

## Top Height Estimation in Lodgepole Pine Sample Plots

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### Outline

- ◆ Top height definition
- ◆ Estimates
- ◆ Data
- ◆ Relative biases
- ◆ Discussion & Conclusions

This research is part of Batho's M.Sc. thesis, on developing a site index model for Interior lodgepole pine.

We are grateful to the MoF Forest Sciences Program and to the MSRM Terrestrial Information Branch for providing the data.

### Introduction

#### ◆ Top Height:

*"Top height is the height of the largest diameter tree on a 0.01 ha plot, providing the tree is suitable." (FPC, 1998)*

[http://www.for.gov.bc.ca/mef/fpc/standards/topheight/top\\_height.htm](http://www.for.gov.bc.ca/mef/fpc/standards/topheight/top_height.htm)

Official definition.

### Introduction

#### ◆ Top Height:

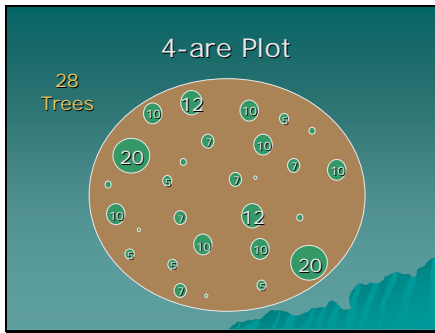
*Top height is the height of the largest diameter tree on 1-are plots, providing the tree is suitable.*

- ◆ *What if we don't have 1-are plots?*

Top height is a stand property, so change "a ... plot" to "plots".

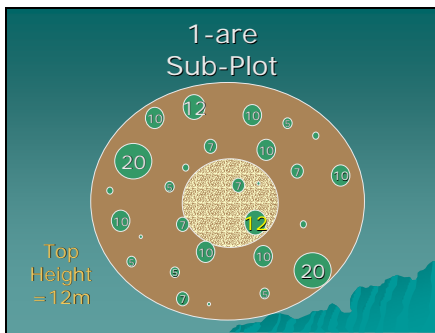
Hectare = 100 ares.

Problem: Estimate top height with no sub-plot information.



4-are plot example, for clarity (will use 5- and 8-are plots later).

Numbers are tree heights, in metres.

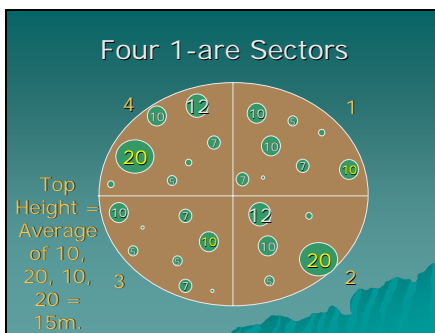


Straightforward application of the definition.

Assume heights estimated from a monotonic height-dbh regression, so largest by diameter equals largest by height.

Unbiased.

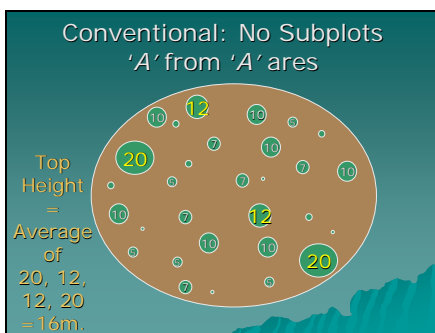
Not available for most existing data.



Alternative: 1-are sectors. Mean of largest height per sector.

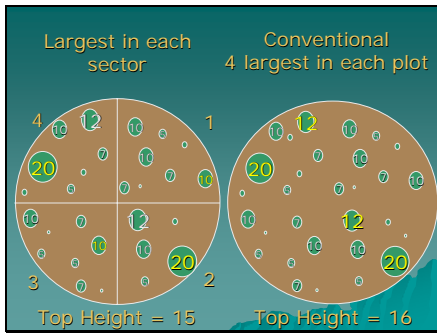
Unbiased, ignoring any possible sub-plot shape effects (shape is not specified in the FPC definition). Lower variance than single sub-plot.

Sector information not available for all plots.



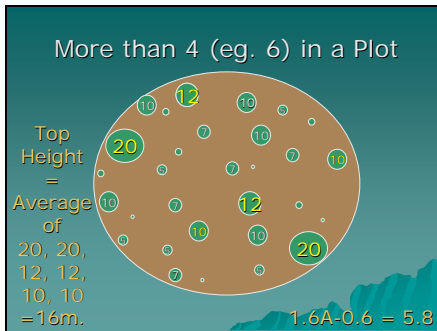
No sub-plots?

