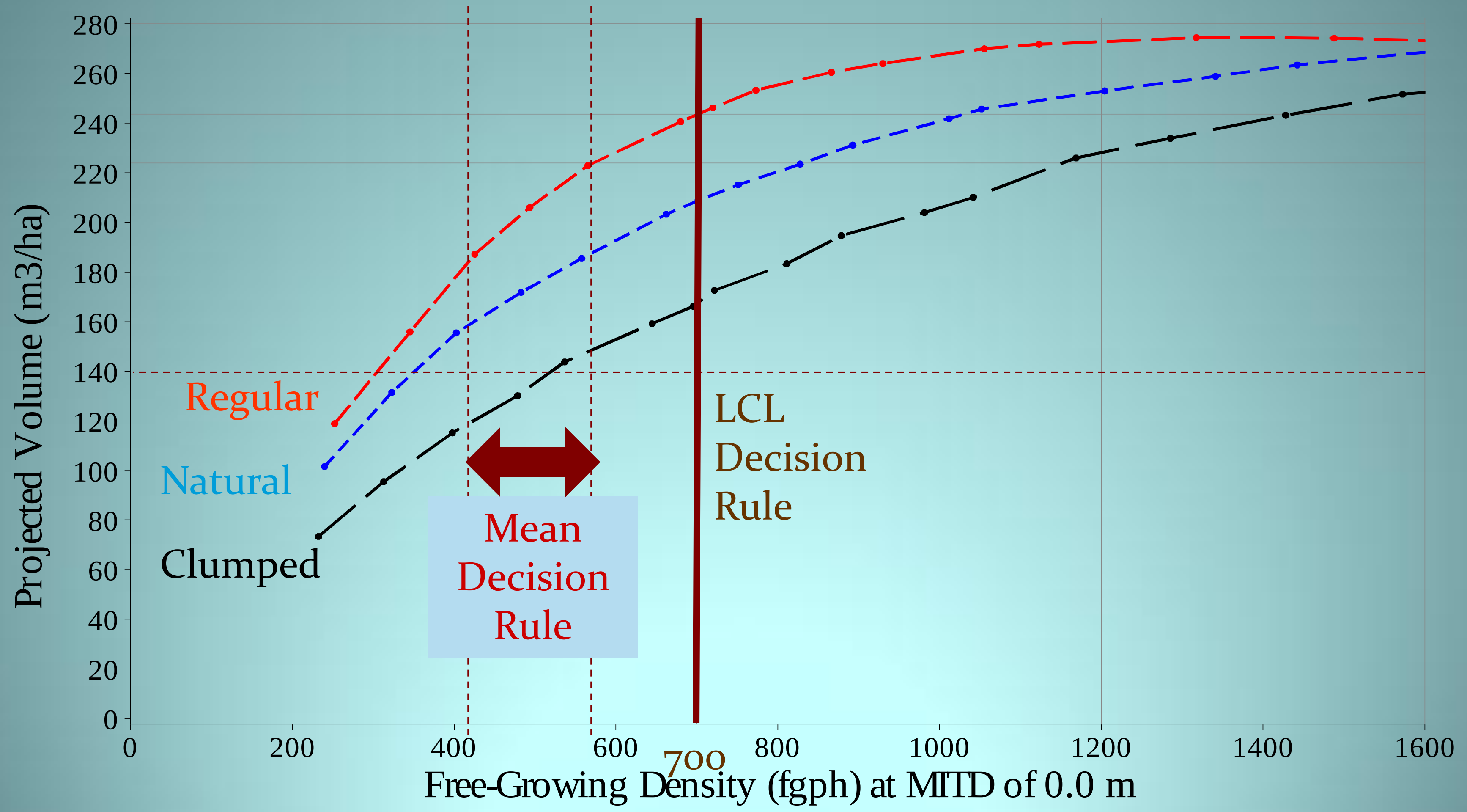
Projected Volume: FG Density (MITD = 2.0 m)



Projected Volume
(MITD = 1.6 m)



Projected Volume: Total Density (MITD = 0.0 m)



