Defining optimal sample plot in a multipurpose forest inventory

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Defining optimal plot type and size

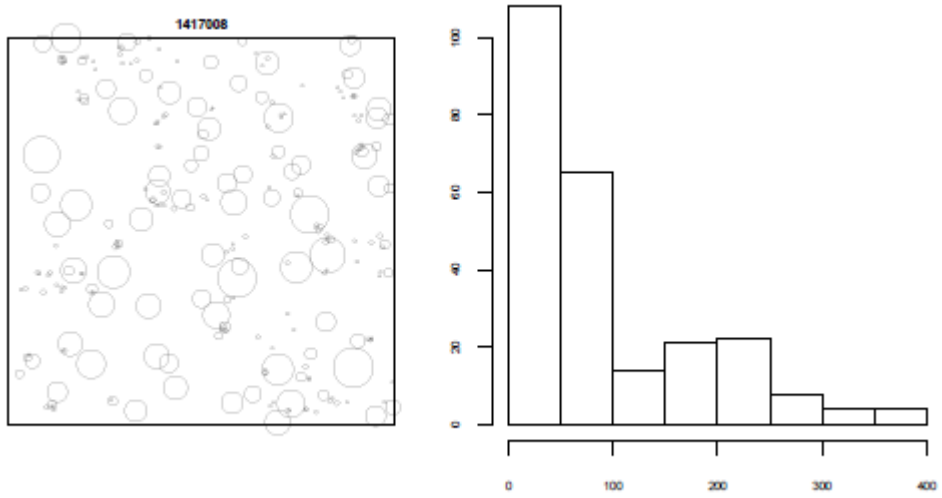
- Has been an important topic in forest inventory since 1950's

- No universal optimum can be found, so we can optimize for specific conditions
- Optimization can be based on
  - Anticipated (super)population variance
  - Simulated sample from a real or simulated population

- The optimal plot type and size is different for each forest characteristics
  - a compromise is needed

Case study in Northern Finland

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



Plot types compared

- The studied plot types were
  - Fixed-sized plots with radius from 3 m to 11 m
  - Combination of two co-centric sample plots
    - The combinations of radii 11/7 m, 9/6 m, 7/5 m, 6/4 m and 5/3 m
    - The diameter limit 5, 7.5, 10, 12.5 or 15 cm
  - Angle-count plot with relascope factor from 1 m^2 to 3 m^2
    - Maximum radius from 6 m to 11 m

- We simulated one plot within each test area
- 1000 simulations

Sample tree selection strategies compared

- Only a sub-sample of all tally trees was selected as sample trees
  - For sample trees the volume was assumed to be known without error
  - For tally trees the volume was estimated with a model including prediction error

- Two strategies
  1. Fixed: Measure all trees within a 1 meter radius from plot center and all trees with $d_{1.3}$>25 cm (S1)
  2. Angle-count: Measure all trees with relascope factor 5 (S2)

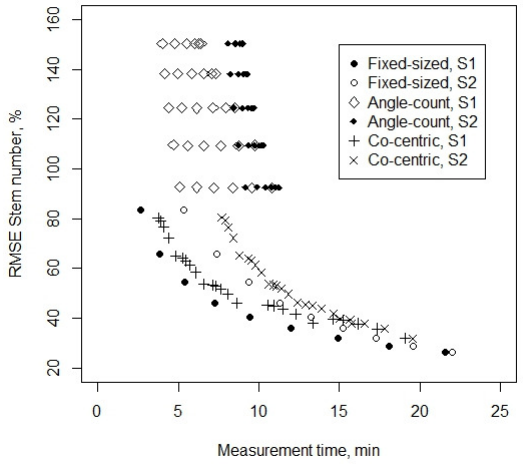
Costs

- 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)

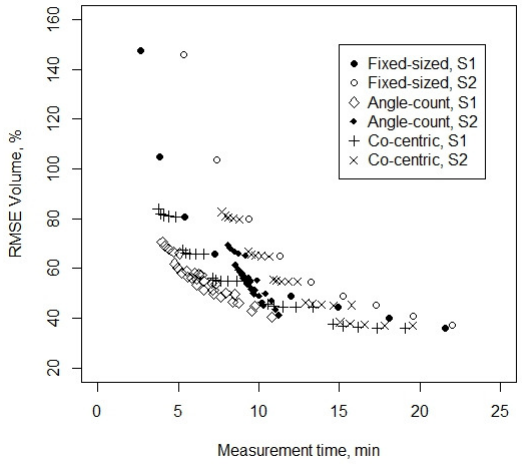
RMSE as a function of measurement time

- Fixed-sized plots most efficient for stem number but angle-count plots most efficient for volume
- The fixed sample tree selection strategy (S1) takes much less time than the angle-count strategy (S2)

