Geoinformatiikan tutkimuspäivät 3.5.2018

Metsien kaukokartoituksesta

Markus Holopainen
University of Helsinki
markus.holopainen@helsinki.fi

- Laserkeilaustutkimuksen huippuyksikkö
- Helsingin yliopiston, Metsävarojen hallinta & geoinformatiikka; tutkimuksen painopistealueet laserkeilaustutkimuksen huippuyksikössä
  - Kaukokartoitus & seuraavan sukupolven metsävaratieto – esimerkkejä tutkimuksista
  - MMM-kärkihanke – metsätieto ja sähköiset palvelut http://mmm.fi/metsatieto-ja-sahkoiset-palvelut
  - Päätelmät – kohden mobiilia laserkeilausta

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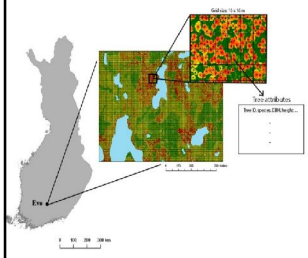
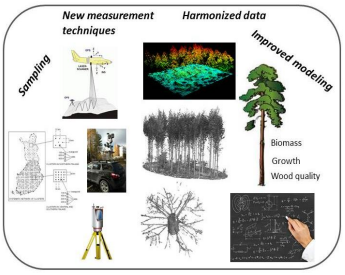
Research directions

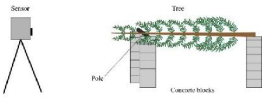
3D/4D Precision forestry

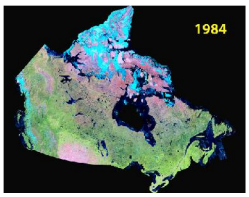
Towards comprehensive tree attribute modelling using 3D point clouds

Forest health, above ground biomass and biodiversity assessment by improved mapping and monitoring









Operational applications in forestry

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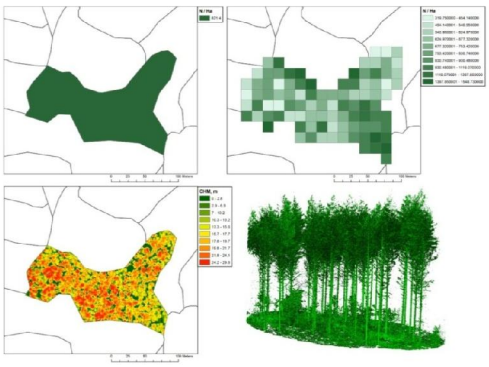
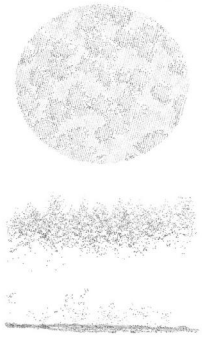
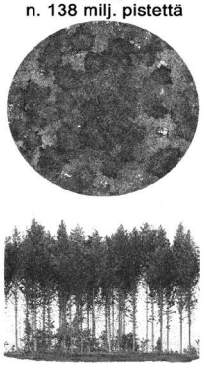
Vision: More accurate forest information – from stand to tree (branch) level



ALS
n. 10 200 pistettä



TLS
n. 138 milj. pistettä



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Next Generation precision forestry

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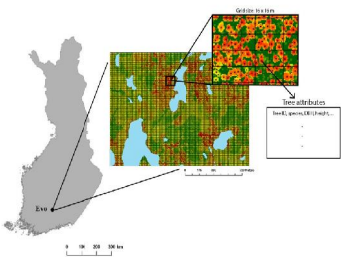
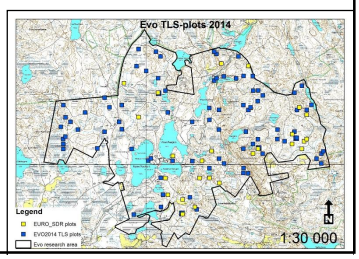
- Outlook for the next Generation's precision forestry
  - Vision: Multisource, -scale and –temporal inventory
  - How to estimate more accurately species-specific stem distributions and tree quality?
  - How to update forest information in different scales?
  - What is accuracy of TLS, MLS and 3D RS methods in various forest conditions?
  - Added value of accurate forestry information?
- Evo test site for international benchmarking studies
- Benchmarking studies: Measurements of single tree-level attributes by means of LS point clouds: (1) tree biomass, (2) timber assortments, (3) timber quality and (4) stem curve.





