Crop Parameter Estimation for Precision Agriculture Using Drone Based Photogrammetry, Hyperspectral Imaging and Machine Learning

Session Big Data: Screening and Sensoring

Eija Honkavaara, National Land Survey
Food safety 2020, 11-13 June 2018,, Seinäjoki Finland

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Outline

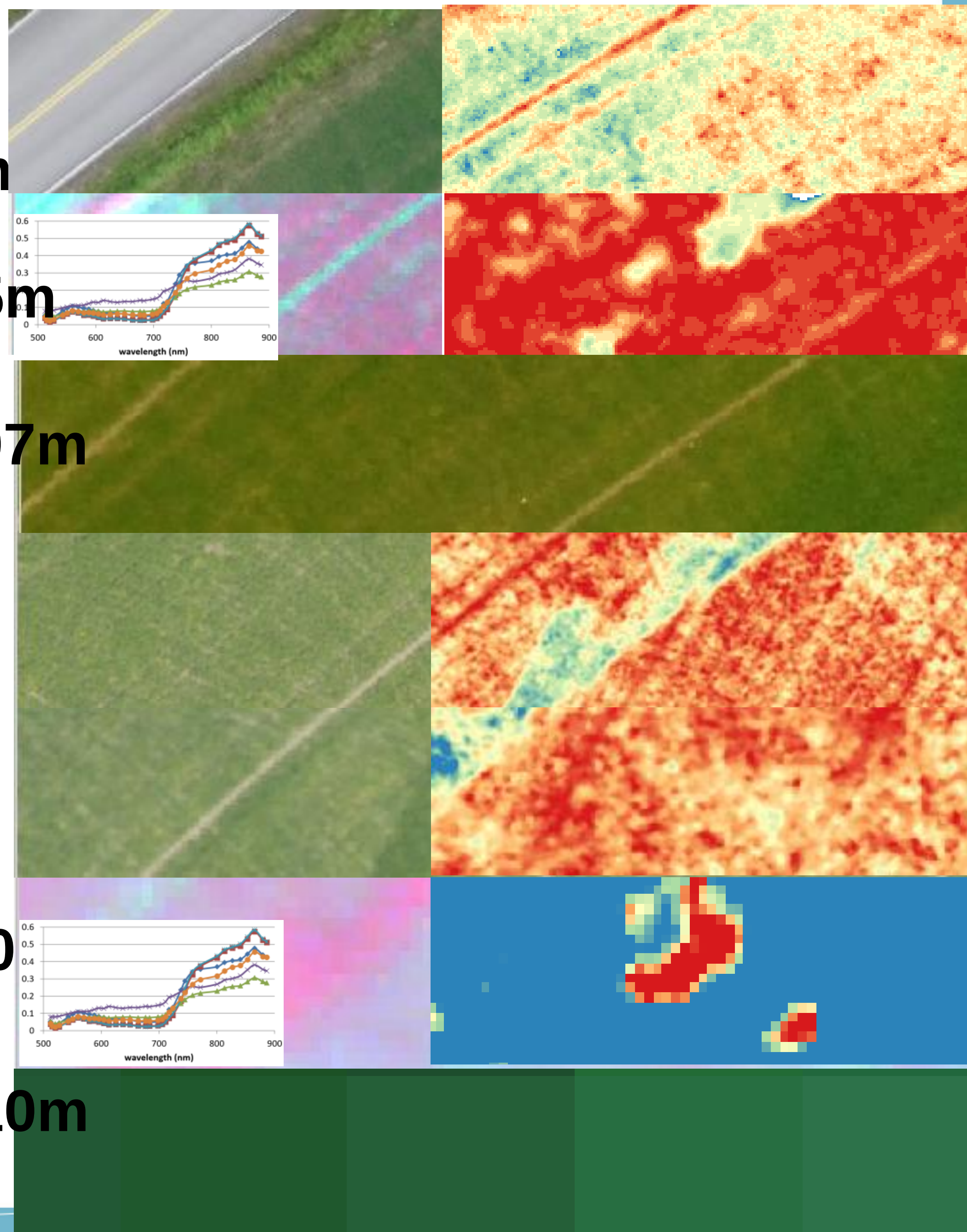
- Background
- Drone remote sensing research at @dronefinland
- Vegetation parameter and condition estimation using drones
  - Case 1: Grass Quantity and Quality estimation with low-cost multi-spectral photogrammetric system
  - Case 2: Identification of bark beetle infestation in spruces using hyper-spectral imaging
- Conclusions and outlook

Background

- Sustainable management of agricultural processes is required in order to respond to the global food challenges and climate change
- In future, precision agriculture and AI based farm management will become standard
- Novel remote sensing technologies – facilitators of sustainable agricultural management:
  - Novel satellite programs (Landsat, Sentinel) capture globally daily datasets free-of-charge
  - Drones bring the remote sensing and robotics available for everyone
- Spatially resolved, up-to-date Information required for precision agriculture
  - Crop parameters: biomass, nitrogen content
  - Weed detection
  - Disease and pest detection
  - Assessment of soil and parcel condition: drainage network, soil moisture and compaction etc.

