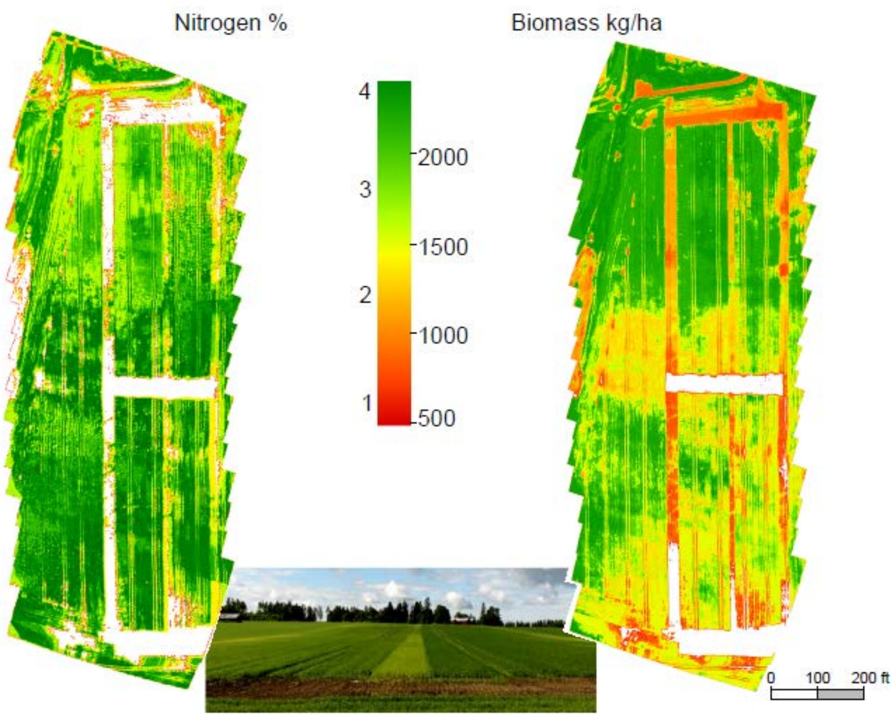
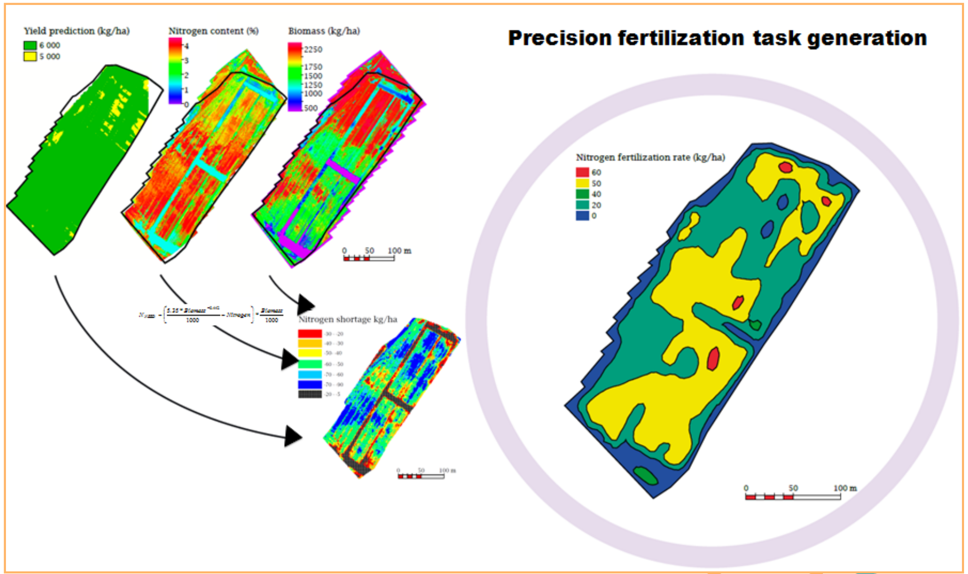
DroneKnowledge and its agricultural applications

Jere Kaivosoja

NATURAL RESOURCES INSTITUTE FINLAND

Precision Agriculture





NATURAL RESOURCES INSTITUTE FINLAND

DroneKnowledge

Towards knowledge based export of small UAS remote sensing technology

- Finnish joint project funded by Business Finland
  - FGI Finnish Geospatial Research Insititute
  - VTT Technical Research Center Finland
  - JYU University of Jyväskylä
  - LUKE Natural Resources Institute Finland

- ~15 companies inveloved
  - Boreal, Yara Finland, Valio

Targets: Agriculture, forests, lakes

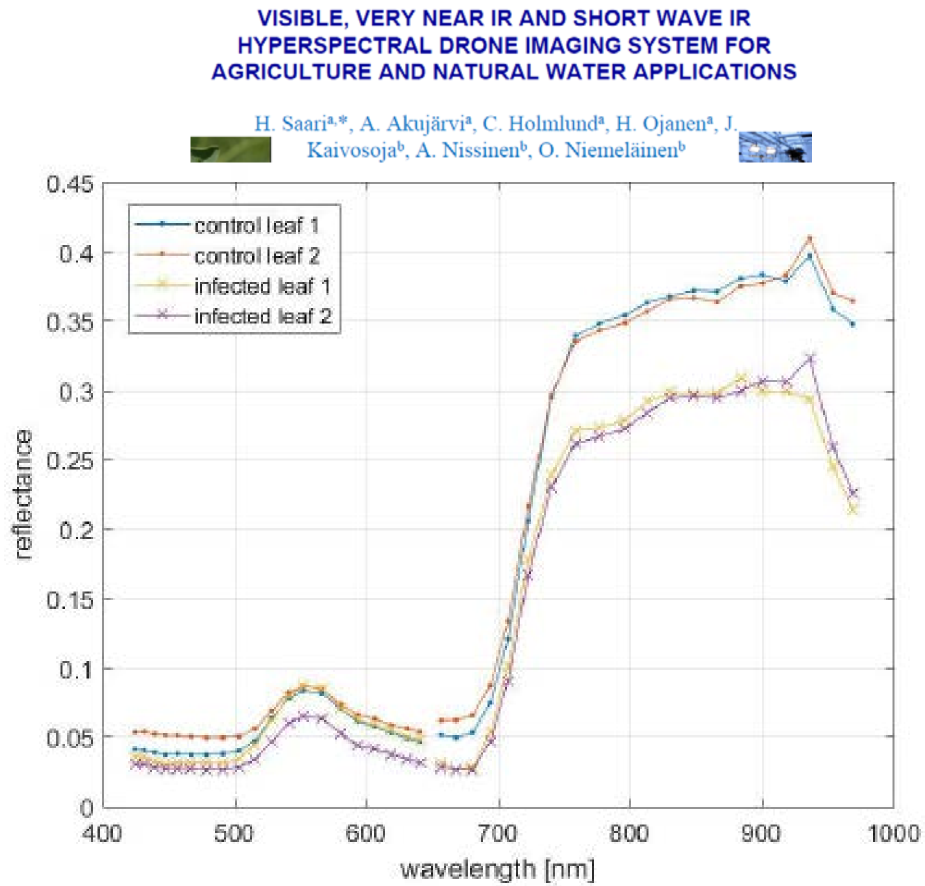
Luke NATURAL RESOURCES INSTITUTE FINLAND


FPI hyperspectral camera
RGB camera

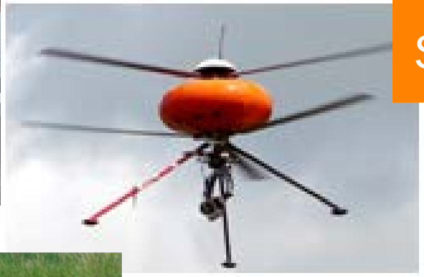
- Grass was the main focus
  - Biomass
  - Dry matter
  - Digestibility
  - Nitrogen
  - Sugars