Evo campaign 2014-2017

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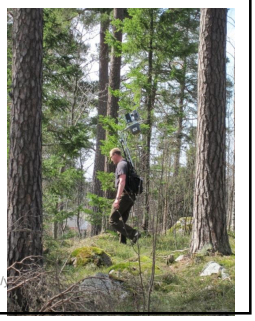
- Test site area 4 km x 6 km
- Located in Evo ~100 km north of Helsinki
- 91 forest test plots (32 x 32 m)
- 24 test plots selected for EuroSDR comparison of tree extraction using TLS data
- Field inventory, TLS
- MLS with ATV and PLS using backpack
- Satellite: VHR optical stereo, TSX stereo, TDX INSAR
- Airborne data (NLS): ALS and aerial images with different flying altitudes



Aboveground biomass components

Kankare, V., Holopainen, M., Vastaranta, M., Puttonen, E., Yu, X., Hyyppä, J., Vaaja, M., Hyyppä, H. & A Individual tree biomass estimation using terrestrial laser scanning. ISPRS Journal of Photogrammet Remote Sensing, 75(2013):64-75.

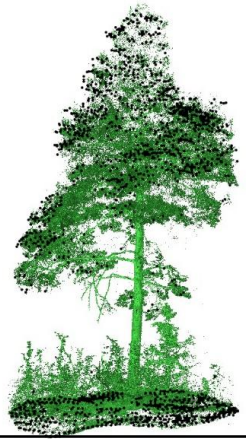
Kankare, V., Räty, M., Yu, X., Holopainen, M., Vastaranta, M., Kantola, T., Hyyppä, J., Hyyppä, H., Alho R. Single tree biomass modelling using airborne laser scanning. ISPRS Journal of Photogrammetry Sensing 2013c, 85: 66-73.

Motivation:

- The methods utilizing TLS and ALS derived metrics in biomass component estimation have not been developed and evaluated before at component level
  - especially with destructively sampled reference data

Highlights of the results:

- Total AGB was estimated with RMSE of:
  - 12.9% / 22.1kg (Scots pine) and 11.9% / 26.0kg (Norway spruce)
- Branch AGB was estimated with RMSE of:
  - 23.4% / 3.8kg (Scots pine) and 38.1% / 14.0kg (Norway spruce)
- **TLS-derived metrics improved especially the estimation accuracy of canopy related AGB components compared to state-of-the-art allometric models.**
  - Existing model accuracy on branch biomass: 62.1% / 10.2kg (Scots pine) and 101.1% / 37.25kg (Norway spruce)



Impact:

"TLS data could provide the means to collect the required reference data for biomass modelling non-destructively"

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Timber assortments, tree quality and stem curve

Kankare, V., Vauhkonen, J., Tanhuanpää, T., Holopainen, M., Vastaranta, M., Joensuu, M., Krooks, A., Hyyppä, J., Hyyppä, H., Alho, P. & Viitala, R. 2014. Accuracy in estimation of timber assortments and stem distribution – A comparison of airborne and terrestrial laser scanning techniques. ISPRS Journal of Photogrammetry and Remote Sensing, 97:89-97.

Kankare, V., Joensuu, M., Vauhkonen, J., Holopainen, M., Tanhuanpää, T., Vastaranta, M., Hyyppä, J. Hyyppä, H., Alho, P., Rikala, J. & Sipi, M. 2014. Estimation of the Timber Quality of Scots Pine with Terrestrial Laser Scanning. Forests 2014, 5(8 1879-1895.