More data than ever

- -UAV prof. RGB, GSD 0.03m
- -UAV prof. Spec., GSD 0.15m
- -UAV comm. RGB, GSD 0.07m
- -Aircraft RGB, GSD 0.05m
- -Aircraft RGB, GSD 0.10m
- -Aircraft spectral, GSD 0.50
- -Satellite Sentinel-2, GSD 10m



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DroneFinland.fi

- Research and innovation center for drone remote sensing at NLS
- Drones, sensors and systems
- Photogrammetry, Hyperspectral imaging, Laser scanning, Spectrometry, Thermal imaging
- Rigorous calibration of the data
- Analysis using machine learning techniques
- Applications: Mapping and surveying, Agriculture, Forests, Water, Security etc.
  - collaboration
- Satellite-drone integration
- 20+ scientific publications on drone remote sensing and photogrammetry during the past year
- Follow us
  - www.dronefinland.fi
  - Twitter: @dronefinland

FGI fleet 2018

FGI built drones

FGI Hexacopter UAV, Payload 3 kg, Flight time: 20 min

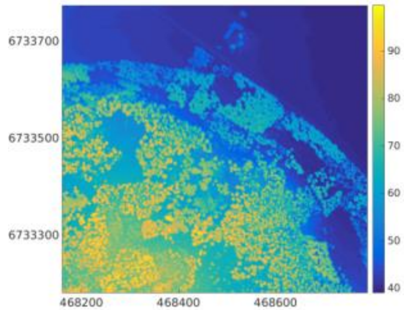
FGI Quadcopter UAV, Payload 2 kg, Flight time: 30 min

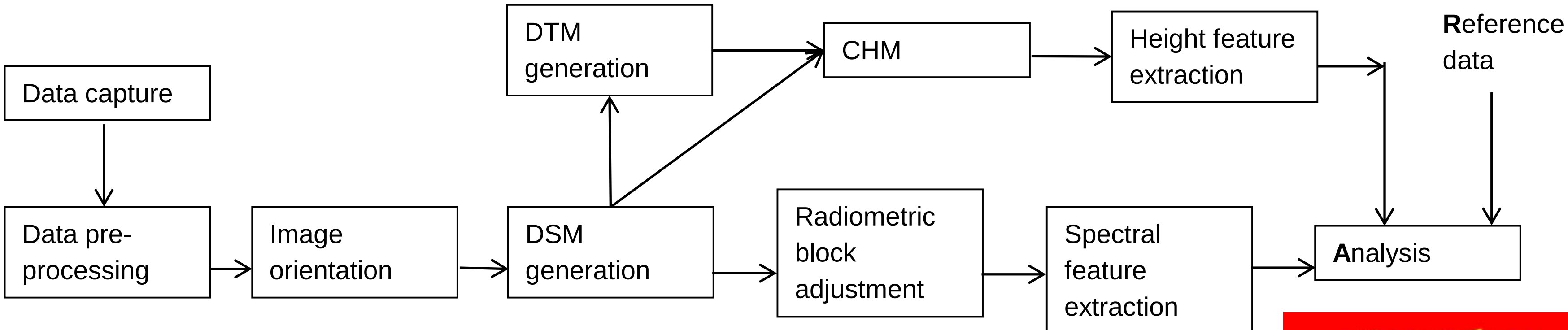
Commer-cial drones

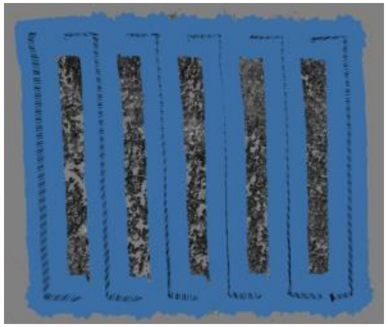
DJI Phantom 4, Payload: 200 g, Total weight: 1.4 kg, Flight time: 20 min

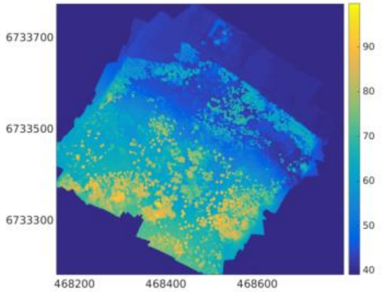
Avartek ARX-30 octocopter, payload 10 kg, Total weight: 25 kg, Flight time: 30 min

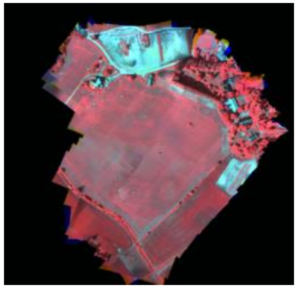
Data Processing flow for multi- and hyperspectral UAS data

