CENTRE OF EXCELLENCE IN LASER SCANNING RESEARCH

FINNISH GEODETIC INSTITUTE – UNIVERSITY OF HELSINKI – UNIVERSITY OF OULU – AALTO UNIVERSITY

UNIVERSITY OF EASTERN FINLAND

Precision forestry in Finland

ICT Smart Precision Forestry with Laser Scanning, Finland-Japan Joint Symposium (3rd edition), Tokyo

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- Forestry in Finland
- Forest management planning in privately-owned forests
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  - Seedling stand inventories
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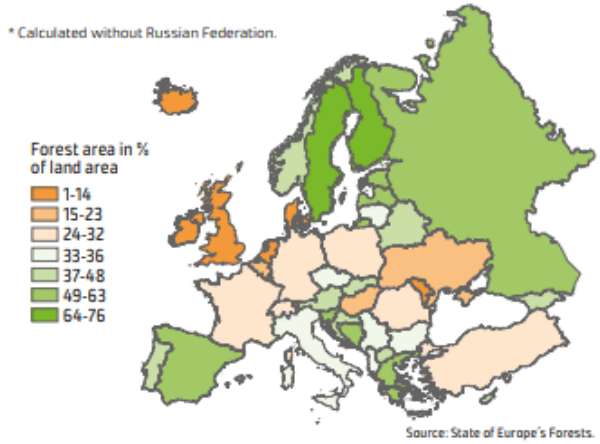
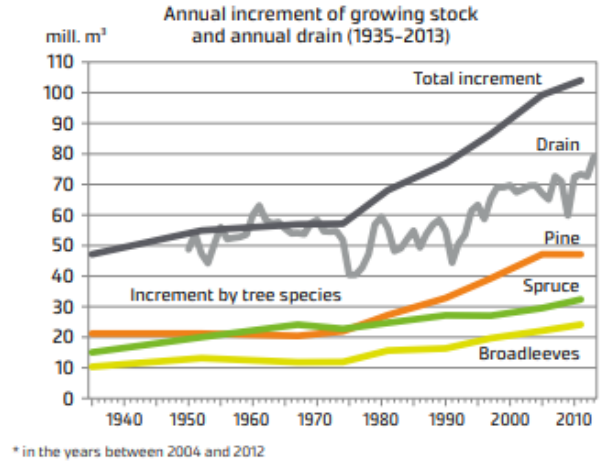
- Precision forestry in Finland 2025

Forests and forestry in Finland

- Finland is the most extensive forest cover country in Europe (75% from the land area).
- Forests are mainly privately-owned; small forest holdings (average size is only 30 ha)
- Growing stock has steadily increased over 40% during the last 50 years according to National Forest Inventory.
- The annual increment of growing stock has been +100 million m^3 and the amount of fellings below 80 million m^3.
- Finland's forest are a considerable carbon sink. Recently the forest sink has covered about 60% of the Finland's total emissions excluding the emissions and removals of land use and forestry.
- Extensive forest road network





Source: Natural Resource Institute Finland

Forests and forestry in Finland

- Forests are important for Finland
  - The current bioeconomy output is approximately € 65 billion and its share from exports is about 25% (The Finnish Bioeconomy Strategy, 2014).
  - More than half of the bioeconomy relies on forest utilization.
  - The Finnish Bioeconomy Strategy (2014) aims at increasing the output of Finnish bioeconomy to € 100 billion and creating 100,000 jobs within the next 10 years.
    - Increase in the harvests of Finnish forests.
    - Numerous industrial investments.
    - Finnish forest industry may need 10–30 million m^3 yr^{-1} more wood in the coming years (Heinonen *et al*. 2017)
  - Changing climate is estimated to increase forest growth, but the extreme weather phenomena, notably local storm and bark beetle damages will probably become more common in the future.
    - Mild winters are problematic for wood procurement

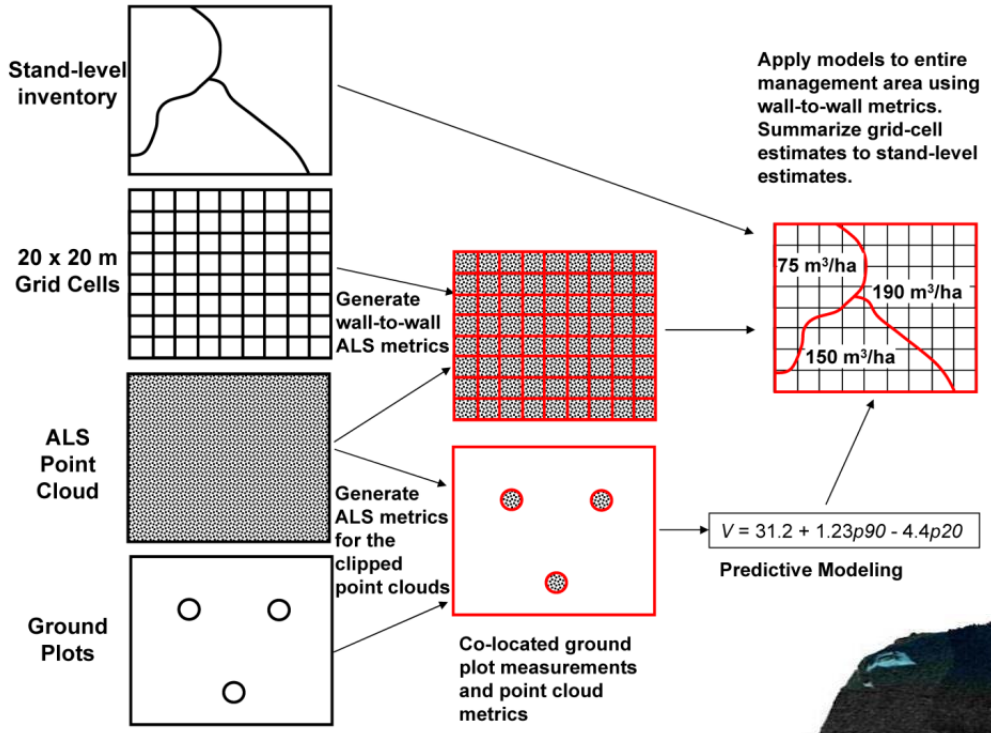
Forest management and wood procurement in Finland

