Experiences on redesigning NFI-plot to support classification of laser scanning data

Kai Mäkisara

Natural Resources Institute Finland (Luke)

Other people who participated in the work:
Erkki Tomppo, Helena Henttonen, Nea Kuusinen, Nina Vainikainen, Matti Katila, Juho Pitkänen, Mikael Strandström, Ville Pietilä, Jouni Peräsaari and unnamed field personnel.

Luke
NATURAL RESOURCES
INSTITUTE FINLAND

Topics

- Background and scope
- Differences in field work between MPI and NFI
- Practical constraints on co-operation
- Number of re-usable plots
- Field measurements for studies
- Experiments with different plot designs
- Time aspects (updating, change detection)
- Conclusions

Background

This presentation is (somewhat) specific to Finland.

We have two inventories: National Forest Inventory (NFI), carried out by Luke, and management planning inventory (MPI), carried out by Finnish Forest Centre (SMK).

Both do field work each year around Finland.

Many people (including the government funding the inventories) ask: Should the inventories (or some parts of them) be combined to, for instance, save money?

History and current status

- many kind of small scale co-operation in the past
- the Ministry of Agriculture and Forestry (MMM) initiated in 2012 an effort to investigate possibilities of co-operation between (or combining) the two inventories
  - two reseach projects funded by MMM, Forest Centre, and Luke (Metla)
    - first project in 2013-2014, investigating possibilities of co-operation, and measuring 2000 field plots in the Ähtäri ALS area of MPI
    - second 2014-2015, developing methods for joint use of field plots
- NFI12 (2015-2019) is currently using a fixed radius field plot (9 meters, trees above 9.5 cm after 5.64 meters, above 4.5 cm below 5.64 meters, small relascope trees)
  - up to NFI11 a truncated relascope plot with maximum radius of 12.5 m, relascope factor 1.5 or 2.0
- MPI uses NFI plots as test material in 2015

Differences in the field work

NFI

- five year rotation, one fifth of 60 000 plots measured yearly
- systematic sampling over whole Finland
- a small number of measured trees per plot is needed
- many stand level measurements
- computation of results adapted to the system

MPI

- ALS used to produce raster and small segmented areas
- 10 - 15 areas of 100 000 - 200 000 hectares inventoried yeach year
- 500 - 1000 field plots for each area, sampling optimized to cover all forest types within area, plots entirely within one stand
- 9 m fixed radius plot, all trees above 4.5 cm, separate plot for seedling stage
- sampling optimized for each area

Constraints for unification

Human and organizatorial constaints:

- all parties must accept the system
- based on the current opinions of what is necessary
- system must be implementable in current organizations

Notable differences in requirements:

- acceptable number of trees within plot
- sampling design
- timeliness

Finding re-usable plots

Number of NFI plots in Central Finland within 100 000 hectares is 255 (392 ha/plot, including seedling plots and plots covering several stands).

MPI can't get all plots from NFI. A practical solution for MPI is to use as many NFI plots as possible and then measure additional plots.

The situation would be better if MPI would not need as many plots as it currently uses.

- longer term research topic

Requirements for the common field plot

- NFI does not need many trees per plot, the accuracy comes from the number of plots (except for Multisource NFI ... maybe)
  - plot not dependent on development class
  - permanent and temporary plots
  - many stand level observations
- MPI needs for ALS more accurate plot-wise information, especially in certain kinds of forest (e.g., young forest)
  - currently 9 m fixed radius plot, all trees $\geq$ 45 mm measured + plot for the seedling stage
  - is the NFI12 plot sufficient for MPI?

The field measurements

Measurements have been performed on the MPI laser scanning area in Ähtäri, Central Finland.

First field work in 2013: 2468 field plots in a systematic grid in 431 000 hectares of forestry land.

- form L, 8 plots in each cluster, distance between plots 250 m, distance between clusters 4.3 km => 231 ha/plot
- fixed radius 9 meters, all trees $\geq$ 45 mm measured + three subplots for small trees
- 1867 plots within forestry land, 1441 forestry land plots entirely within single stand, 1150 in NFI development classes 4 - 6 (young thinning stand, advanced thinning stand, mature stand)

Second field work in 2014: 120 16x16 meter plots

- groups of 2 by 2 plots, i.e., 32x32 meter square measured
- locate so that the 16 by 16 meter plots fit the MPI grid
- located using a two-phase GNSS method => small error
- all trees above 25 mm diameter measured

Experiments with 1150 field plots (Erkki Tomppo, Nea Kuusinen ja Matti Katila)

- NFI development classes 4 - 6, plots entirely within one stand
- the following plot types were computed (radius always 9 meters):
  - fixed radius plot, trees $\geq$ 45 mm (MPI)
  - fixed radius plot, trees $\geq$ 75 mm from 5.64 to 9 m, $\geq$ 45 mm below 5.64 m (k75)
  - fixed radius plot, trees $\geq$ 95 mm from 5.64 to 9 m, $\geq$ 45 mm below 5.64 m (k95)
  - truncated relascope plot, factor 1.0 (q1)
  - truncated relascope plot, factor 1.5 (q1,5)
  - truncated relascope plot, factor 2.0 (q2)
  - in the experiments presented here trees $<$ 45 mm omitted

Table : Mean number of tally trees in NFI development classes 4 - 6. Number of plots 1150.

	Tally trees					
	MPI	k75	k95	q1	q1,5	q2
Dev. classes 4-6	29.5	24.8	22.5	14.8	11.5	9.2
Dev. class 4	38.4	31.0	26.7	13.9	9.4	7.1
Dev. class 5	26.9	23.5	21.9	15.8	12.5	9.9
Dev. class 6	23.4	19.4	17.8	13.4	11.7	10.2

Good-enough methods for comparison of different plots:

- improved k-NN (ik-NN) method, feature weights using genetic algorithm
- "standard" features from laser returns and aerial photographs
- total results but also results from cases where small number of small trees might affect results (young forests)
- *comparison* of field plot estimates and results estimated using ALS and aerial photographs

Table : Field data based forest parameter estimates calculated from the MPI, k75, k95, q1, q1.5 and q2 plots. Number of plots 1150.

	Mean					
	MPI	k75	k95	q1	q1,5	q2
Volume m^3/ha	154.36	154.30	154.35	154.69	154.65	154.63
Pine vol. m^3/ha	97.78	97.81	97.77	98.05	98.50	98.56
Spruce vol m^3/ha	36.54	36.53	36.54	36.25	35.94	35.80
Broadl. vol m^3/ha	20.04	19.97	20.03	20.38	20.22	20.27
Mean diam. cm	18.74	18.76	18.77	18.85	18.94	19.01
Mean height dm	153.99	154.10	154.16	154.68	154.96	155.38
Basal area m^2/ha	19.49	19.48	19.49	19.52	19.53	19.49
Nbr of trees/ha	1157.71	1152.35	1153.51	1160.19	1154.67	1144.16

Including trees $<$ 45 mm increases, e.g., the total volume of relascope plots by 2 m^3/ha.

Table : Differences between estimates computed from specific plot type and the MPI plot. Number of plots 1150.

	RMSE				
	k75	k95	q1	q1,5	q2
Volume m^3/ha	1.85	3.55	11.39	18.80	25.64
Pine volume m^3/ha	0.85	1.88	7.36	13.25	19.85
Spruce volume m^3/ha	0.98	1.82	5.52	9.10	12.92
Broadl. volume m^3/ha	1.22	2.36	6.54	9.89	11.94
Mean diameter cm	0.27	0.39	0.88	1.16	1.42
Mean height dm	1.60	2.33	5.00	6.48	7.90
Basal area m^2/ha	0.45	0.77	2.03	3.04	3.89
Number of trees/ha	157.64	196.56	422.81	541.32	621.23

Table : RMSE and bias of leave-one-out estimates of forest variables using ALS and aerial photographs. Number of field plots 1150.