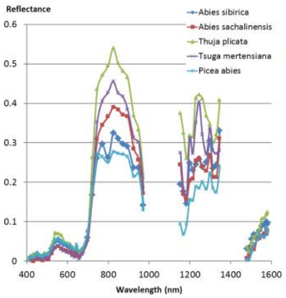


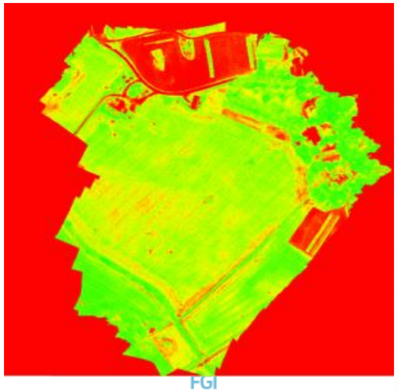




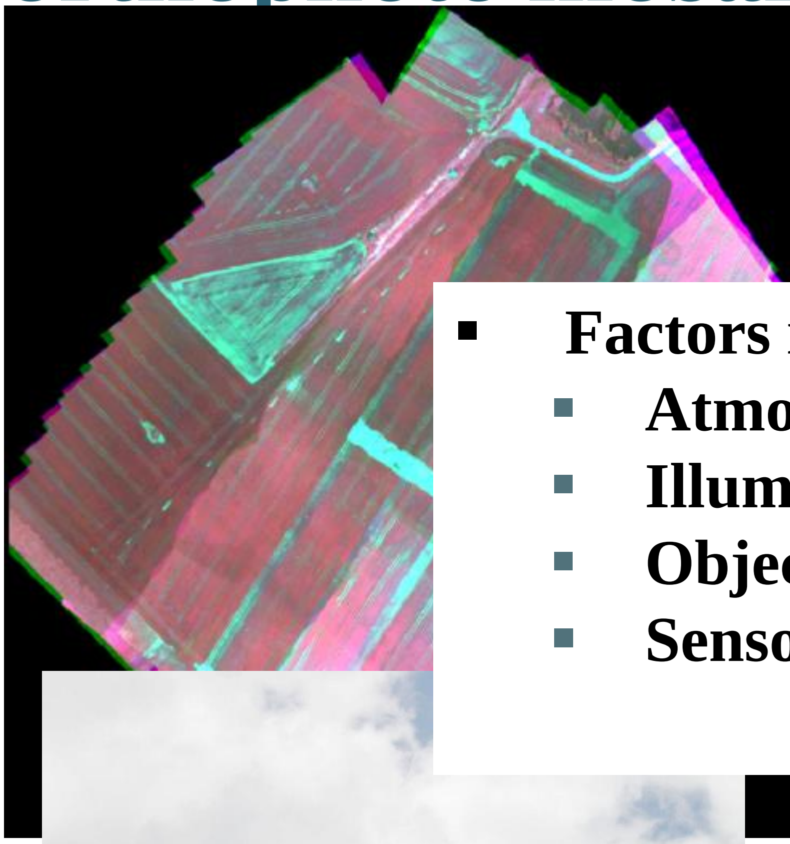


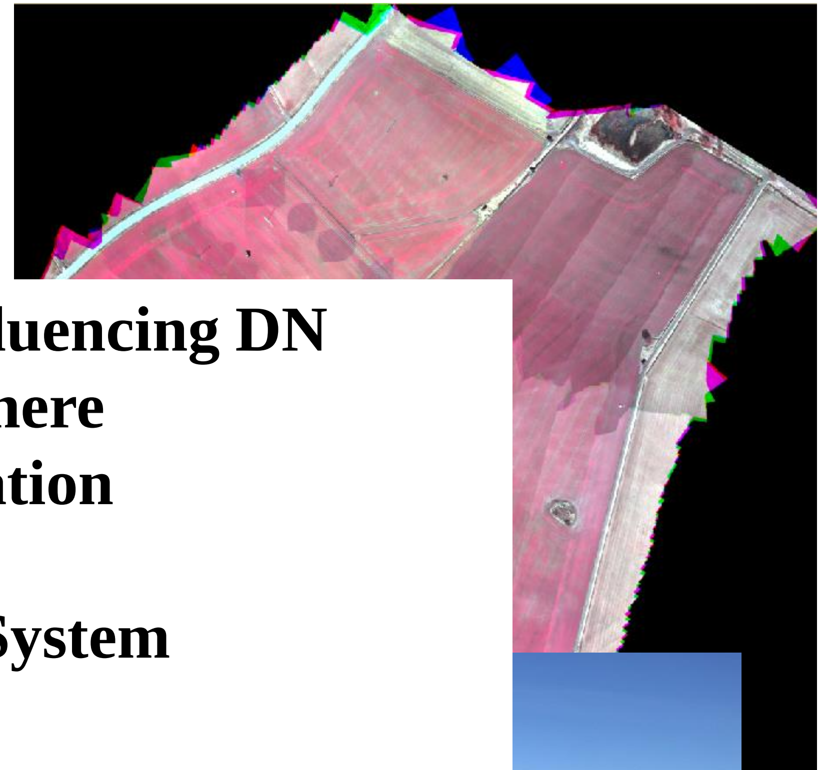




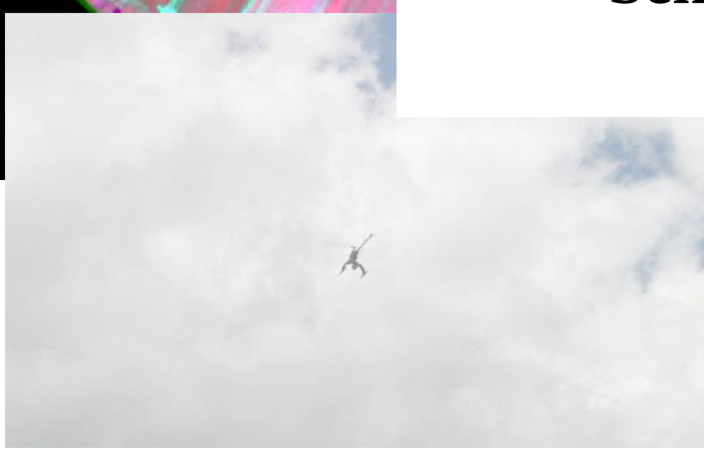


Radiometric processing: orthophoto mosaic





- Factors influencing DN
  - Atmosphere
  - Illumination
  - Object
  - Sensor/System