Motivation:

- Methods for TLS and ALS data derived metrics and multisource approach, to estimate timber assortments and external tree quality, have not been developed and evaluated at single tree-level before
  - Unique harvester data and NFI guided tree quality measurements as a reference
- Automation of the data processing is mandatory if TLS data is to be used operationally
  - Development of new automatic stem curve algorithms

Highlights of the results and impact:

- Timber assortments were estimated the most accurately with **novel multisource approach**, which combines the best features of ALS and TLS
  - Saw log volume 16.8% (0.12m^3)
- **External tree quality features** can be measured accurately to further improve the value of forest resource information and possibly to optimize wood supply in the future
  - Classification accuracies of ~84% were achieved when focusing on operationally important quality classes
- **Automatic processing of TLS data was demonstrated to be effective and accurate and could be utilized to make future TLS measurements more efficient**.
  - Overall stem volume accuracy was 9.5% with overall stem curve accuracy of ~1 cm

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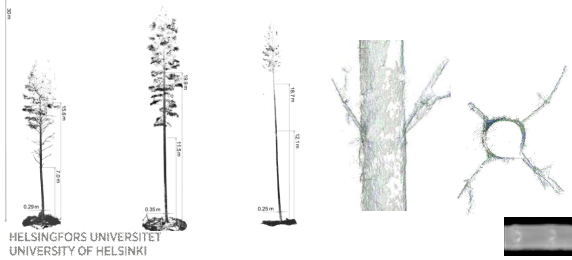
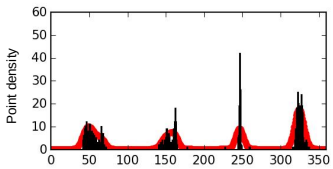
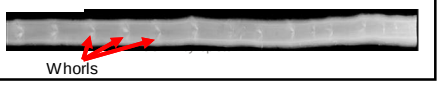
Assessment of standing trees wood quality using laser scanning

Pyörälä, J., Kankare, V., Vastaranta, M., Rikala, J., Holopainen, M., Sipi, M., Hyyppä, J. & Uusitalo, J. 2017. Comparison of terrestrial laser scanning and Xray scanning in measuring Scots pine (Pinus sylvestris L.) branch structure, Scandinavian Journal of Forest Research,

- Essential for optimizing the value and sustainability of industrial wood procurement processes
- Branches are considered as the key indicators of wood quality
  - 87.5 % of branches detected within log-section, 43.2 % log grading accuracy achieved compared to operational **X-ray reference**
- Next steps:
  - Automatic branch detection and measurement using TLS point clouds --> Automatic wood quality assessment for sample plots
  - Generalizing wood quality terms of sample plots over larger areas with MLS and ALS







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Multisource single-tree inventory

Kankare, V., Liang X., Vastaranta, M., Yu, X., Holopainen, M., Hyyppä, J. 2015. Diameter distribution estimation with laser scanning based multisource single tree inventory. ISPRS Journal of Photogrammetry and Remote Sensing 108, 161-171.

Motivation:

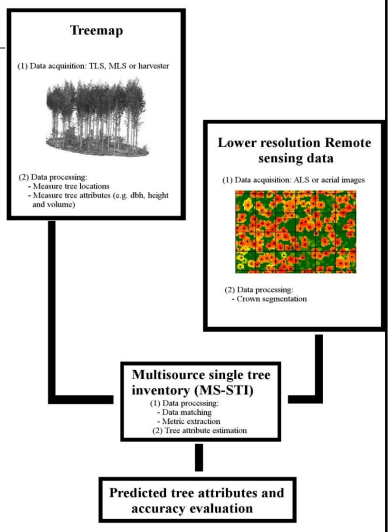
- A novel multisource single-tree inventory approach have not been evaluated in diverse forest conditions before.
  - Evaluation will give us very important indications where this approach can be utilized and with what accuracy range

Highlights of the results:

- Method combines **accurate treemaps** and **lower resolution RS** data in a novel way to predict forest attributes.
- DBH accuracy varied between 1.4 cm and 4.7 cm in diverse forest conditions

Impact:

- **Knowledge towards the "best practices" workflow on single-tree inventory:**
  - Initial results showed that forest structure plays a major role in accuracy outcome of the tree parameters
- **Multisource approach will provide new possibilities to improve the accuracy of single-tree measurements but also for predicting values for larger areas**
  - Utilizing harvester data in multisource approach creates vast opportunities in forest inventory applications



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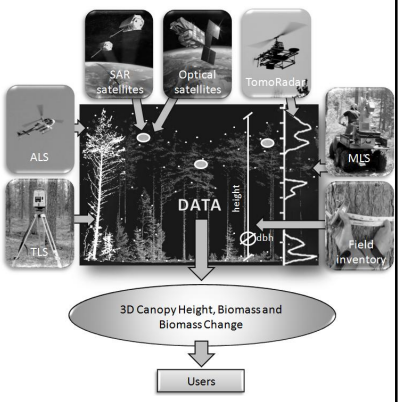
Investigating the capabilities of select 3D remotely sensed data sources to characterize forest structure

