Optimizing sample plot measurements in a multipurpose forest inventory

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The earliest papers on optimizing sample plot size come from 1950's

- One variable (typically stem volume) considered

- The estimation is based on simple random sampling

- The results are condition-specific

- The results depend on what criterion is used to measure optimality

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What is missing from these early studies

- The number of variables of interest may be very high in NFI
- The measurements on the plot are not error-free
- The plot-level (volume) estimates and cost estimates depend on the within-plot measurements
  - Number (and size) of sample trees
  - Characteristics measured from each sample tree
  - Models and methods used to predict stem volume (among others) from the tree-level measurements
- Regression estimation / model-assisted estimation / model-based estimation may require different type of plot than SRS

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Case study in Northern Finland

- 18 plots of size 50 m * 50 m with all trees measured and located
- The spatial arrangement and diameter distribution of trees in most plots highly uneven

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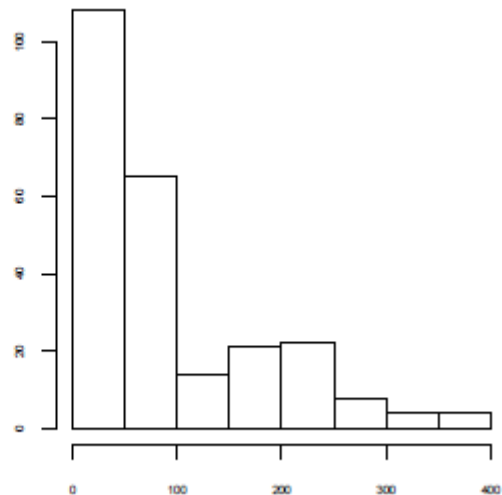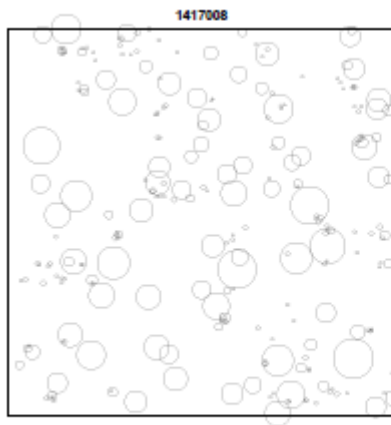
Plot types compared

- The effect of plot size and type simulated by simulating 1000 different samples with one plot within each of the large plots
- The studied plot types were
  - Fixed size with radius from 1 m to 11 m
  - Two co-centric sample plots
    - The radius of the larger plot from 5 m to 11 m
    - The diameter limit 5, 7.5 or 10 cm
  - Angle-count plot
    - Relascope factor from 1 to 3
    - Maximum radius from 6 m to 11 m
- Every 7th tally tree is measured as a sample tree

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Costs

- Costs measured as a function of
  - Time to move from plot to plot (10 – 20 min)
  - Number of tally trees (measurement time 0.5 min/tree)
  - Number of sample trees (measurement time 4.5 min/tree)
  - Number of borderline trees (checking time 0.5 min/tree)

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Optimization

- The optimal plot type and size with fixed sample size n defined using analytic cost-plus-loss approach
    - Loss a weighted sum of standard errors of the variables
- The optimal sample size and plot type and size for one cluster defined minimizing (weighted) standard error with budget constraint
    - Sum of between-plot and within-plot (depending on sample plot size) variation was assumed to describe the total population variance
   - Budget defined for one day of work (420 minutes of efficient work)

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Results with fixed sample size