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Estimation and classification using machine learning

Feature extraction, *different feature combinations*

Drone data

Hyperspectral frame sensor

RGB sensor

Spectral

- -36 reflectance bands
- +11 spectral indices (RDVI, NDVI, OSAVI, REIP, GNDVI, MCARI, MTVI, MTCI, CI-re, CI-gr, PRI)
- -RGB bands + indices (GRVI, ExG)

52 (spec)

3D

- -Photogrammetric point cloud
- -DTM exctraction from DSM
- -CHM=DSM-DTM
- -8 CHM based 3D features (mean, min, max, p50, p70, p80, p90, std) from Hyperspectral sensor and RGB

16 (3D)

68 (all)

55 (hyp)

13 (RGB)

Reference data samples for crop parameters
-Biomass
-Nitrogen content
etc

Estimation model
Random Forest algorithm and others
1. Feature selection
2. Model building with reference data
3. Leave-one-out for validiation
Weka

Output
Validation results
-R2, RMSE
Crop parameter maps
-Biomass
-Nitrogen

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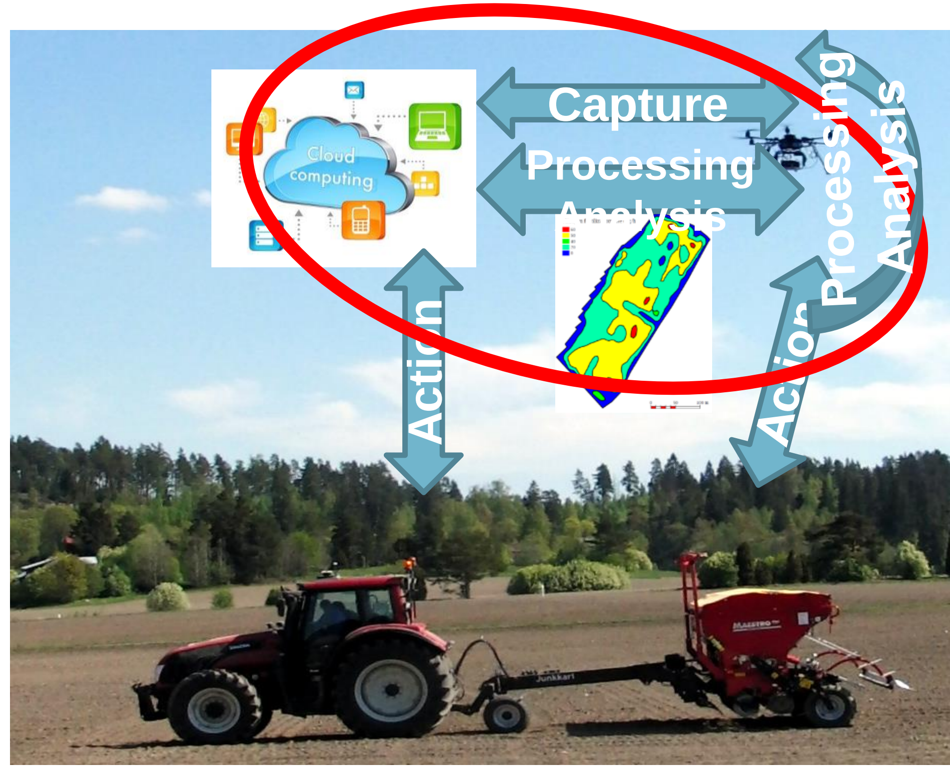
Towards autonomous, real-time applications

Traditional insitu



Overall objective: To develop automated, low-cost and real-time drone-based crop parameter estimation tools for PA

