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Model based stratification for sampling of soil carbon stock changes

Mikko Peltoniemi, Juha Heikkinen, Raisa Mäkipää

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FINNISH FOREST RESEARCH INSTITUTE
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Introduction

- Models provide a tempting way to monitor soil carbon stock changes.
- However, ultimate verification of predictions comes from measurements
- Measuring soil carbon stock changes is notoriously laborious
- Stratification of sampling improves the precision

Aim

- To seek an answer to hypothesis:
  - Model-predicted changes of soil carbon stock may be used to improve the precision of soil sampling

Content

- Stratification method
- Simulations for stratifications
- Results: simulations, stratification, relative precision, within site variability, comparison of stratification
- Conclusions

Stratification method

- Stratification may be used to improve the precision of sampling
  - More similar sites to same strata
- Approximately optimal stratification by dividing the cumulative distribution function of $\sqrt{PDF}$ to equal intervals (Cochran, 1977)
  - Here, the PDF is for measured soil carbon stock change
  - I.e. stratification by soil carbon stock change
- Measured soil carbon stock changes unknown -> **use simulated values**

Sampling from strata

- Simple random sampling (SRS) without replacement
- Sampling from strata by
  - Equal allocation of samples
  - Proportional allocation
  - Neyman allocation
- With/Without within site variability and measurement error

Simulations for stratification

- What is the predicted change of soil carbon on each plot during the sampling period (e.g 10 a)?
- Motti stand model + Yasso soil model
  - Typical management scenario assumed
    - most of the Finnish forests are managed
    - Old-growths stand --> the change estimate from last years of the rotation

Material for simulations

- NFI permanent sample plots
  - Representative for Finnish forests
  - Subset of upland mineral soils used
- Data on: location, temperature sum, fertility, dominant tree species, stand age
- Typical seedling stands for each species

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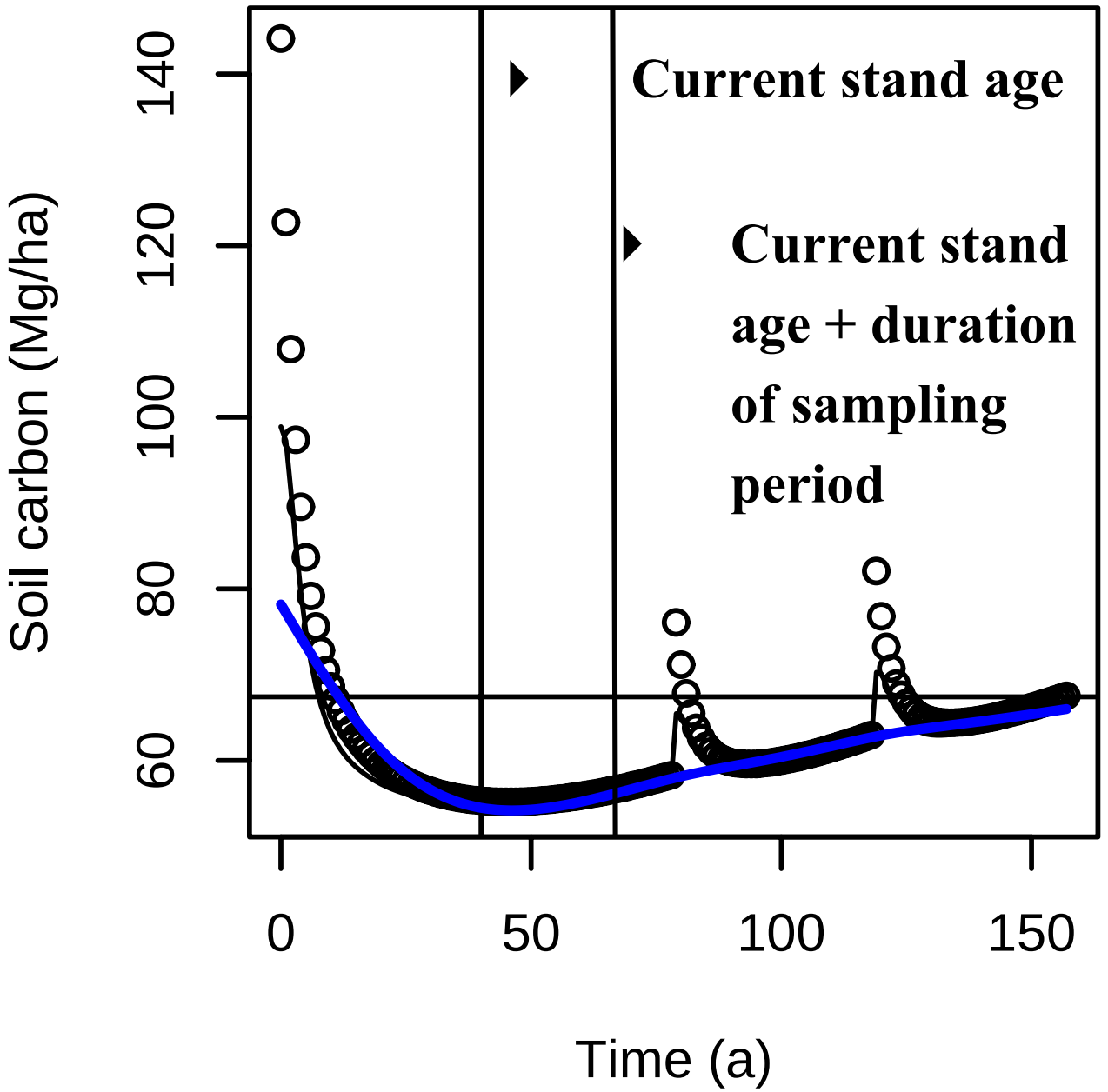
Example of simulation on plot *i*