- Barley and wheat
  - Nitrogen
  - Biomass, yield
  - Density
  - Diseases

- Peas
  - Pea aphid



SOME OF THE USED PLATFORMS FROM 2010->



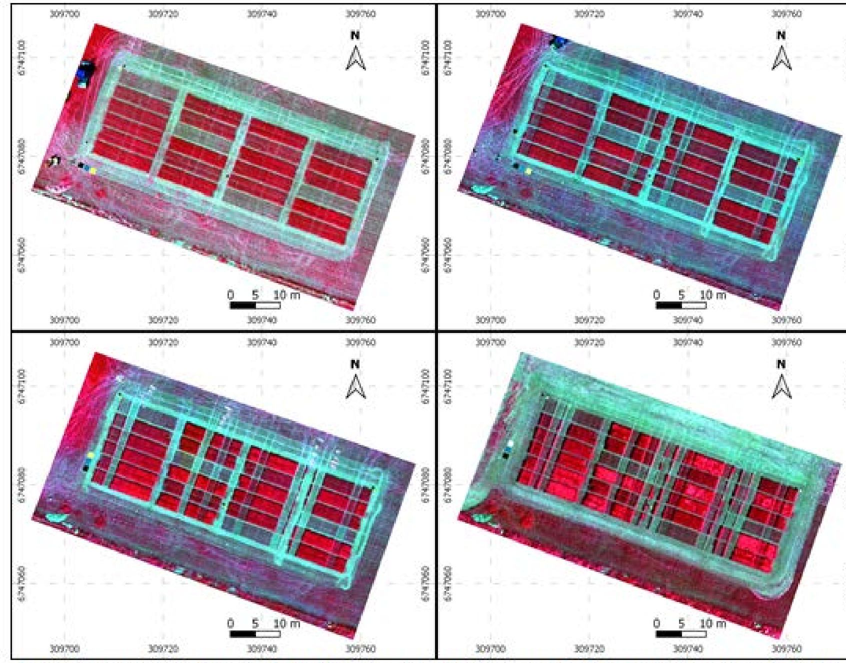
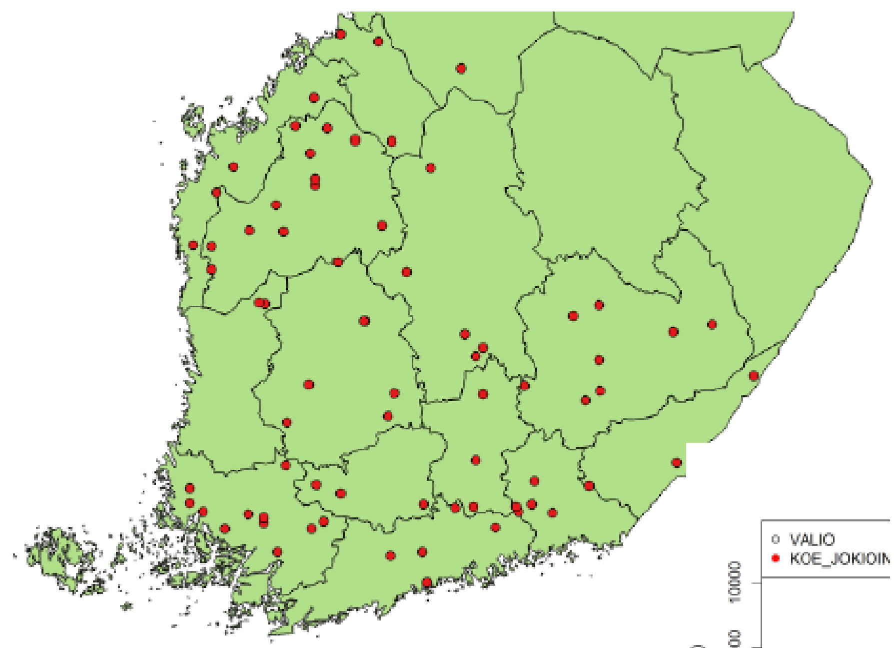
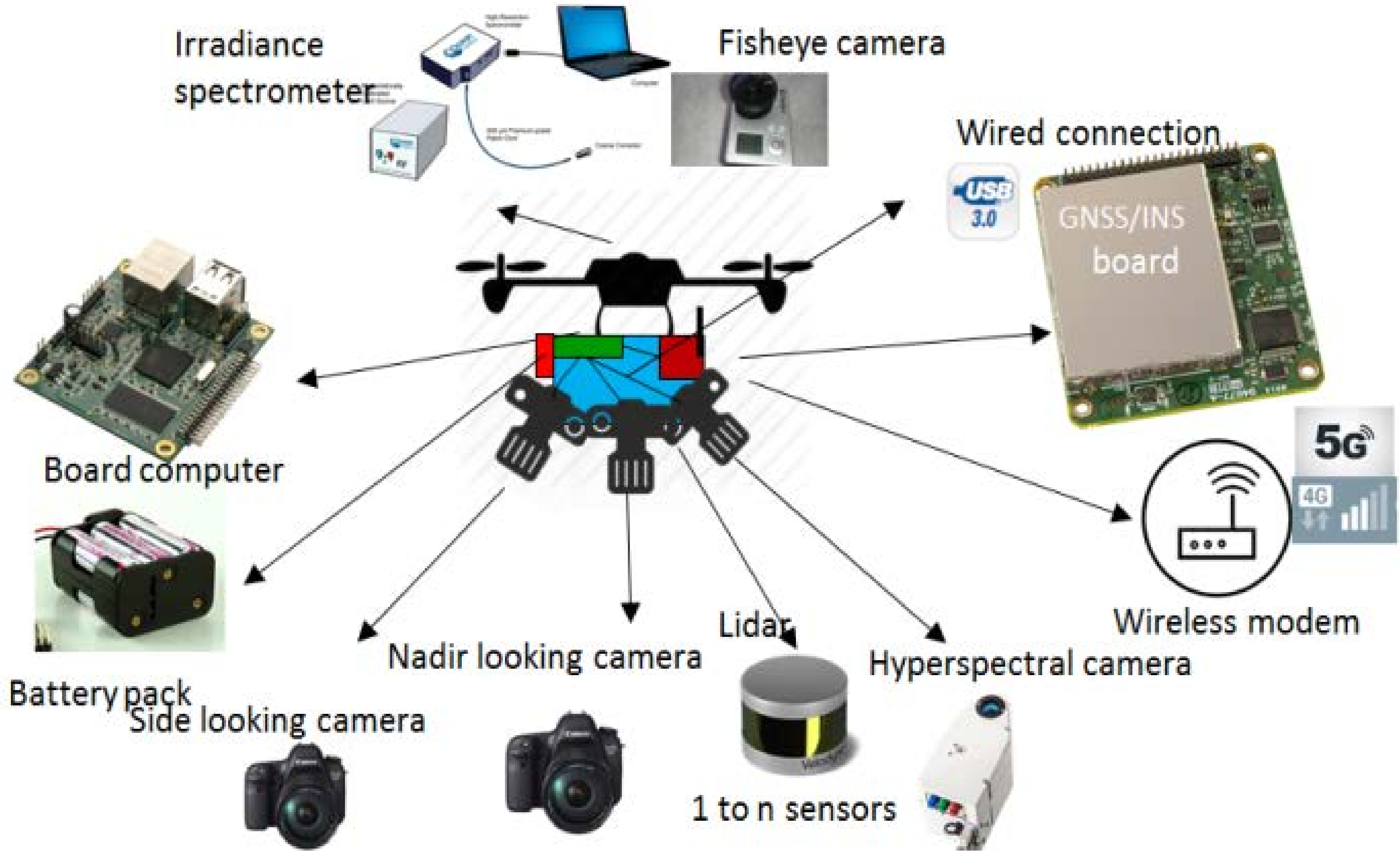
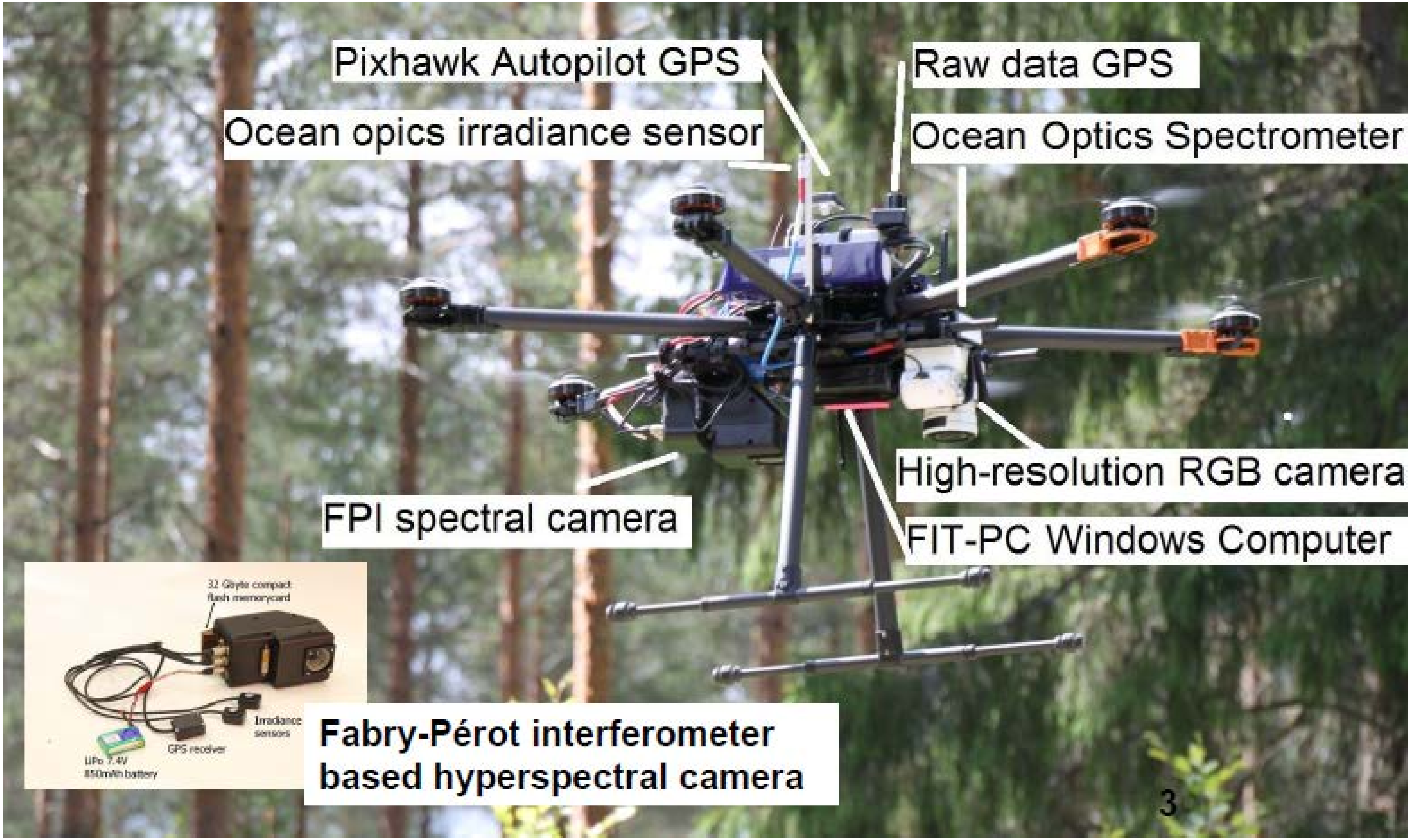


Figure: Orthomosaics Bands 29 (790.85 nm), 17 (656.34 nm), 6 (545.62 nm) for datasets (a) J1_F2,





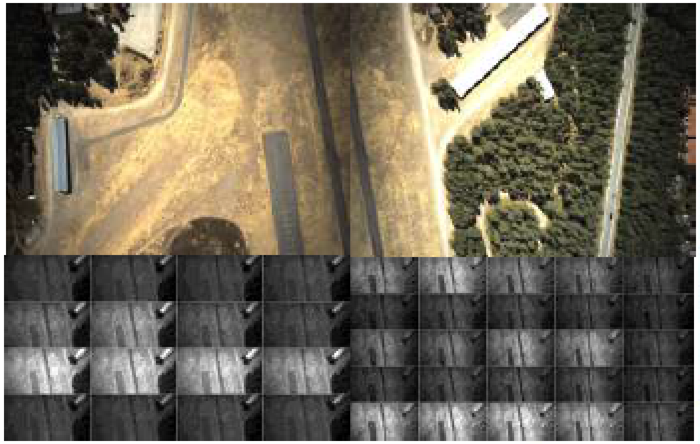
- **3D hyperspectral mapping**



Pixhawk Autopilot GPS
Ocean opics irradiance sensor
Raw data GPS
Ocean Optics Spectrometer
High-resolution RGB camera
FIT-PC Windows Computer
FPI spectral camera
32 Gbyte compact flash memorycard
Irradiance sensors
GPS receiver
LiPo 7.4V 850mAh battery
Fabry-Pérot interferometer based hyperspectral camera
3

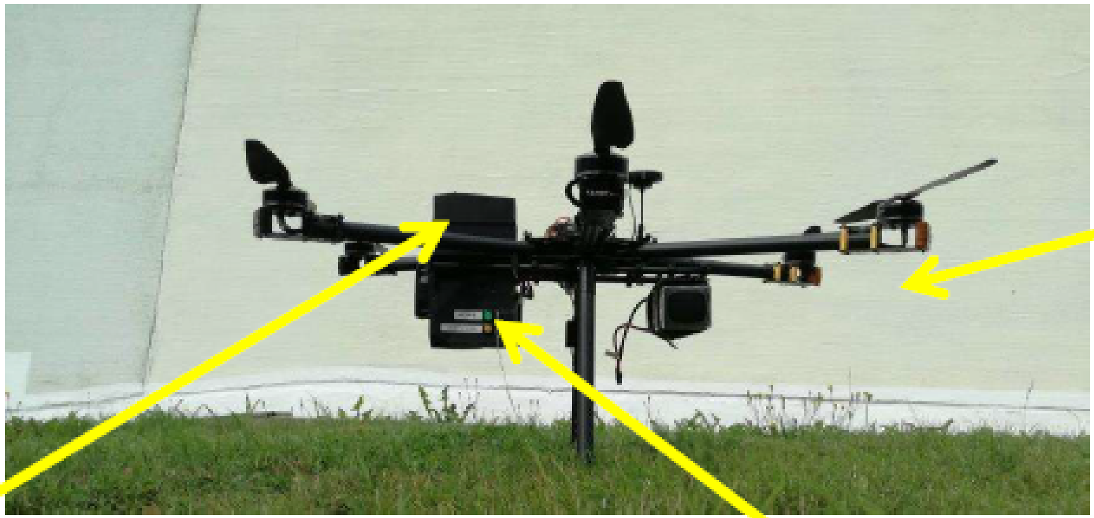
FGI REHU - *Real-time Hyperspectral Camera and Processing Unit*

