Metsikkökoealaharjoitus

featuring Topical Research vuodesta 2007

Contents

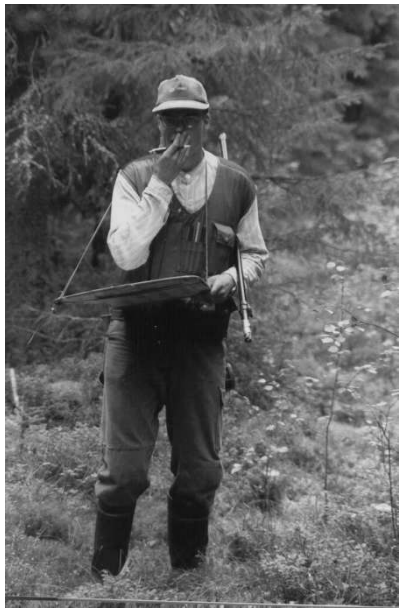
- Some quite historical notes & 3D views
- More recent history and background information on how we got here, and on how you can contribute to research done at our Department
- Instructions for a successful campaign in the next days to come

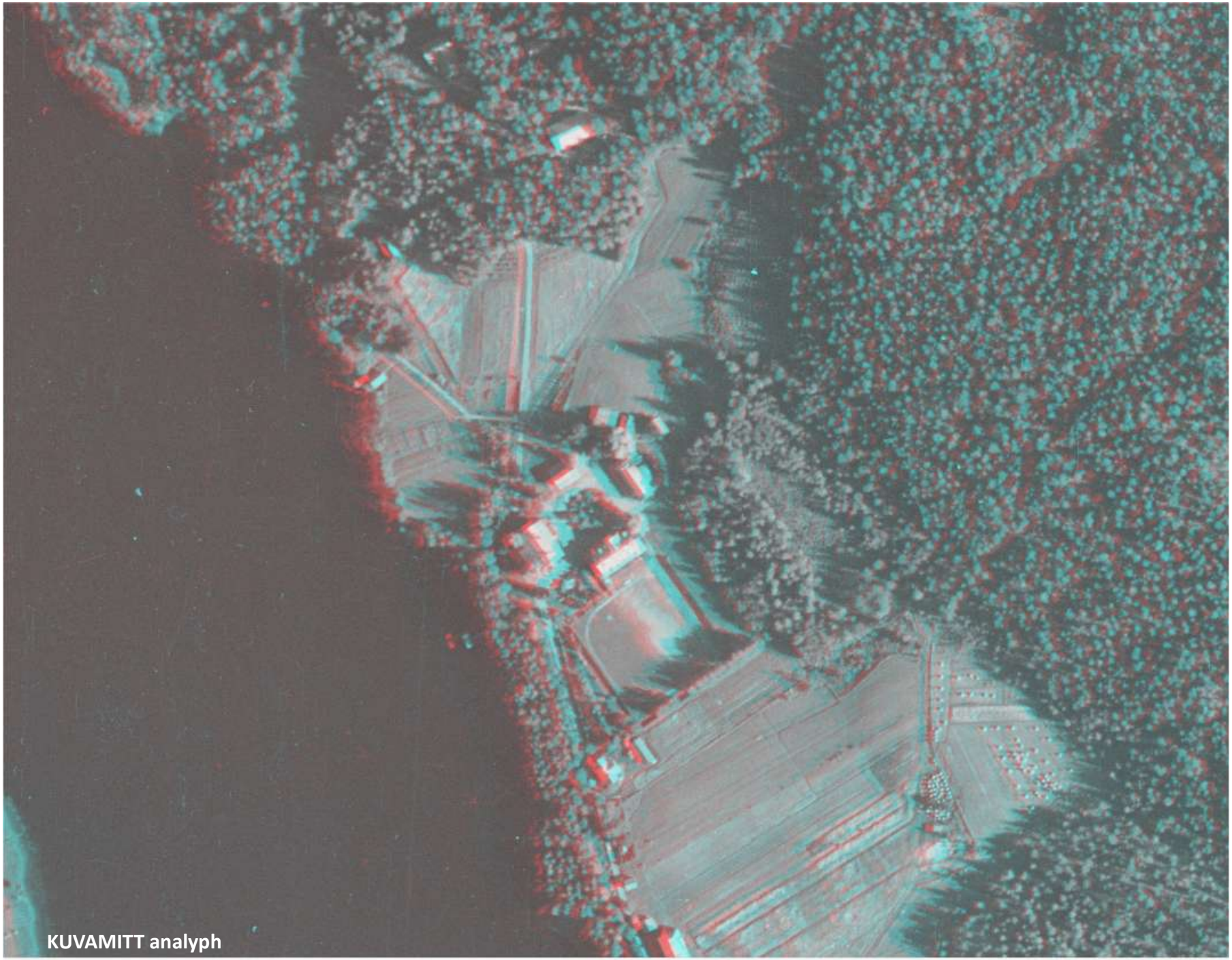
Lauri Korhonen 2008 (PhD 2011)

Vertex transponder 2008

Test flights with National Land Survey and FGI 2009

A moment devoted to Hikihelmi




KUVAMITT analyph

Forest inventory –related research in Hyytiälä

• Very little **before 1980s**

• **1980s** Aerial films, stereo interpretation, 2-phase sampling designs applying satellite images

• **1990s** Low-altitude images, stereophotogrammetry, Hyperspectral imaging, Digital photogrammetry in tree mapping Permanent field plots 1995-

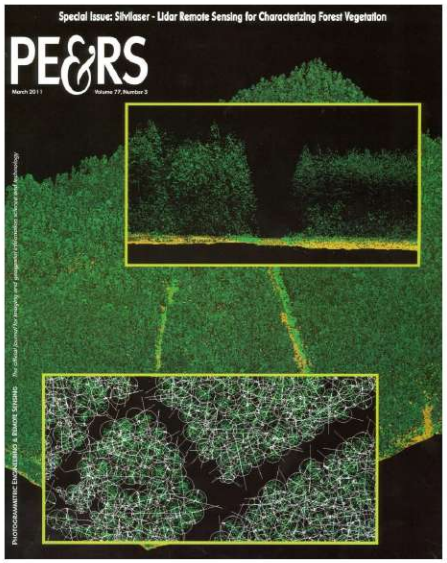
• **2000s** Field observations: 'Relashnikov', 'Harvester as mobile caliper', Terrestrial laser scanning, Terrestrial photography (outsourcing) and photogrammetry

Allometric biomass modeling

Remote sensing applications: GCP network & aerial image time series established; Radiometry of aerial imaging in canopies; Use of UAV images; Single-tree remote sensing with LiDAR and machine vision; Laser scanning applications in mire ecology; silviculture; change detection; LAI estimation in LiDAR/Satellite images, Hyperspectral imaging; Waveform-recording laser scanners

About Metsikkökoealaharjoitus

We will together combine the effort of learning by doing and an ’on-the-side -effort’ of maintaining a permanent remote sensing experiment



The Hyytiälä experiment

- Accurate reference data of **trees** in plots 1995 –
- **Airborne** optical **images** 1946 –
- **Airborne LiDAR** (laser scanning) data 2004–
- Spaceborne **images**
- **Terrestrial photogrammetry** and imaging of trees, bottom flora, canopy
- Terrestrial laser scanning of trees