$$\Delta C_{i,10a}$$

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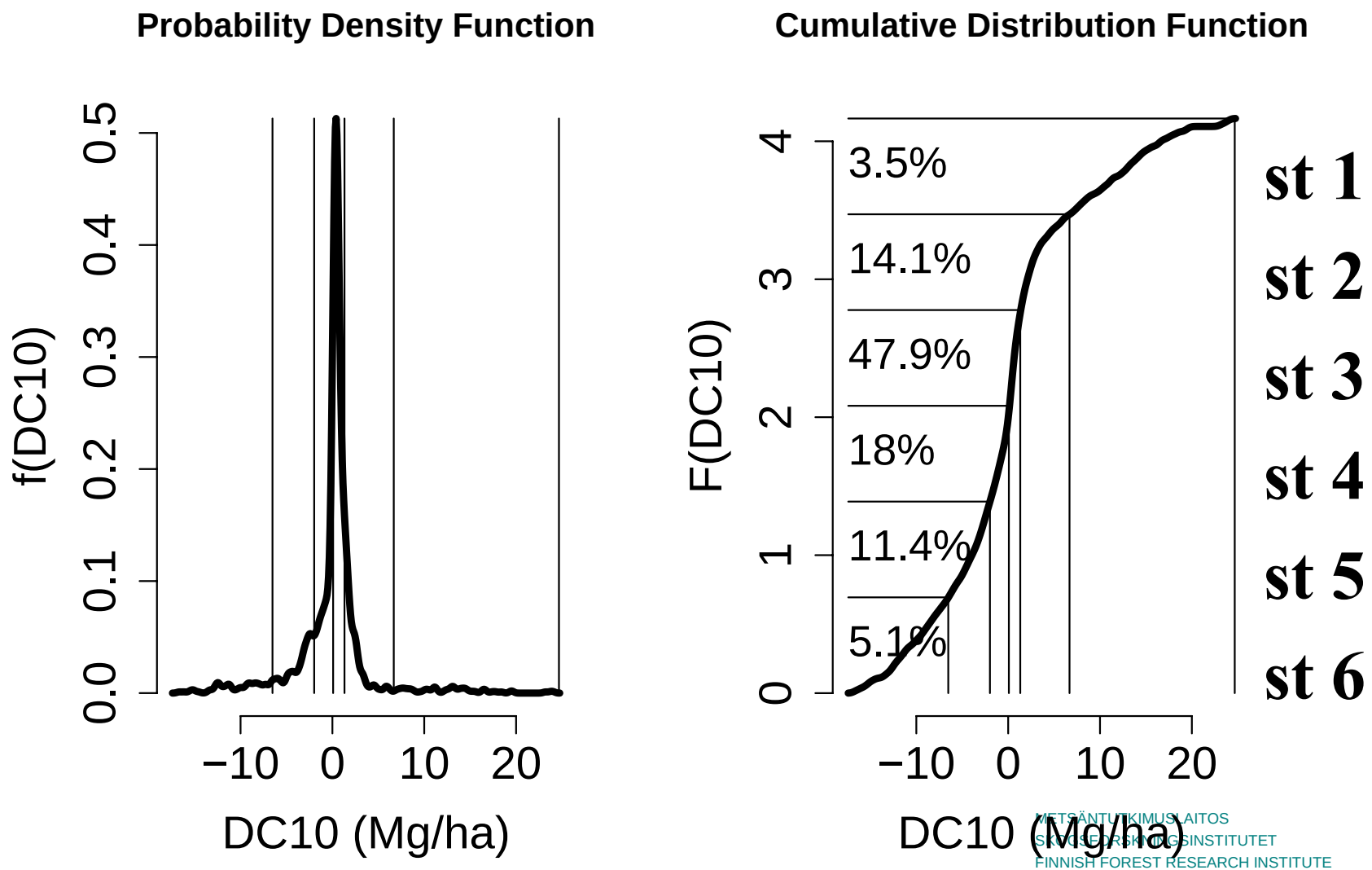
Stratification, 6 strata