	RMSE/bias					
	MPI	k75	k95	q1	q1,5	q2
Volume m^3/ha	40.09	40.10	40.06	40.28	41.21	41.81
	0.21	0.19	0.22	0.50	0.89	1.36
Pine vol. m^3/ha	47.29	47.29	47.28	47.33	47.63	47.95
	1.48	1.52	1.48	1.77	2.61	2.90
Spruce vol. m^3/ha	44.54	44.55	44.55	44.70	44.87	44.95
	-0.30	-0.31	-0.30	-0.59	-0.92	-0.85
Broadl. vol. m^3/ha	20.73	20.73	20.76	20.89	21.12	21.44
	-0.96	-1.01	-0.96	-0.68	-0.80	-0.69
Mean diameter cm	2.66	2.66	2.67	2.68	2.70	2.73
	-0.18	-0.16	-0.15	-0.08	-0.00	0.04
Mean height dm	13.09	13.09	13.11	13.20	13.27	13.35
	-1.23	-1.13	-1.06	-0.56	-0.29	-0.04
Basal area m^2/ha	4.65	4.65	4.65	4.71	4.86	4.95
	0.15	0.15	0.15	0.18	0.25	0.27
Number of trees kpl/ha	479.20	488.69	492.21	517.75	540.36	556.71
	10.48	8.65	8.97	14.56	13.67	8.16

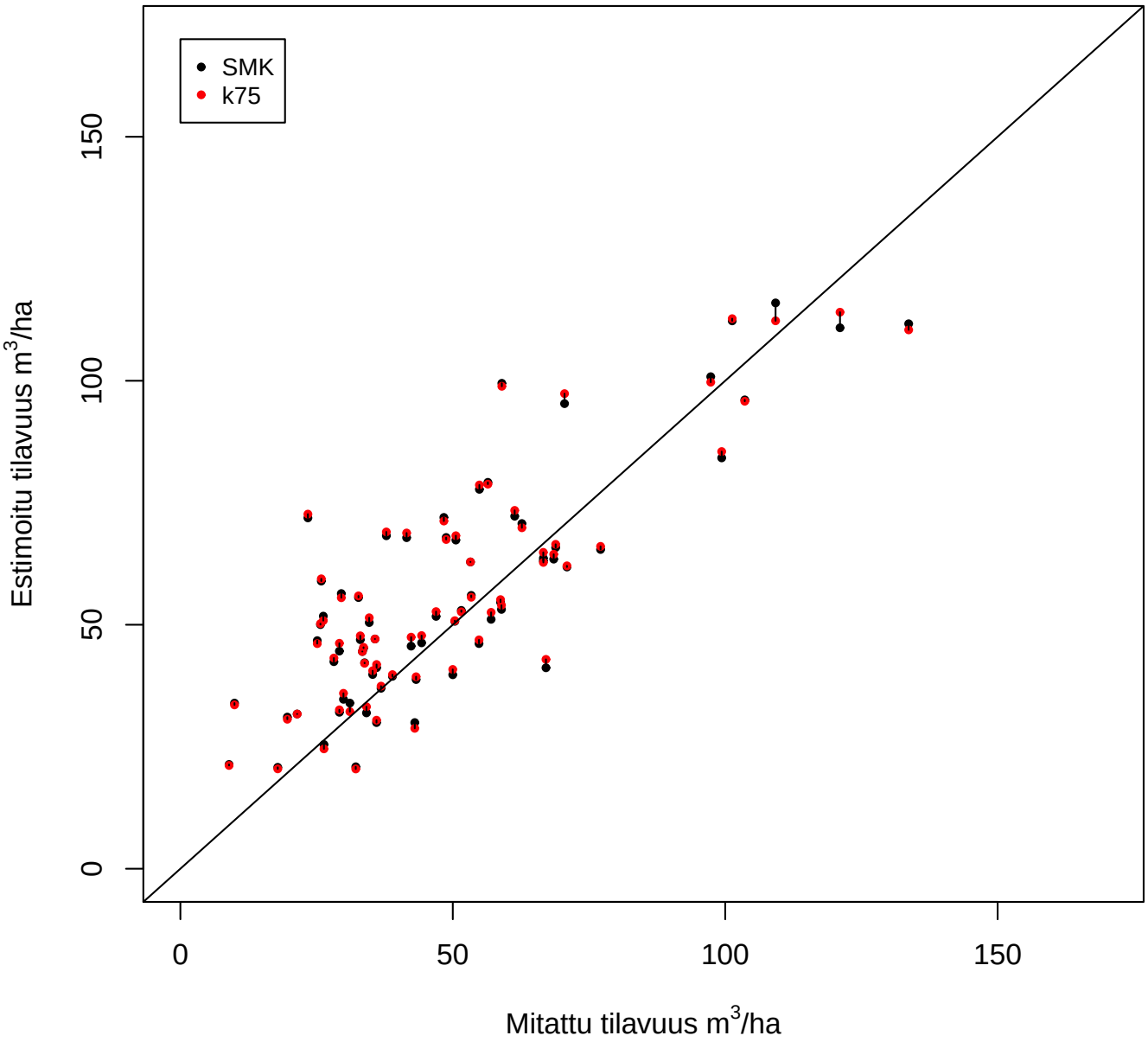
Table : Differences between field plot estimates between a plot type and the MPI plot. All plots within one stand with mean diameter $\leq$ 11 cm. Number of plots 70.

	RMSEf			Biasf		
	k75	k95	q1,5	k75	k95	q1,5
Volume m^3/ha	3.39	6.67	17.33	0.72	0.93	2.80
Pine vol. m^3/ha	2.02	3.81	10.88	0.23	0.13	1.07
Spruce vol. m^3/ha	1.31	2.05	5.46	0.16	0.17	0.61
Broadl. vol. m^3/ha	2.37	4.99	13.12	0.32	0.64	1.11
Mean diameter cm	0.29	0.35	1.16	-0.03	-0.04	0.19
Mean height dm	1.75	2.20	6.90	-0.30	-0.43	0.57
Basal area m^2/ha	0.87	1.50	3.65	0.18	0.21	0.59
Number of trees/ha	290.91	369.00	928.71	64.15	72.13	147.99