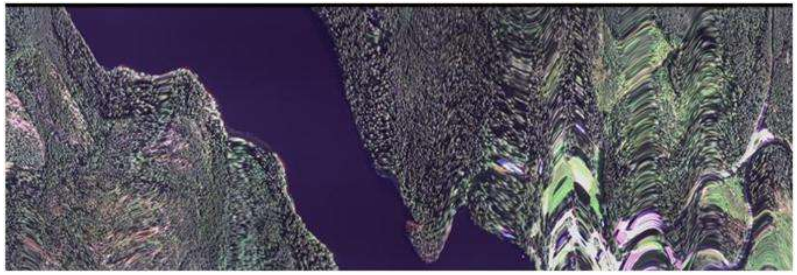
- Co-operation with/between sensor manufacturers, research institutes, PI’s, and research fields resulting in PhD and MSc theses, as well academic and commercial projects

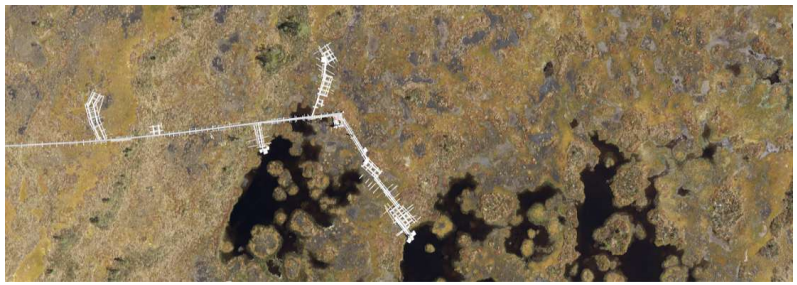
Some qualities of the experiment

Multi-use of plots (LAI detectives)

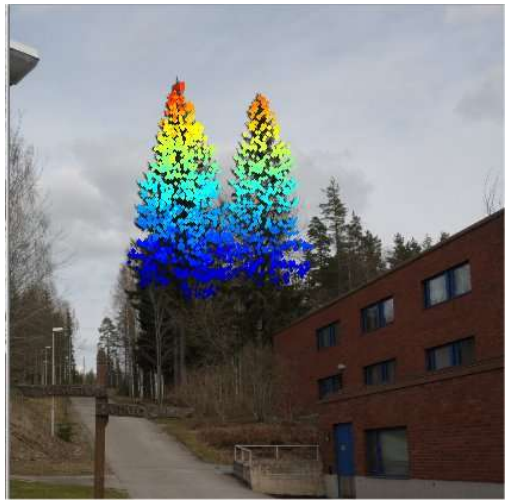
Accurate georeferencing (RTK in 2000)

Precise measurements



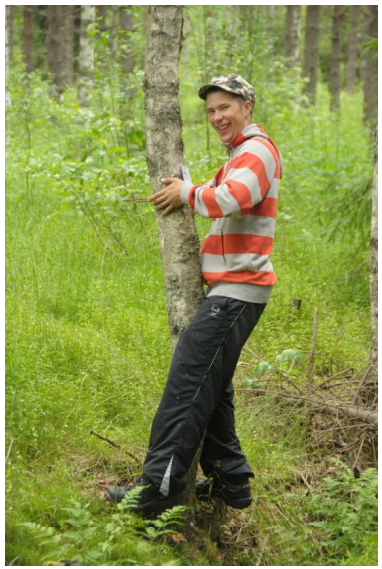


Joint campaigns: Here with Finnish Geodetic Institute, UH Dpts of Geography and Physics

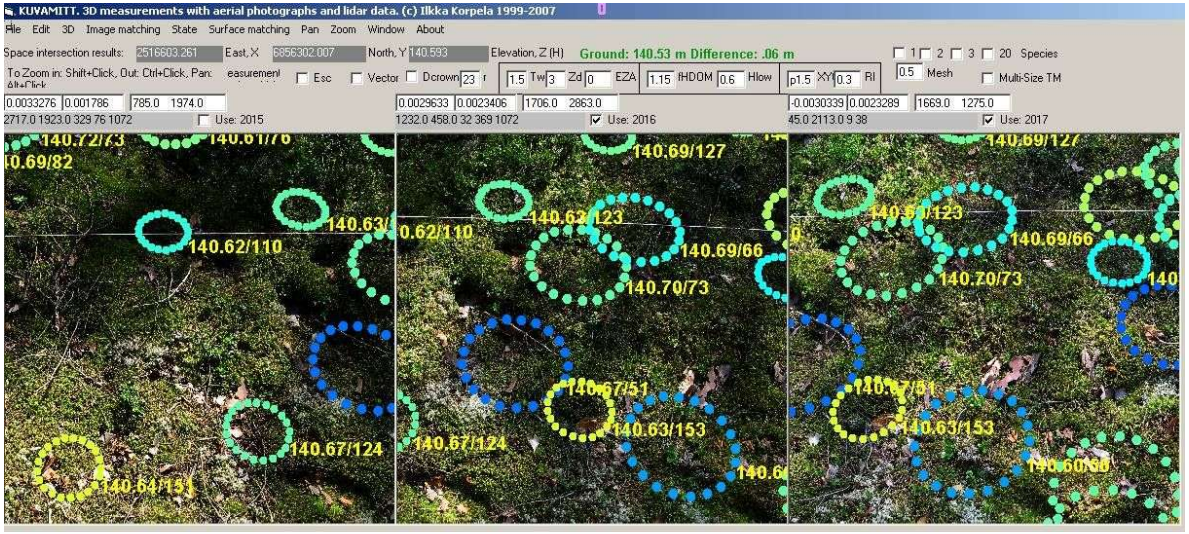


Fun

Some qualities of the experiment



Students participating



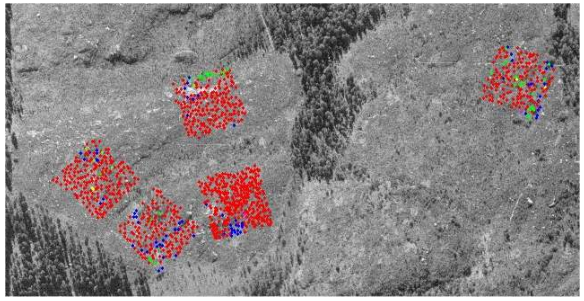
One datum: field photogrammetry 2008 and LiDAR footprints of 2006 & 2007

SINGLE-TREE FOREST INVENTORY USING LIDAR AND AERIAL IMAGES FOR 3D TREETOP POSITIONING, HEIGHT AND CROWN WIDTH ESTIMATION AND SPECIES RECOGNITION

I. Korpela, H. Virtanen, H. Schäfer, J. Honkasalo, V. Kuutti, M. Linkosalmi, E. Bruun, M. Salo, O. Suomi, J. Mustonen, S. Ilvesniemi, F. Haapaniemi

Department of Forest Resource Management, POB 27, 00014 University of Helsinki, Finland – ilkka.korpela@helsinki.fi

Commission III



Thinning experiment

- Redundancy — Repetitions, Plenitude of observations, members, treatments
- Known accuracy — Well-established controlled measurements
- One ‘datum’ — Co-use of different data, time-series analyses