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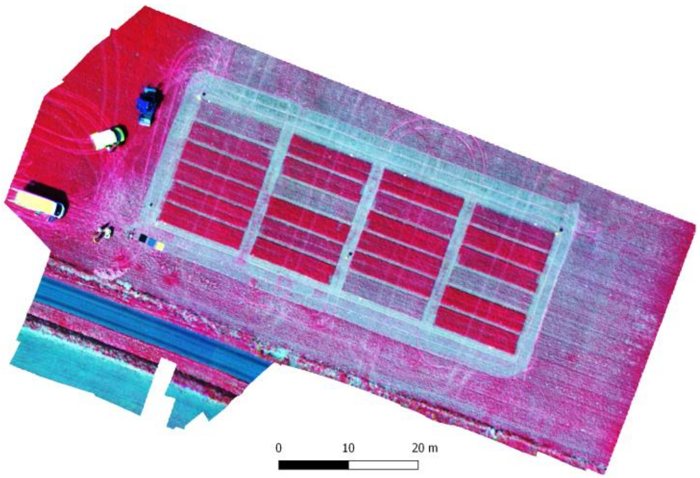
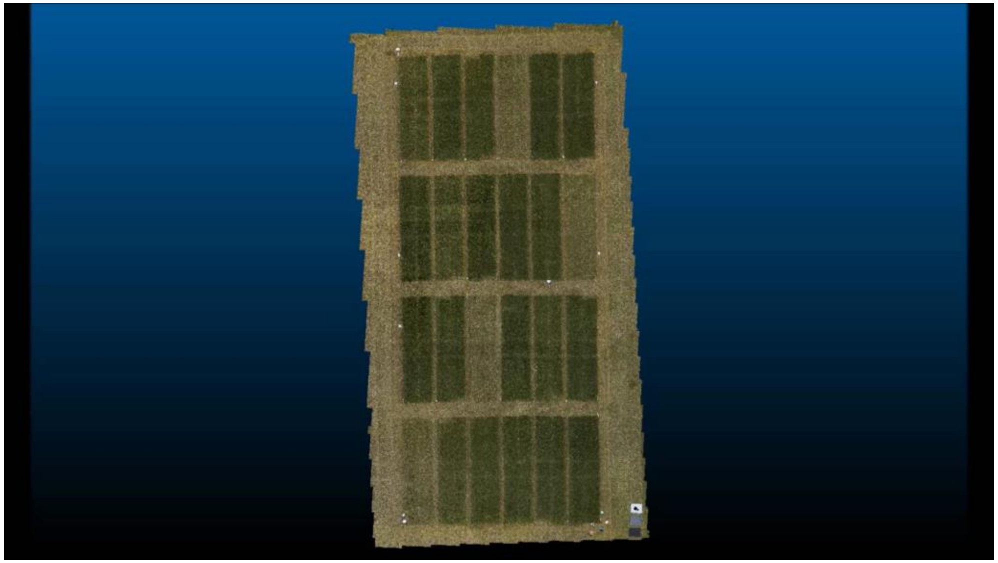
Case 1: Grass Quantity and Quality estimation with low-cost multi-spectral photogrammetric system





RGB mosaic
- **GSD 1 cm**

Multi- and hyperspectral mosaic
- **GSD 5 cm**

Ultra high resolution DSM and CHM
- **GSD images: 6.4 mm**
- **Point density 5920 pts/m^2**

(Dates: 6, 15,19 and 28 June 2017)

Viljanen, N.; Honkavaara, E.; Näsi, R.; Hakala, T.; Niemeläinen, O.; Kaivosoja, J. A Novel Machine Learning Method for Estimating Biomass of Grass Swards Using a Photogrammetric Canopy Height Model, Images and Vegetation Indices Captured by a Drone. Agriculture 2018, 8, 70.

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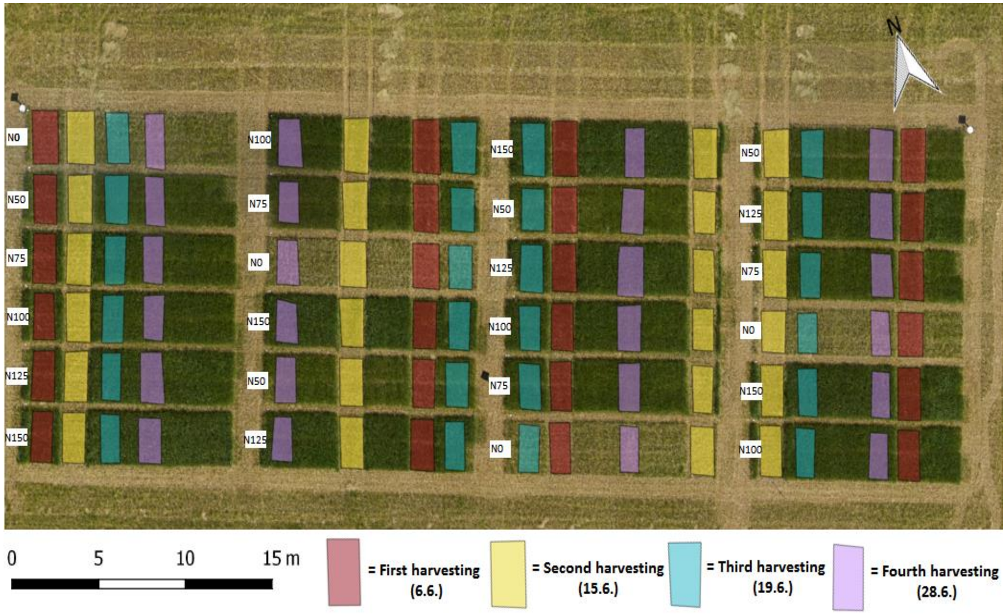
Grass trial site in Jokioinen 2017



- Large variation of biomass by using six different N-fertilization rates 0, 50, 75, 100, 125, 150 kg/ha
- 4 sampling dates before the first cut: 06.06., 15.06., 19.06. and 28.06.
- 96 samples
- Physical measurements:
  - DMY: Dry Matter Yield
  - FY: Fresh yield
  - Height
  - Nitrogen content
  - Digestibility

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- **Natural Resources Ínstitute Finland**