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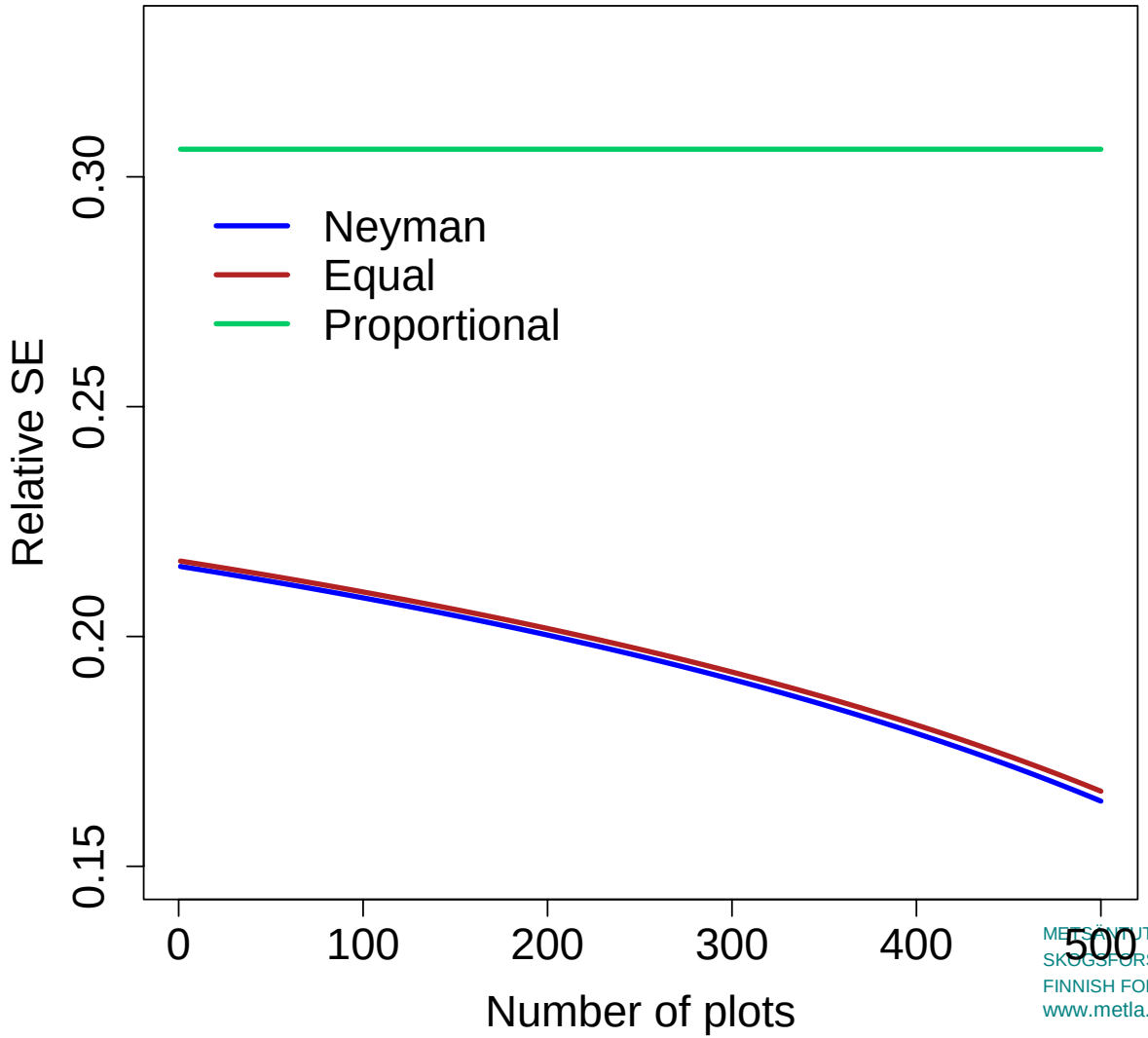
Sampling from strata: precision relative to Simple random sampling