- Acquires:
  - Wide-angle RGB images for accurate 3D reconstruction, ~2cm GSD @100m
  - Hyperspectral cameras: 41 bands in VNIR, ~20cm GSD @100m
- Onboard computer for real-time radiometric processing and georeferencing
- Output to cloud over 4G modem



NATURAL RESOURCES INSTITUTE FINLAND

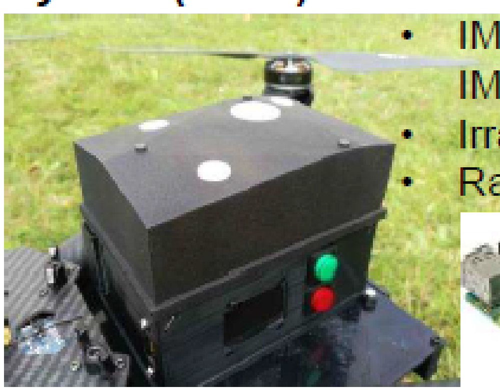
WP 4. FGI Real Time Hyper-spectral Camera System-concept



4G Modem

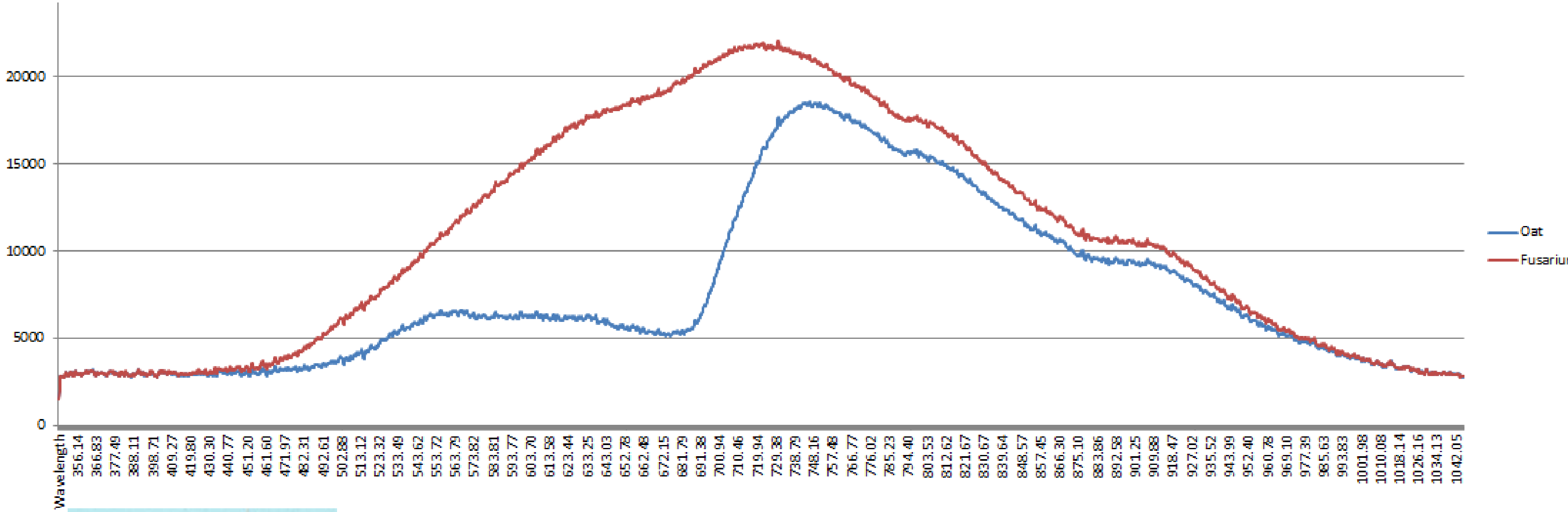
***FGI Aerial Image Reference System*(AIRS)**

- GNSS: u-blox NEO-M8T
- IMU: Vectornav VN-200 IMU
- Irradiance
- Rasberry-PI

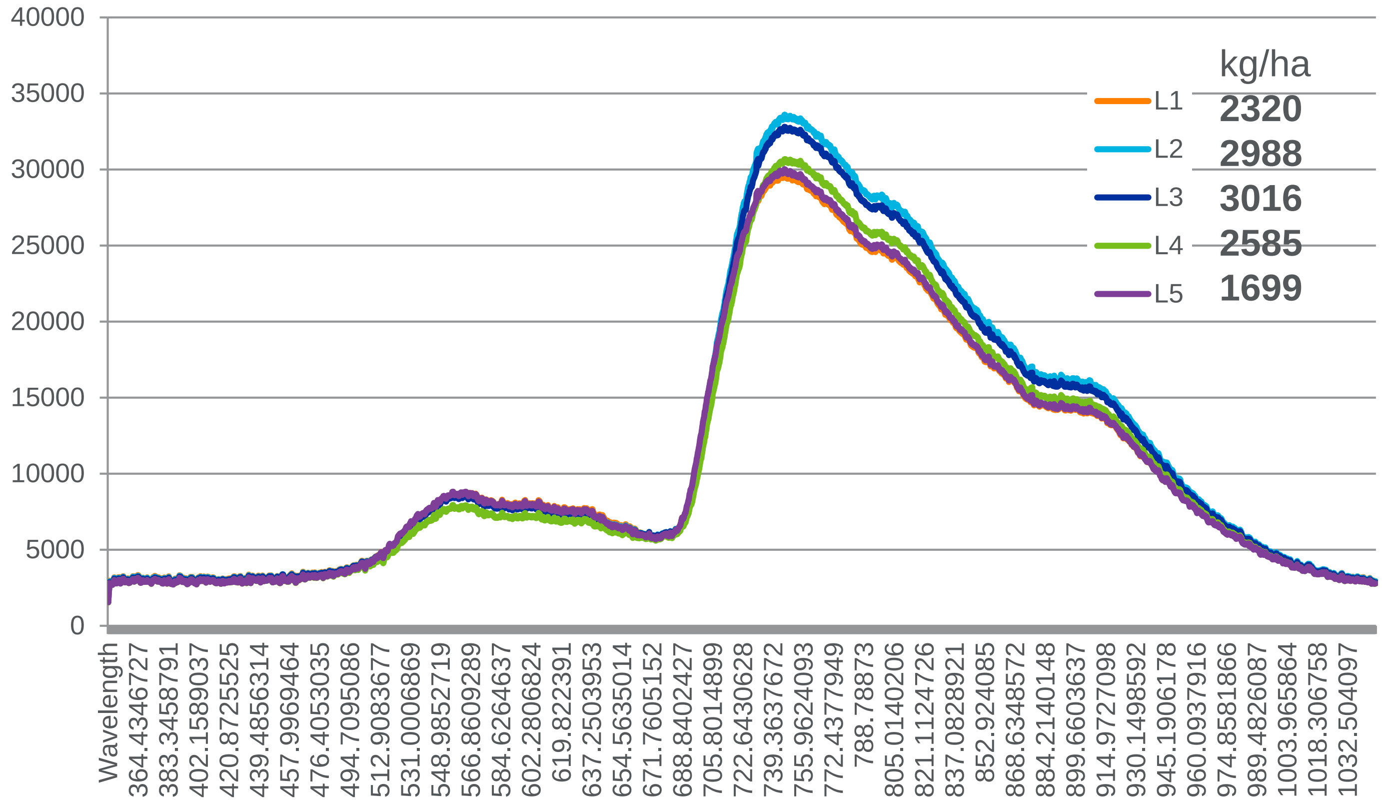


Hyperspectral Camera System

- High-resolution wide angle RGB
- 41 band snapshot hyperspectral
- Jetson single-board computer