M. Vastaranta, T. Yrttimaa, et al. X. Yu, N. Saarinen, M. Karjalainen, K. Nurminen, K. Karila, V. Kankare, V. Luoma, J. Pyörälä, S. Junttila, T. Tanhuanpää, H. Kaartinen, A. Kukko, E. Honkavaara, A. Jaakkola, X. Liang, Y. Wang, M. Vaaja, H. Hyyppä, M. Katoh, M.A Wulder, M. Holopainen & J. Hyyppä. Manuscript.

Yu, X., Hyyppä, J., Karjalainen, M., Nurminen, K., Karila, K., Vastaranta, M., Kankare, V., Kaartinen, H., Holopainen, M., Honkavaara, E., Kukko, A., Jaakkola, A., Liang, X., Wang, Y., Hyyppä, H., Katoh, M. 2015. Comparison of Laser and Stereo Optical, SAR and InSAR Point Clouds from Air- and Space-Borne Sources in the Retrieval of Forest Inventory Attributes. Remote Sensing 7, 15933-15954.

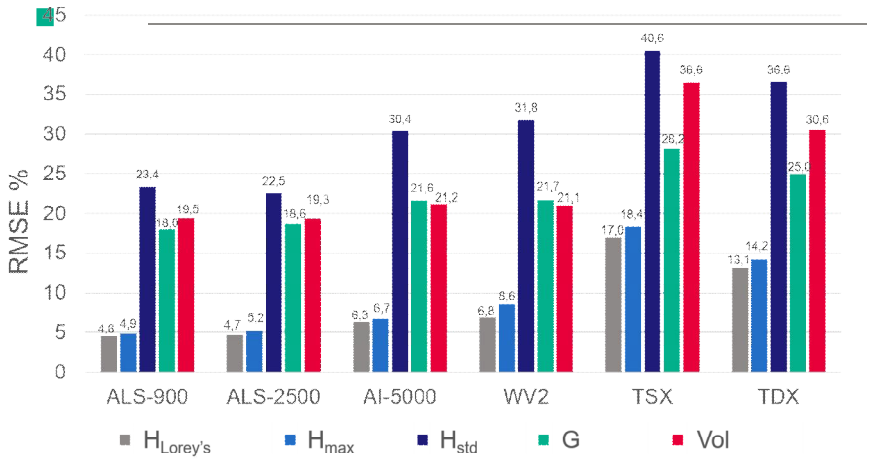
Objectives:

- To better understand the strengths and limitations of various 3D remote sensing data sources for measuring height and capturing variation in forest height and canopy cover density
- Forest inventory attributes predicted using airborne laser scanning (ALS), aerial imagery (AI), WorldView-2 satellite imagery (WV2), Tandem-X interferometry (TDX) and TerraSAR-X radargrammetry (TSX)



Results

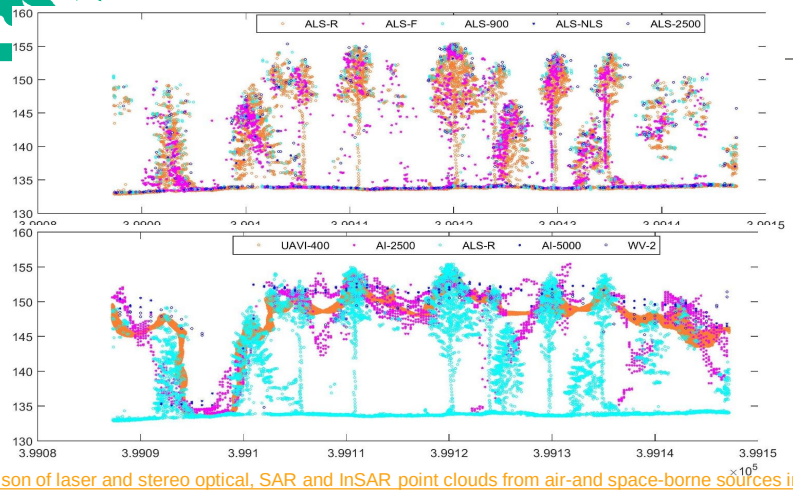
Prediction accuracy of forest structural attributes