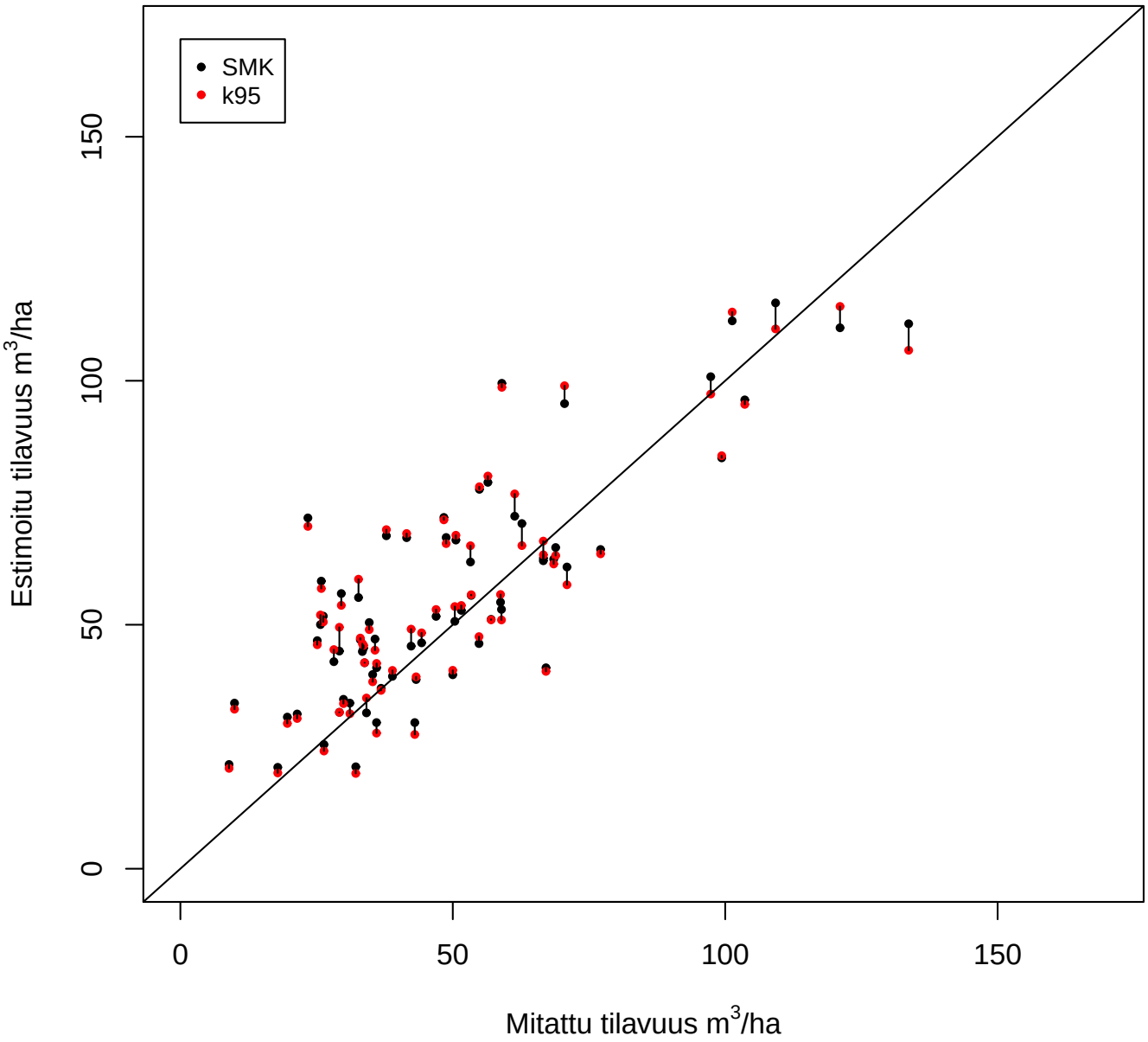
Table : RMSE and bias of estimates, all plots within one stand with mean diameter $\leq$ 11cm. Number of plots 70.

	RMSE/bias			
	MPI	k75	k95	q1,5
Volume m^3/ha	15.98	16.04	16.35	18.24
	6.98	7.27	7.02	9.38
Pine vol. m^3/ha	21.83	21.93	22.00	22.59
	6.40	6.63	6.39	7.52
Spruce vol. m^3/ha	13.03	13.01	13.09	13.70
	0.51	0.63	0.77	0.69
Broadl. vol. m^3/ha	11.67	11.56	11.16	12.06
	0.07	0.01	-0.14	1.17
Mean diameter cm	2.15	2.14	2.16	2.47
	1.68	1.66	1.66	1.84
Mean height dm	12.37	12.32	12.44	14.06
	8.27	8.08	8.08	9.07
Basal area m^2/ha	2.88	2.88	2.97	3.29
	0.61	0.70	0.64	1.08
Number of trees/ha	749.17	746.34	760.36	808.08
	-306.80	-273.00	-281.37	-191.27

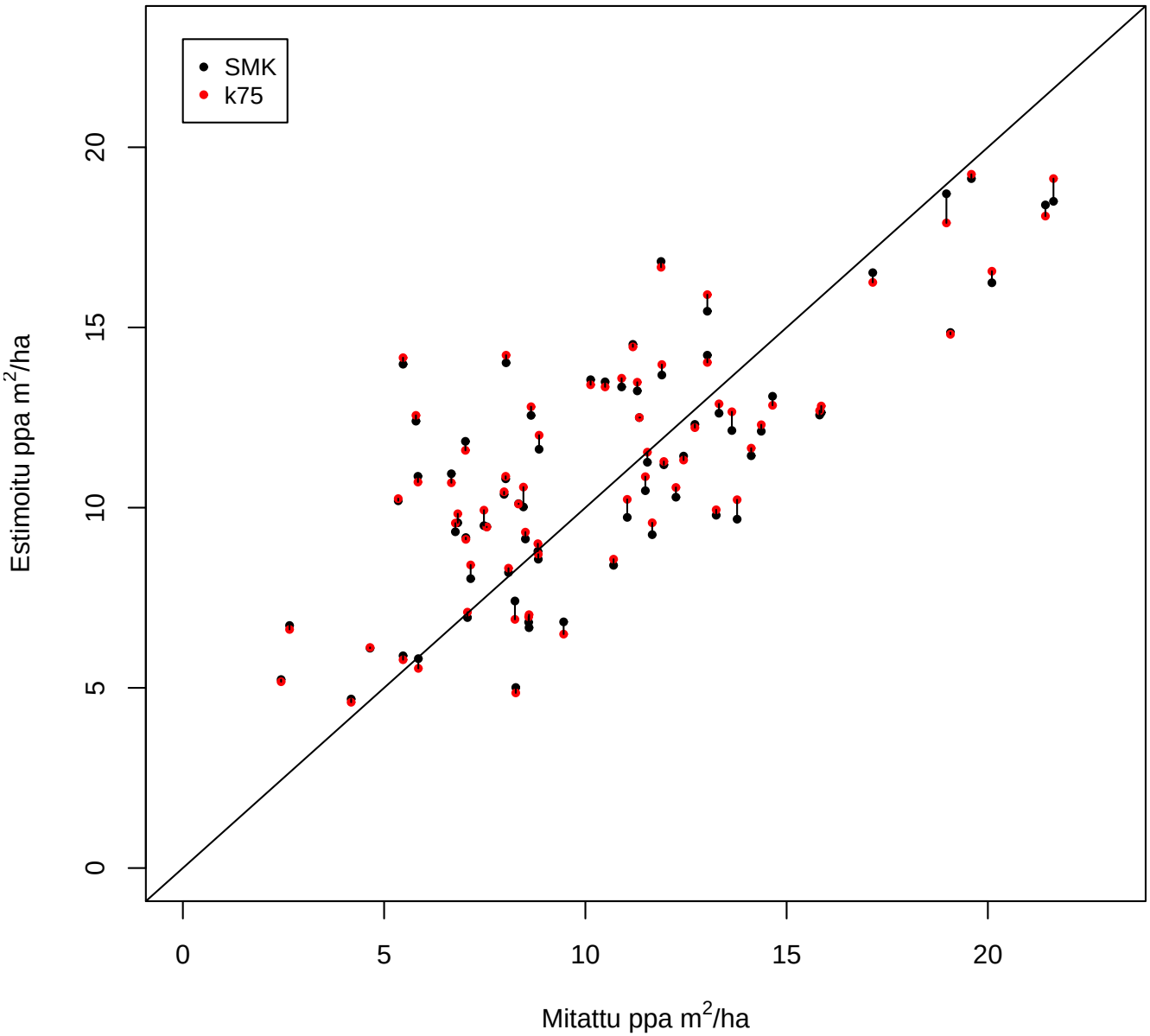
Total volume, plots where mean diameter $\leq$ 11 cm (N=70)