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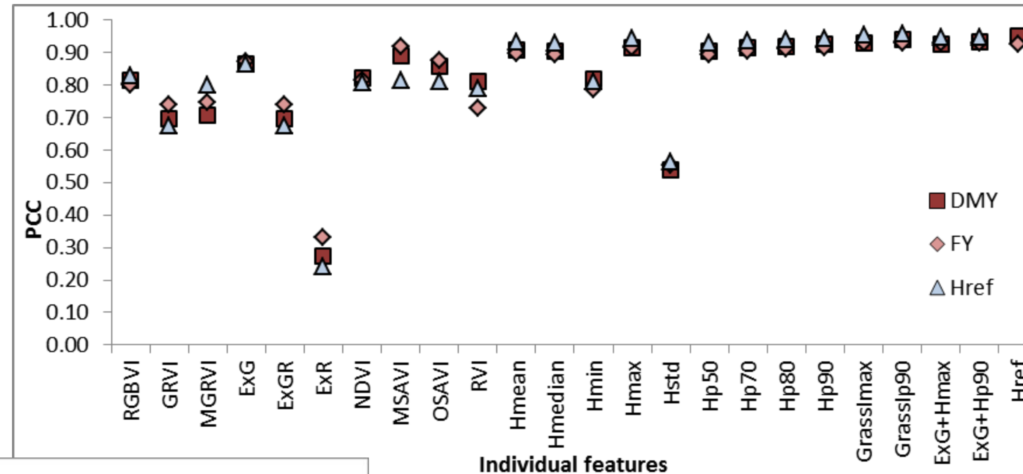
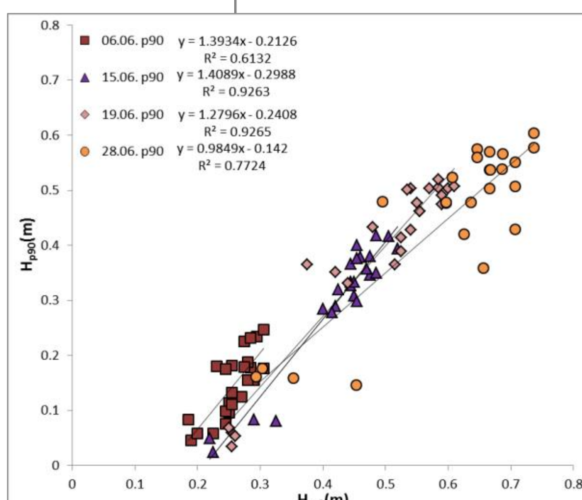
Simple regression of all features of DMY, FY, height

- Best correlations for height features (>0.9)
- Best vegetation indices
  - MSAVI
  - ExG I Hp90

Pearson correlation coefficient



Regression of photogrammetric canopy heights vs height stick



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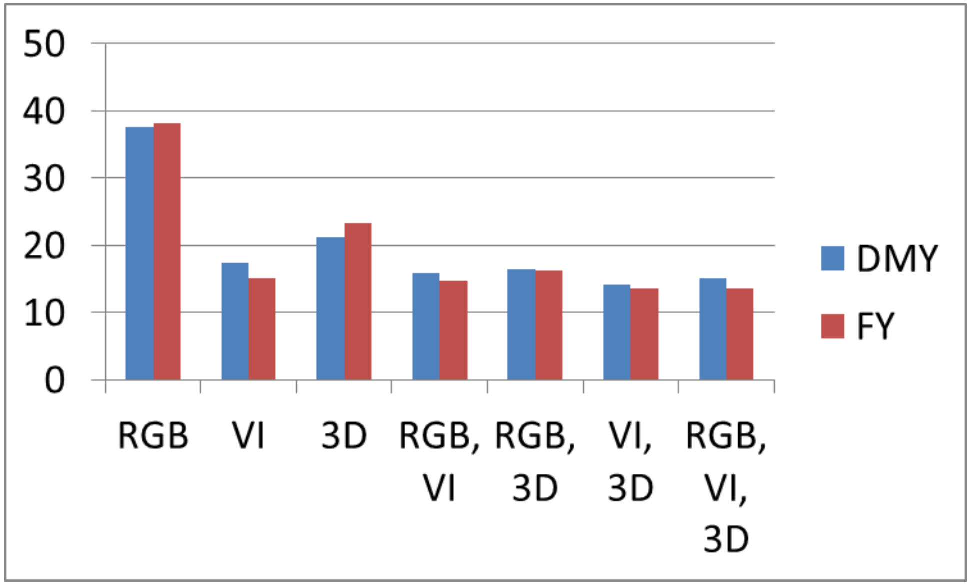
Estimation of biomass with Random Forest using combined features

- Estimation with different feature combinations
- Single feature types:
  - VI the best, NRMSE 15-17%
- Multiple features gave the best results
  - NRMSE 13-15%
- Currently investigating wih different hyperspectral features

NRMSE% for different features



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Case 2. Identification of bark beetle infestation in spruces using hyper-spectral imaging

- Serious death in spruce forests due to bark beetle in Southern Finland
- Objective:
  - Early detection of infection using hyperspectral images from manned and unmanned aircrafts
  - Mapping of infested and dead trees

[1] Näsi, R.; Honkavaara, E.; Blomqvist, M.; Lyytikäinen-Saarenmaa, P.; et al.. Remote sensing of bark beetle damage in urban forests at individual tree level using a novel hyperspectral camera from UAV and aircraft. *Urban Forestry & Urban Greening* 2018, *30*, 72–83, doi:10.1016/j.ufug.2018.01.010.
[2] Näsi, R.; Honkavaara, E.; Lyytikäinen-Saarenmaa, P.; Blomqvist, M.; et al.,. Using UAV-Based Photogrammetry and Hyperspectral Imaging for Mapping Bark Beetle Damage at Tree-Level. *Remote Sensing* 2015, *7*, 15467–15493, doi:10.3390/rs71115467.