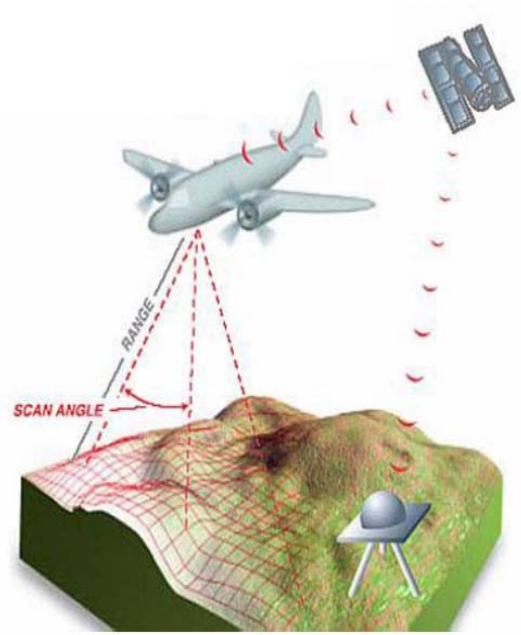
- Operating environment can be seen challenging due to:
  - Private ownership, small forest holdings, multi-use of forests, small stand size, long rotation periods, varying weather conditions, etc.
- High quality forest resource information is required for optimizing use of resources as well as for ensuring sustainability
  - Forest planning
  - Wood procurement planning
  - Production planning

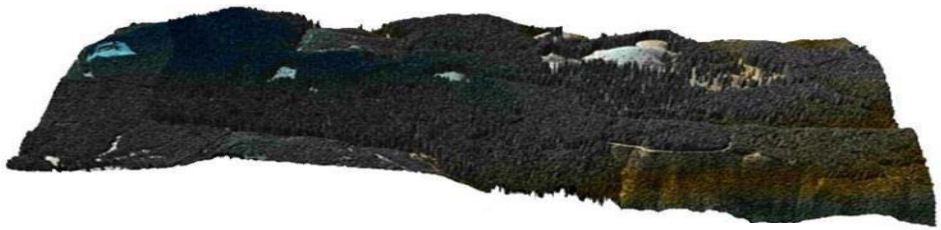
How forest resource information is collected in Finland? - short background

- National forest inventory: first in the world in 1924
  - In every five years
  - ~81 000 field plots in clusters systematically across country
  - Statistical estimations not accurate for areas < 200 000 ha
  - Landsat TM + field plots: thematic maps of forest inventory attributes
- Stand-wise field inventory: operationally used more than 60 years
  - For forest management planning, in every 10 years
  - Bitterlich sampling for species-specific forest inventory attributes for each stand
  - Diameter distributions estimated based on field measurements + suggested forest management activities
    - →estimations for future income and costs
- Laser-scanning based forest inventory (With in the next years 100% of forested area)
  - → Forest inventory attributes for 16 m x 16 m grid cells; available online for forest owners