- Fixed sized plots most effiecient for stem number but angle-count plots very effcient for volume
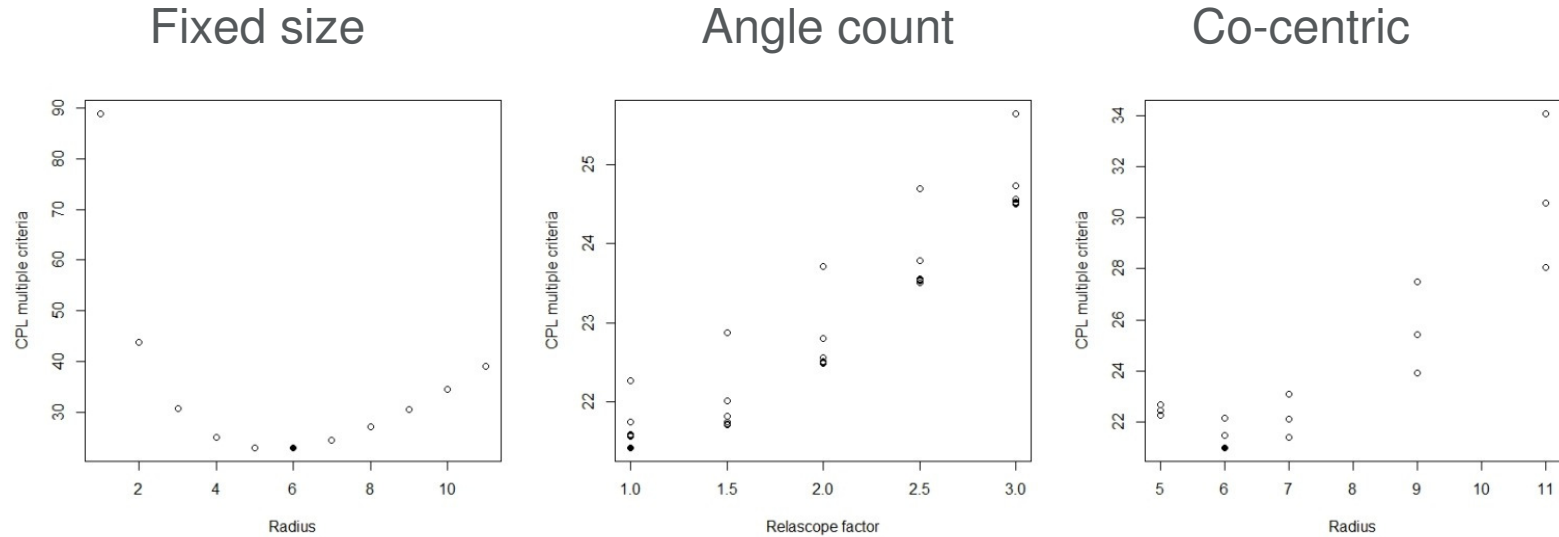 - Fixed ◯, angle count ●, co-centric x.

Stem number   Volume

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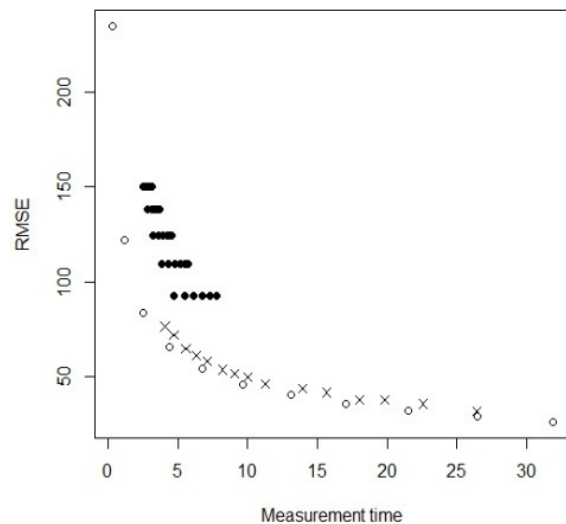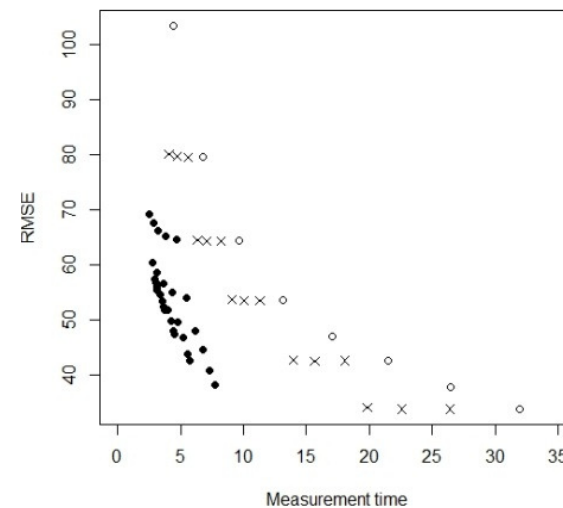
Results with fixed size sample

- When stem number, volume and basal area had equal weight in the loss function, co-centric sample plot was optimal with lowest CPL