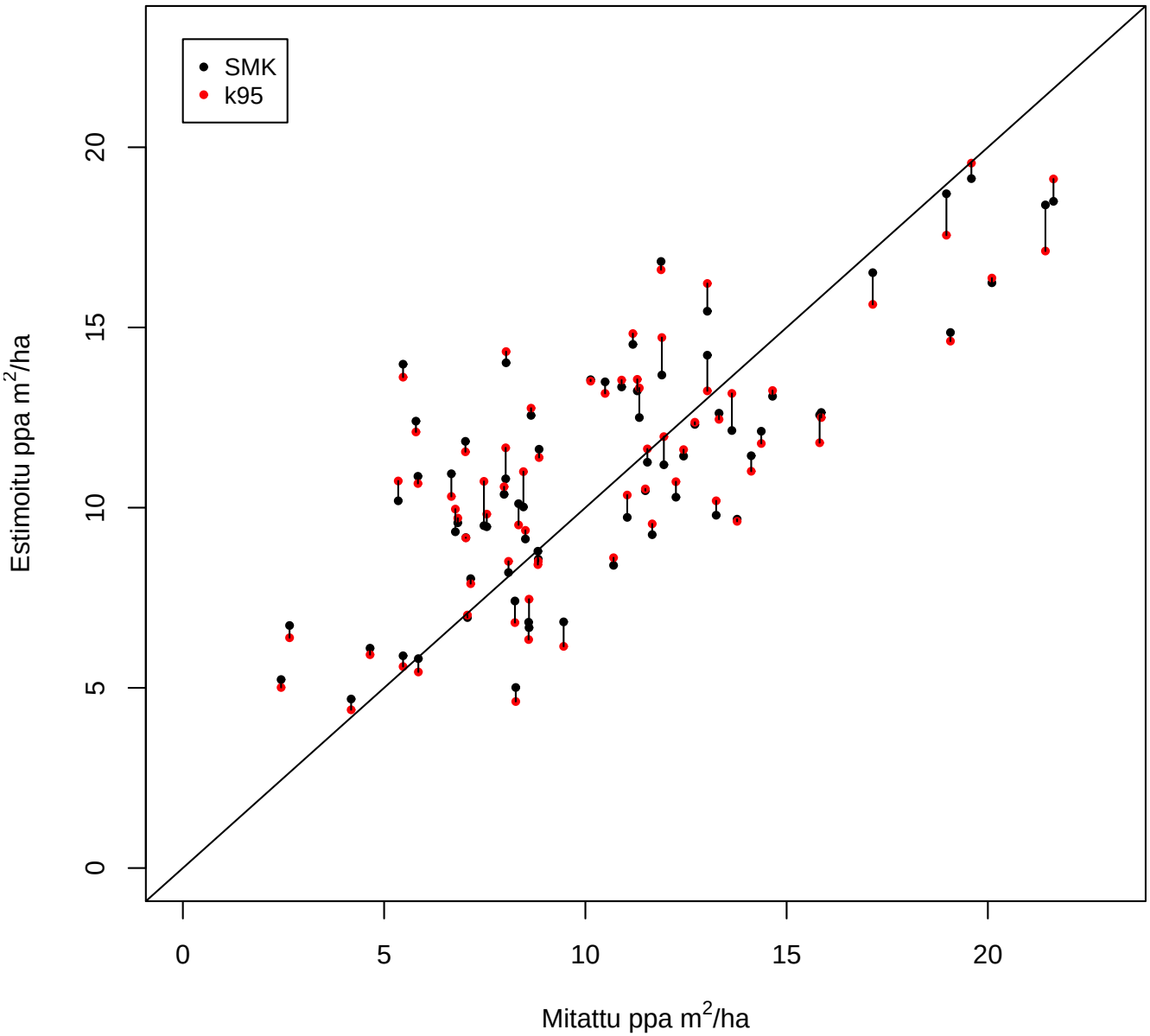
Total volume, plots where mean diameter $\leq$ 11 cm (N=70)



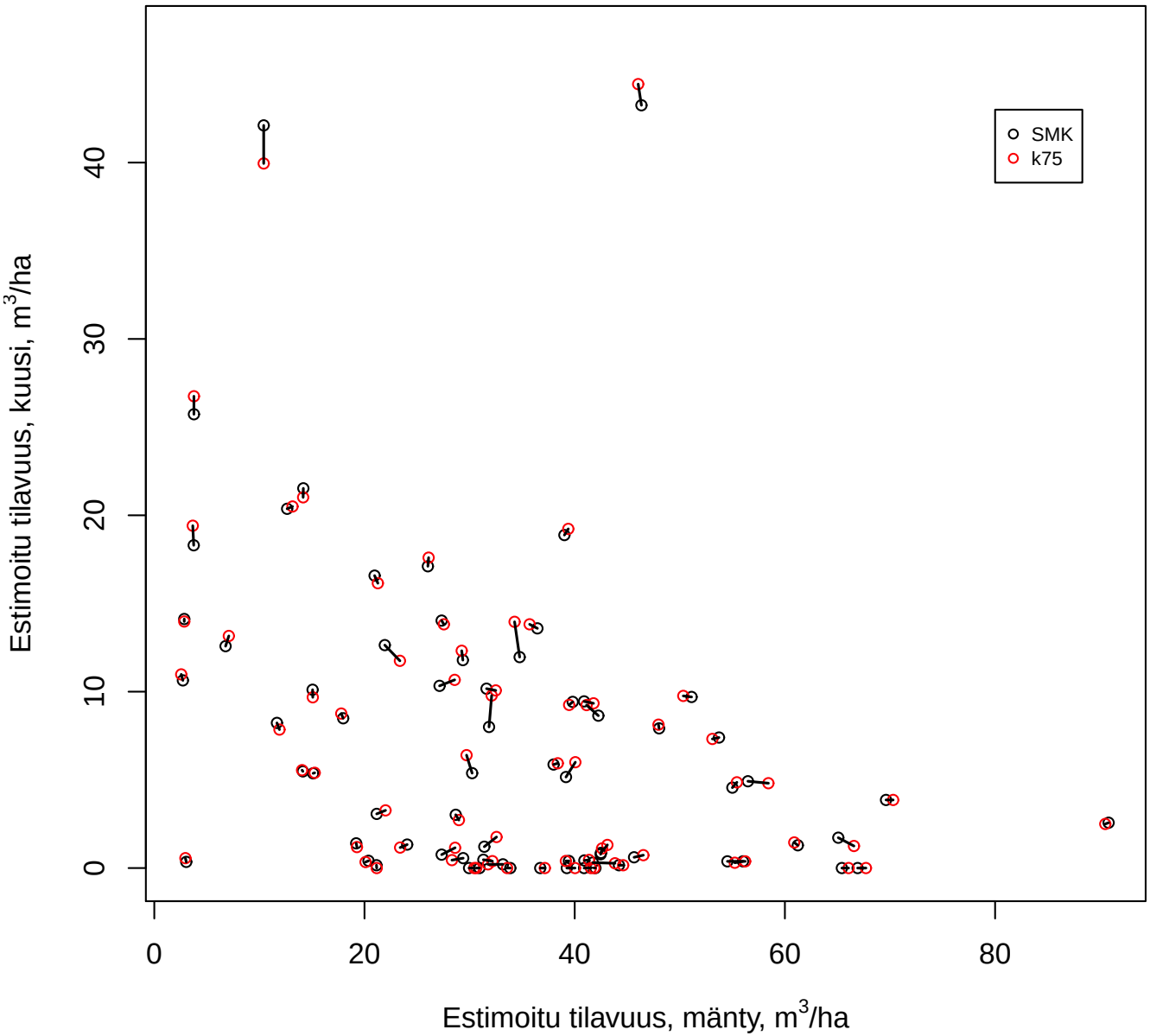
Basal area, plots where mean diameter $\leq$ 11 cm (N=70)