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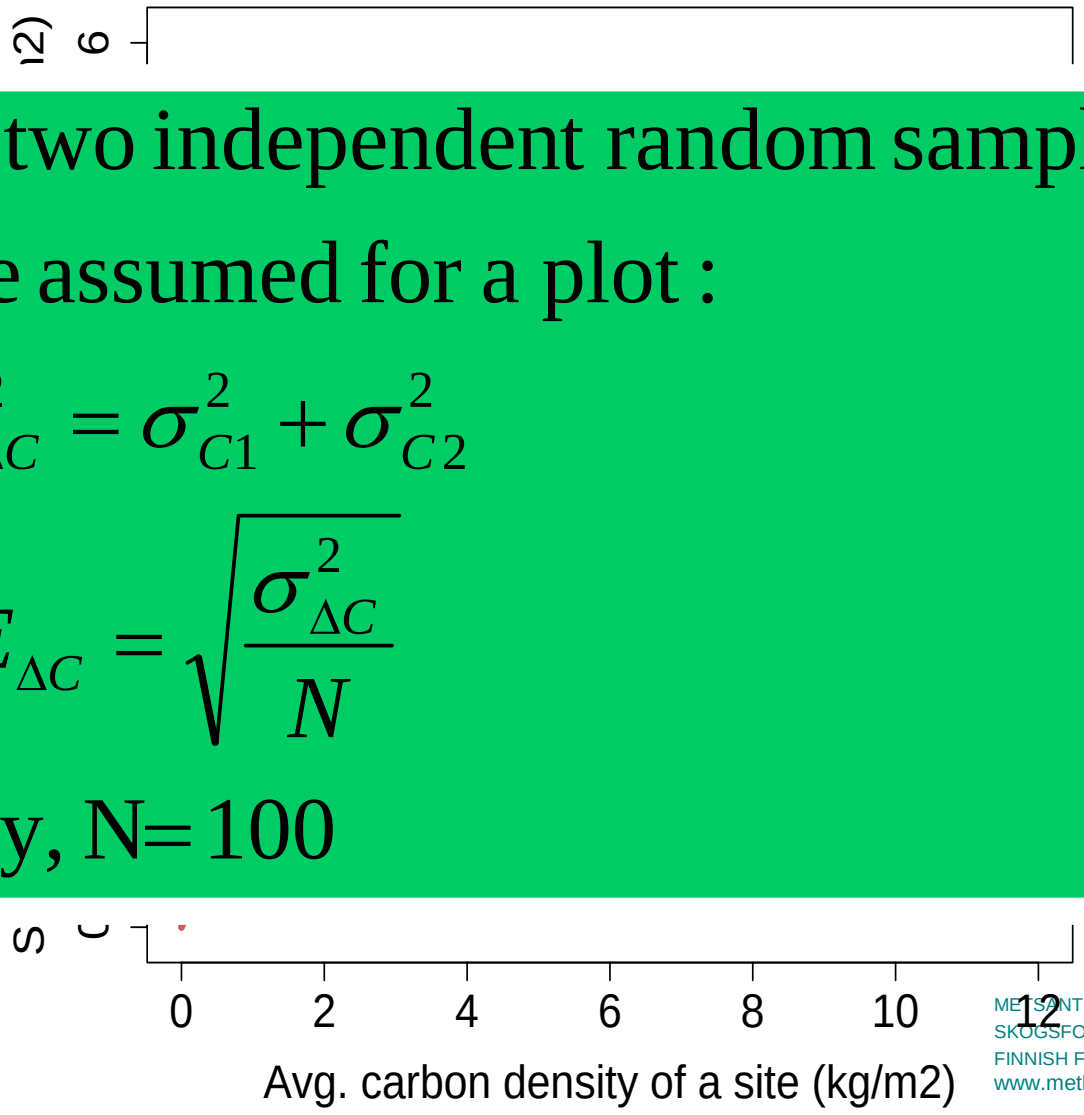
Within site variability and measurement precision, preliminary assumption