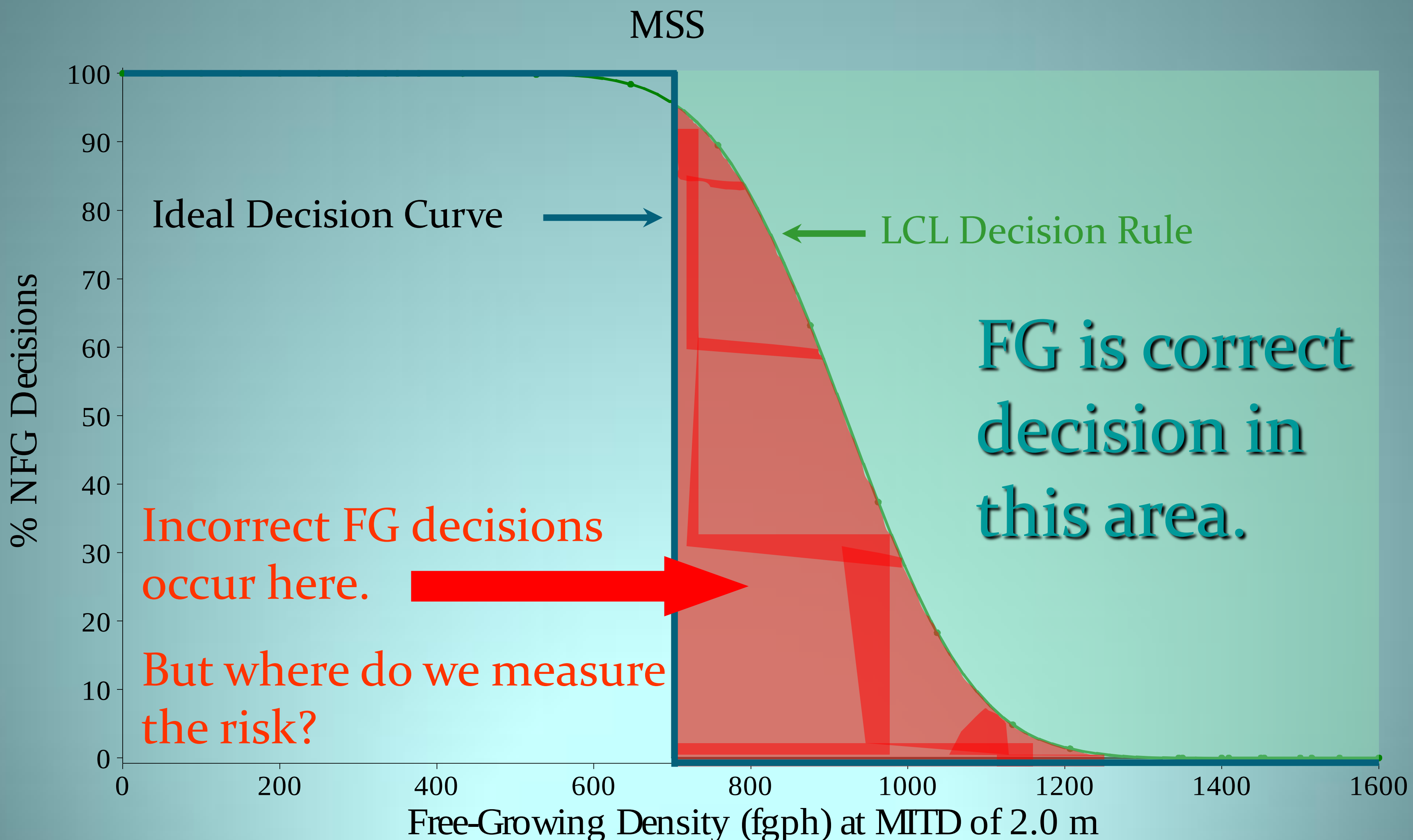
Mean Decision Rule
(Ministry's risk is high and unknown)

- Can easily lose a lot of projected volume if used carelessly.
- Could still control risk if require variability (measured by SE, LCL or CV) to be within a narrow limit.
  - This might require larger sample sizes.
- Easier to simply use LCL rule at a lower MSS.