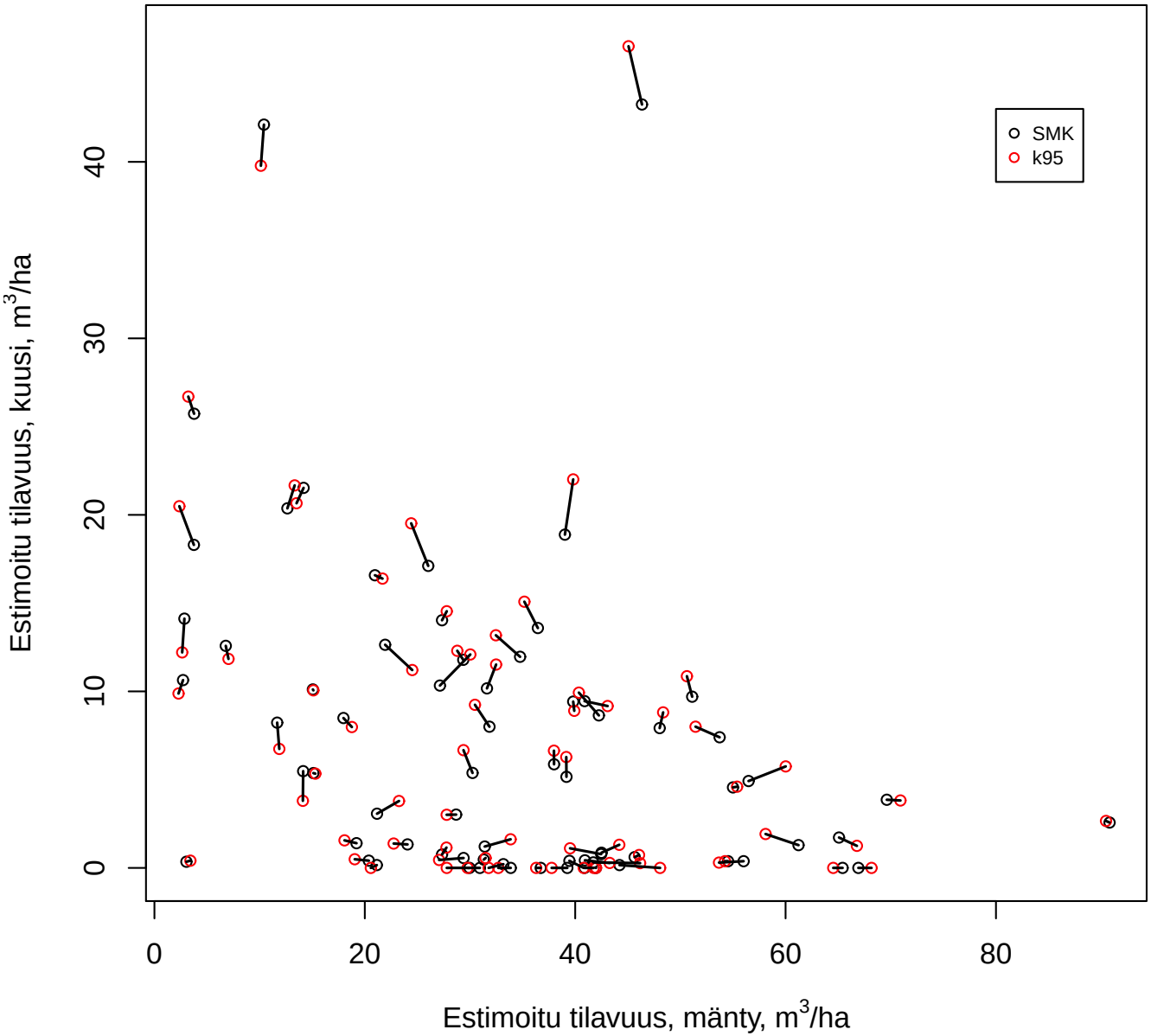
Basal area, plots where mean diameter $\leq$ 11 cm (N=70)



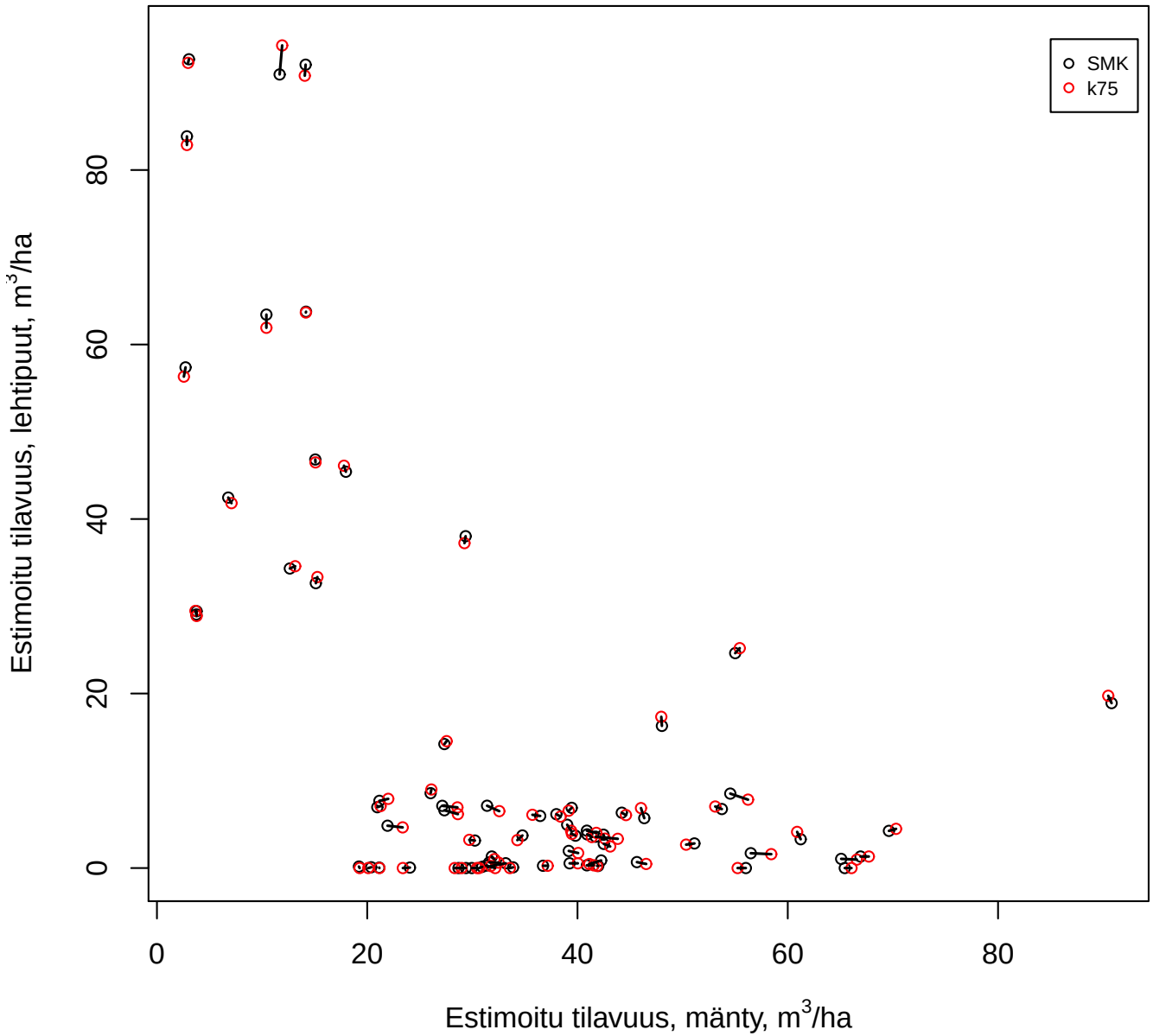
Volume of pine, plots where mean diameter $\leq$ 11 cm (N=70)