Customary to average over the proportion corresponding to the 100 largest per hectare. Here, the 4 largest chosen from the whole plot.



The conventional method produces an overestimate: (4 largest in plot)  $\geq$  (4 largest constrained to be one in each sub-plot). "Selection effect".

General awareness of this bias appears to be low. The few available studies found average biases of 15 to 80 cm, varying with species and plot size. Perhaps acceptable for routine inventory, but undesirable in growth and yield work.

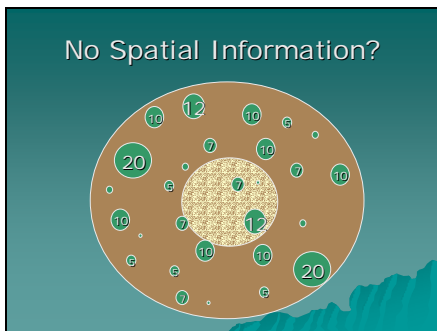


A simple bias reduction strategy is to select more than A largests in an A-are plot.

Theoretical arguments suggest the 1.6 A - 0.6 largests as a reasonable approximation (Garcia, O., Can.J.For.Res. 28: 1509-1517, 1998).

Call this the "adjusted largests" procedure.

Another method:



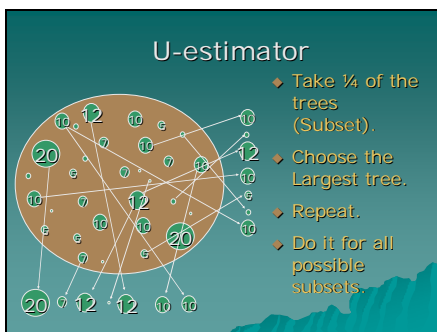
The 1-are subplot represented  $\frac{1}{4}$  of the plot.

Without spatial information, we could instead select  $\frac{1}{4}$  of the plot trees, at random, and use the largest height from those.

This would be nearly unbiased, ignoring any possible spatial autocorrelation effects.

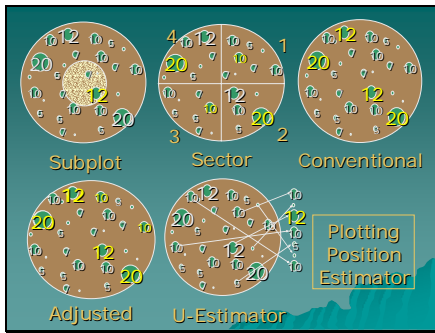
$\frac{1}{4}$  of the trees is  $28/4 = 7$  trees in this example (rounding or interpolation could be used for non-integers).

Better, we could average over several 7-tree subsets.



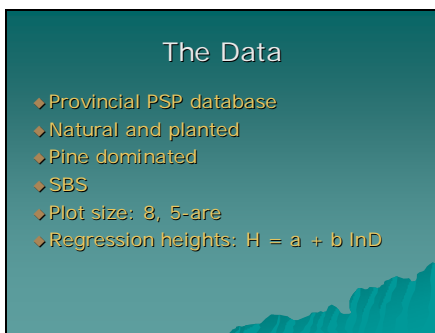
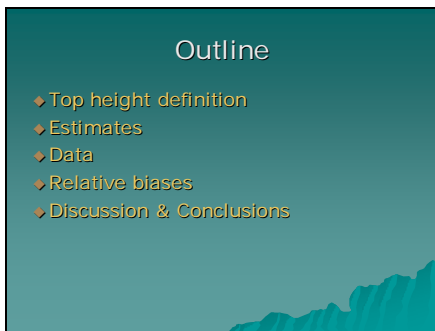
Or we can take this further, and use **all** the possible 7-tree subsets.

This average of the largest in each of the possible subsets is an instance of a U-estimator, and has some nice statistical properties. It can be calculated as a simple weighted average, with weights reflecting how many times a tree appears as the largest in a subset (Garcia, op.cit.)