Licensees' Risk

LCL Decision Rule - FG decisions

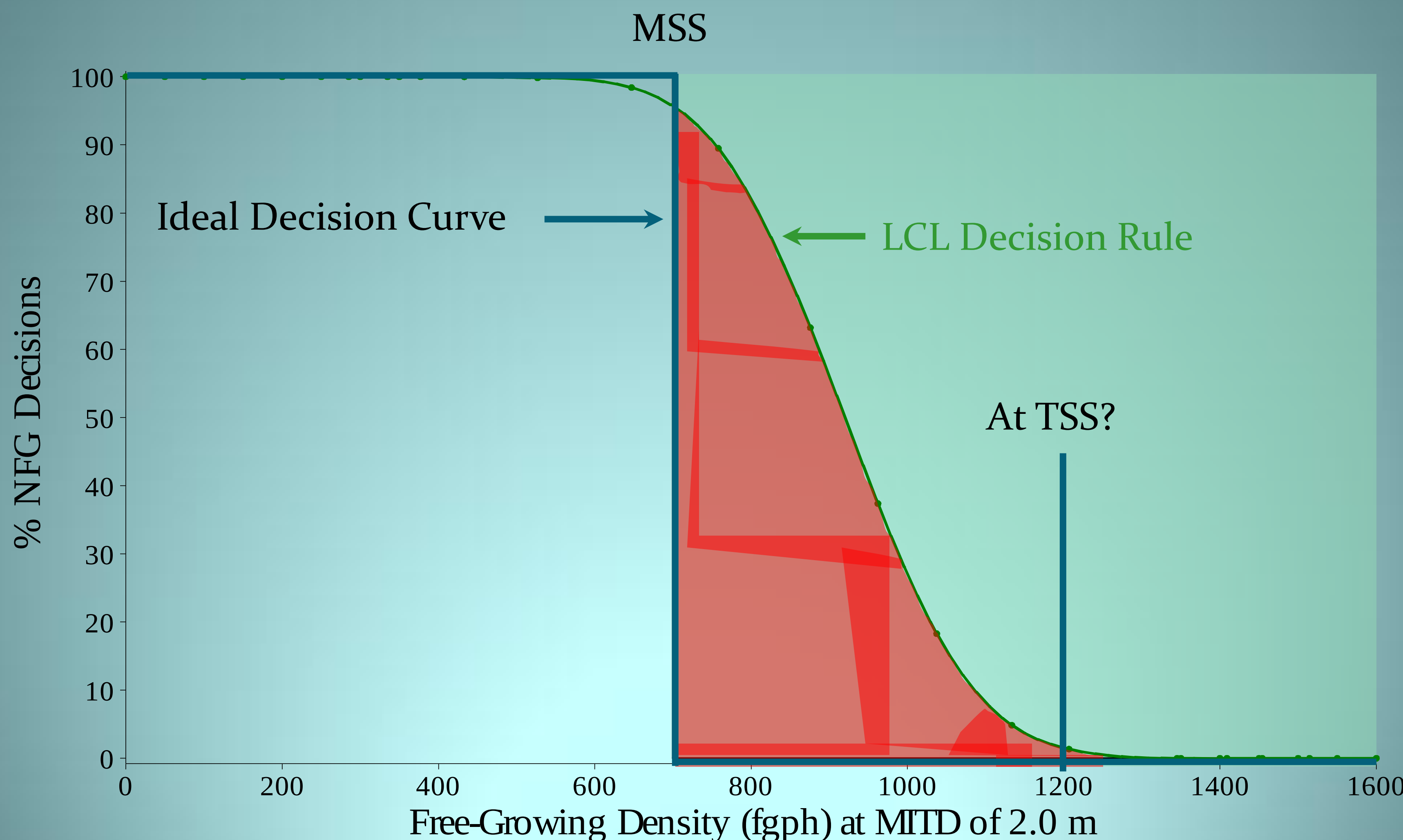
(Licensees' risk)