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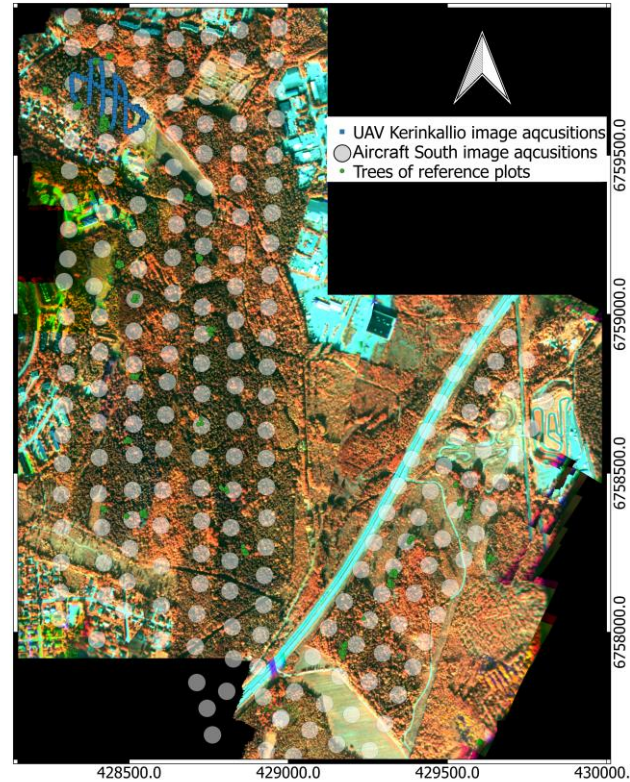
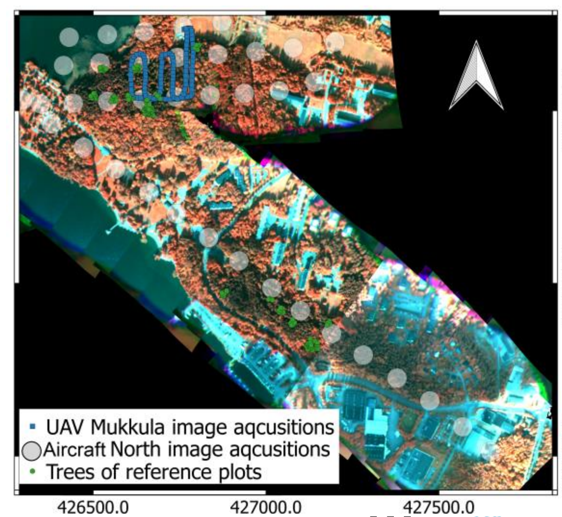
Datasets

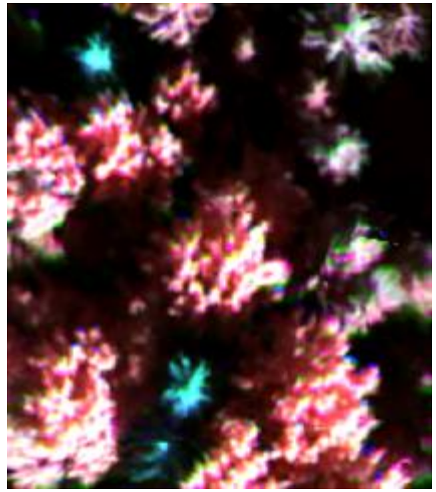
- UAV Campaign in 23.8.2013
  - Two areas of ~4 ha each
  - Flight speed 3 m/s
  - GSD:
    - FPI: 4 to 9 cm;
    - RGB: 1.1 cm to 2.3 cm
- Manned aircraft Cessna 13.9.2013
  - Two areas: 3 km^2, 0.5 km^2
  - Flight speed 35 m/s
  - Flying height
    - FPI: 500 m, GSD 50 cm
    - Nikon 3DX: 400 m , GSD 5 cm
- Field work by ForestHealthGroup at Helsinki University
  - Crown color: normal: green, infested: yellow, dead: grey
  - 78 trees for UAV areas; 330 trees for aircraft areas