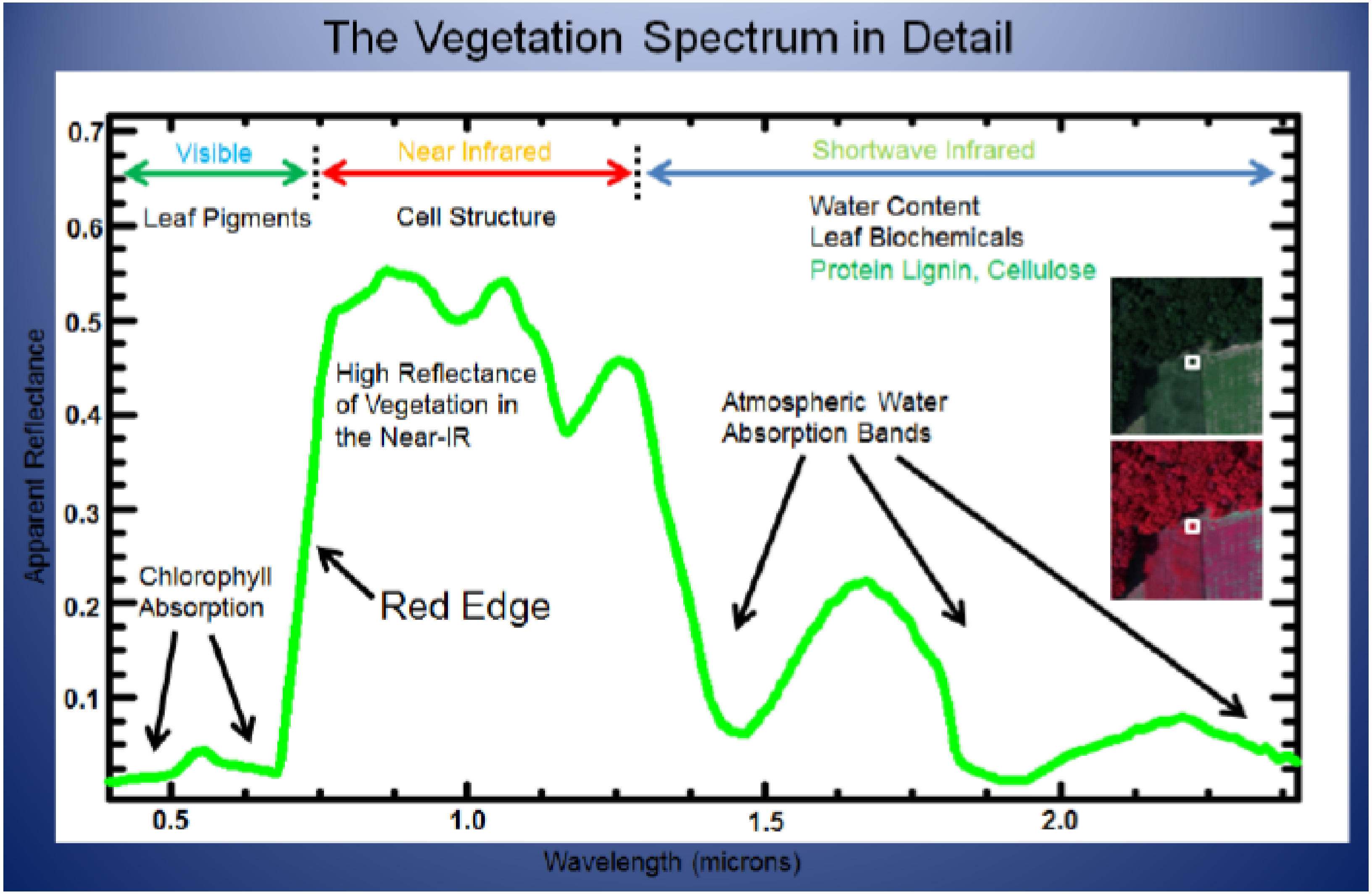
NATURAL RESOURCES
INSTITUTE FINLAND

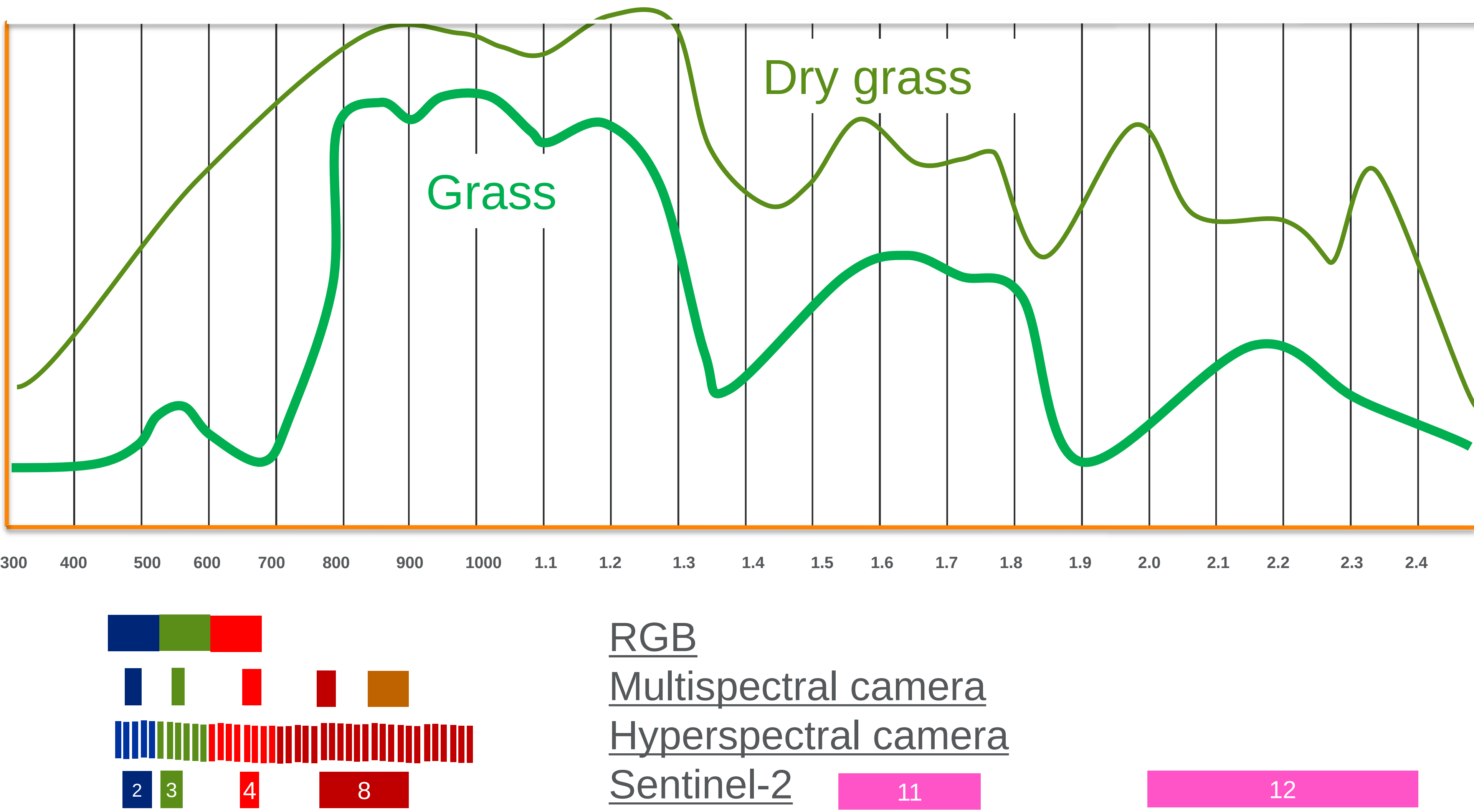


NATURAL RESOURCES INSTITUTE FINLAND

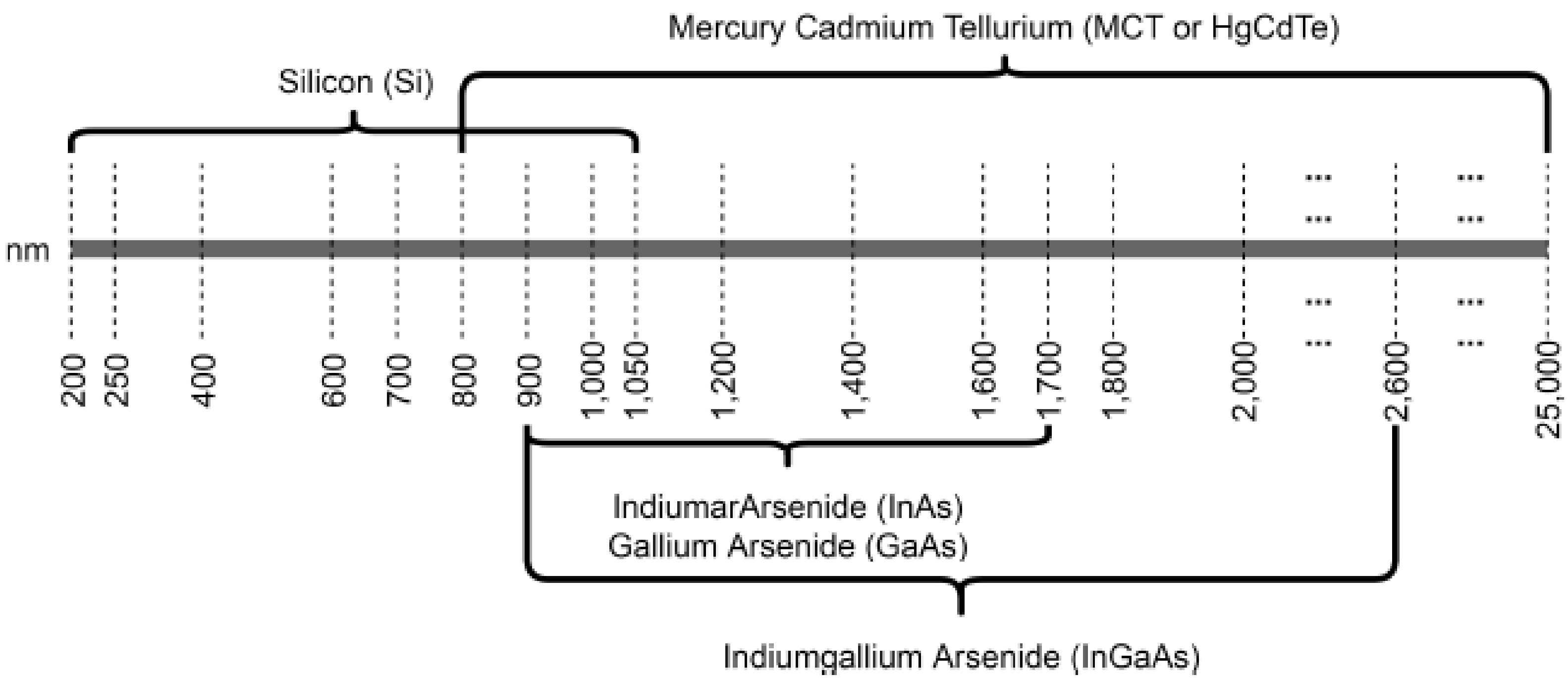
Vegetation reflectance spectrum

ref. http://www.markelowitz.com/Hyperspectral.html

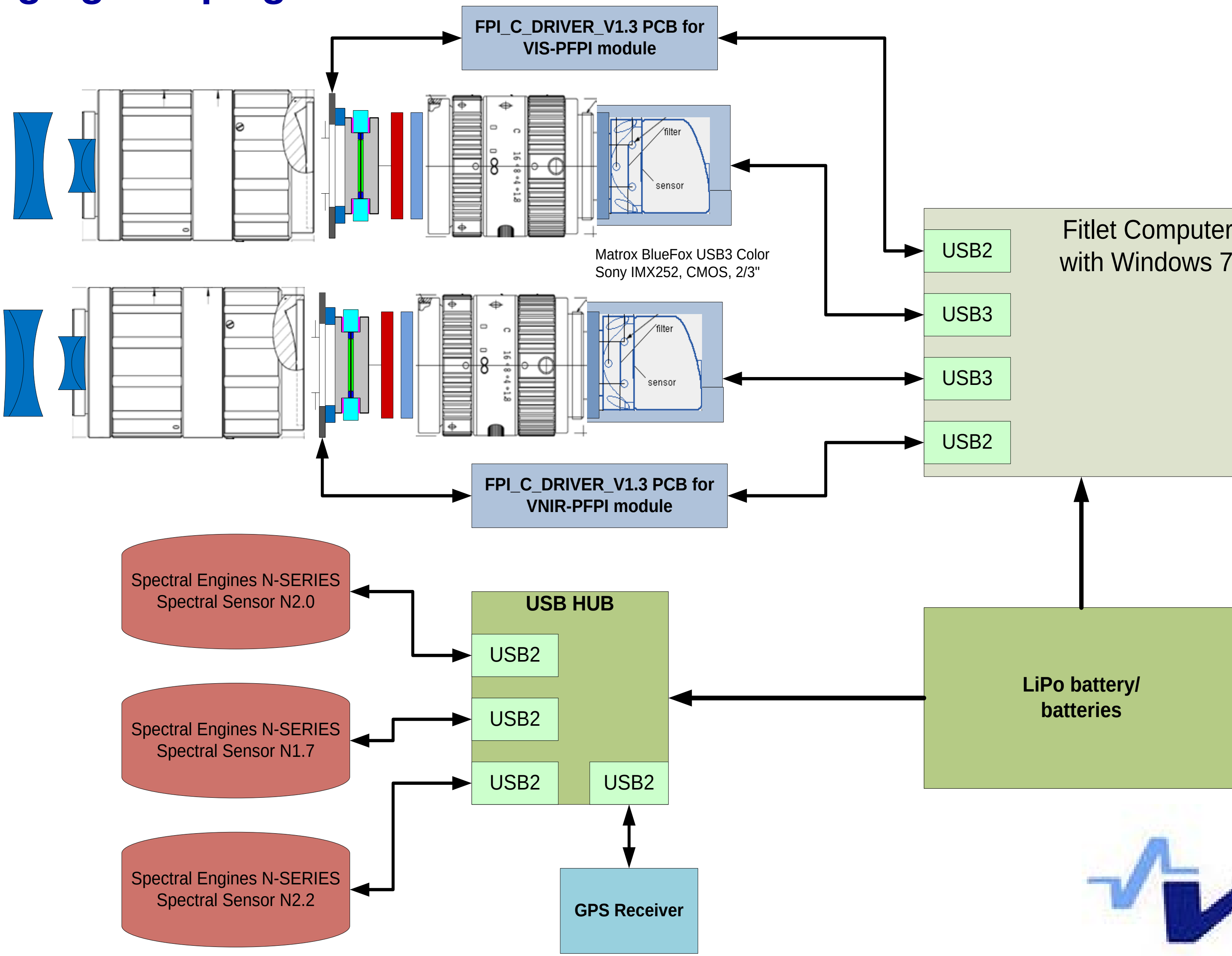



Dry grass
Grass
300
400
500
600
700
800
900
1000
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
RGB
Multispectral camera
Hyperspectral camera
Sentinel-2
2
3
4
8
11
12