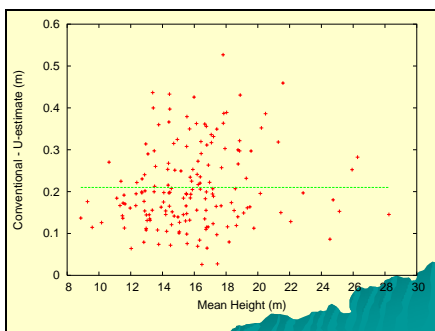
We have not yet obtained sub-plot or sector information. Therefore, for now we compare only the three whole-plot estimation methods: Conventional, Adjusted, and U-Estimator.

We include also a fourth method, a “plotting-position” estimator, which we do not describe here.



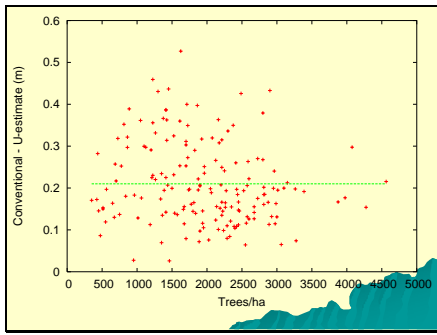
Most frequent plot sizes: 5 ares in planted, and 8 are in natural origin stands.

We show only the natural stands below.

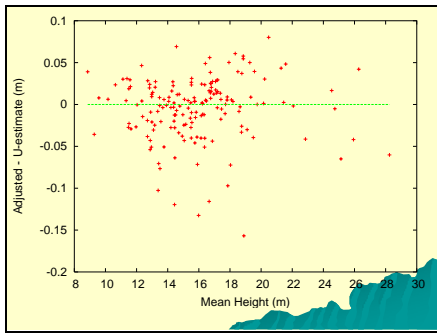


Bias of the conventional method relative to the U-estimator. Or bias of the conventional method, assuming that the U-estimator bias is negligible.

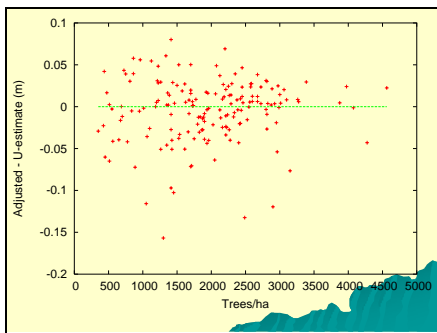
Mean bias is 21 cm (green line), seemingly uniform for all heights.



No obvious trend with stand density either.



The adjusted largests and the U-estimator have about the same (lack of?) bias.

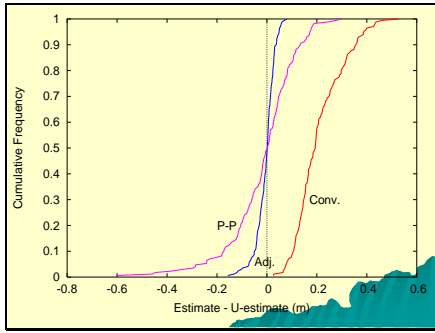


Again, no trends are evident.

	Natural (170 8-are plots)		Planted (21 5-are plots)	
	Top height (m)	Rel. bias (cm)	Top height (m)	Rel. bias (cm)
Conventional	18.78	21	8.43	9
Adjusted largests	18.57	0	8.34	0
Plotting-positions	18.56	-1	8.35	1
U-estimator	18.57	0	8.34	0

Mean heights and biases (relative to the U-estimator).

Based on 170 natural and 21 planted plot measurements.



Empirical distributions of differences from the U-estimate.

The “bias” in the conventional estimate is clear.

Both the Adjusted and the Plotting-Position estimates are unbiased (or equal the bias of the U-estimator), but the Adjusted has better precision.

Reference	Species	Plot size (ares)	Bias (cm)
Fries (1974)	Scots pine	10	47
Fries (1974)	Norway spruce	10	82
García (1998)	Planted D. fir	4	15
García (1998)	Planted D. fir	16	20
García (1998)	Eucalypt	10	29
Magnussen (1999)	Douglas-fir	3	70
Magnussen (1999)	Douglas-fir	5	80
Magnussen (1999)	Douglas-fir	100	150
This study	L. pine (planted)	5	9
This study	L. pine (natural)	8	21

Conventional method bias was on the low side

### Conclusions

- ◆ Conventional is biased (~21 and 9 cm).
  - Don't use
- ◆ Adjusted seems adequate for inventory.
  - Cost-free bias reduction
- ◆ U-Estimator possibly worthwhile for more exacting work.
- ◆ (to be confirmed...)

Comparison with sub-plot or sector data is pending.