The forests

PLOTS

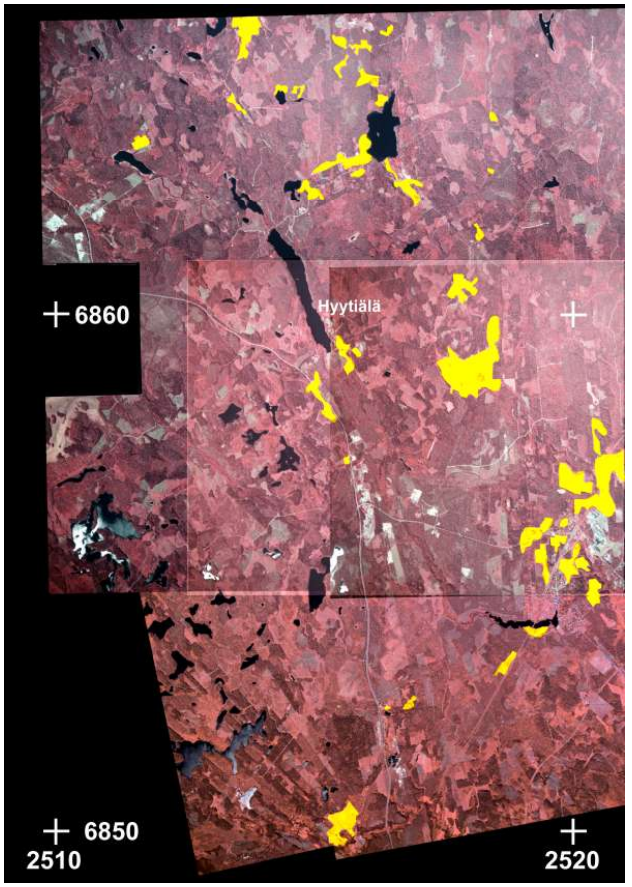
- Rectangular or ’free in shape’ (fixed-area), diameter criterion
- Variation in stand variables
- Last est. in 2011
- 1-4 measurements

TREES

- 28 000 with 3D coordinates
- Species, DBH / $d_{1.3}$
- Status of the crown (new in 2014)
- Height (h)
- Height of the lowest living branch (h_c)
- Crown diameter (d_{cr}), diameter increment (i_d)

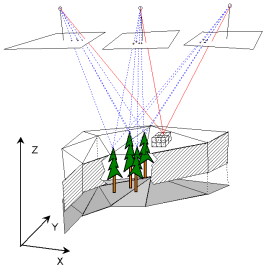
STUDENTS

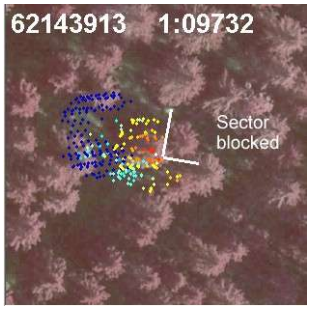
- Involved since 2007



How were the students introduced?

* **In 2004-06** research in ’precision forestry’ at its peak of hype





* Georeferenced **data** were **laborious** to collect in the forest

Jouni Kalliovirta (Simosol)

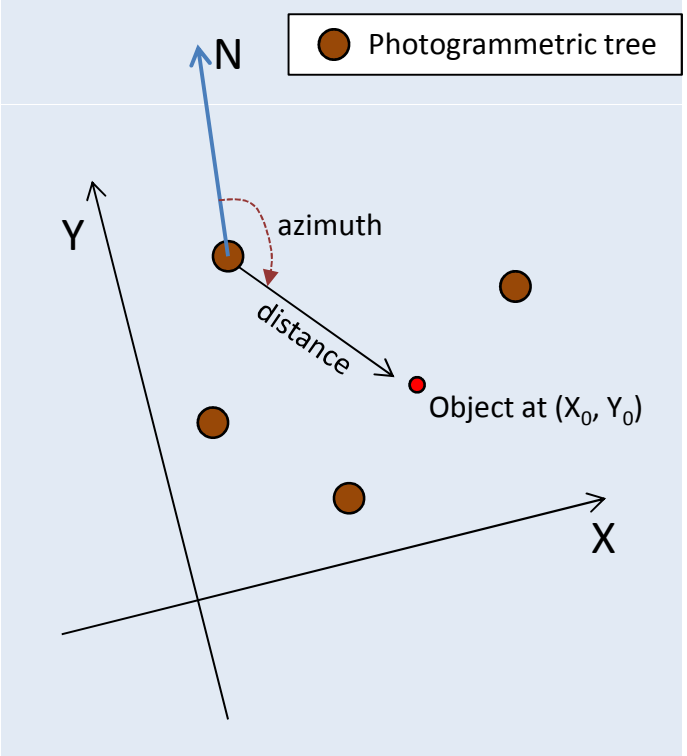
Heikki Surakka (Ramboll)

Kuivajärvi Black alder forest (Metadata)

2005 Kartoitus takymetrillä ja puumittaukset:
* Kartoitus takymetrillä 10.5-11.5.2005. Ilkka Korpela & Sirpa Rantanen. Neljä puuta paikannettu etäisyysmenetelmällä.
* Puidenluku ja pituusmittaukset 11.5.2005 Sirpa Rantanen & Mikko Vastaranta

A new ”one-man method” for tree positioning in 2006

- Using multiple aerial images, positioning of treetops.
  0.1–0.3-m XY, 0.5 m Z accuracy.
- 200–400 trees/h
- The tree list is incomplete, ‘height-challenged’, and
  may contain false cases as well, thus it needs filling in and polishing.



1. Solve the deviation between Y and N
2. Observe from many non-slant trees the object
3. Each compass azimuth ⇒ half-line
4. Each intratree distance ⇒ circle
5. Find position (X_0, Y_0) such that ||deviations|| is minimal

Distance between P_0 and P_A: $\sqrt{(X_0 - X_A)^2 + (Y_0 - Y_A)^2} - d_{(obs)} = 0$ (1)

Azimuth between P_0 and P_A: $\arctan\left(\frac{(Y_0 - Y_A)}{(X_0 - X_A)}\right) - \alpha_{(obs)} = 0$ (2)

Coordinates of points P_A: $X_A - X_{A(obs)} = 0$ (3)

$Y_A - Y_{A(obs)} = 0$ (4)

$$\sigma_0 = \sqrt{\frac{\mathbf{y}^T\mathbf{P}\mathbf{y}}{r}}$$

$$\mathbf{Q}_{xx} = (\mathbf{A}^T\mathbf{P}\mathbf{A})^{-1}$$

$$\sigma_{Xi} = \sigma_0 \sqrt{diag(\mathbf{Q}_{xx})}$$

$$\mathrm{eig}(\mathbf{Q}_{xx})$$

$$\mathbf{Q}_{vv} = \mathbf{P}^{-1} - \mathbf{A}\mathbf{Q}_{xx}\mathbf{A}^T$$

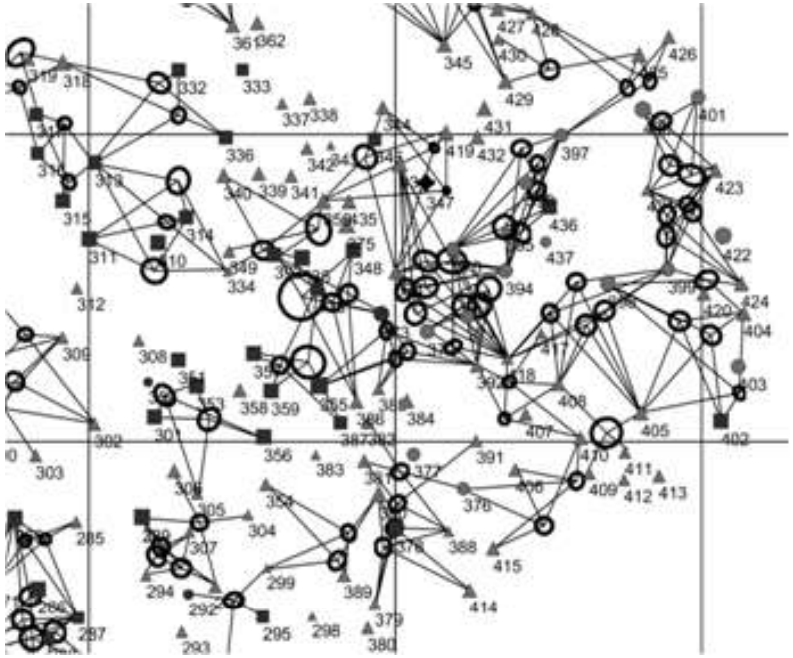
$$w_j = \frac{y_j}{\sigma_0\sqrt{q_j}}$$