Sensors; array of photodiodes that might be built using different materials:



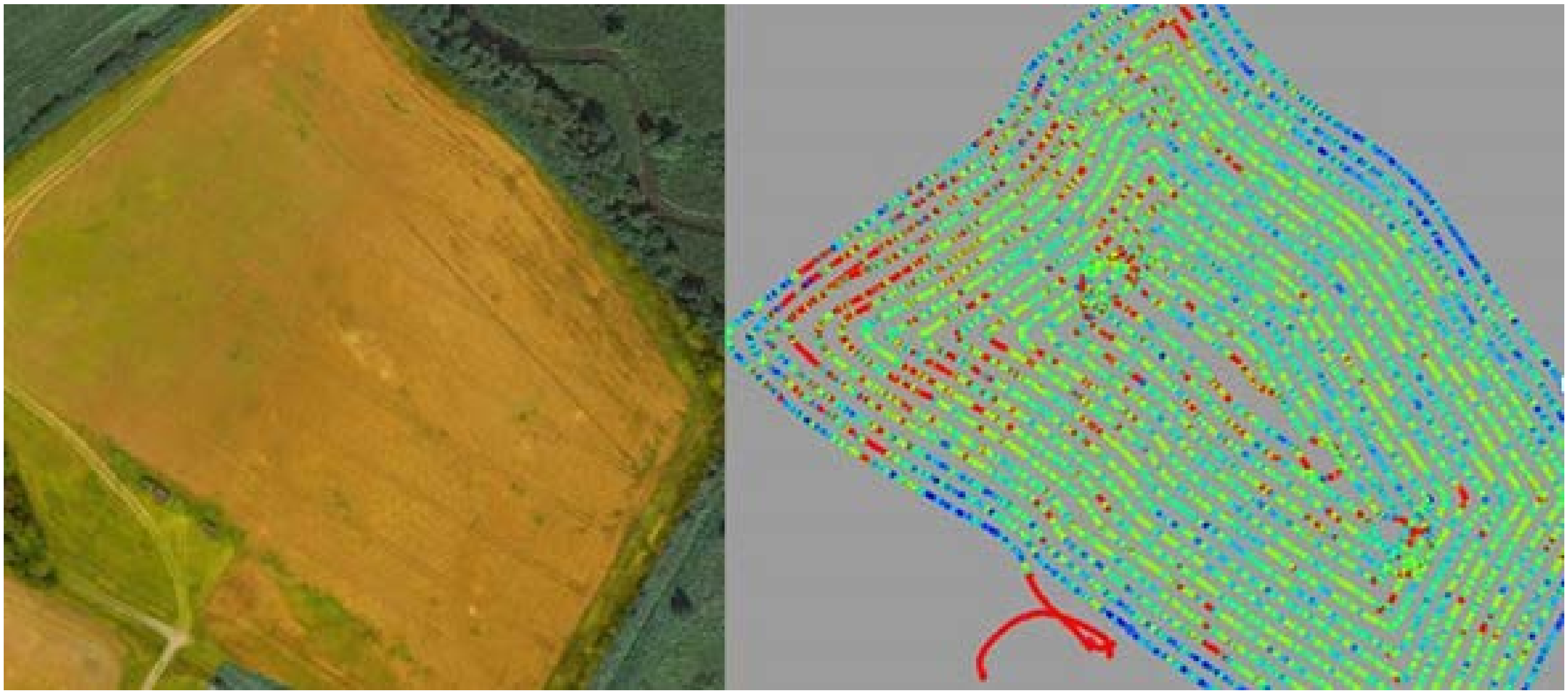
Preliminary concept of the DroneKnowledge VIS-VNIR-SWIR HSI prototype for the growing Season 2017 drone imaging campaigns

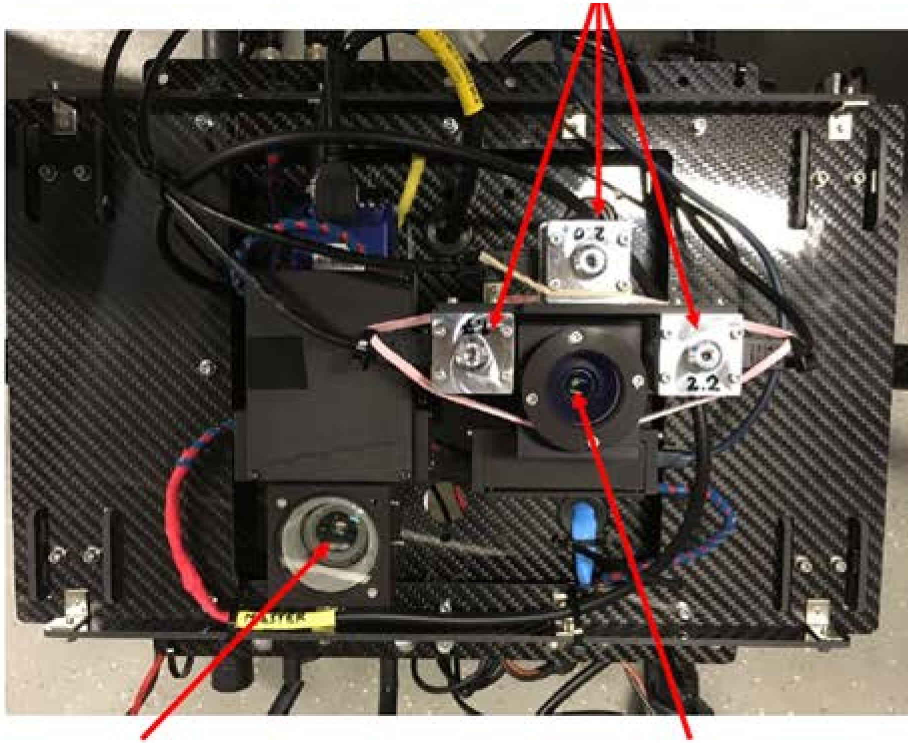


Parameter	Specified value	Remarks
Minimum object distance	< 2.0 m	The focal length of the optics is 12 ± 1 mm
Horizontal / Vertical FOV	> 8.5°/> 8.5°	
System focal length	3 mm ± 0.1 mm	
Ground pixel size	200 cm	
Spectral ranges SE N1.7 SE N2.0 SE N2.2 (N2.45)	0.90 – 1.35 µm 1.35 – 1.65 µm 1.55 – 1.95 µm 1.75 – 2.15 µm	VTT PFPI module Spectral Engines N-Series microspectrometer modules N1.7, N2.0 and N2.2 (N2.45)
Resolution @ FWHM	12– 16 nm/N1.7 14 – 20 nm/N2.0 18 – 24 nm/N2.2	

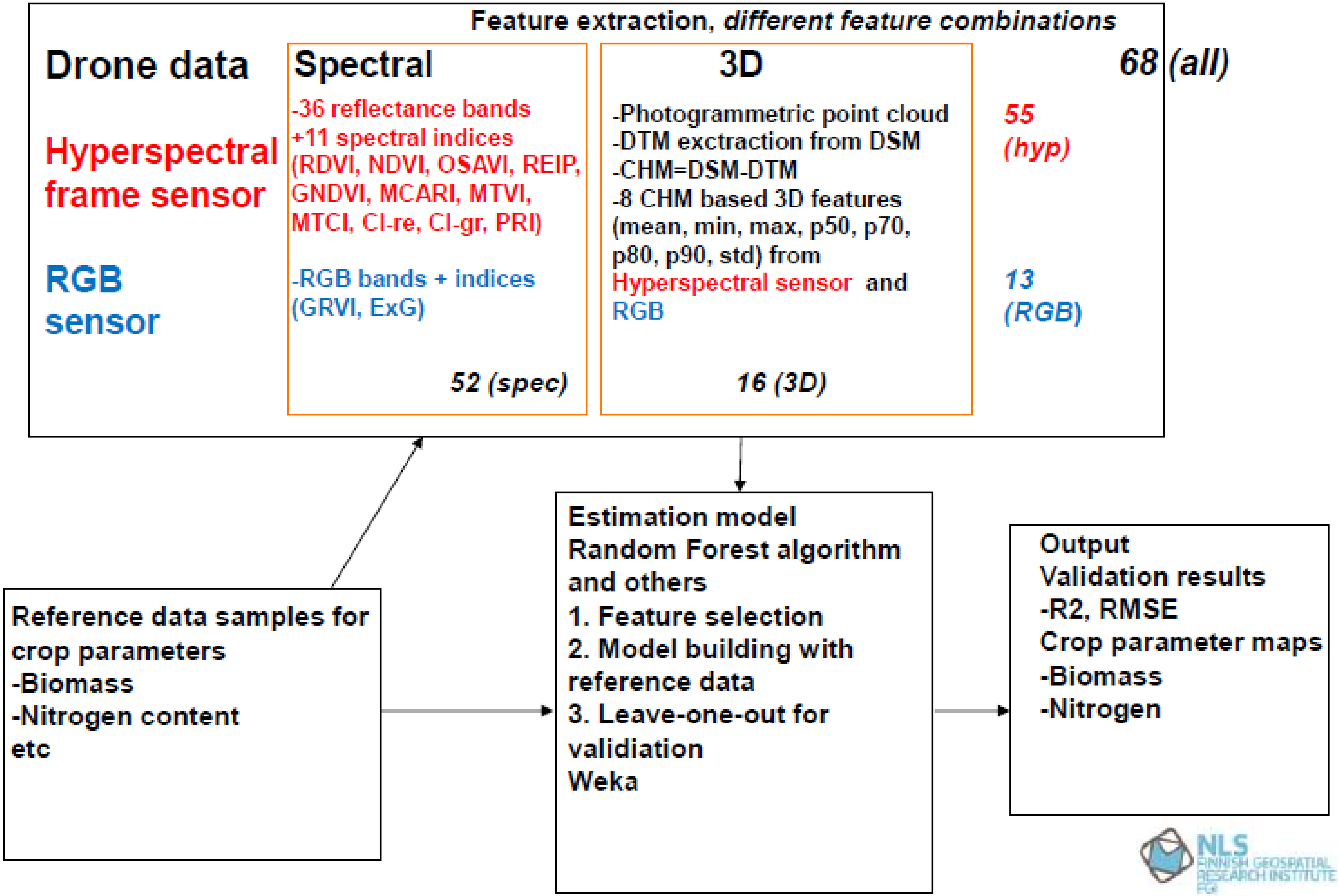
Boreal nurminata measurement 1

- 07:01:50 - 07:40:13 UTC
- 20180716-070150_900-DATA




2.2

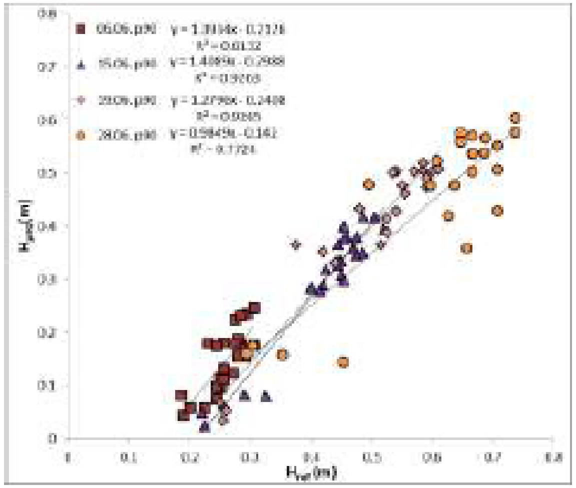
Estimation and classification using machine learning