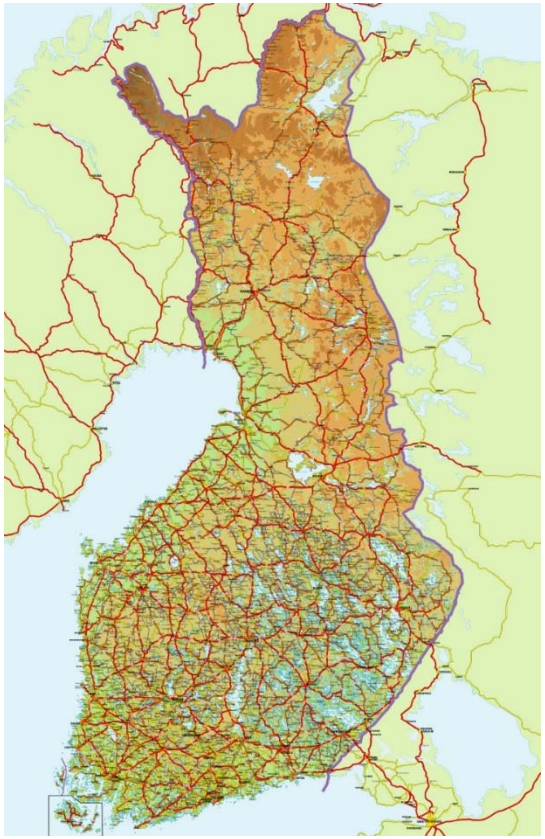
Area-based approach

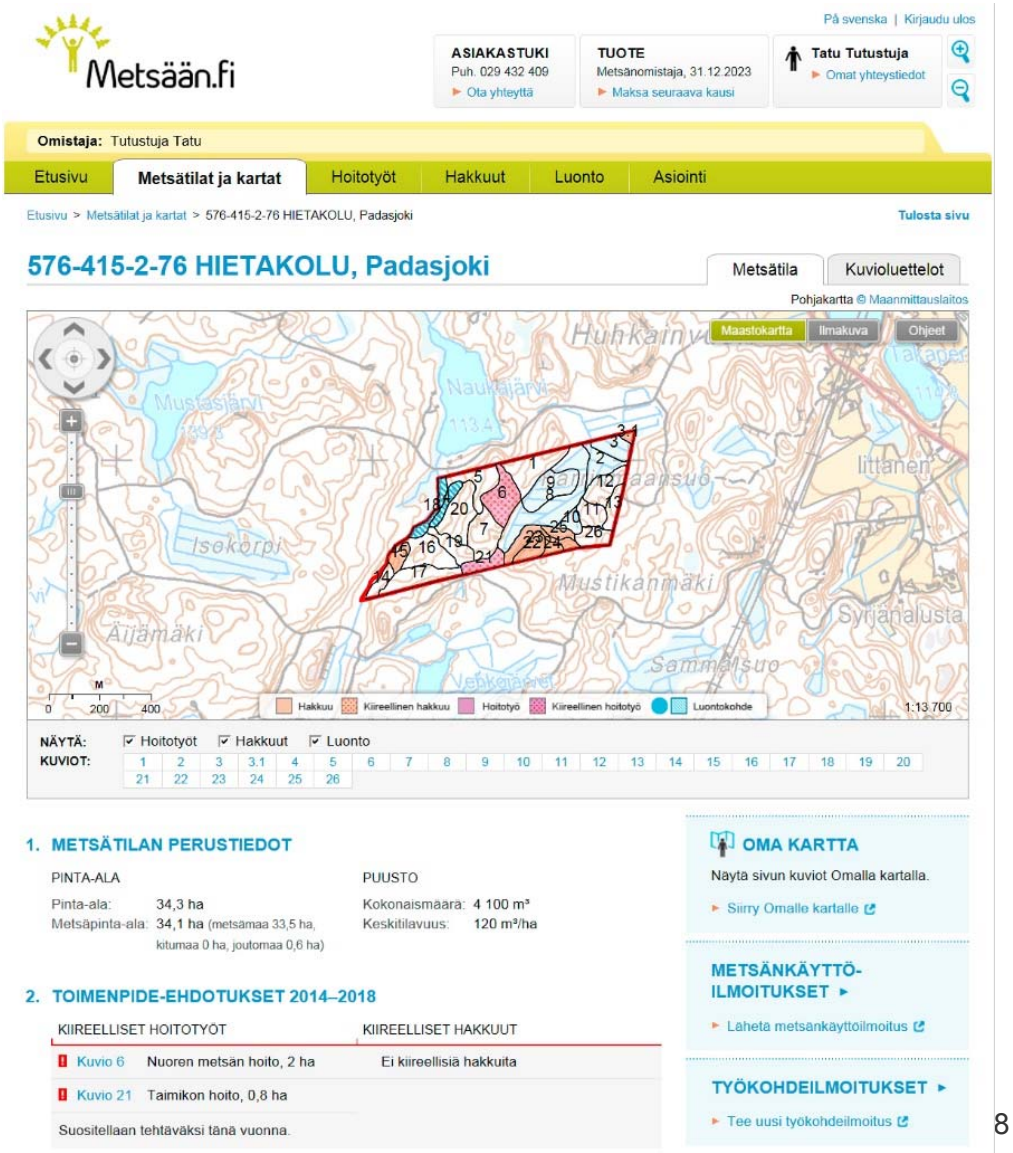






Forest resource information is open data





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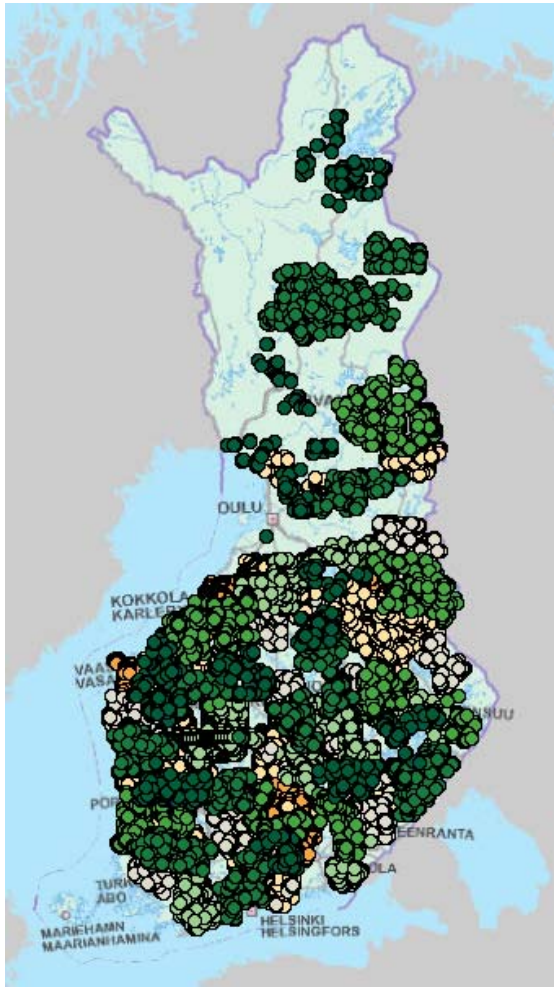