Clumped distribution

LCL Decision Rule - FG decisions

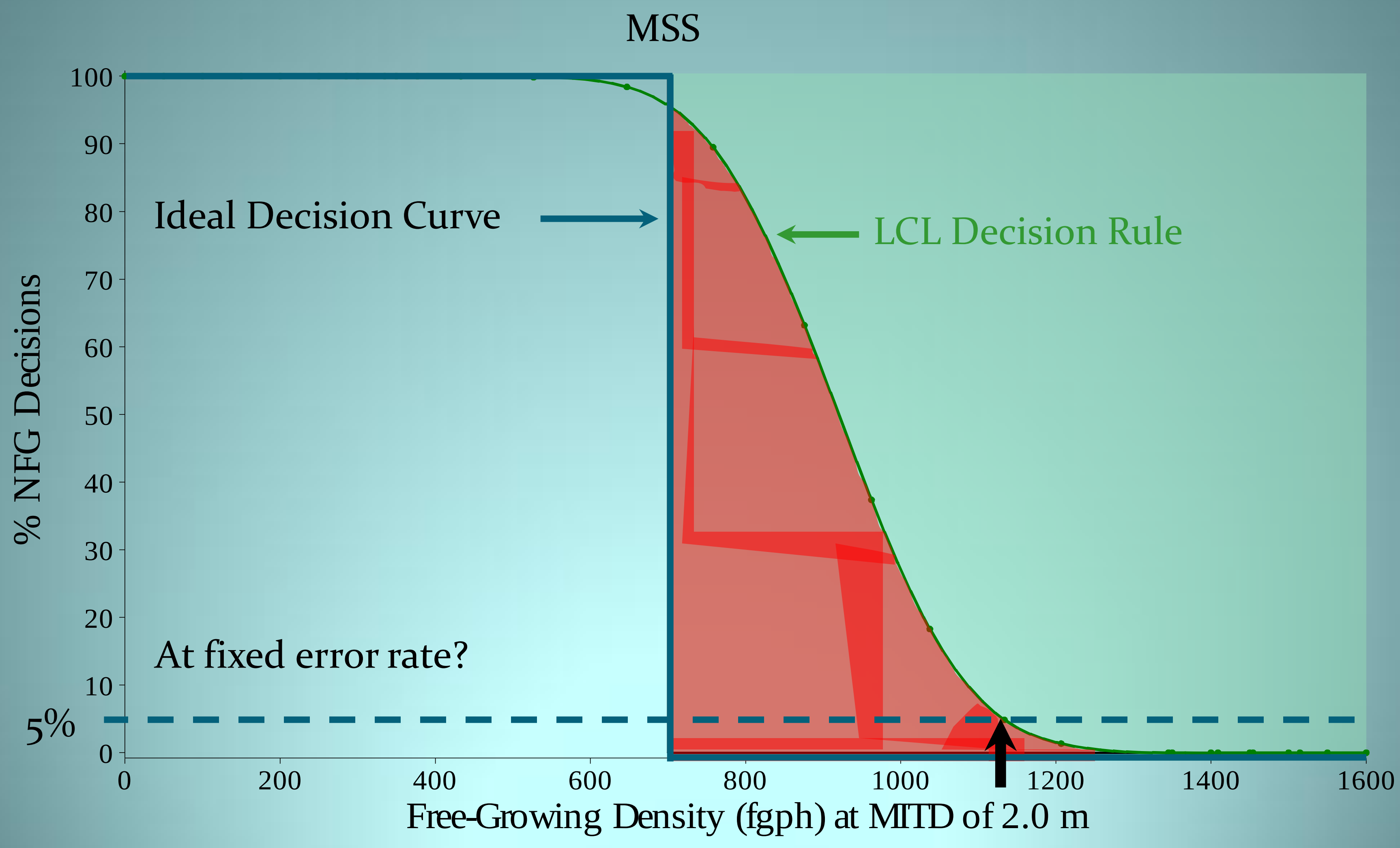
(Licensees' risk)