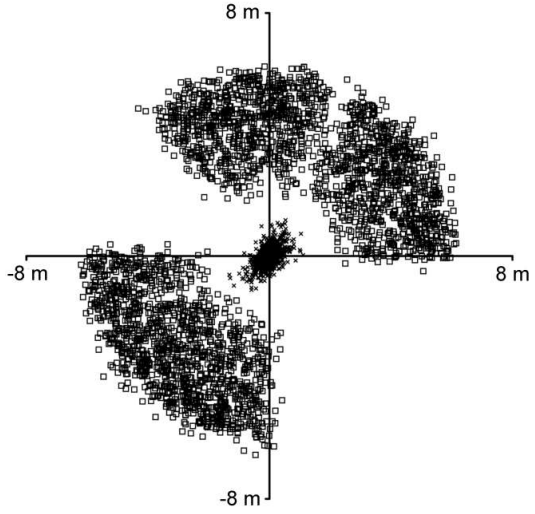
Non-linear regression, partial derivates of observations equations in **A**, deviations in **y**, weights in **P**.

σ_{Xi} = standard errors of unknown coordinates (m)

Error ellipses for the solution.

Math for finding possible gross observation errors. (standardized residuals).





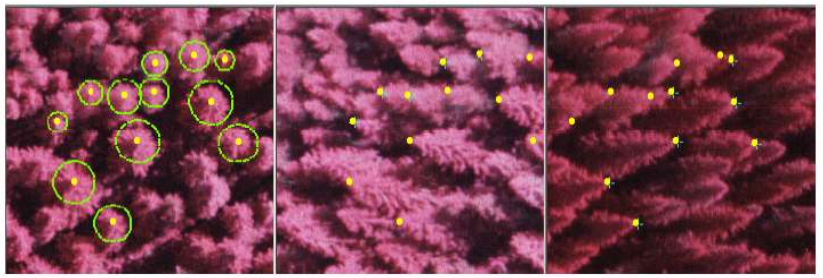
August 2006, Authors of the study (test phase)

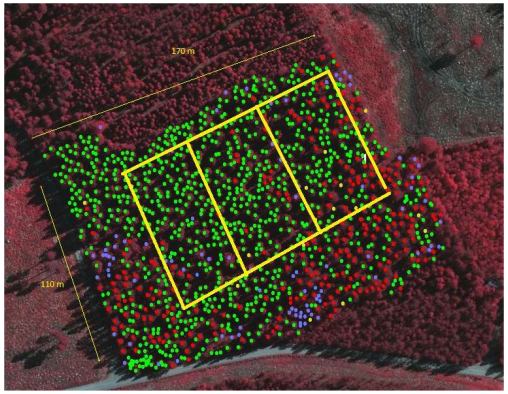
Tuukka Tuomola	(Silvadata)
Esko Välimäki	(Tapio)
Ilkka Korpela	(HY/S akatemia)

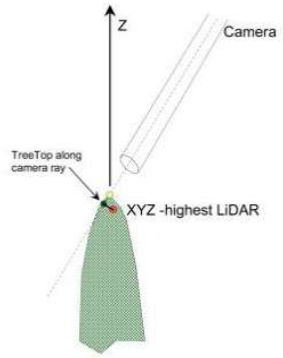
Plot mapping - METHOD

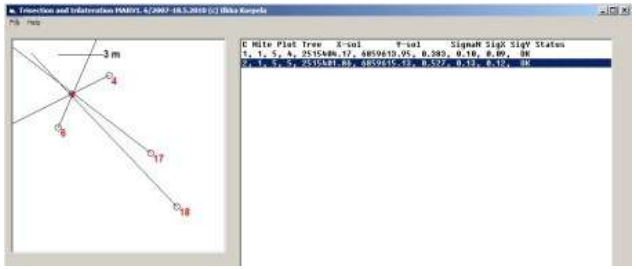
1. Acquire airborne LiDAR / images
2. Treetop positioning in these data
   ($h_{relative}$ > 0.5–0.6)
3. Prepare maps and tree labels
4. Identify trees in the field
5. Position the non-visible trees
6. Compute tree positions
7. Whatever measurements on the trees

In 2014: phases 3-7 on established plots.