Stem number

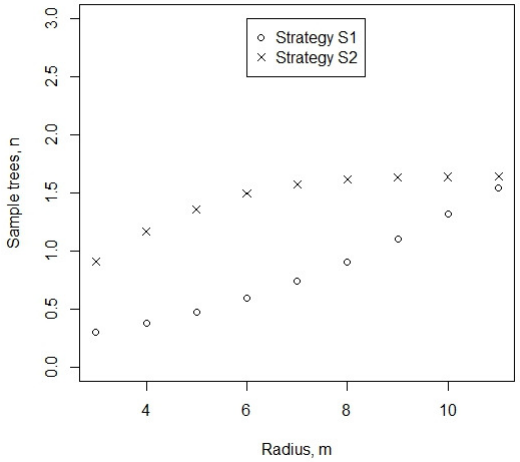


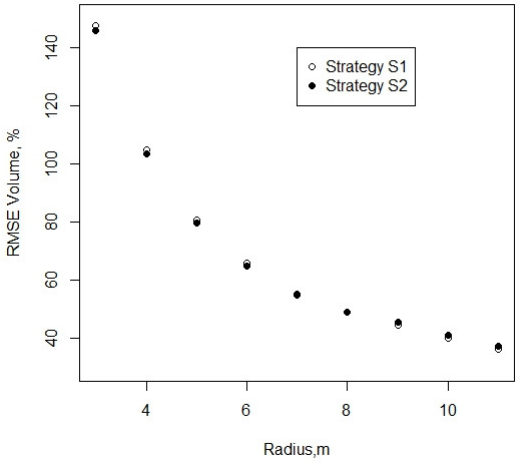
Volume



Sample tree selection strategies in fixed-sized plots

- In angle-count strategy (S2) the number of sample trees is on average larger than with fixed strategy (S1) with the limits set
- Effect on RMSE of volume is quite small
  - Angle count strategy (S2) better with smallest radii
  - Fixed strategy (S1) better with largest radii

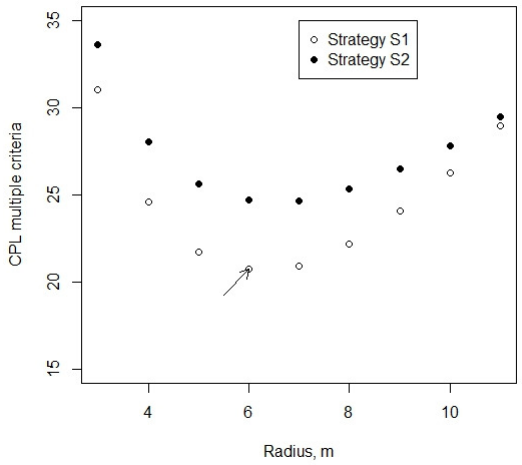




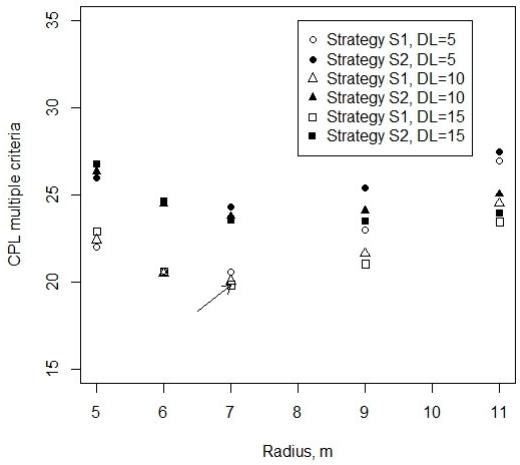
Optimization in plot level

- The optimal plot type and size defined using analytic cost-plus-loss approach
- Loss defined as a weighted sum of RMSEs of volume, basal area and stem number
- Sample tree selection strategy very important in optimization