Clumped distribution

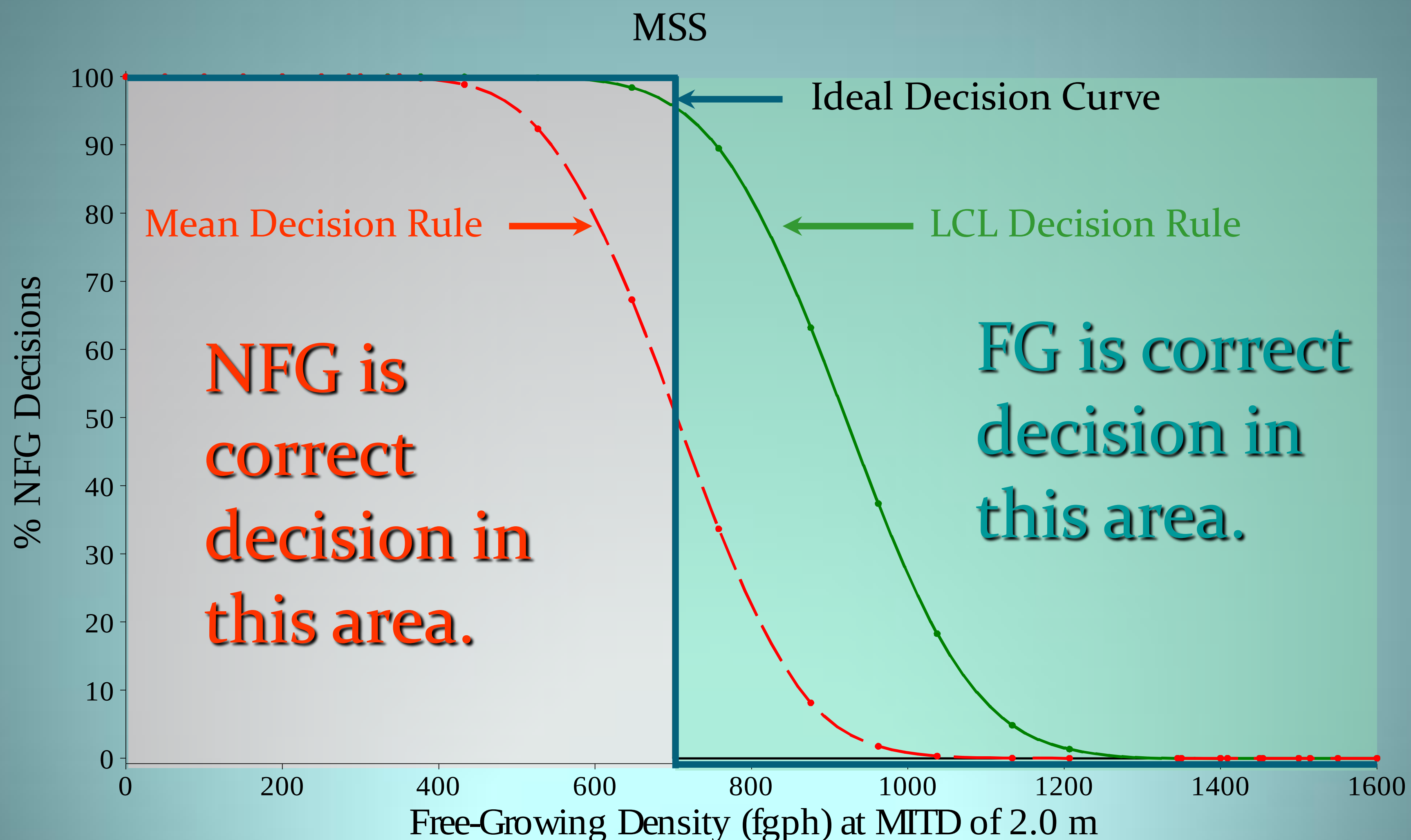
LCL Decision Rule - FG decisions

(Licensees' risk)



Clumped distribution

LCL & Mean Decision Rules



Clumped distribution

Conclusions

- Stocking standards are currently measured in free-growing density NOT total density.
- The purpose of the Silviculture Survey is to make a decision.
- The LCL decision rule controls the Ministry's risk of incorrectly accepting understocked strata.

Conclusions

- The MITD is an essential part of the definition of free-growing.
- The M-value is important for heterogeneous or clumpy areas, BUT
- Stratification can do a better job of ensuring that understocked areas are properly identified.

Conclusions

- Considerable preparation work is required to demonstrate that we will get the same results as before if:
  - We change the method of determining if free-growing has been achieved.
  - We change current standards from density measures to projected volume measures.