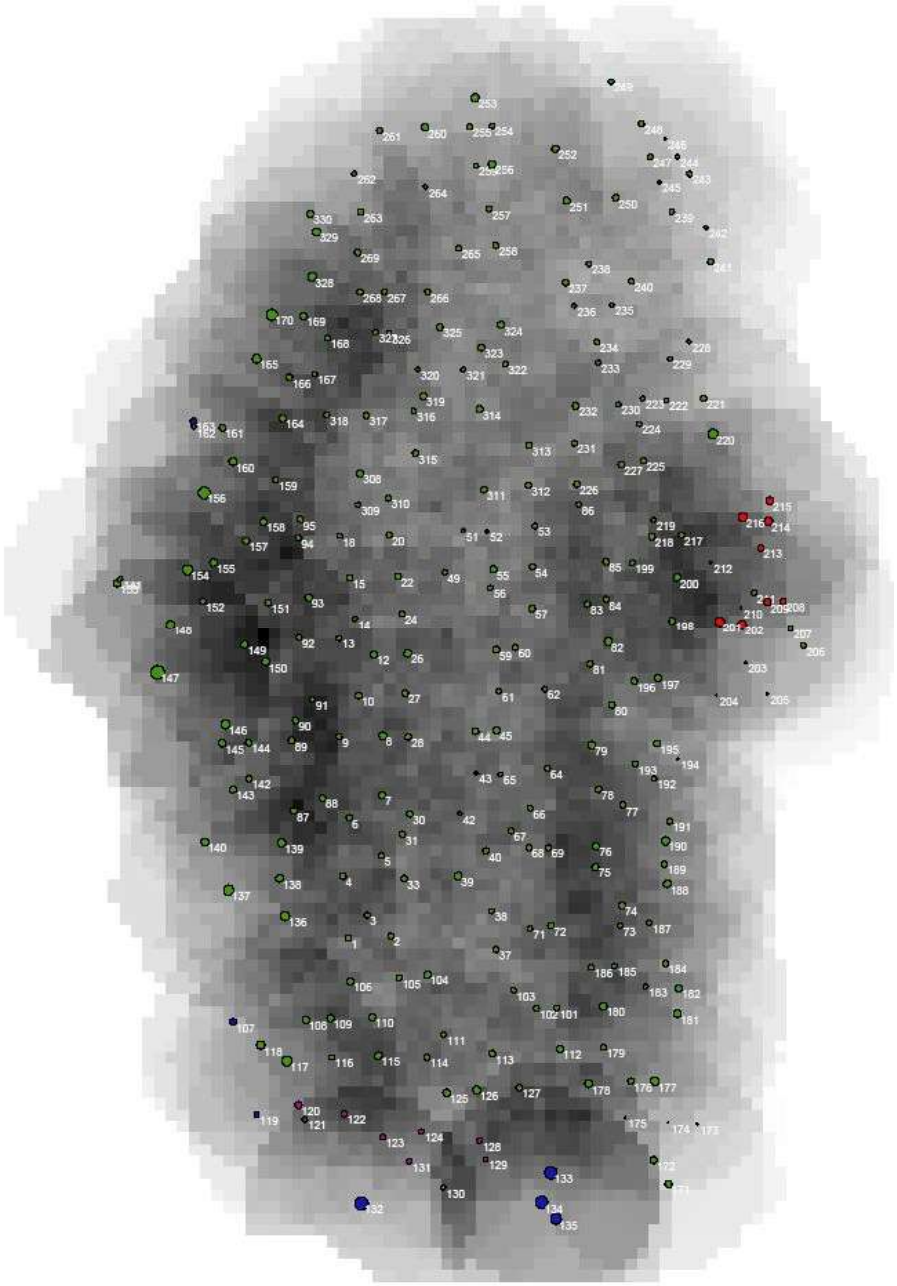






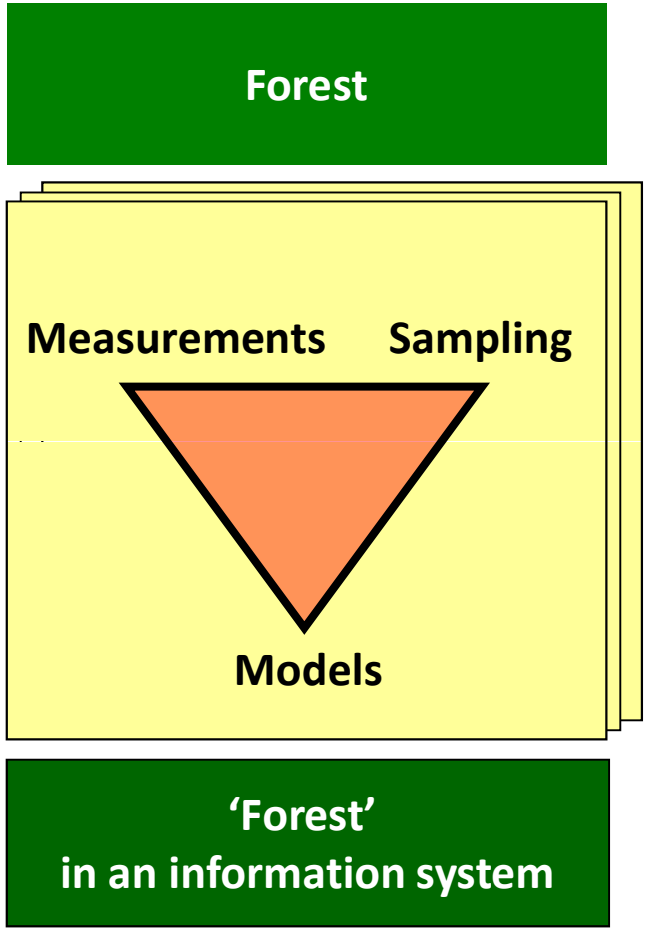
Gain from having tree positions?

- Tree-level monitoring becomes feasible
- Neighborhood (spatial) analyses for dependencies in growth, mortality, diseases etc.
- The plots are valuable not only for remot sensing research



So much for history...

Instructions for a successful learning experience



The main goal is to **learn** how to measure the current structure and recent changes of a forest, using

* different ways of selecting the trees of interest (plots),
* by carrying out measurements on these trees,
* by making special measurements on a selection of trees, and by applying these observations to existing tree models to predict new variables of interest
* to construct, for these new variables, stand-specific models to generalize them to all trees of interest

The research goals are reached simply by careful and accurate work!

TREE

AboveGroundTree == Σ TruncatedCones + Weighted branches

- Sampling; observations; assumptions
- Data for allometric TreeModels (some of which you applied also)

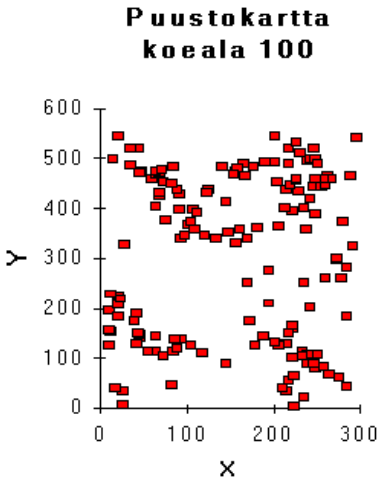
Tree_variables: species, classes, sortiment potential, DBH ($d_{1.3}$), d_x, h, h_c, v, i_r, i_d, i_v, b, age_x, …

Tree_models: taper curves, volume functions, increment functions, age models, …

TREE SETS and STANDS

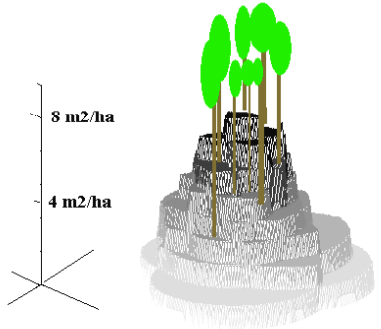
A) Forest == Σ Trees

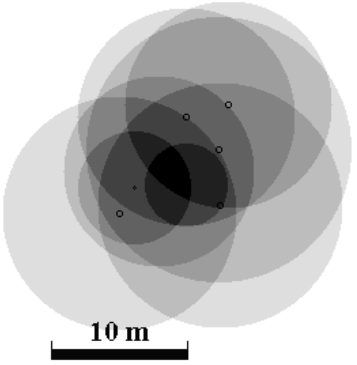
- Forest is characterized by trees sampled by given probabilities
- A tree is characterized by direct/indirect observations and model estimates
- Results apply to a 2D point (e.g. m^3/ha) or an area (m^3)



B) Forest == 'Flux of cylinders'

- Volume = Form-correction × 'Cylinder Density' × Cylinder Heights (V=FGH)
- 'Cylinder Density' = Basal area, m^2/ha with a **relascope**
- FH = f (species, height, BA); Pine stands FH = 0.4116-0.04275*H^1.5+0.6359*H
- Results apply to a 2D point (m^3/ha)
- Size of trees ⇒ Height and diameter observations and models needed
- quick 'n dirty -method

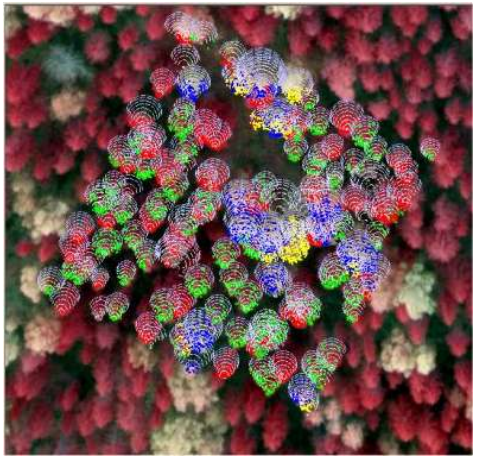




Stand_variables: species proportions by X, site class, D_{gm}, D, G (BA), 'density',H_L, H_{dom}, age(s), treatment proposals, soil type, etc.