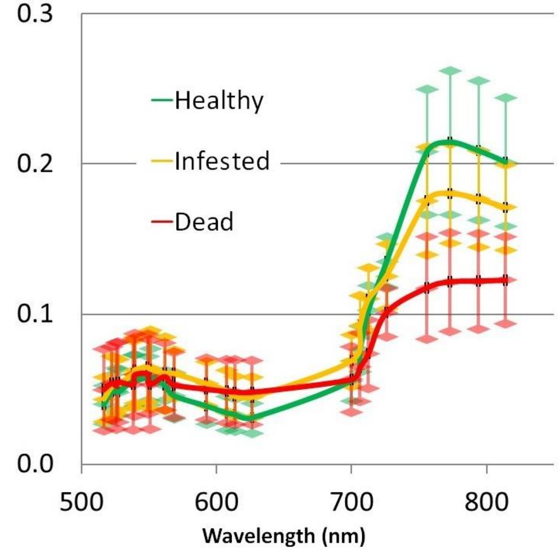




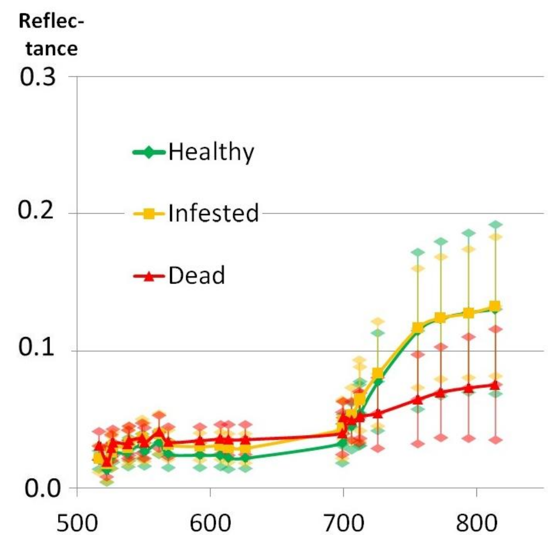
Spectral data, 22 bands

UAV, GSD 10 cm





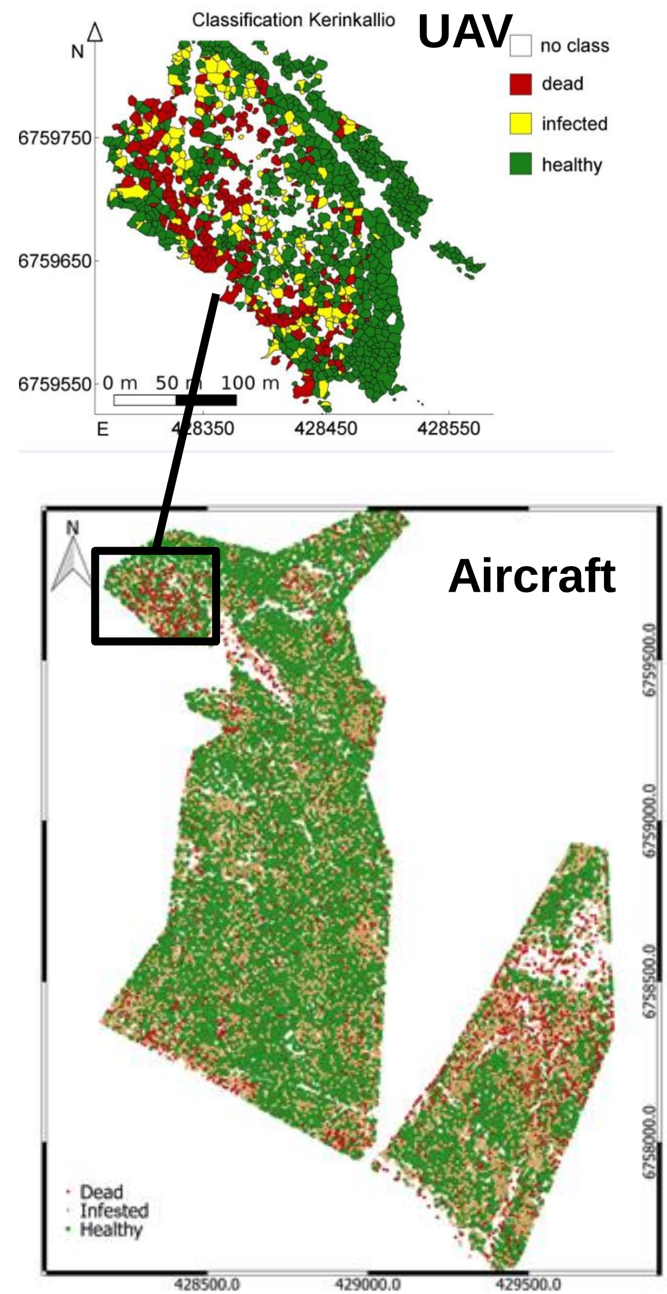
Aircraft, GSD 50 cm



Comparison of UAV and aircraft

- Classification by SVM-classifier.
- Features: The original 22-band spectra and three different normalized channel ratios (indices). Band selection using ANOVA.
- Leave-one-out crossvalidation
- Individual trees were classified as healthy, infested and dead
- Overall accuracy >10% better for UAV than for aircraft.

Data	Producer's accuracies (%) Health.	Infest.	Dead	Overall accuracy (%)	Kappa
UAV	86	67	81	81	0.70
Aircraft	86	40	74	73	0.56



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Conclusions

- New remote sensing technologies are revolutionizing precision agriculture and monitoring activities by farmers and authorities
- Optical satellite sensors with a few days revisit times
  - In Northern regions clouds are the challenge
  - Suitable for monitoring of slowly changing phenomena
  - At spring cloudiness less serious problem
  - New cubesat systems potentially capture data several times in day
- Drones
  - Highly weather resistant -> data when needed
  - Detailed object analysis, spatial resolutions 5 mm ->
  - Potential for autonomous operation
  - BVLOS operation proceeds
- FGI's current development activities: calibration, real-time, artificial intelligence

More info:
http://dronefinland.fi/
@dronefinland
@eijahonkavaara1

Thank you!

www.nls.fi

E. Honkavaara, R. Näsi, N. Viljanen, R. Oliveira, T. Hakala, L. Markelin, S. Nezami, J. Suomalainen, FGI

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