CyberGrass I –Final seminar

Silage sward yield estimation by drone imaging

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Experiences of grass stand yield and quality estimation by drone from previous projects

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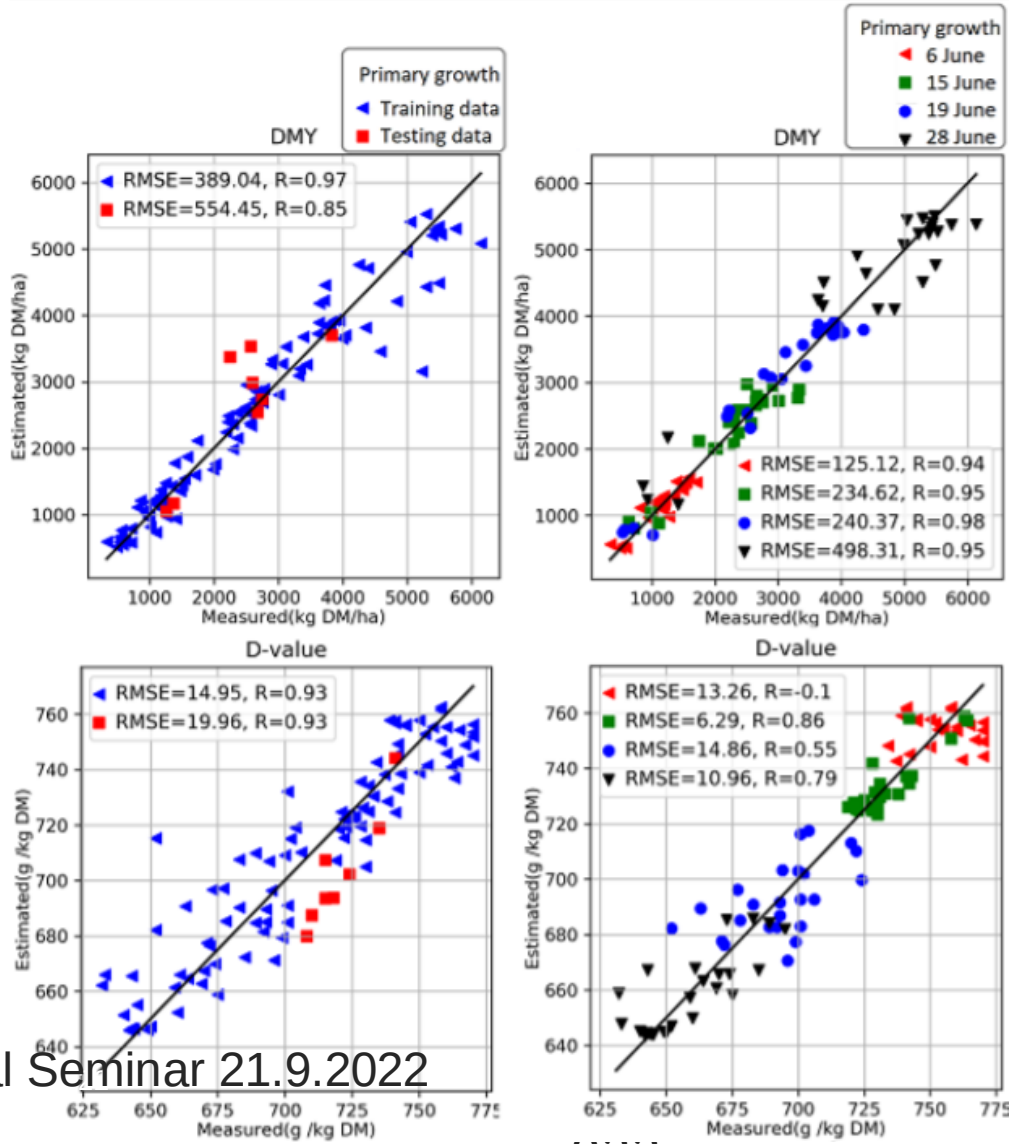
-Yield (DMY) and quality (D-value) are possible to estimate based on drone data and machine learning

-Accuracy is enough to optimaze harvesting time (RMSE ~2-3 days of growing in primary growth)

- Spectral data (VNIR 46 bands) were suitable for the DMY and D-value estimation, 3D data was suitable especially for DMY and height of grass.