Stand_models: FH-functions (relascope tables), diameter distribution models, height models, timber sortiment models, growth models,…

BY REMOTE SENSING A and B have 'counterparts'



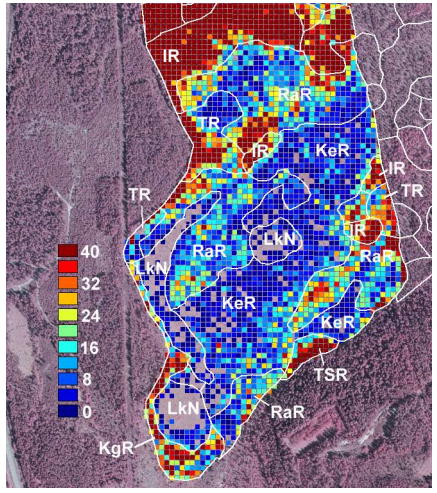
A) Forest == Σ Trees
⇒ Single-tree remote sensing

d13 = f_1(species, height, crown size)
v = f_2(species, height, d13)

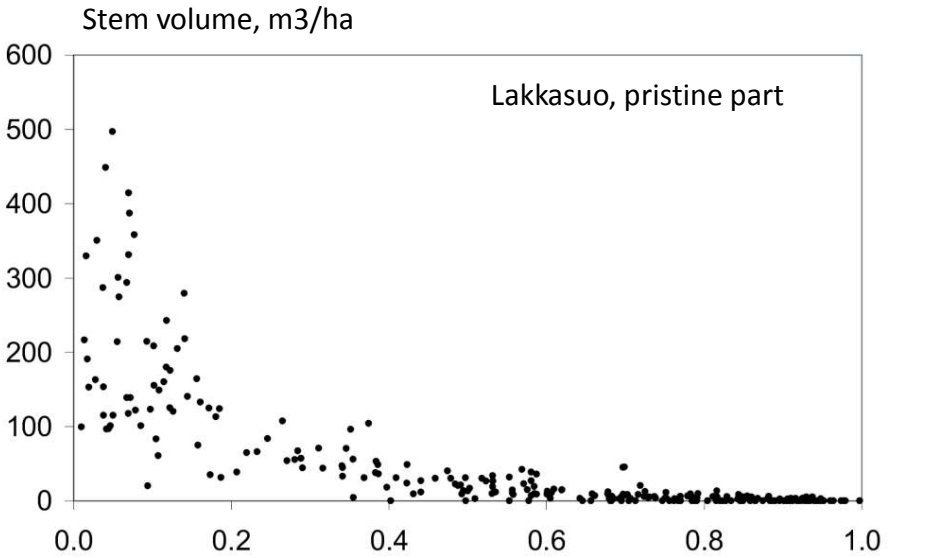
http://www.helsinki.fi/~korpela/Hyytiala/Espoonlahti.avi

B) Forest == 'Flux of cylinders' ⇒ Area-based remote sensing

Basal area ≈ canopy density



Percentage of pulses absorbed by the canopy (Lakkasuo ombrotrophic parts)



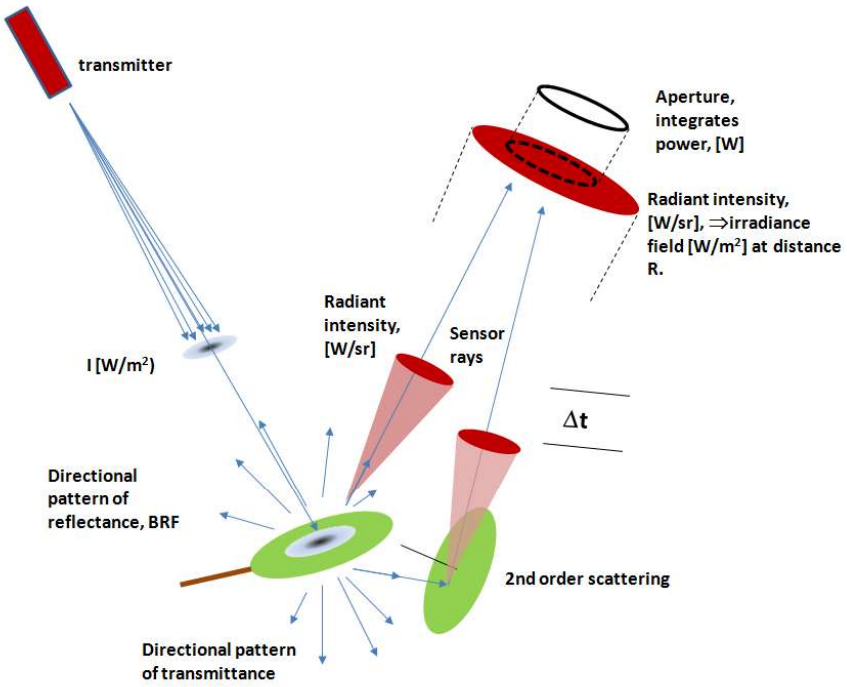
Percentage of pulses reaching ground (400 m² plots)

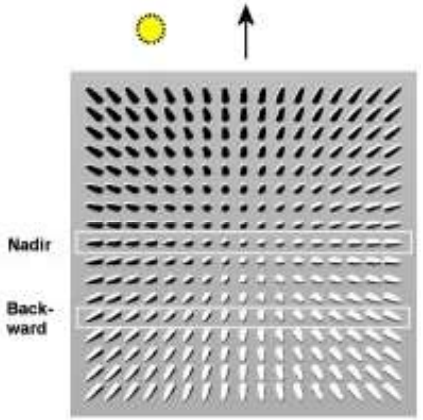
What will the 2014 data used for...

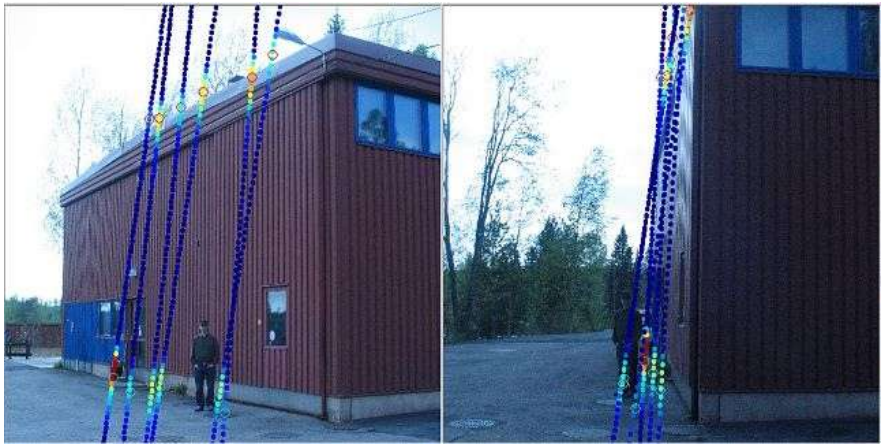
Topical research

* Simulation of LiDAR signal from canopies
http://www.helsinki.fi/~korpela/Liisi/birch_animation.gif

* Enhanced tree species classification: a) using so-called waveform features, b) directional reflectance signatures in images, c) Novel geometric and radiometric LiDAR features







What next...