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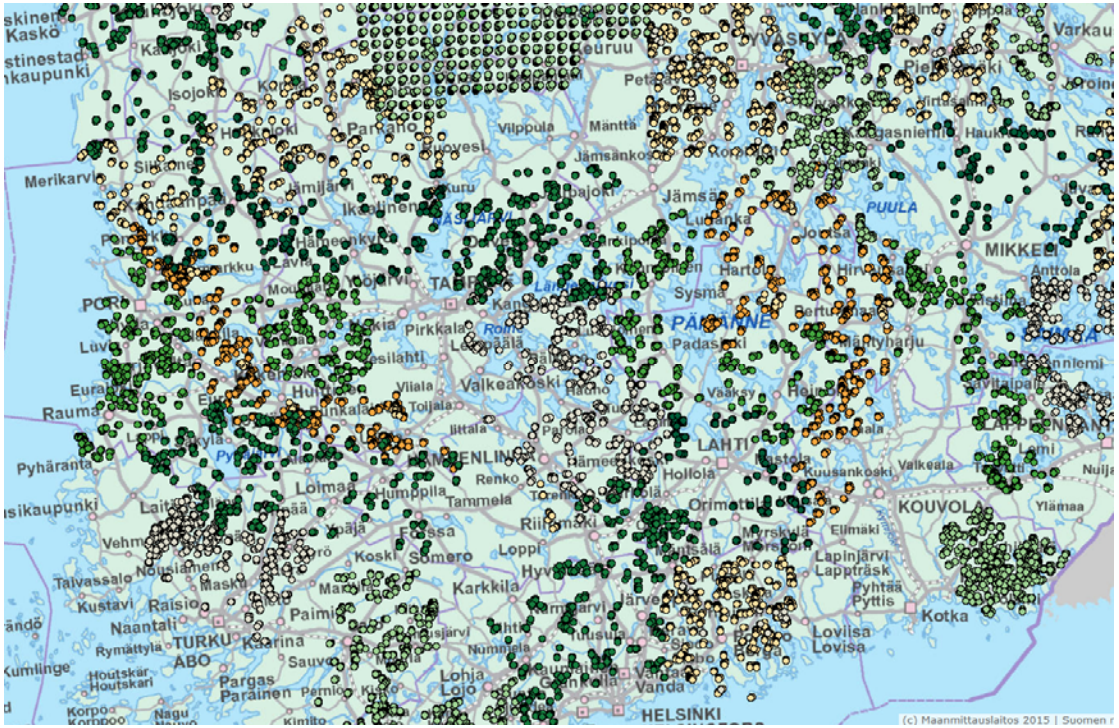
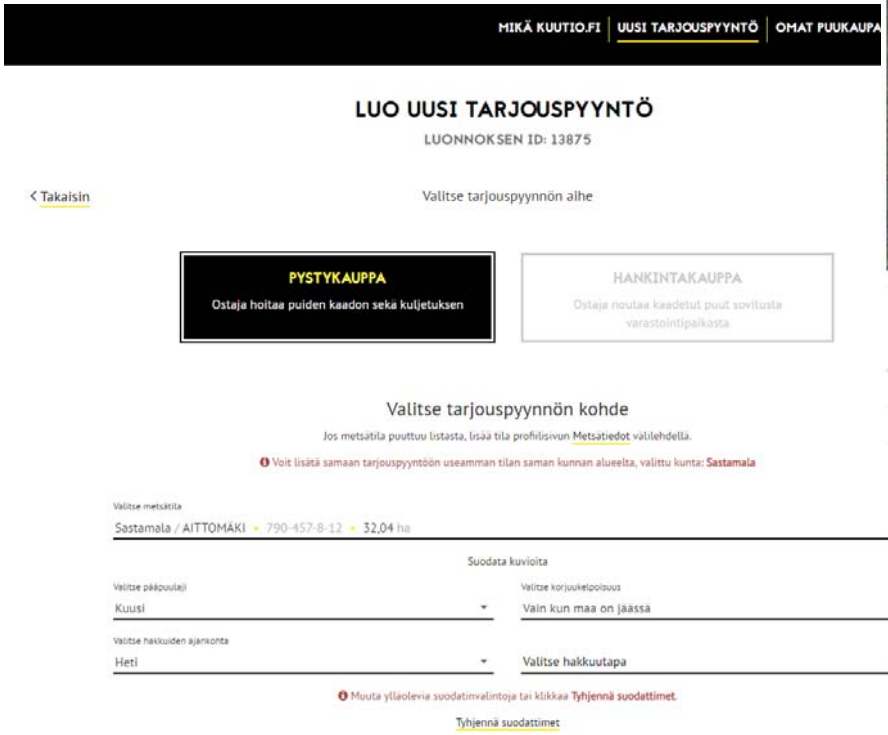