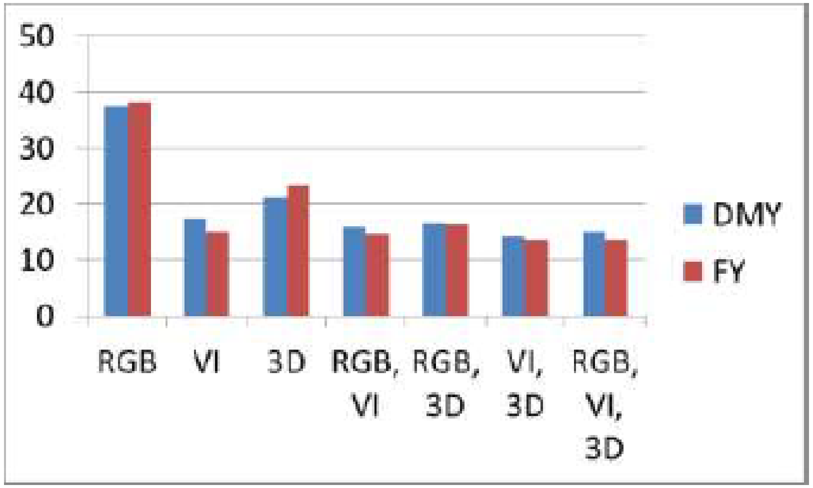
Estimation of biomass with Random Forest using combined features

- Estimation with different feature combinations
- Single feature types:
  - VI the best, RMSE% 15-17%
- Multiple features gave the best results
  - RMSE% 13-15%

Regression of photogrammetric canopy heights vs height stick



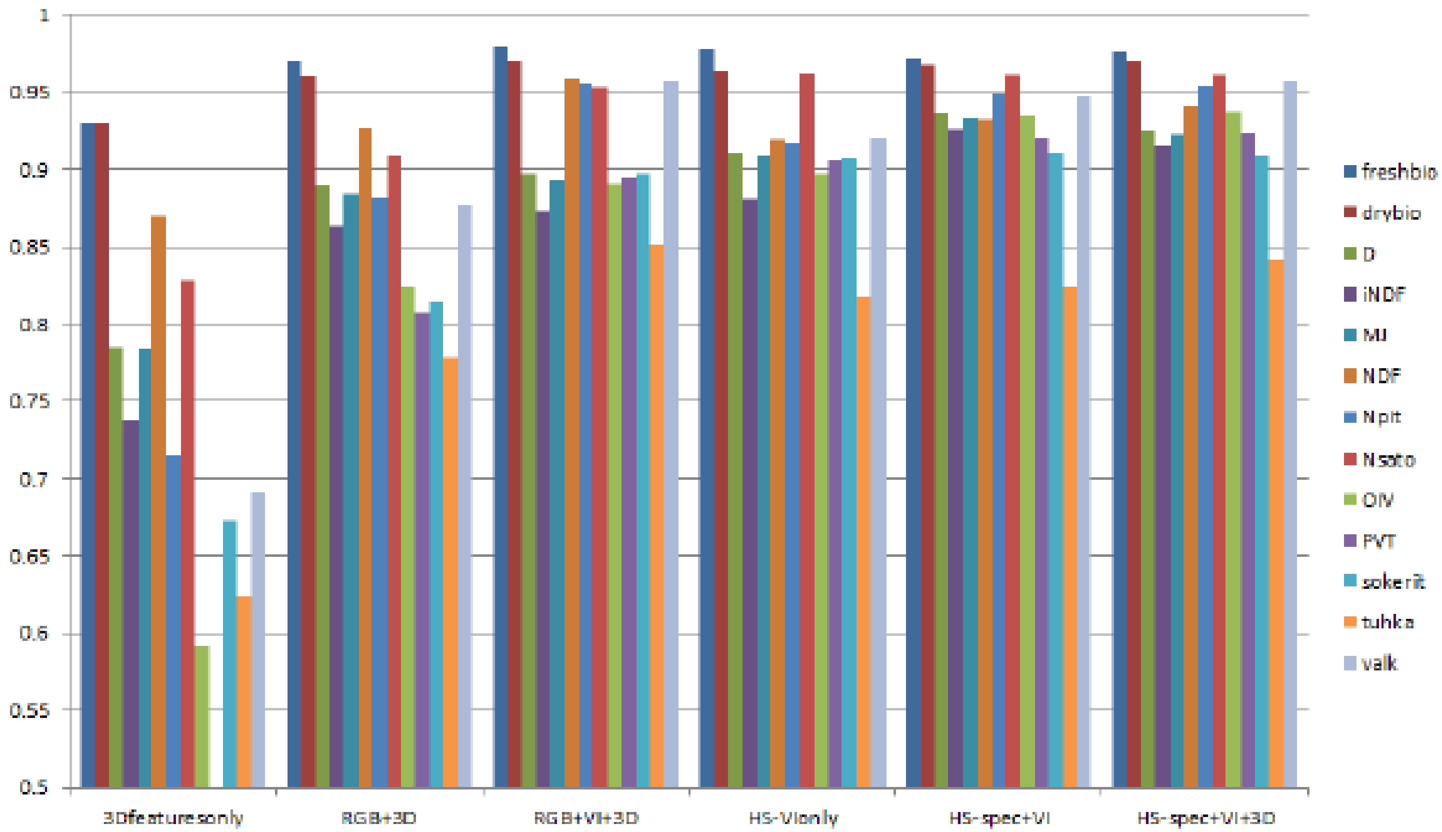
NRMSE% for different features



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.