Another moment devoted to Hikihelmi

Flow of the Metsikkökoealaharjoitus

0. Lecture and practice in Hyytiälä

⇒ **forest**

1. Getting to know the **large rectangular forest plot** with Hikihelmi
2. **Finding the trees and attaching labels** 1.3 m AGL; stripwise ordering; in two teams.
   If needed, labeling and positioning of trees by means of triangulation.
3. Careful **tally tree measurements** of each existing tree for the five variables:
   {Species, Canopy layer, Timber sortiment potential, **Crown status**, DBH}

⇐ **office**

4. Systematic **selection of 'sample trees'** representative of the DBH-distribution
   by species and canopy layers. Used later for building functions for the indirect estimation of volume, timber volume and past volume growth of trees of particular size and species.

⇒ **forest**

5. Very careful **sample tree measurements** on **height, height of the lowest living branch**,
   and the 6-meter diameter. A subset of trees is measured for variables needed in growth estimation.
6. Measuring the trees of interest using an **angle cauge** and a **circular delineation**

⇐ **office, data delivery** (paper sheets, 1:1 with xlsx-file of the plot), permission to continue

7. Generalizing the results, using sample tree information into estimates of the stand volume, timber sortiments, value, growth etc.

”MITÄ?, OHO ja HUPSISTA!” --- On accurate work

’Evidence from observations’

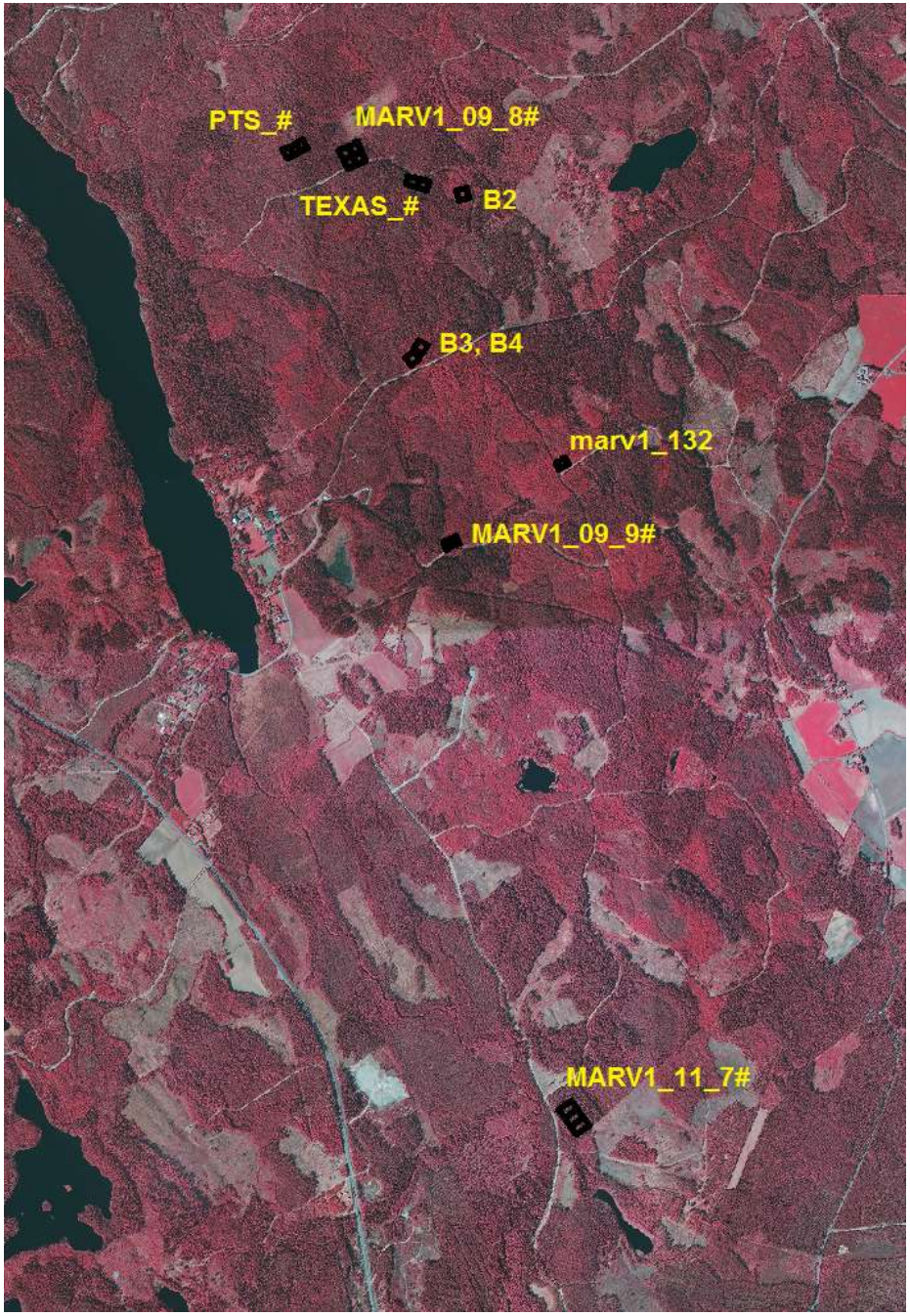
- **Labeling**: Built-in error control

- **Tallying:** Communication, documenting and data typing errors;
  Q/C against old data; Watch out for odd caliper scales; 1.3 m height

- **SampleTree measurements**: Communication, gross errors such as reading the wrong hypsometer scale, adding when supposed to substract, 6m caliper at wrong height or recording i_r for i_d, or B for 2xB. Recording wrong units.

- **How to control?** Re-measured sample $\Rightarrow$ deviations, their mean and dispersion are informative of systematic (bias) and random errors. Logical reasoning for known dependencies and thinking of a reasonable range of values.

Devote yourself to reading Hikihelmi


PTS_#
MARV1_09_8#
TEXAS_#
B2
B3, B4
marv1_132
MARV1_09_9#
MARV1_11_7#

JAKSO

1 Ainoa tai ylempi
2 Alempi

PUULAJI

1 Mänty
2 Näre
3 Raudus
4 Hies
5 Haapa
6 Harmaaleppä
7 Tervaleppä
8 Tuomi
9 Lehtikuusi
13 Raita
16 Pihlaja
20 Muu lehtipuu
21 Muu havupuu

LATVUSLUOKITUS

11 Normaali
12 Normaalista poikkeava + LISÄMÄÄRE
14 Selvästi vino + mahdollinen LISÄMÄÄRE
21 Kelo eli kuollut pystypuu
22 Pökkelö eli katkennut (arvioi katkeamiskorkeus)
23 Kaatunut eli maapuu
31 Kanto eli hakkuupoistumaa
41 Kadonnut

Lisämääreet luokille 12 ja 14:
a1 Latvus selvästi yhdeltä puolen supistunut
a2 Latvus kahdelta tai useammalta puolen supistunut
a3 Tupsulatvainen (lyhyt hyväkuntoinen, elävä latvus)
a4 Elossa, mutta latva katkennut (arvioi katkeamiskorkeus)
a5 Latva kuollut/kuivunut
a6 Kuoleva, erittäin harsu (tn. kuolee 5 vuoden sisällä)
a7 Harsu (metsikön muihin puihin verrattuna selvästi)

RUNKOLAJI

1 tukkipuu ($d_{1.3} \geq 20$ cm, hyvälaatuinen)
2 kuitupuu ($d_{1.3} < 20$ cm)
3 kanto (hakattu) (latvusluokka 31)
4 kelo/pökkelö (kuollut, latvusluokka 21 tai 22)

LATVUSLUOKITUS

ESIM.
11
12a1a5
12a1a3
12a1a7
14a1
21

11 Jos puusto on hoidettua ja terve; ”**normaali**” latvustyyppi vallitsee.

LISÄMÄÄREET

12a1; 12a2 Lisävalta- ja välipuut monesti supistuneita/piiskaantuneita yhdeltä (a1) tai useammalta puolelta (a2) (latvus ei siis ole ympyräsymmetrinen). Jos **poikkeama on yli 50%,** kirjataan.