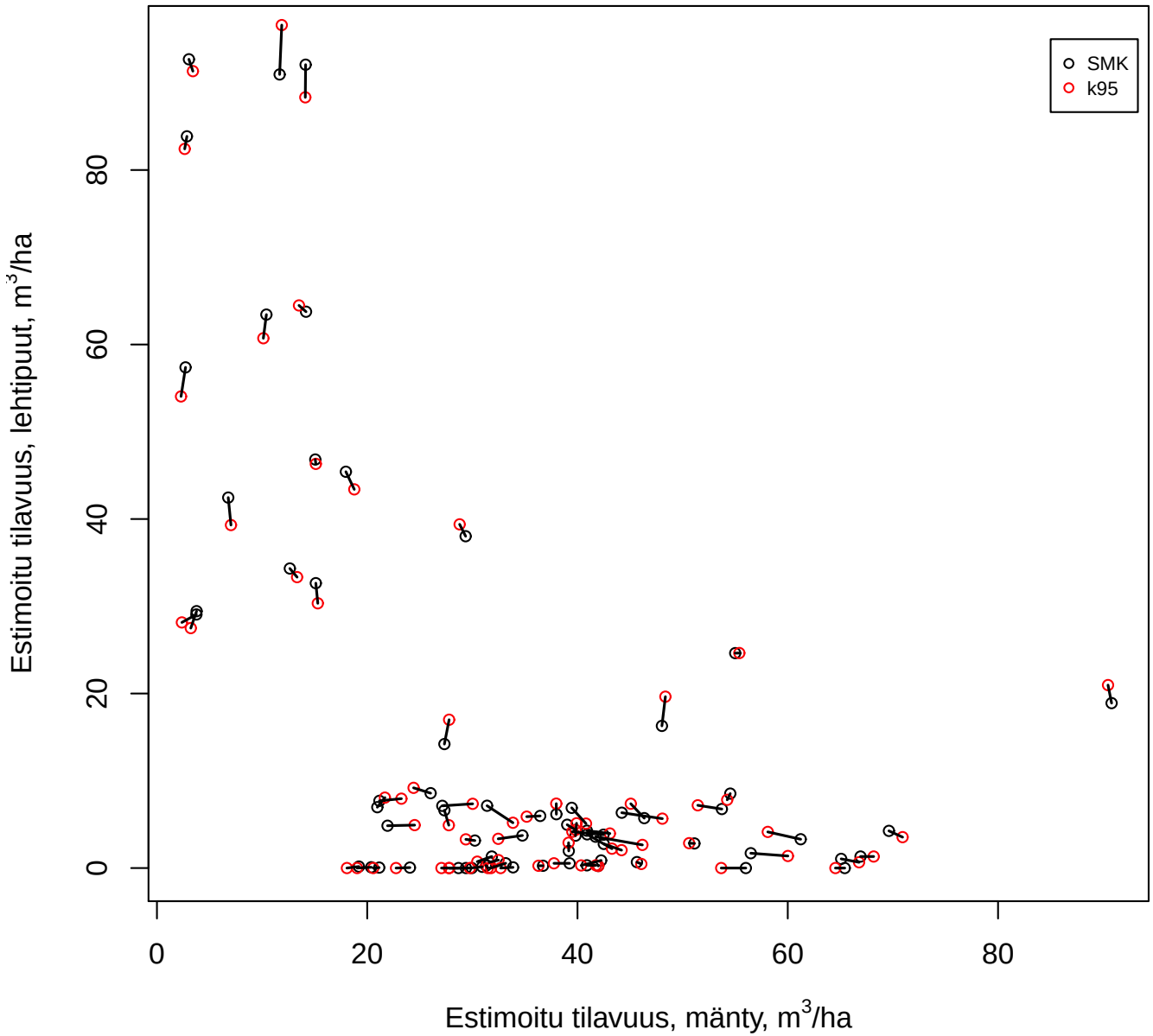
Volume of pine, plots where mean diameter $\leq$ 11 cm (N=70)



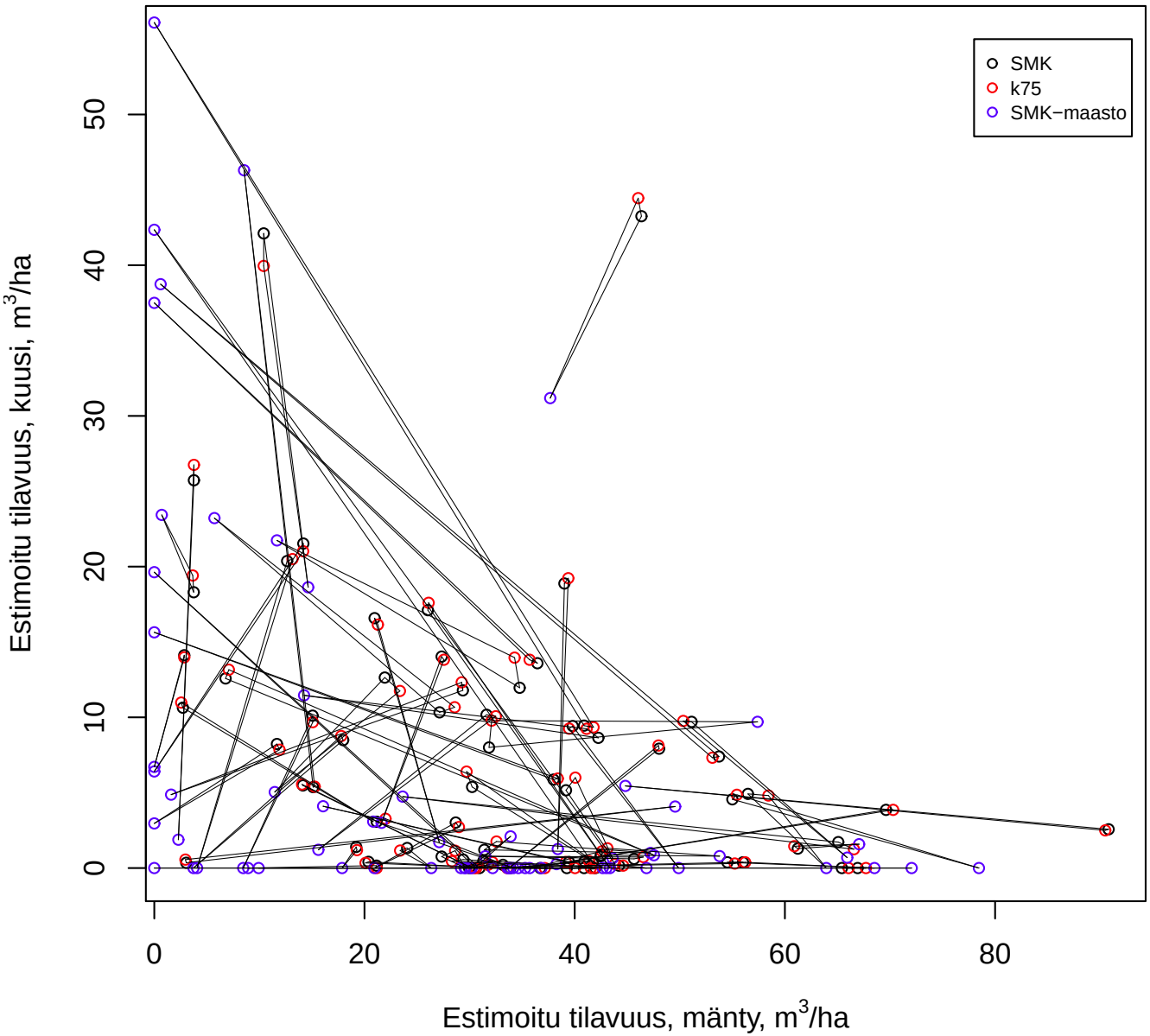
Volume of broadleaved, plots where mean diameter $\leq$ 11 cm (N=70)