Digital wood trade



Forest resource information and new digital services

- Key project in Finnish Government Programme
- Includes following topics (among others):
  - Seedling stand inventories
  - Improved estimation of tree quality
  - Bearing capacity estimation
  - Use of information collected by harvesters
- R&D-projects funded by:

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MINISTRY OF AGRICULTURE AND FORESTRY

Seedling stand inventories

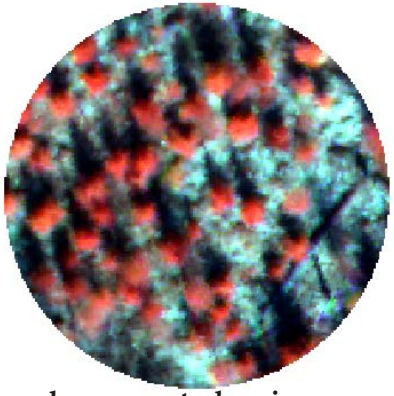
- Field visits are still used for collecting information from seedling stands.
- Alternatives for more efficient data collection:
  1) Biometric modelling of the stand early-development
  2) Dense airborne laser scanning point clouds
  3) Drones (dense photogrammetric point clouds)

Example sample plot

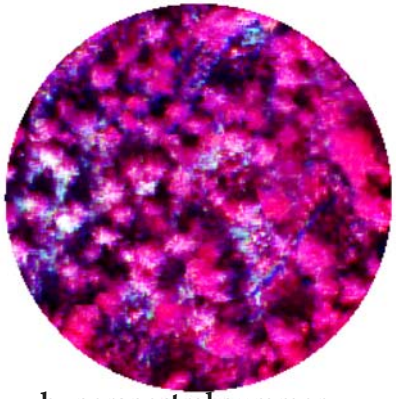
Tree number: 2228 ha^{-1}

Ortho-mosaic spring

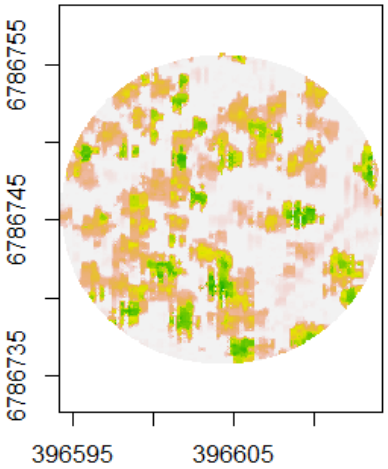
Ortho-mosaic summer



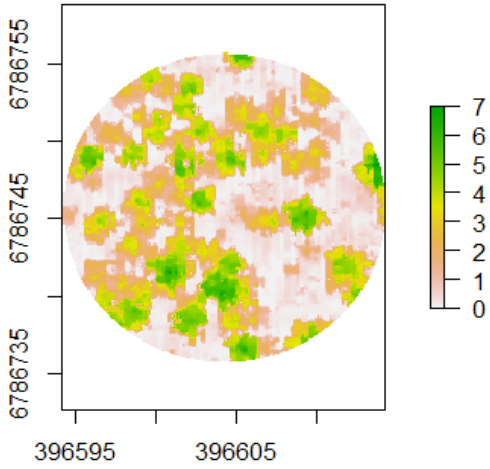
hyperspectral spring



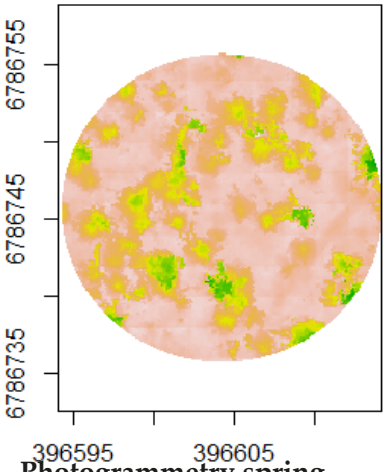
hyperspectral summer



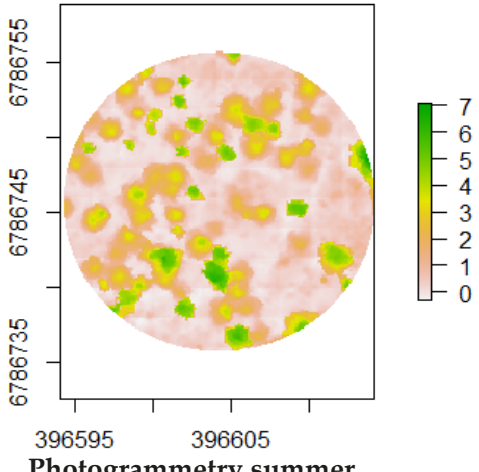
ALS spring



ALS summer