12a3 Joillain puilla voi olla **hyvin lyhyt latvus** suhteessa muihin saman puulajin puihin. Esim. vallitseva latvussuhde on 40% ja joukossa yksittäisiä puita, joilla se on 15-20% (”tupsu”), yl. väli- tai lisävaltapuumänty tai –koivu.

12a4 Lumi- tai myrskytuhon jäljiltä, **elossa olevia puita**, joiden **latva** on **poikki**

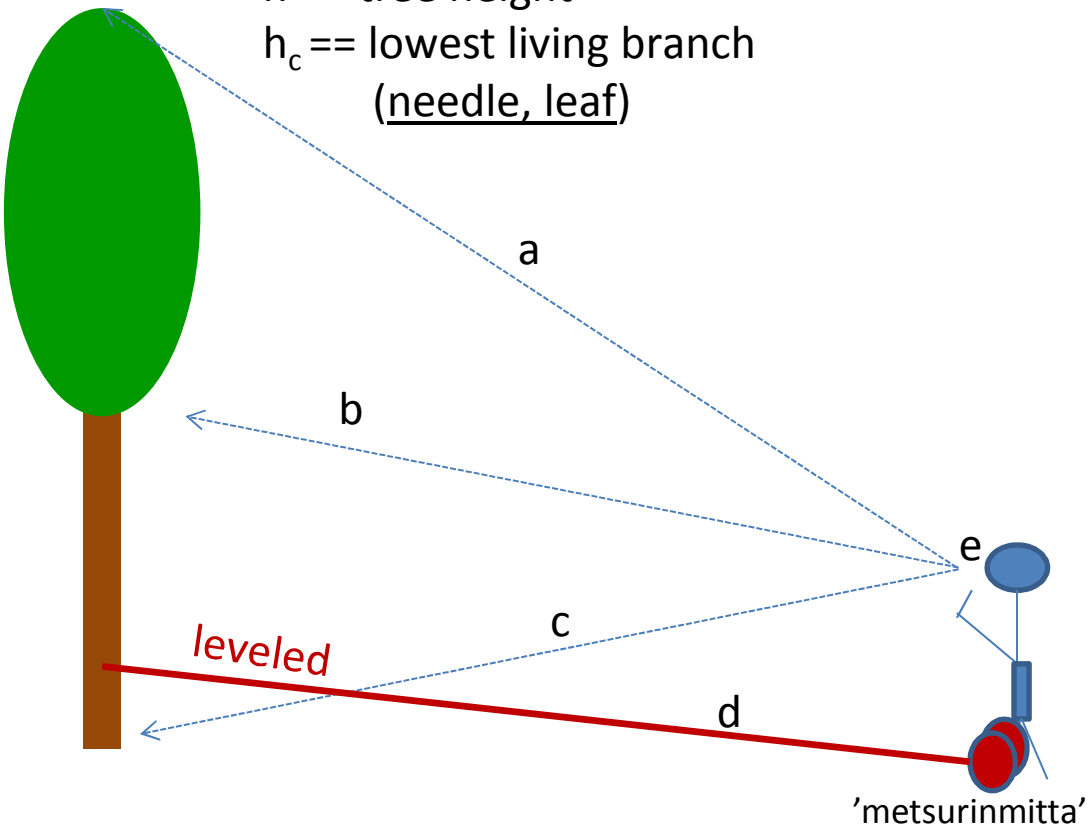
12a5 Latvuksen ylin osa (latva) voi olla **kuivunut** (esim. versosurma kuusella, tervasroso, koivujen latvojen kuivuminen, latvan piiskaantuminen)

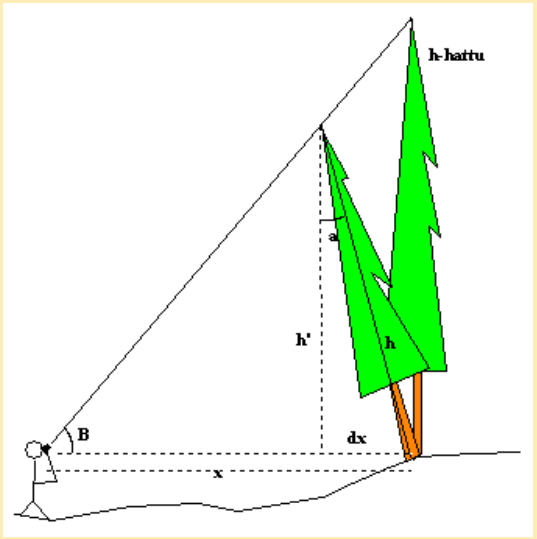
12a6 Puu voi **tehdä varmaa kuolemaa**.

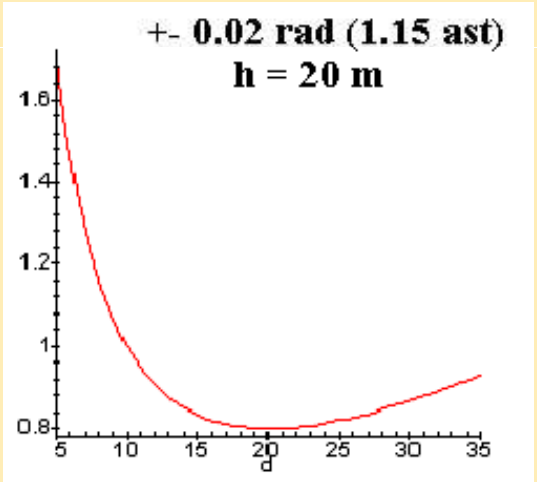
12a7 Joukossa voi olla **harsuja puita**, joissa on suhteessa muihin samassa asemassa oleviin puihin nähden alhainen lehtimassa.

The h and hc measurements are crucial

h == tree height
h_c == lowest living branch
(needle, leaf)







Effect of hand tremor on the absolute error in height measurement at different distances for a 20-m-high tree

Option (for the use of optical distance fixes)

1. Choose d 'freely' and fix e, the scale in hypsom.
2. Observe a, b and c.
3. Record a, b, c, d and e.
4. Deduce h and hc in the office

kulmanmittaus-asteikolle, on laskettu valmiiksi etäisyyden ja kulman tangentin tulo

What are available?

- Tree labels, ordered in strips, n = N, thick paper
  http://www.helsinki.fi/~korpela/MARV1_2014/Numerolaput/

- 2N pins

- A4-size forms to document measurements (water proof), the files are here
  http://www.helsinki.fi/~korpela/MARV1_2014/Maastolomakkeet/

- Printed and covered tree maps n = 2
  http://www.helsinki.fi/~korpela/MARV1_2014/Puukartat/

- http://www.helsinki.fi/~korpela/MARV1_2014/Resection/marv_2014_puut.csv
  File with existing measurements, with tree-records, used with RESECTION

- HIKIHELMI!

Program

Assigning you with a plot and an assistant, and the per-plot material.

Forest walk to see **24 different tree crowns**

Reading-the-Hikihelmi-and-consulting-the-assistant-so-as-to-know-exactly-what-you-are-about-to-do-next – session

Lunch and off to the forest

Forest walk - route

Tel. 0400-218305

Challenge!