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(5):70. https://doi.org/10.3390/agriculture8050070

Oliveira, R. A., Näsi, R., Niemeläinen, O., Nyholm, L., Alhonoja, K., Kaivosoja, J., ... & Honkavaara, E. (2020). Machine learning estimators for the quantity and quality of grass swards used for silage production using drone-based imaging spectrometry and photogrammetry. Remote Sensing of Environment, 246, 111830.

Experiences of grass stand yield and quality estimation by drone from previous projects

- To improve:
- Generalization of the method to real farms needs developments
  - Handle different grass mixtures
  - Different growing conditions

    ->Machine learning model needs data for whole phenomenon

    -> More data
- Optimization of spectral data (new sensors e.g. SWIR)
- Enhanced machine learning techniques
  - Deep neural network techniques

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Grass stand yield and quality estimation by drone data and machine learning - concept

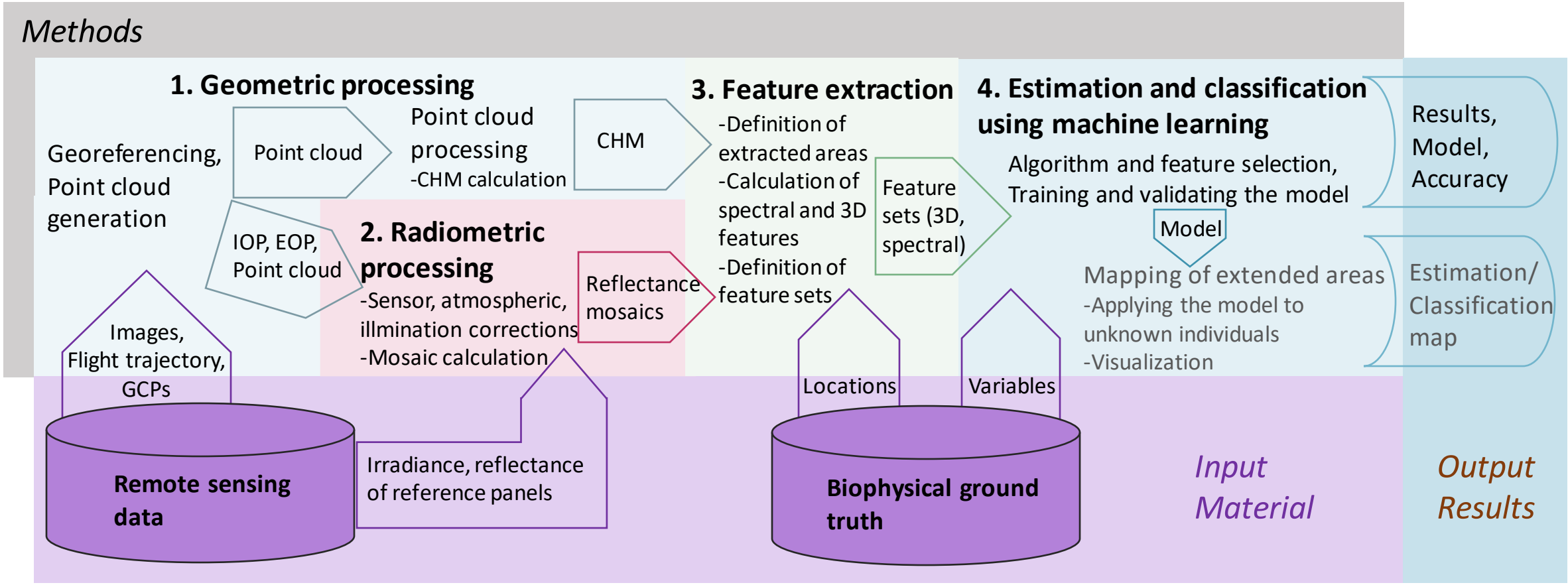
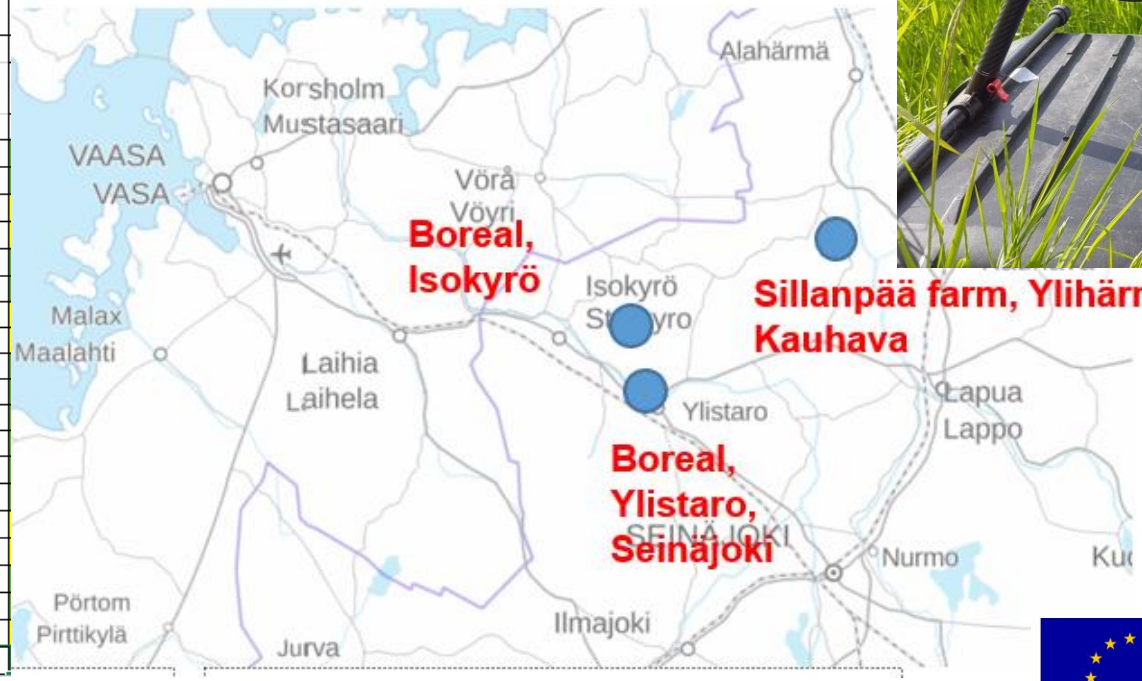