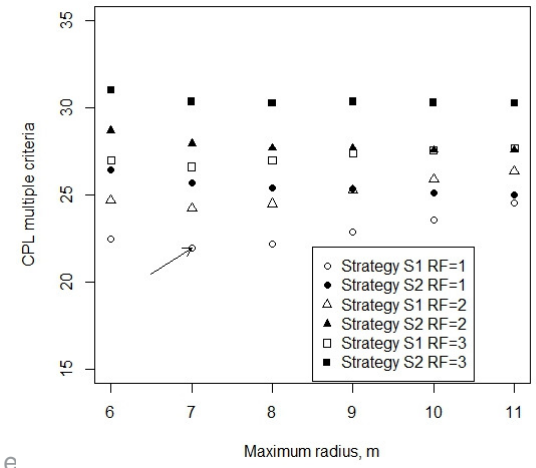
Fixed-sized



Co-centric

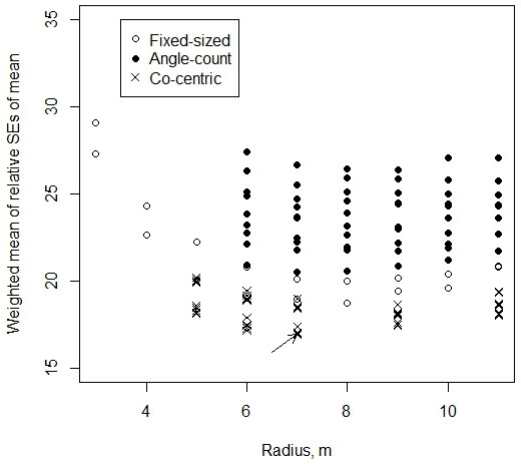


Angle-count



Optimization in cluster level

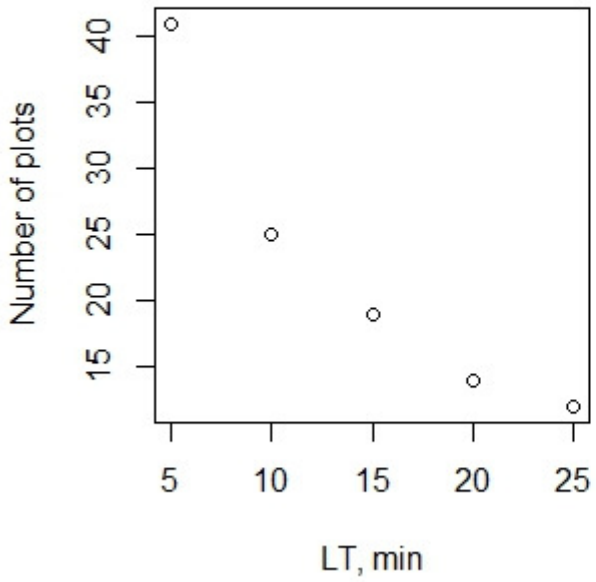
- The optimal sample size and plot type and size for one cluster defined minimizing
  - (weighted) relative mean of standard errors of mean
  - with budget constraint of 420 minutes per day
  - accounting for both within-test-area and between-test-area variance

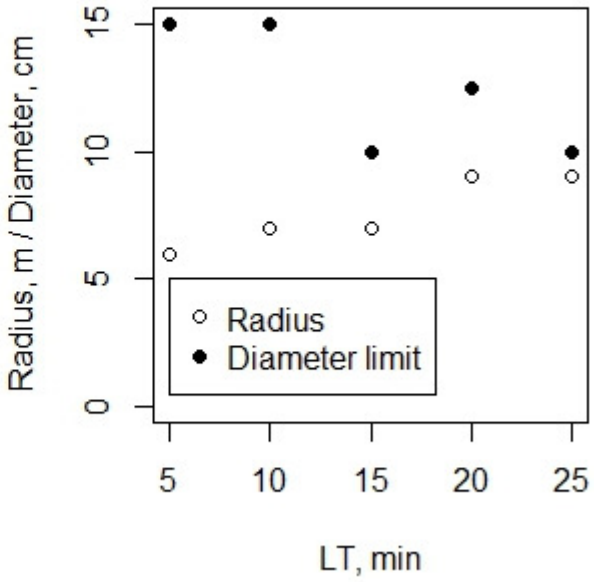


- Optimal cluster 19 co-centric plots with radii 7/5 m

Sensitivity to time for transfer between plots

- As time to transfer between plots increase,
  - optimal number of plots decrease,
  - radius (co-centric) increases

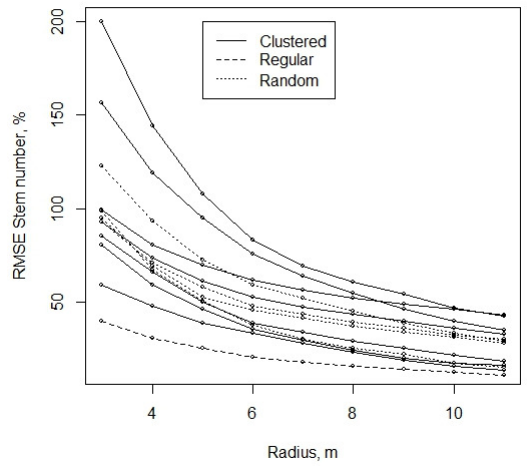




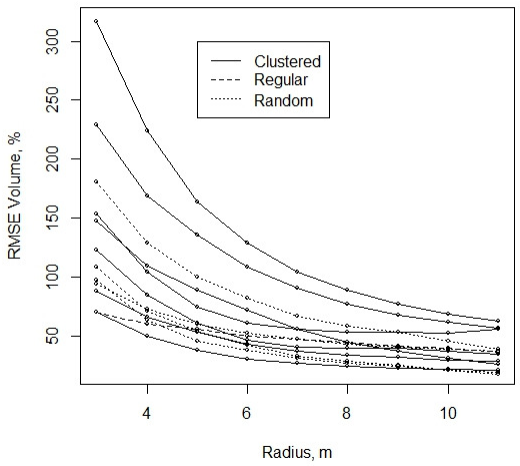
Effect of spatial pattern

- For clustered areas the radius of the plot is important, for regular areas not so much
  - Tended forests more regular?

Stem number



Volume



Conclusions

- While the results were sensitive to the cost function parameters, co-centric was optimal in almost all cases
  - Smaller than the one currently used
- Sample tree selection strategies need further study
  - Turned out very important for the costs but not for precision
  - Are the sample trees more important for other variables than volume?
  - Number of possible strategies very large
    - Angle count strategy with RF higher than 5 could have been more efficient still
  - Location of the sample trees may also be of importance

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

Thank you!

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