Estimation of grass quantity parameters with Random Forest using HS data

Correlation coefficient

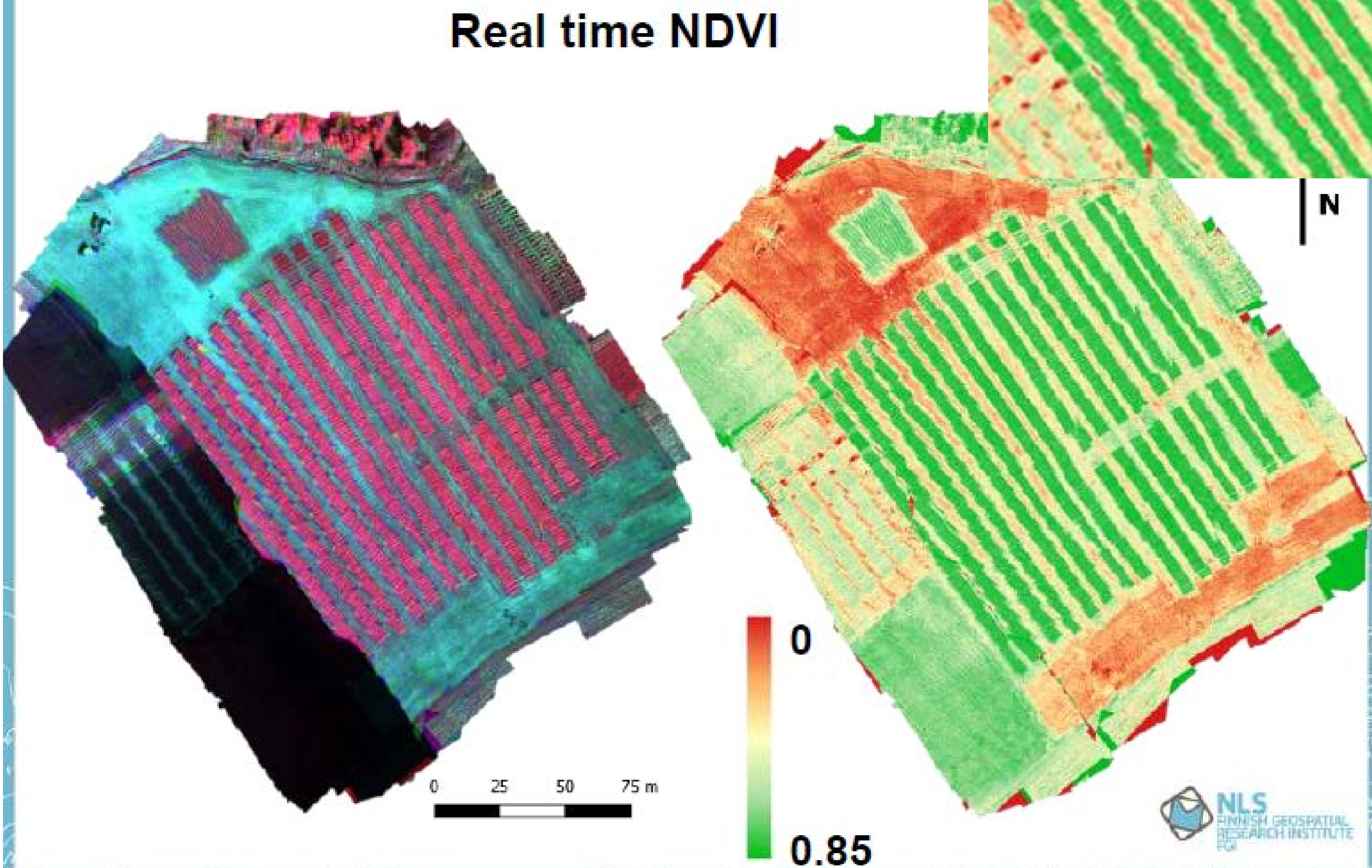


Fresh bio
Dry matter
Digestibilitiy
Nitrogen
Sugar

3D RGD, 3D RGB, VI, 3D VI (HS) HS, VI HS,VI,3D

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

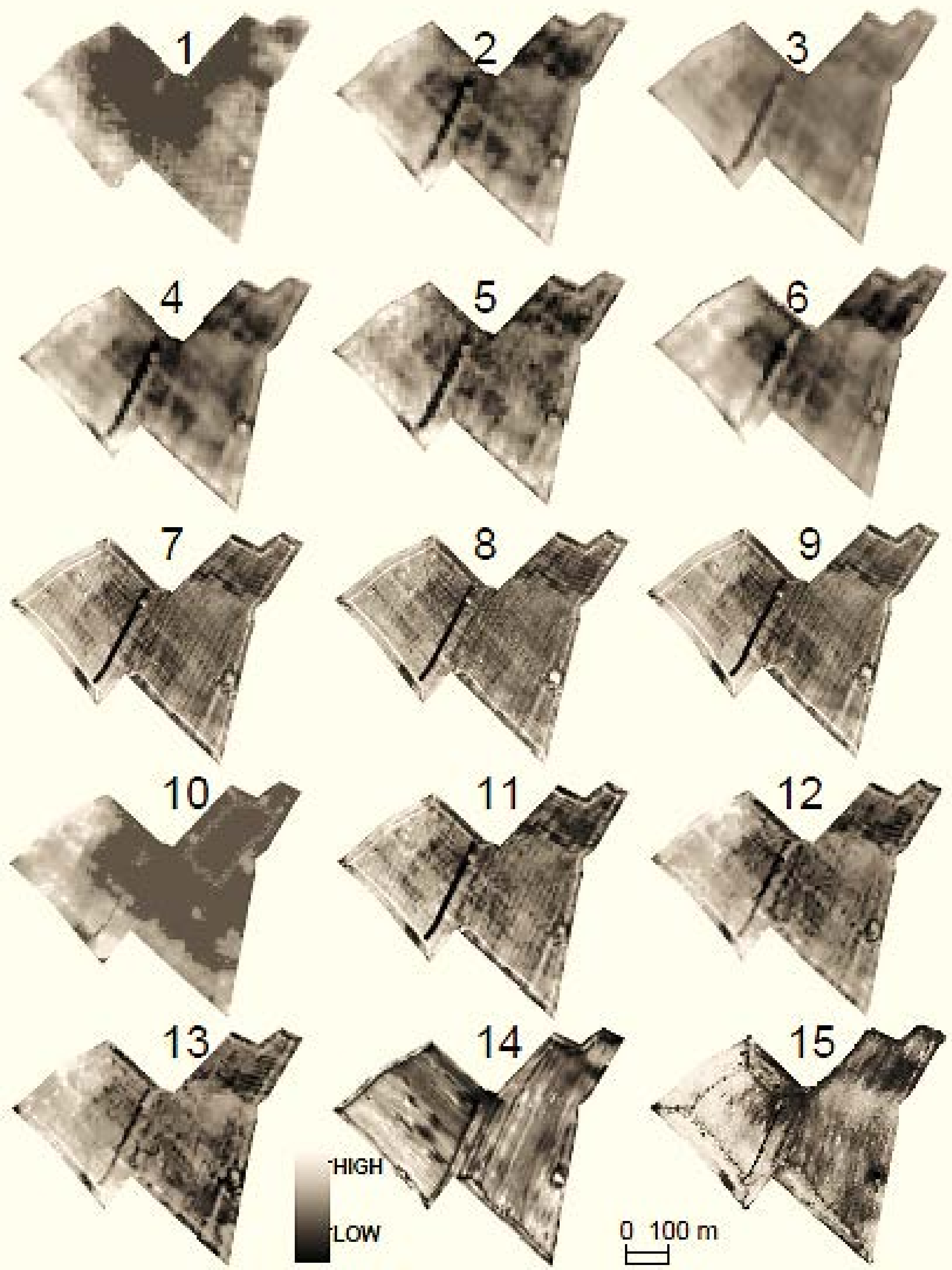
Hyperspectral orthomosaics



3D & biomass

@FGI, Niko Viljanen

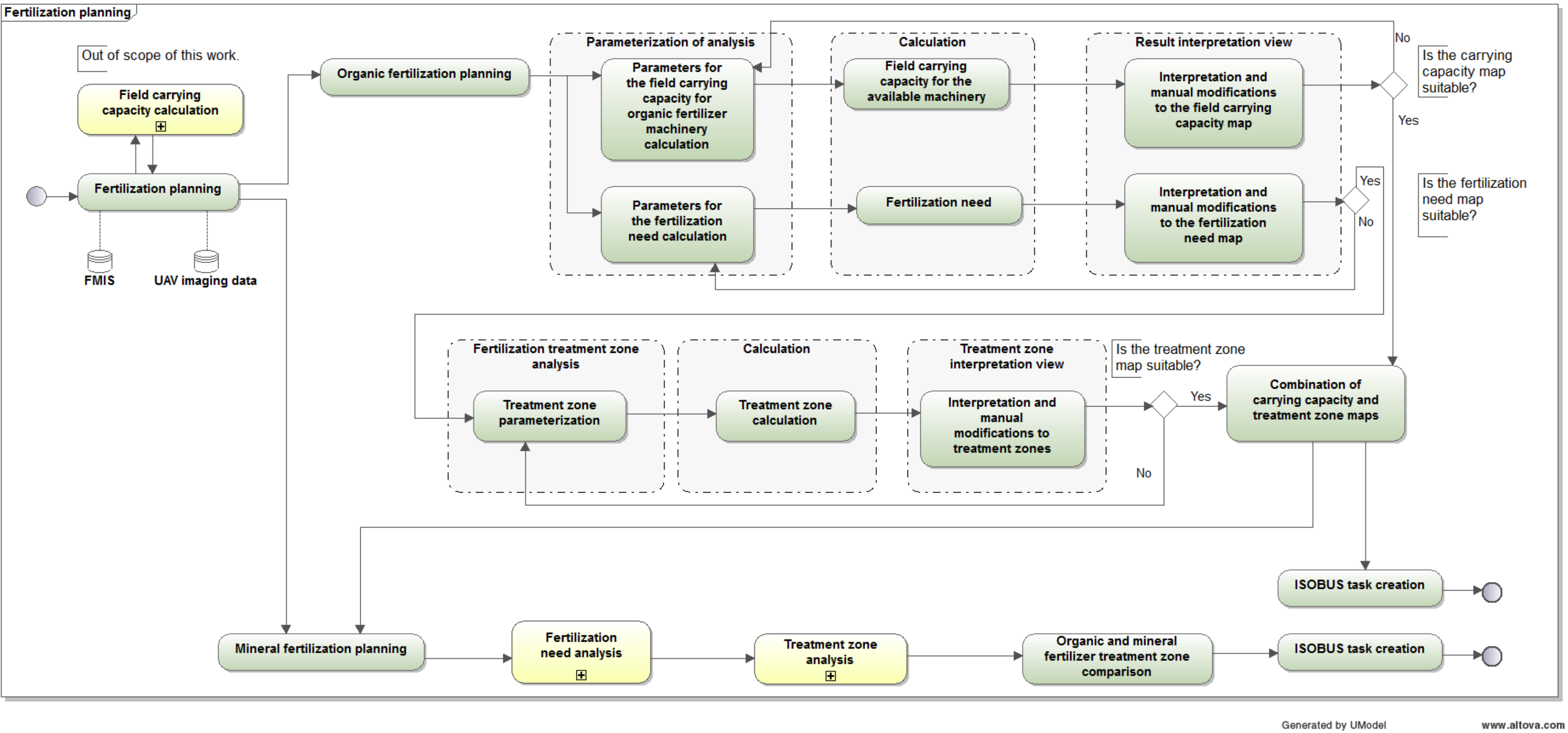
1. Satellite1: NDII, Sentinel-2, 2016/5/23. Entirely bare soil
2. Satellite2: NDII, Sentinel-2, 2016/7/2. For comparison to first
3. Satellite3: NDVI, Sentinel-2, 2016/7/2. typical dataset
4. Satellite4: SAVI, Sentinel-2, 2016/7/2. Reduced soil reflectanc
5. Satellite5: VARI, Sentinel-2, 2016/7/2. Comparison to UAV d
6. Satellite6: NDVI, Sentinel-2, 2016/7/29. Temporal aspect
7. ProUAV1: NDVI, FPI-UAV, 2016/7/4. index based on FPI se
8. ProUAV2: FPI, FPI-UAV, 2016/7/4. Biomass estimation base
9. ProUAV3: CHM, FPI-UAV, 2016/7/4. Crop height
10. Tractor: Yara-N-Sensor, 2016/7/16. Biomass estimation
11. UAV1: VARI, Phantom 4, 2016/7/4. Common UAV data
12. UAV2: VARI, Phantom 4, 2016/7/16. Temporal aspect
13. UAV3: VARI, Phantom 4, 2016/7/16. Constantly changing cl
14. Yield map 2015: Combine harvester. Seasonal variation
15. Yield points 2016: Combine harvester. Field performance



Correlation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.Sat1NDII	1	**.61**	.60	.58	.56	.62	.44	.39	.48	.58	.44	.56	.52	.36	.46
2.Sat2NDII	.61	1	.97	**.97**	.94	.85	.69	.62	.72	.79	.74	.83	.75	.29	.72
3.Sat3NDVI	.60	.97	1	**.99**	.96	.88	.70	.62	.73	.80	.76	.85	.78	.30	.75
4.Sat4SAVI	.58	.97	**.99**	1	.95	.89	.70	.62	.73	.81	.76	.86	.78	.30	.75
5.Sat5VARI	.56	.94	**.96**	.95	1	.81	.67	.60	.70	.75	.76	.80	.72	.29	.69
6.Sat6VARI	.62	.85	.88	**.89**	.81	1	.66	.55	.66	.85	.69	.87	.83	.30	.81
7.Pro1NDVI	.44	.69	.70	.70	.67	.66	1	.89	**.92**	.62	.79	.72	.68	.20	.61
8.Pro2FPI	.39	.62	.62	.62	.60	.55	**.89**	1	.88	.54	.71	.62	.58	.17	.51
9. Pro3CHM	.48	.72	.73	.73	.70	.66	**.92**	.88	1	.62	.79	.73	.67	.21	.58
10. Tractor	.58	.79	.80	.81	.75	.85	.62	.54	.62	1	.67	**.87**	.85	.28	.82
11.UAV1VARI	.44	.74	.76	.76	.76	.69	**.79**	.71	.79	.67	1	.78	.75	.19	.64
12.UAV2VARI	.56	.83	.85	.86	.80	.87	.72	.62	.73	.87	.78	1	**.90**	.26	.81
13.UAV3VARI	.52	.75	.78	.78	.72	.83	.68	.58	.67	.85	.75	**.90**	1	.25	.82
14.Yield2015	**.36**	.29	.30	.30	.29	.30	.20	.17	.21	.28	.19	.26	.25	1	.29
15.Yield2016	.47	.72	.75	.75	.69	.81	.61	.51	.58	.82	.64	.81	**.82**	.29	1
Average	.52	.75	.76	**.76**	.73	.73	.66	.59	.67	.70	.68	.75	.71	.26	.66
Nitrogen	.24	.40	.45	.44	.41	.50	.70	.56	.56	.38	**.74**	.53	.49	.34	.49
Biomass	.34	.66	.67	.66	.65	.48	.79	.73	**.81**	.47	.81	.69	.69	.54	.61

Fertilization



Nikander, J., Huitu, H., Koistinen, M., Laajalahti, M., Niemeläinen, O., Kaivosoja, J. (2018). Application of Drone-Based Maps in Planning Farm Operations for Sward Management in Silage Production. 7 p.. European Society of Agricultural Engineers (EurAgEng)

Näsi, R.; Viljanen, N.; Kaivosoja, J.; Alhonoja, K.; Hakala, T.; Markelin, L.; Honkavaara, E. (2018) Estimating Biomass and Nitrogen Amount of Barley and Grass Using UAV and Aircraft Based Spectral and Photogrammetric 3D Features, Remote Sens. 2018, 10(7), 1082; https://doi.org/10.3390/rs10071082

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.