If two independent random samplings are assumed for a plot :

$$\sigma_{\Delta C}^2 = \sigma_{C1}^2 + \sigma_{C2}^2$$

$$SE_{\Delta C} = \sqrt{\frac{\sigma_{\Delta C}^2}{N}}$$

Say, N= 100



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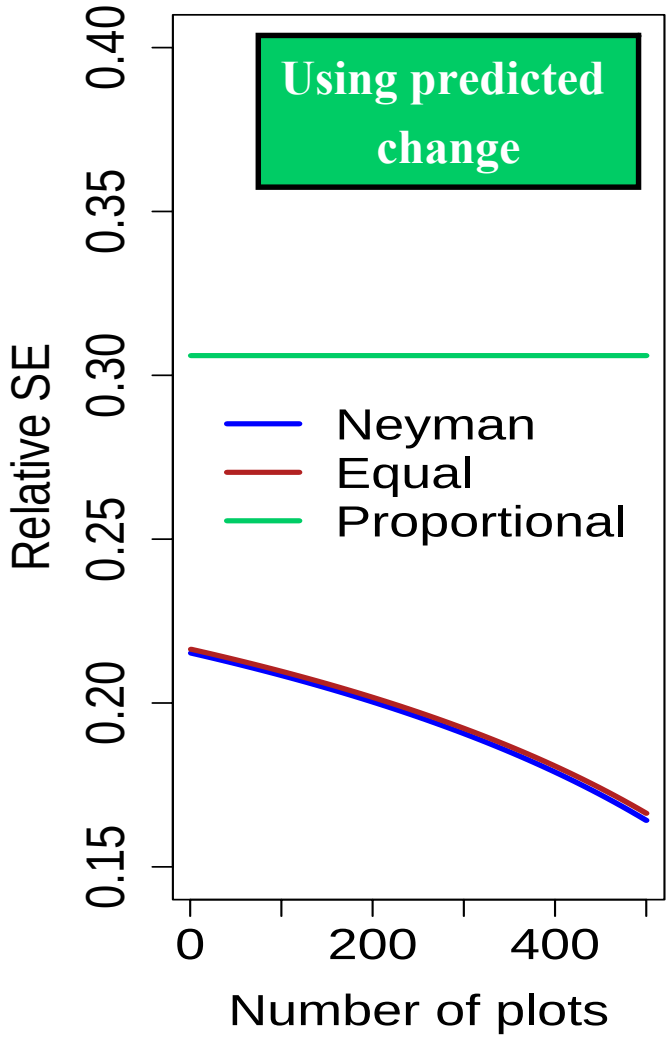
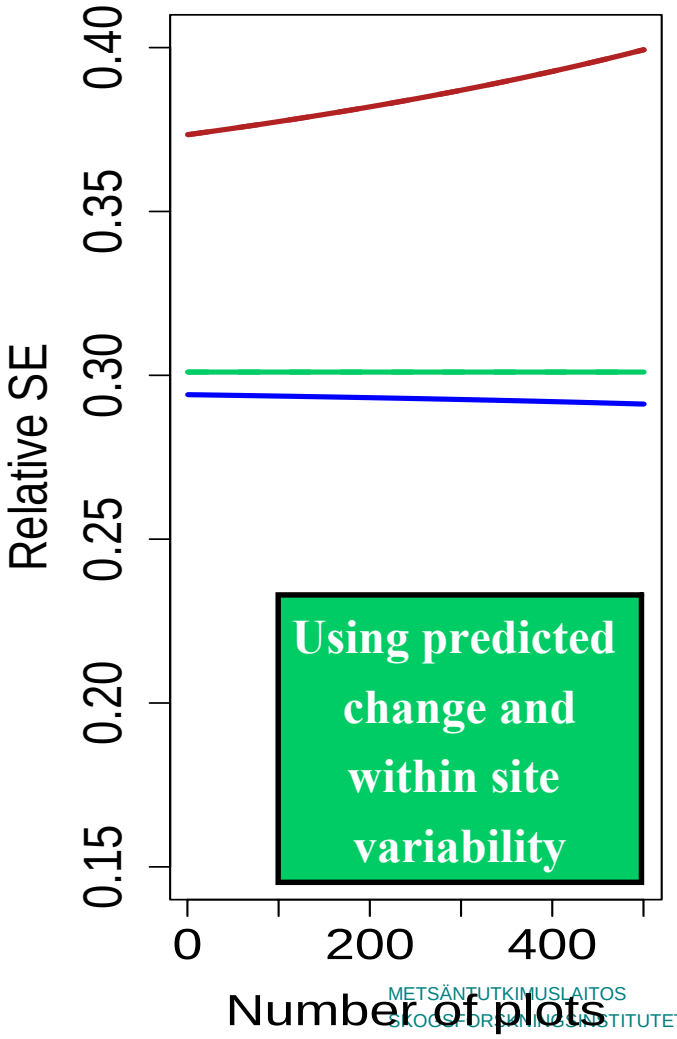
Variability reduces the benefits of stratification