Fixed size	Angle count	Co-centric

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Problems

- The results are very sensitive to the relative weight of costs and the RMSE of different variables
- Yet objective weights are not available

- The costs depend very much on the number of measured sample trees, which is highest in the large fixed sized plots
- Yet the accuracy of the results is assumed to be the same irrespective of the number of sample trees or their size distribution

Results with fixed budget

- Results highly dependant on the time required to move from plot to plot
  - Increasing this time
    - reduced optimal cluster size
    - increased optimal plot size
   - and/or reduced optimal diameter limit
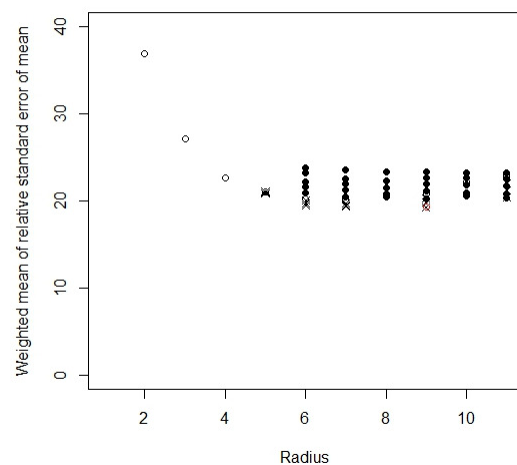
Optimal plot type and size with walking time 15 minutes

Every 7th tree sample tree

Equal weight of variables

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Results with fixed budget

- Results highly dependant on the number of sample trees measured per plot
- Limiting measured sample trees to 3 trees / plot irrespective of plot size made fixed sized plots optimal

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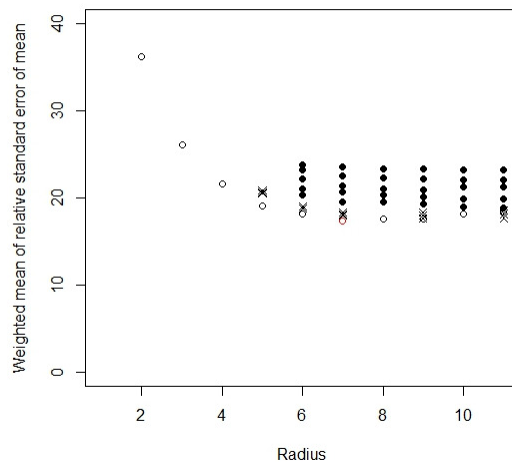
Results with fixed budget

- Assuming regression estimation rather than SRS

- And assuming an decreasing correlation between the auxiliary information and plot measurements as a function of plot-level RMSE

- Optimal plot size was the fixed sized plot with 11 m radius

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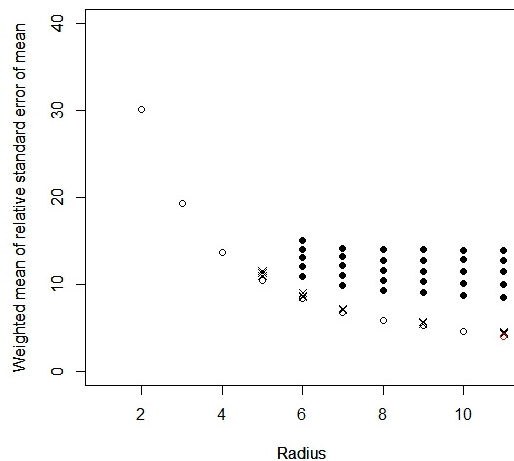
Problems

- The between-plot variation depends also on the distance between plots
  – Measurement costs and variation are not truly independent
- In model-assisted and model-based the selected model shape may affect the optimal plot type and size

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Conclusions

- The whole system
    - Cluster design
    - Plot type
    - Plot size
    - Number of sample trees
    - Sample tree measurements from each tree
    - (Measurement devices)
    - Estimation method

  need to be accounted in the optimization process at the same time in order to get truly optimal plot size and type

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Conclusions

- The results are dependant on the forest structure in Northern Finland

- The optimal plot type and size probably different in Southern Finland

- Separate optimization for different regions needed?

- The 18 plots used for simulations may include "more difficult" and "less difficult" plots which also may affect the results

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Thank you!