Conclusion – 3D RS comparison

- ALS-based DEM/DTM is needed in all 3D RS methods
- Stand height prediction accuracies of different 3D RS materials are close to each other.
  - In addition to ALS, forest inventory attributes that are correlated with height can be predicted rather well also with AI, WV2, and TDX
- However, only ALS can provide information on variation in tree heights and canopy cover density, i.e. **If it is important to characterize also the canopy cover density and height variation, ALS should be used.**
- It has been suggested in Finland that ALS data could be acquired at regular time periods (i.e., every 3-5 years)

Photogrammetric vs LS Point Cloud



Comparison of laser and stereo optical, SAR and InSAR point clouds from air-and space-borne sources in the retrieval of forest inventory attributesX Yu, J Hyyppä, M Karjalainen, K Nurminen, K Karila, M Vastaranta, ... Remote Sensing 7 (12), 15933-15954

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Towards comprehensive tree attribute modelling using point clouds

The main goal of this research direction is to take a big leap towards a comprehensive modelling process including data collection and model development that can be used in forest biomass assessment worldwide.

The specific tasks aim to improve:

- stem volume and biomass modelling
- modelling of the branches and canopy characteristics
- optimize data collection for model development
- The first paper: Saarinen, N., Kankare, V., Vastaranta, M., Luoma, V., Pyörälä, J., Tanhuanpää, T., Liang, X., Kaartinen, H., Kukko, A., Jaakkola, A., Yu, X., Holopainen, M. & Hyyppä, J. 2017. Feasibility of Terrestrial laser scanning for collecting stem volume information from single trees. ISPRS Journal of Photogrammetry and Remote Sensing 123 (2017) 140–158

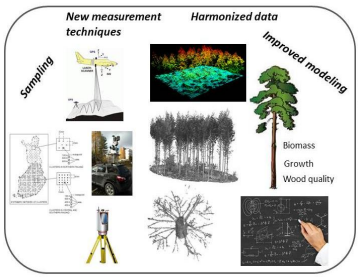

Figure 1. Dense 3D point clouds provide a solid base for equation development and data harmonization worldwide.

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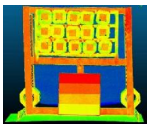
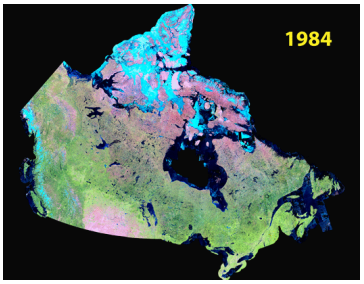
Forest health assessment by improved mapping and monitoring

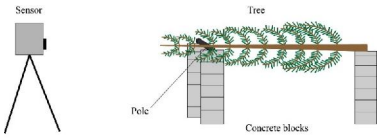


The main goal of this research direction is to improve forest health status assessments at varying scales

The specific tasks aim to improve:

- Techniques and methods that can be used in mapping and monitoring of wind disturbances, insect damage and forest recovery
  - Laboratory tests
  - Pilot studies in selected study areas
  - Developed methods will be applied over vast areas





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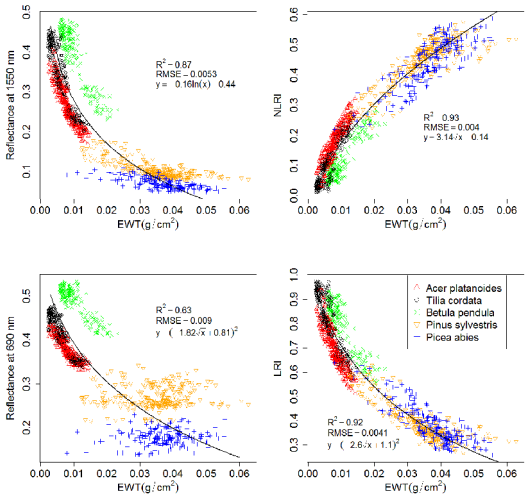
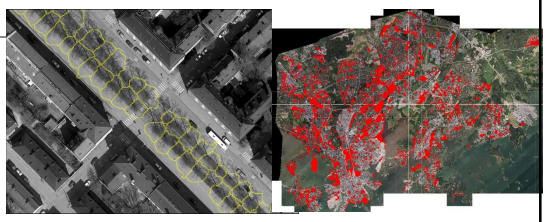