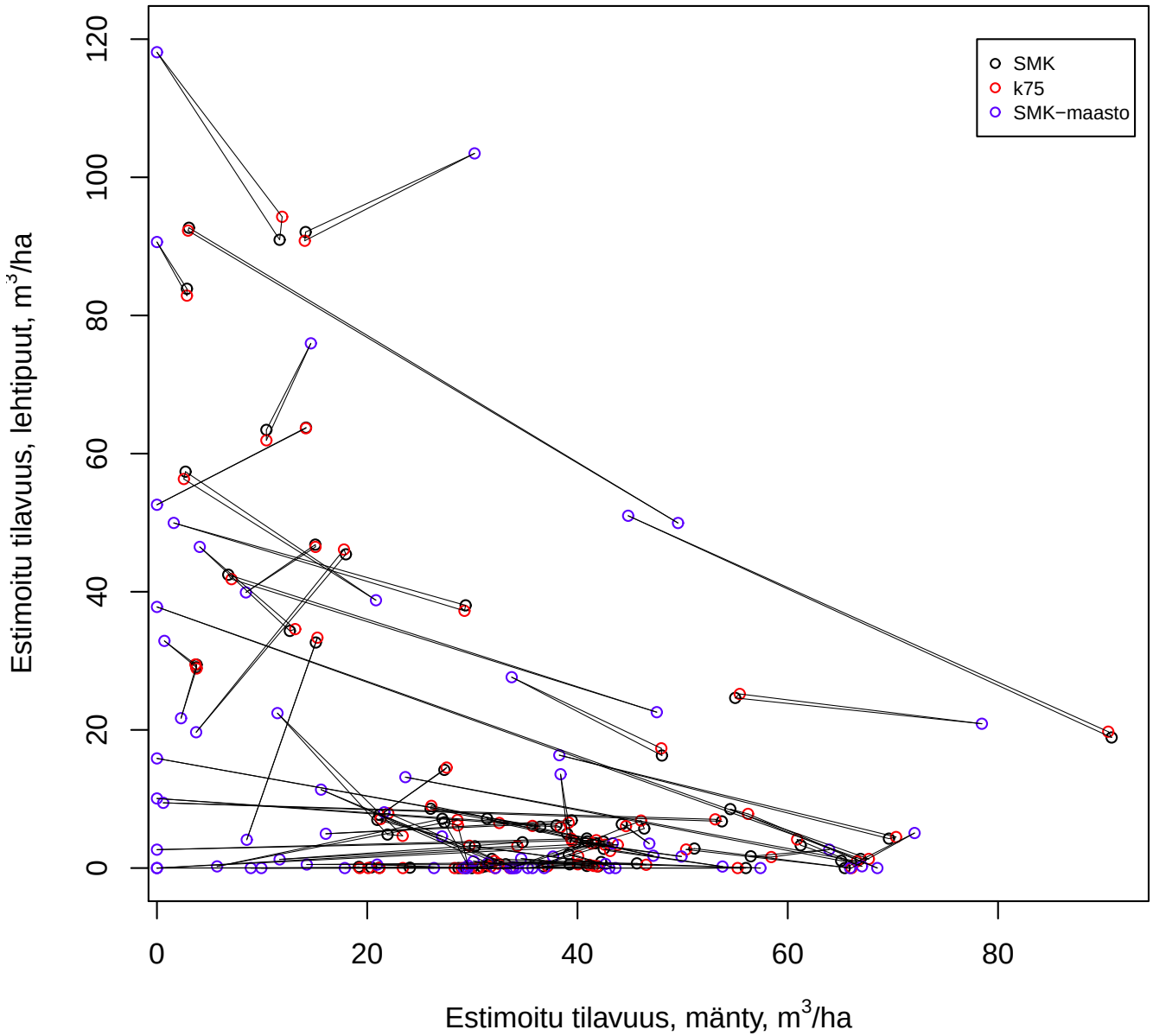
Volume of broadleaved, plots where mean diameter $\leq$ 11 cm (N=70)



Volume of pine, plots where mean diameter $\leq$ 11 cm (N=70)



Volume of pine, plots where mean diameter $\leq$ 11 cm (N=70)



Updating of the field plot data

Two tasks:

- computational updating of the tree measurements
- finding the trees that have disappeared (or grown in)

Computational updating is not a problem because the time interval is not long.

Identifying of missing trees (Nina Vainikainen)

The task is to find if significant changes have occurred on the plot => have trees disappeared?

The interpretation should be done as early as possible so that a cut field plot is not used.

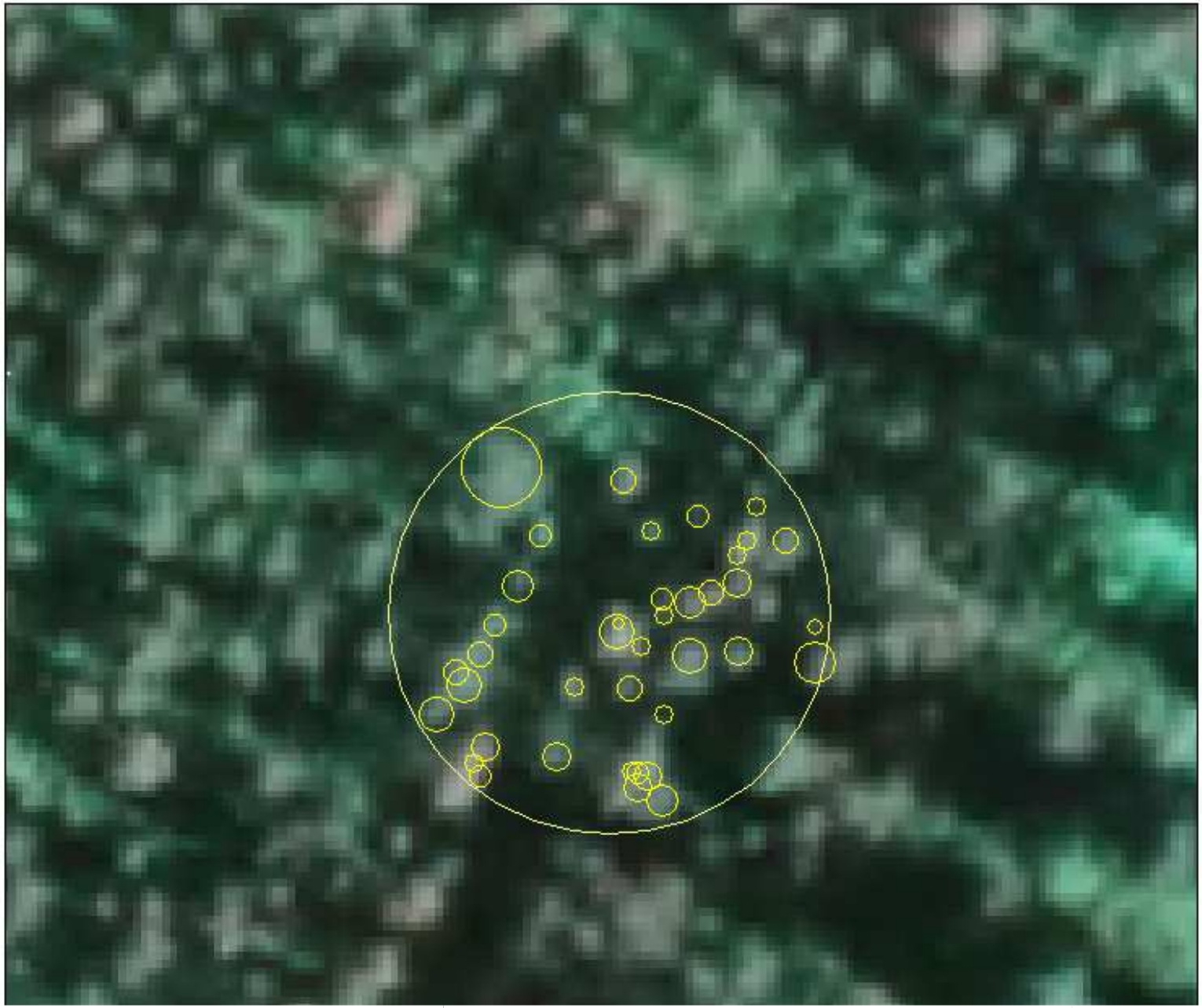
- based on satellite images in Multi-Source NFI
- based on aerial photographs before imaging season
- using ALS data and aerial photographs after imaging

The research concentrated on the last to approaches, using the Ähtäri data and the permanent plots of NFI.