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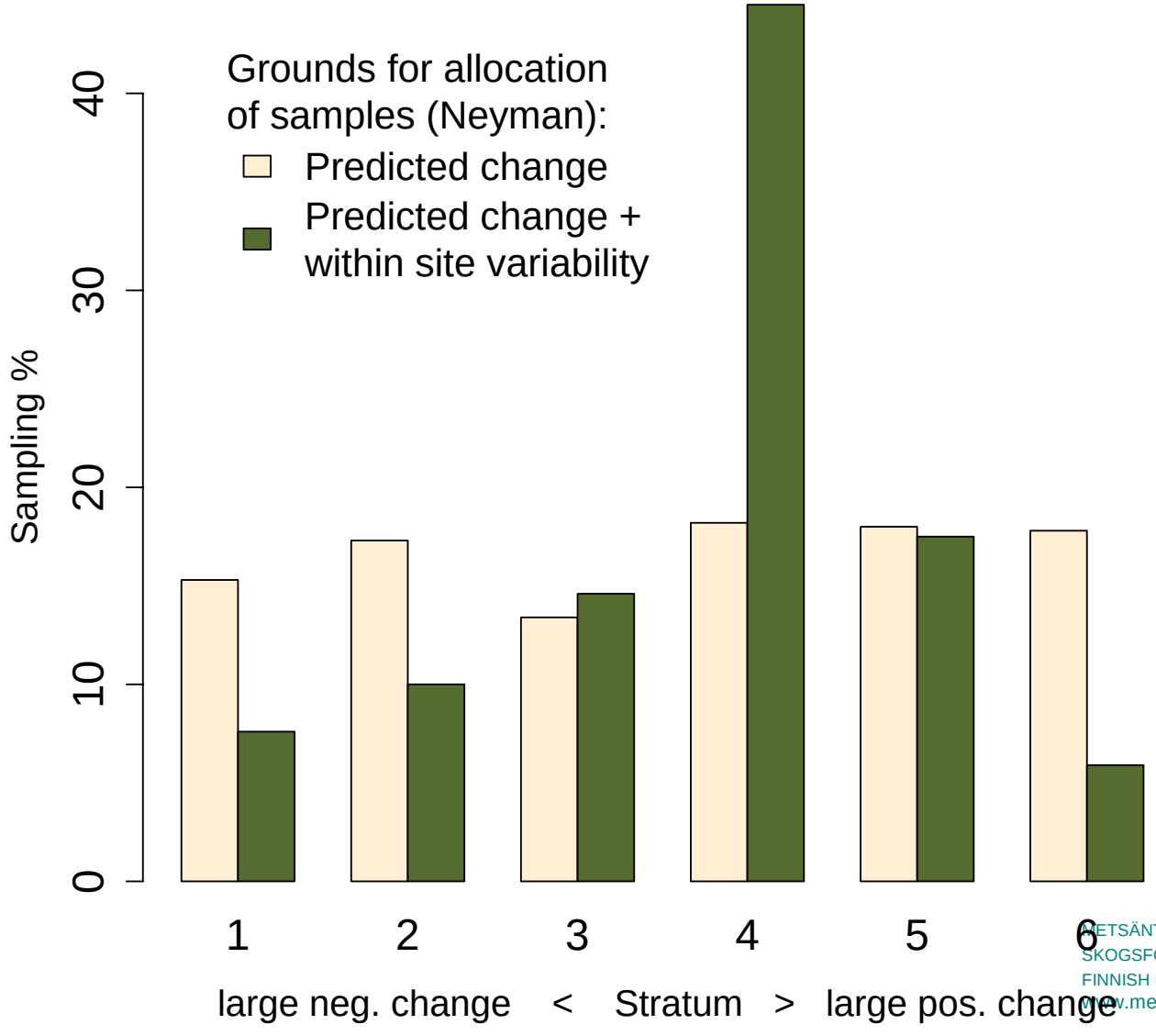
Allocation of samples



Conclusions

- Within site variability changes the allocation of samples to strata completely from that of using only model predictions
- Hypothesis:
  - true, but only if effects of within site variability can be controlled.
  - Why: Large within site variability makes it difficult to say to what strata this site belongs to
- If stratification will be used in soil sampling it would be useful to have information on within site variability
- Need for precise measurements on each plot

Continuation of work

- Check the variance-mean relation on plot level
- Replace independent repeated sampling on a plot level to produce better estimates of N and variance of mean
- Run tests with refined assumptions
- Stratification for permanent monitoring of sites instead of one repeated sampling
  - combination of permanent and temporary plots

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Thank you

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Variability reduces the benefit of stratification