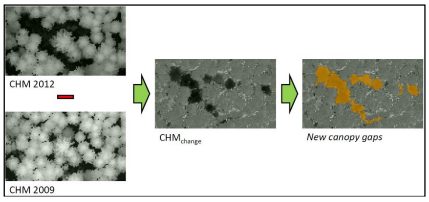
Junttila, S., Vastaranta, M. Liang,X., Kaartinen, H., Kukko, A., Kaasalainen, S., Holopainen, M., Hyyppä, H. and Hyyppä, J. 2017. Measuring Leaf Water Content with Dual-Wavelength Intensity Data from Terrestrial Laser Scanners. *Remote Sens.* **2017**, *9*(1), 8.

Developing laser scanning applications for mapping and monitoring single tree characteristics for the needs of urban forestry

- The aim is develop LS-based methods for assessing tree-level information from urban forests and maintaining the tree registers.
  - See, e.g.: Tanhuanpää, T., Vastaranta, M., Kankare, V., Holopainen, M., Hyyppa, J., Hyyppa, H., Alho, P. & Raisio, J. 2014. Mapping of urban roadside trees - A case study in the tree register update process in Helsinki City. Urban Forestry & Urban Greening. 13 (3), 562-570.
  - Tanhuanpää, T., Kankare, V., Vastaranta, M., Saarinen, N., Holopainen, M. (2015). Monitoring downed coarse woody debris through appearance of canopy gaps in urban boreal forests with bitemporal ALS data. Urban Forestry & Urban Greening, 14(4): 835–843.
- The developed methods have already been put into practice in the city of Helsinki and are currently further developed for park trees.



Method for updating a roadside tree register and mapping of park trees.



Mapping of fallen trees in urban areas throught changes in canopy height

Taimikoiden tiedonkeruun kehittäminen

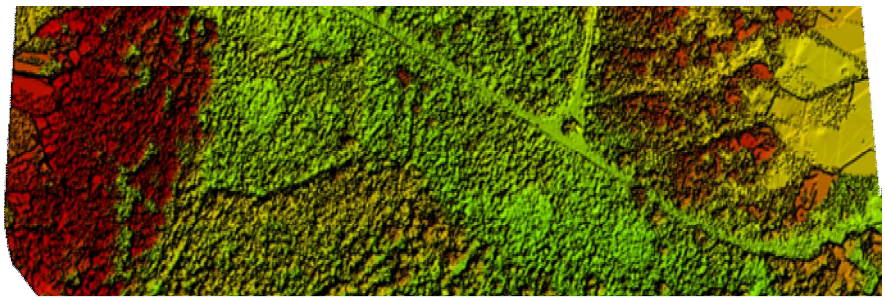
Koordinaattori: Itä-Suomen yliopisto, UEF (Timo Tokola)
Partnerit:
Helsingin yliopisto, HY (Markus Holopainen, Mikko Vastaranta)
Paikkatietokeskus, FGI (Juha Hyyppä, Eija Honkavaara)
Luonnonvarakeskus, LUKE (Timo Saksa, Jouni Siipilehto, Jari Miina)
Suomen Metsäkeskus (Juho Heikkilä)
VTT (Tuomas Häme)

Hankkeen tavoite

Hankkeen päätavoite on kehittää menetelmiä taimikon hoidon tarpeen ennustamiseen ja ennusteen arvion luotettavuuden estimointiin. Yleisenä tavoitteena on korvata mahdollisimman suuri osa maastovierailuista uudella menetelmällä.