Machine learning estimators for quantity and quality of grass swards for silage production using spectral imaging and photogrammetry from a drone Raquel Alves Oliveira, Roope Näsi, Oiva Niemeläinen, Laura Nyholm, Jere Kaivosoja, Niko Viljanen, Somayeh Nezami, Lauri Markelin, Teemu Hakala, Eija Honkavaara

A Novel Tilt Stabilization Technique for UAV Irradiance Sensors and Spectrometers

Juha Suomalainen [1,*], Teemu Hakala [1], Raquel Alves de Oliveira [1], Lauri Markelin [1], Niko Viljanen [1], Roope Näsi [1], and Eija Honkavaara [1]

[1] Finnish Geospatial Research Institute (FGI), National Land Survey of Finland (NLS), Geodeetinrinne 2, 02430 Masala, Finland, firstname.lastname@nls.fi

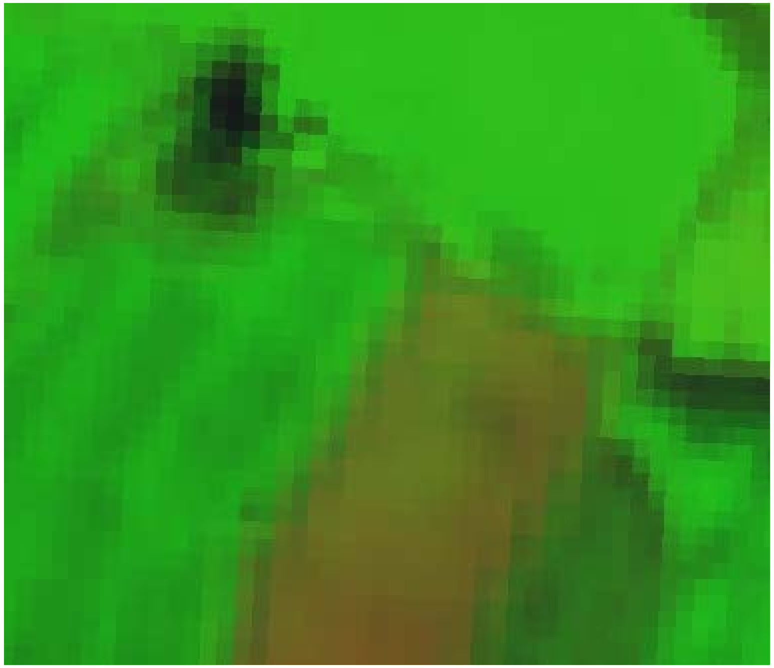
[*] Correspondence: juha.suomalainen@nls.fi; Tel.: +358-50-300-4034

Luke
NATURAL RESOURCES
INSTITUTE FINLAND

Hyperspectral vs. RGB

Hyperspectral:

- Better spectral resolution
- Lower spatial resolution



In the spectral unmixing scope, there are several approaches such as

- linear unmixing widely used in the past decade
    - linear combination of the contributing signals
- pure pixel-based (which assumes the presence in data of one or more pure pixels per endmember)
- based on non-pure pixels (endmembers are inferred by fitting a minimum volume simplex to data in the case of lack of pure pixels)
- sparse regression unmixing (demands ground spectral libraries to find the optimal subset of signatures that can best model each pixel)

Bioucas-Dias, J.M.; Plaza, A.; Camps-Valls, G.; Scheunders, P.; Nasrabadi, N.; Chanussot, J. Hyperspectral Remote Sensing Data Analysis and Future Challenges. *IEEE Geosci. Remote Sens. Mag.* **2013**, *1*, 6–36. [CrossRef]

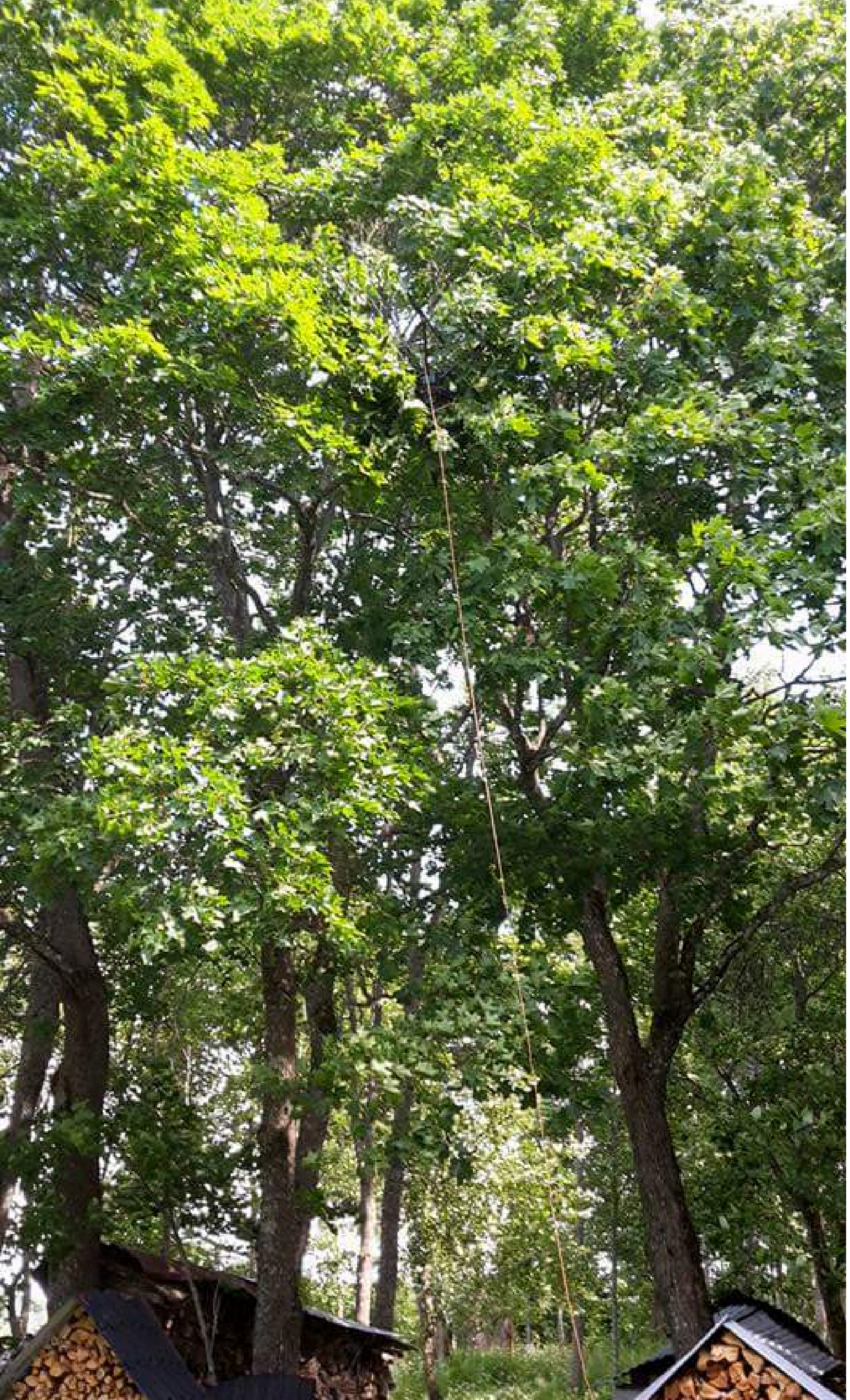
Luke
NATURAL RESOURCES INSTITUTE FINLAND

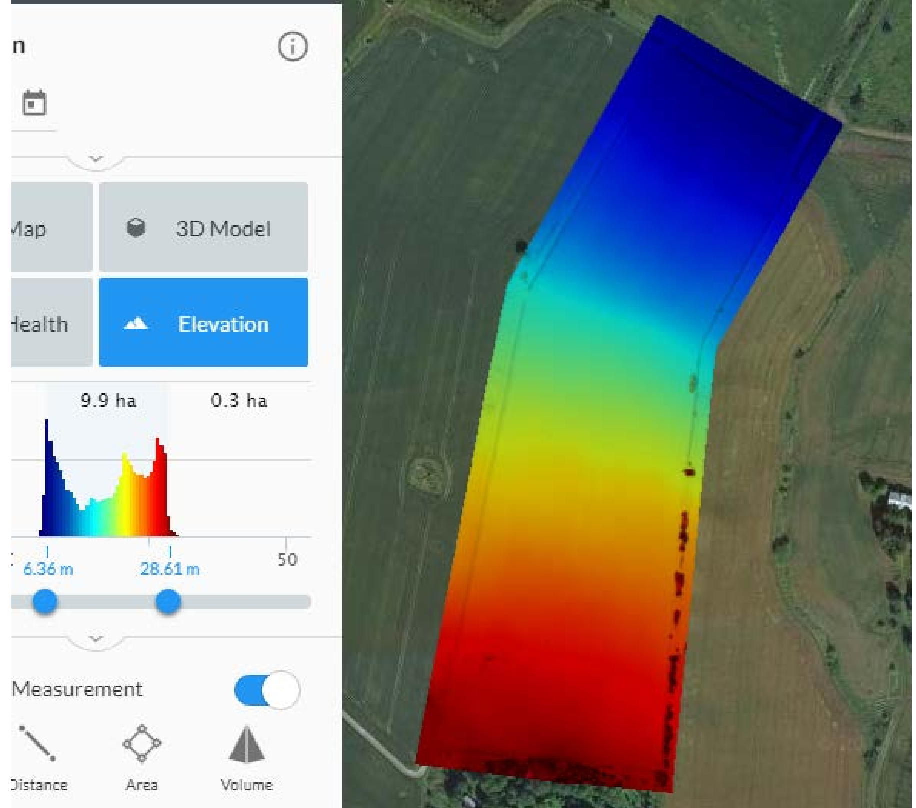
Future:

Let the drones do the work

- Pesticide control, plant nutrition
- Daily visits, no soil compaction/ vegetation distructions

What would that mean from the plant breeding perspective?




n
Map
3D Model
Health
Elevation
9.9 ha
0.3 ha
6.36 m
28.61 m
50
Measurement
Distance
Area
Volume

http://drones2018.utu.fi/en/congress/

.

Drones in Finnish Agriculture and Forestry -**congress**

29.-30.11.2018 in Naantali Spa is a meeting for Finnish drone specialists and researchers of agriculture and forestry to discuss the possibilities of drones and to solve scientific and technical problems related to their use. We have invited top specialists of the field to give talks, and several companies are expected to show interesting products and services. The congress will be interesting also for end users like farmers and forest owners.

>100 participants

Thank you!

NATURAL RESOURCES INSTITUTE FINLAND