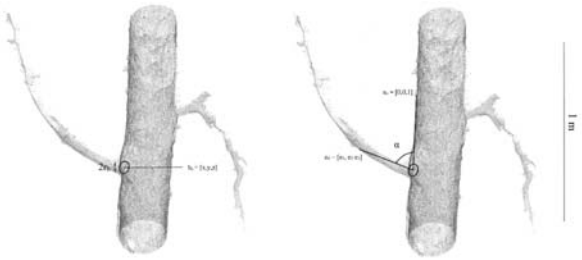


Photogrammetry spring

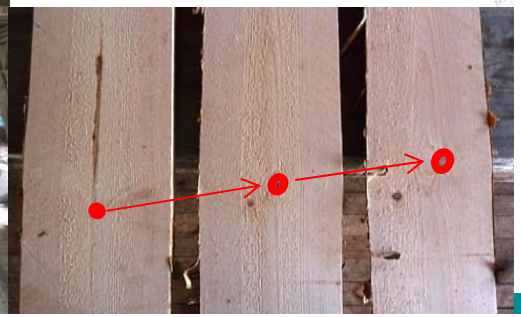


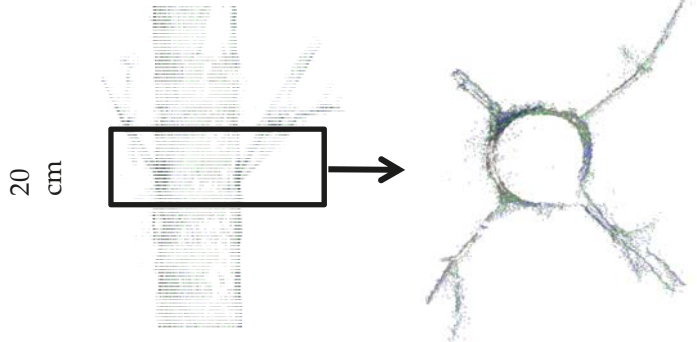
Photogrammetry summer

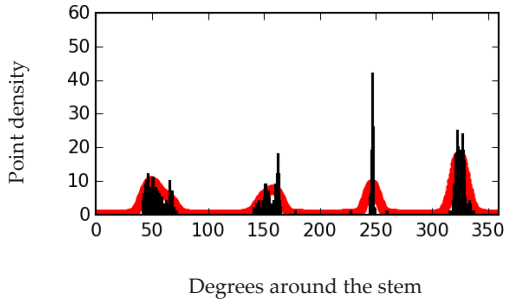
Tree quality estimation



- Develop methods for quantitative assessment of Scots pine (*Pinus sylv* environment using terrestrial laser scanning
- Estimate internal wood quality at stand level by linking log X-Ray measurements and airborne laser scanning
- Calibration on tree level quality attributes based on ALS

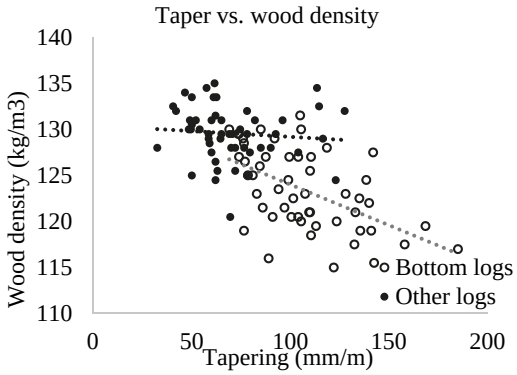


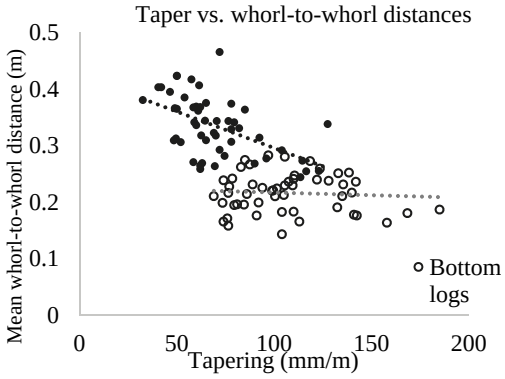




Measuring standing timber stem geometry by the means of terrestrial laser scanning with implications to wood quality

- Preliminary findings:
  - When comparing the TLS stem model geometry to the X-ray data, we found that increasing tapering correlated moderately with decreasing wood density (r = -0.62). Increasing tapering was also associated with decreasing whorl-to-whorl distances (r = -0.70).
  - Our findings are in line with literature, and it seems that TLS stem models could allow logical assessments of expected wood quality in standing timber.