Osatavoitteet:

- Biometriset menetelmät vesakon määrän ja synnyn todennäköisyyden arviointiin
- Vaihtoehtoisten kk-materiaalien (monikanavainen laserkeilaus, ilmakuvat, hyperspektidatat) estimaattien käyttökelpoisuuden ja tarkkuuden arviointi
- Sentinel-2 vesakkoestimaatit ja menetelmät T2 taimikoiden arviointiin ALS aineistosta
- Menetelmä biometristen mallien paikalliseen kalibrointiin kaukokartoitusaineiston avulla



MMM-taimikot
Vaihtoehtoisten kaukokartoitusmateriaalien käyttökelpoisuus

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UEF // University of Eastern Finland

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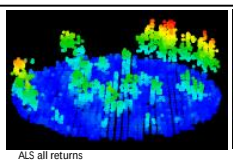
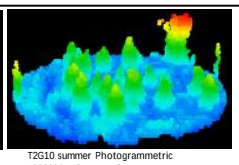
Evon mittaukset ja aineistot

Markelin, L., Honkavaara, E., Näsi, R., Viljanen, N., Rosnell, T., Hakala, T., Vastaranta, M., Koivisto, T., and Holopainen, M. 2017. Radiometric correction of multitemporal hyperspectral UAS image mosaics of seedling stands, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-3/W3, 113-118, https://doi.org/10.5194/isprs-archives-XLII-3-W3-113-2017, 2017.

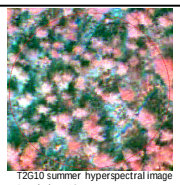
	Airborne laser scanning	Photogrammetric point clouds	Hyperspectral imagery	RGB ortho-mosaics
Acquisition date	April 2016 & June 2016	9 May & 29 June 2016	9 May & 29 June 2016	9 May & 29 June 2016
resolution	30-80 points/m^2	1300-1800 points/m^2	10 cm in 36 bands (500-900nm)	2 cm (red, green, blue)
platform	Fixed wing	UAV	UAV	UAV
sensor	OptechTitan	Samsung Camera	FPI camera	Samsung camera



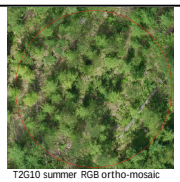
ALS all returns
22484 points per plot (radius:10.7m)



T2G10 summer Photogrammetric
1982086 points per plot



T2G10 summer hyperspectral image
Resolution: 10 cm

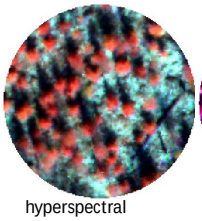


T2G10 summer RGB ortho-mosaic
Resolution: 2cm

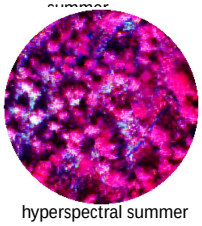
T2G7 Example sample plot
TPH: 2228

Ortho-mosaic spring

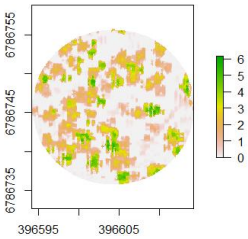
Ortho-mosaic summer



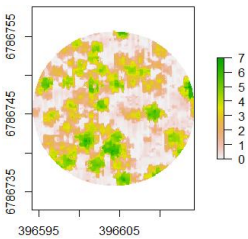
hyperspectral spring



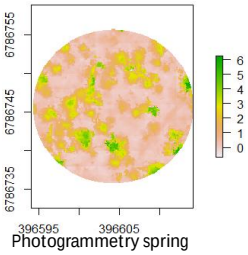
hyperspectral summer



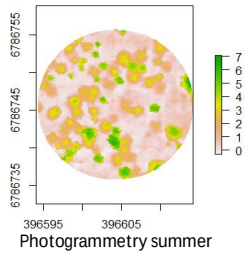
ALS spring



ALS summer



Photogrammetry spring



Photogrammetry summer

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Päätelmiä

- Laserkeilaus vaikuttaa toimivan paremmin taimikon rakenteen arvioinnissa kuin fotogrammetriset pintamallit.
- Kaukokartoitusaineisto taimikkotiedon keräämiseen tulisi kerätä lehdelliseen aikaan.
- Kun runkoluku on yli 2000, yksittäisiä puita ei voida enää tunnistaa luotettavasti.
- Koealatason tunnukset, kuten kasvillisuusosumien määrä, korreloivat hyvin taimikon tiheyden kanssa.
- Taimikoiden pituuden arviointi onnistuu molemmilla aineistoilla.