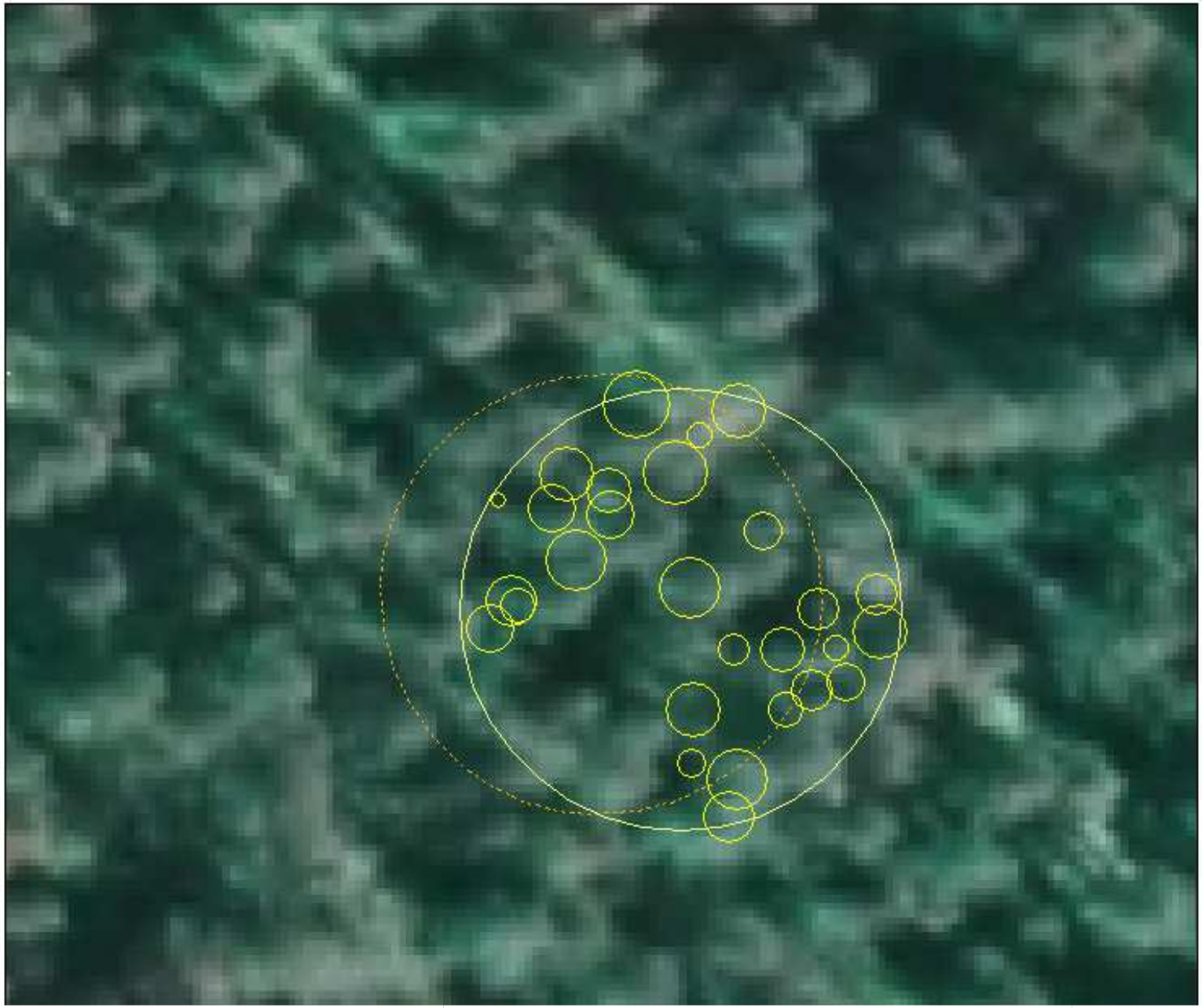
What is done if it is suspected that all trees are not present?

- updating based on the suspicion
- re-visit the plot, possibly re-measuring trees
- don’t use the plot

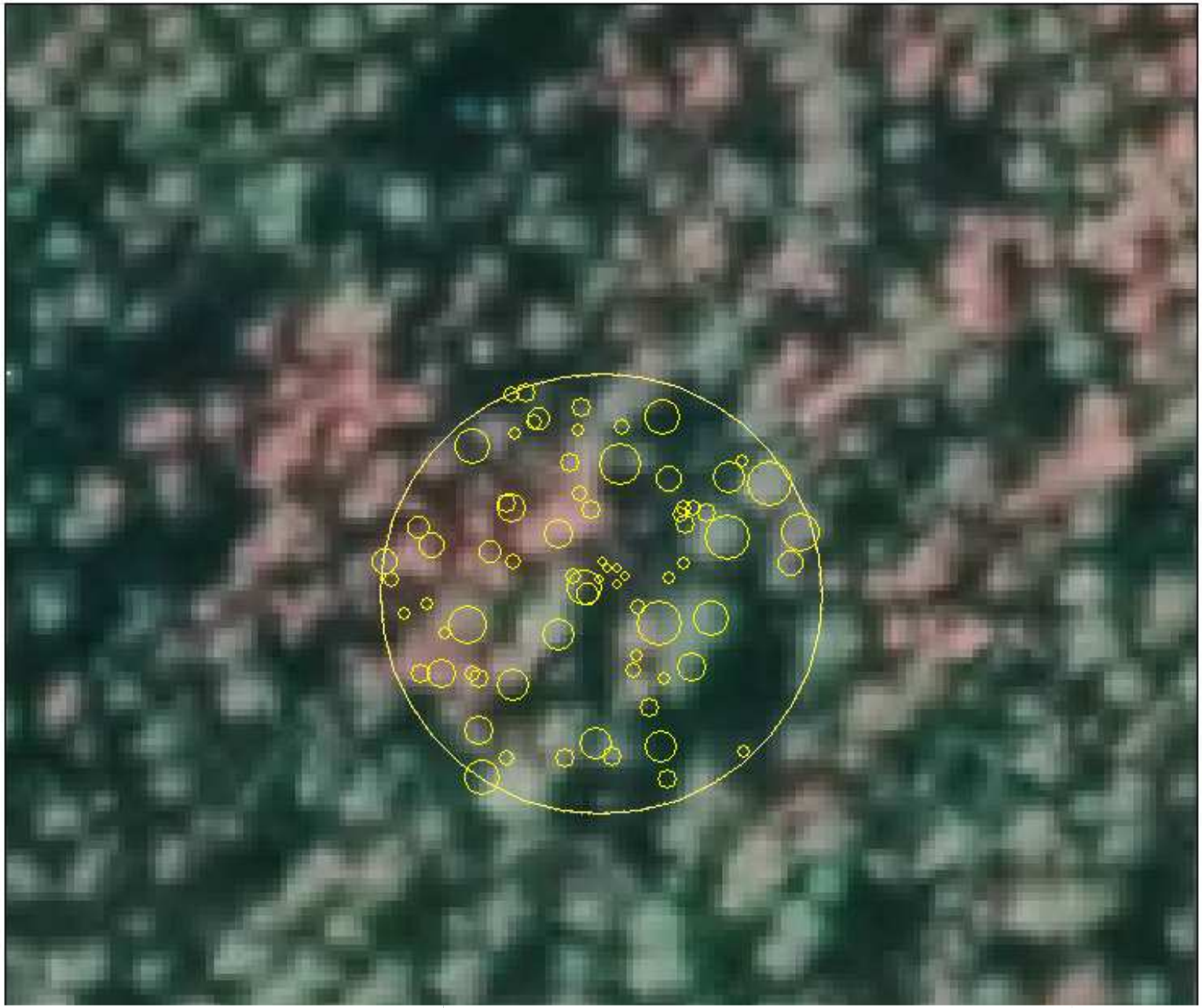
Successful interpretation, no changes.



Slightly uncertain case.



Hopeless case?



Conclusions

Use of same field plots in NFI and management inventory is technically possible.

(Overly) simplistic analysis in the Finnish case is that MPI could get one third of the plots from NFI.

Details:

- the field data collection gets more complicated
- too many trees measured for NFI
- who pays and who benefits?

It is very difficult to determine the exact savings for Finland.