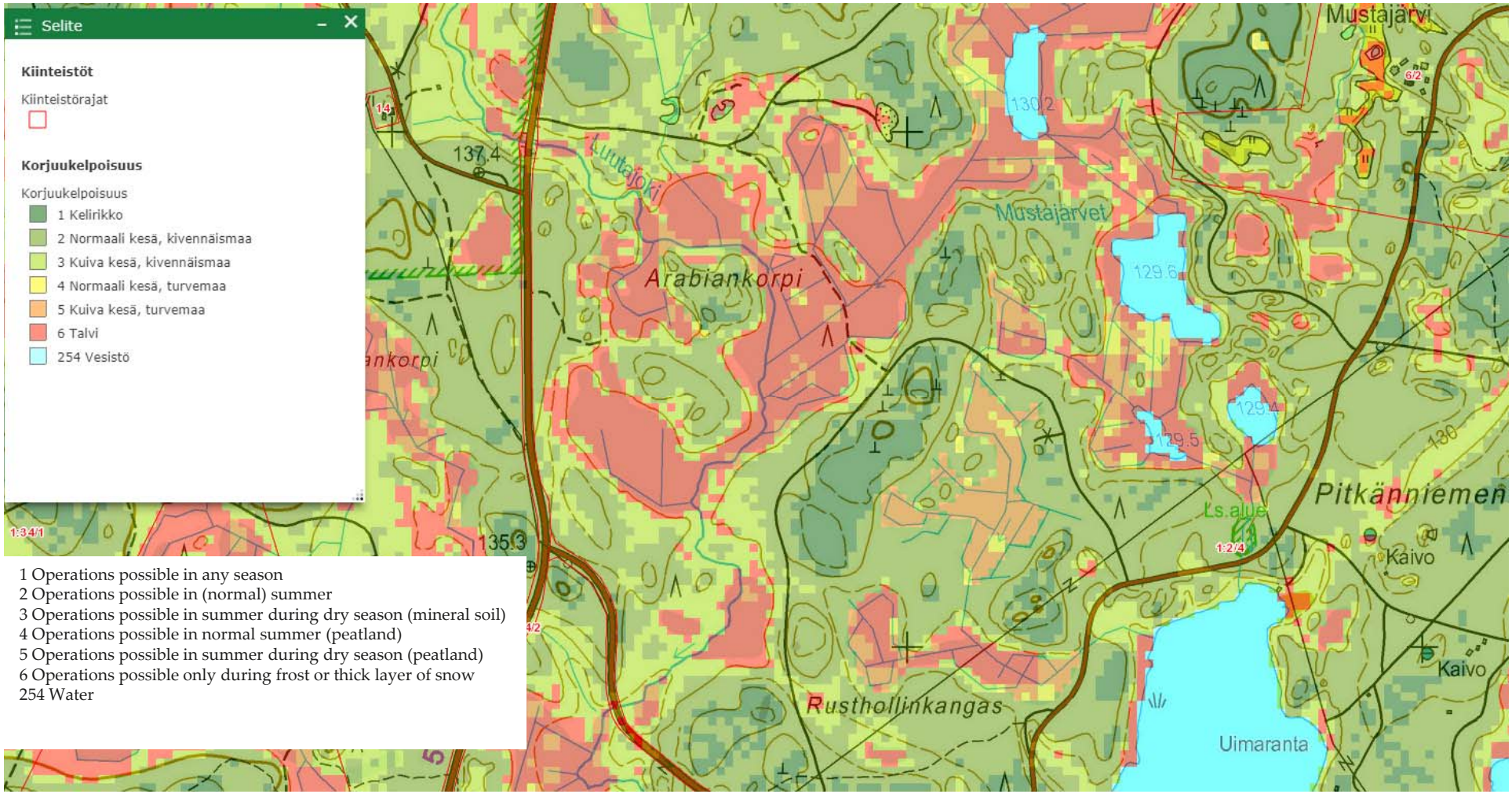


Forest trafficability mapping / bearing capacity estimation

- The trafficability map is a classification of every map pixel to a class describing the season when the harvesting operations may take place without causing significant damages to soil using standard logging machinery (harvester, forwarder). The following classification is used:
  - Operations possible in any season
  - Operations possible in (normal) summer
  - Operations possible in summer during dry season
  - Operations possible only during frost or thick layer of snow
  - Not classified.
- Developed by Arbonaut Oy

Forest trafficability mapping

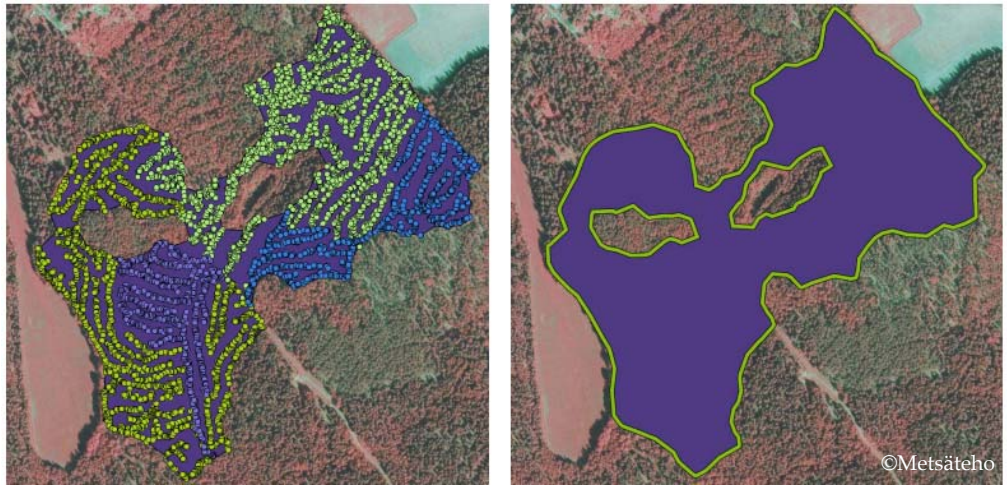
- Trafficability is estimated based on
  - Peatland/mineral soil
  - Average ditch depth/ground water height
  - Topographic wetness index (TWI)
  - Estimate of amount of vegetation based on ALS height distribution
- Forest trafficability maps are freely available