Conclusion: Status of 3D/4D remote sensing based precision forestry in Finland

In Operational use

- 3D-remote sensing (ALS-ABA)
- **Added value** using ALS ABA:
  - cost efficient forest resource mapping
  - Stem distributions and timber assortments by means of theoretical models
  - Predicting stand-thinning maturity
  - Forest biomass and energy wood mapping
  - GIS analyses that are based on accurate DTM or CHM

Still mainly in research stage

- ALS Individual tree approach (ITA)
- 4D-remote sensing – monitoring changes by means of accurate 3D remote sensing
- Terrestrial / mobile laser scanning
- Main Challenges
  - **species-specific stem distribution and wood quality**
  - **Seedling stands**
  - **Added value of the information**

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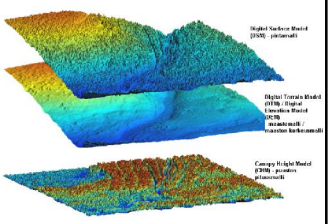
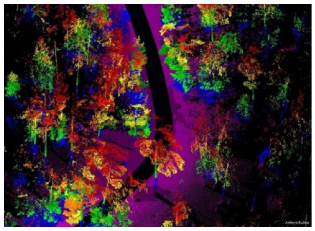
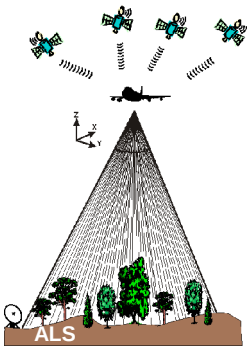




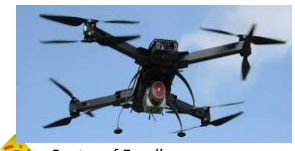
Towards Mobile laser scanning (kuvat MML/FGI)



Airborne Laser Scanning

Terrestrial Laser Scanning

Mobile Laser Scanning



Centre of Excellence in Laser Scanning Research

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- Topi Tanhuanpää (2016). Developing laser scanning applications for mapping and monitoring single tree characteristics for the needs of urban forestry. Dissertationes forestales 230. https://dissertationesforestales.fi/article/2013
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Ongoing PhD Thesis, UH (CoELasR)

- Samuli Junttila: The utilization of new measurement technologies in the mapping of declined trees
- Joanne White: Large-area forest change mapping by means of Lidar and Landsat-TM time series
- Tuula Kantola: Evaluating insect-induced damage in forest landscapes at varying spatial scales
- Jiri Pyörälä: Timber quality estimation by means of terrestrial laser scanning
- Ville Luoma: Improving understanding of forest growth dynamics by using multitemporal characterizations of trees

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- Junttila, S., Vastaranta, M. Liang,X., Kaartinen, H., Kukko, A., Kaasalainen, S., Holopainen, M., Hyyppä, H. and Hyyppä, J. 2017. Measuring Leaf Water Content with Dual-Wavelength Intensity Data from Terrestrial Laser Scanners. *Remote Sens.* **2017**, *9*(1), 8; doi:10.3390/rs9010008
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- Saarela, S., Graström, A., Ståhl, G., Kangas, A., Holopainen, M., Tuominen, S., Nordkvist, K. & Hyyppä, J. 2015. Model-assisted estimation of growing stock volume using different combinations of LiDAR and Landsat data as auxiliary information. Remote Sensing of Environment 158(2015):431-440.
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- Yu, X, Hyyppä, J., Litkey P., Kaartinen, H., Vastaranta, M. and Holopainen, M. 2017. Single-Sensor Solution to Tree Species Classification Using Multispectral Airborne Laser Scanning. *Remote Sens.* 2017, *9*(2), 108; doi:10.3390/rs9020108
- Yu, X., Hyyppä, J., Karjalainen, M., Nurminen, K., Karila, K., Vastaranta, M., Kankare, V., Kaartinen, H., Holopainen, M., Honkavaara, E., Kukko, A., Jaakkola, A., Liang, X., Wang, Y., Hyyppä, H., Katoh, M. 2015. Comparison of Laser and Stereo Optical, SAR and InSAR Point Clouds from Air- and Space-Borne Sources in the Retrieval of Forest Inventory Attributes. Remote Sensing 7, 15933-15954.

Thank you for your time!