1 Operations possible in any season
2 Operations possible in (normal) summer
3 Operations possible in summer during dry season (mineral soil)
4 Operations possible in normal summer (peatland)
5 Operations possible in summer during dry season (peatland)
6 Operations possible only during frost or thick layer of snow
254 Water

Use of information collected with harvesters

- Centralized data warehouse
- Stand boundary update after operation
- Reference data collection for RS
- Bearing capacity measurements
- Rutting measurements
- Measurements of the remaining trees



Role of information collected with harvesters

- Harvester head positioning improves usability of the collected tree data in remote sensing-based prediction of forest inventory attributes.
  - worthwhile to generate larger modelling plots

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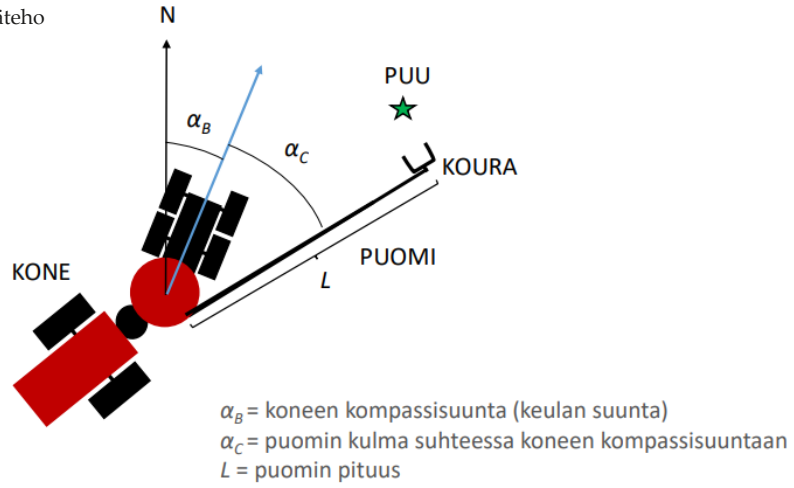
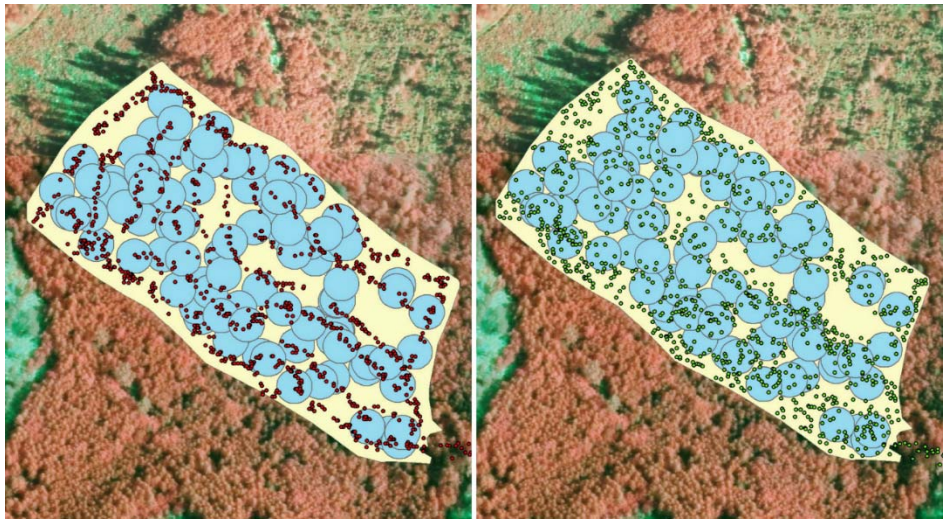
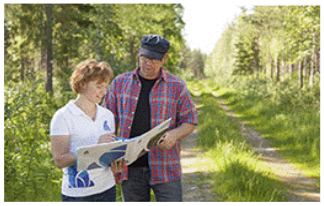




Precision forestry in Finland 2025

Digitalization in forest-based bioeconomy -added value for society, forest owners, entrepreneurs, industry and consumers



Society
- Planning and supporting sustainable bioeconomy

Forest owner
- Sustainable and multi-attribute forest planning

Consumer
- Responsible consumption

Life cycle of a bioeconomy product

Tree planting

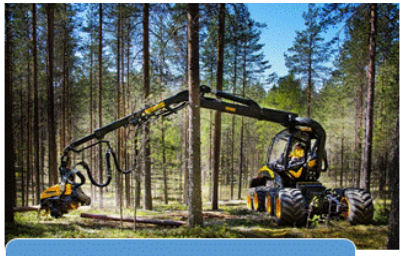
Forest operations

Harvest

Processing

Bioeconomy product

Digitalization enables tracking of single trees from planting trough the processing chain all the way to the bioeconomy products and even further in circular economy. Digital data reserve is collected trought the life cycle and used for creating added values



Bioeconomy industry
- Wood procurement
- Production planning

Forest entrepreneurs
- Planning and execution of forest operations

Thank you!

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