Figure: Näsi, R. (2021). Drone-based spectral and 3D remote sensing applications for forestry and agriculture. Doctoral Dissertation, Aalto University, School of Engineering. http://urn.fi/URN:ISBN:978-952-64-0613-8

Drone data collection 2021

Drone data collection from South Ostrobothnia trials for CyberGrass I
-14 flights, RGB, Multispectral, Hyperspectral (AFX10, AFX17)
-1 farm
-Trial sites in Ylistaro and Isokyrö

Date 2021		Type	Place	Sensor
10.6.		Plot trial	Boreal Isokyrö Jauri	RGB-MS, Luke
10.6.		Plot trial	Boreal Ylistaro Pelmaa	RGB-MS, Luke
10.6.	Primary growth (1)	Farm	Sillanpää	RGB-MS, Luke
				RGB
				MS
				AFX10
21.7		Plot trial	Boreal Isokyrö Jauri	AFX17
				RGB
				MS
				AFX10
21.7		Plot trial	Boreal Ylistaro Pelmaa	AFX17
				RGB
22.7		Farm	Ylihärmä-Sillanpää Navetta	MS
				RGB
22.7	Regrowth (2)	Farm	Ylihärmä-Sillanpää Kairoo	MS
				RGB
				MS
				AFX10
15.9		Plot trial	Boreal Isokyrö Jauri	AFX17
				RGB
				MS
				AFX10
15.9	Regrowth (3)	Plot trial	Boreal Ylistaro Pelmaa	AFX17



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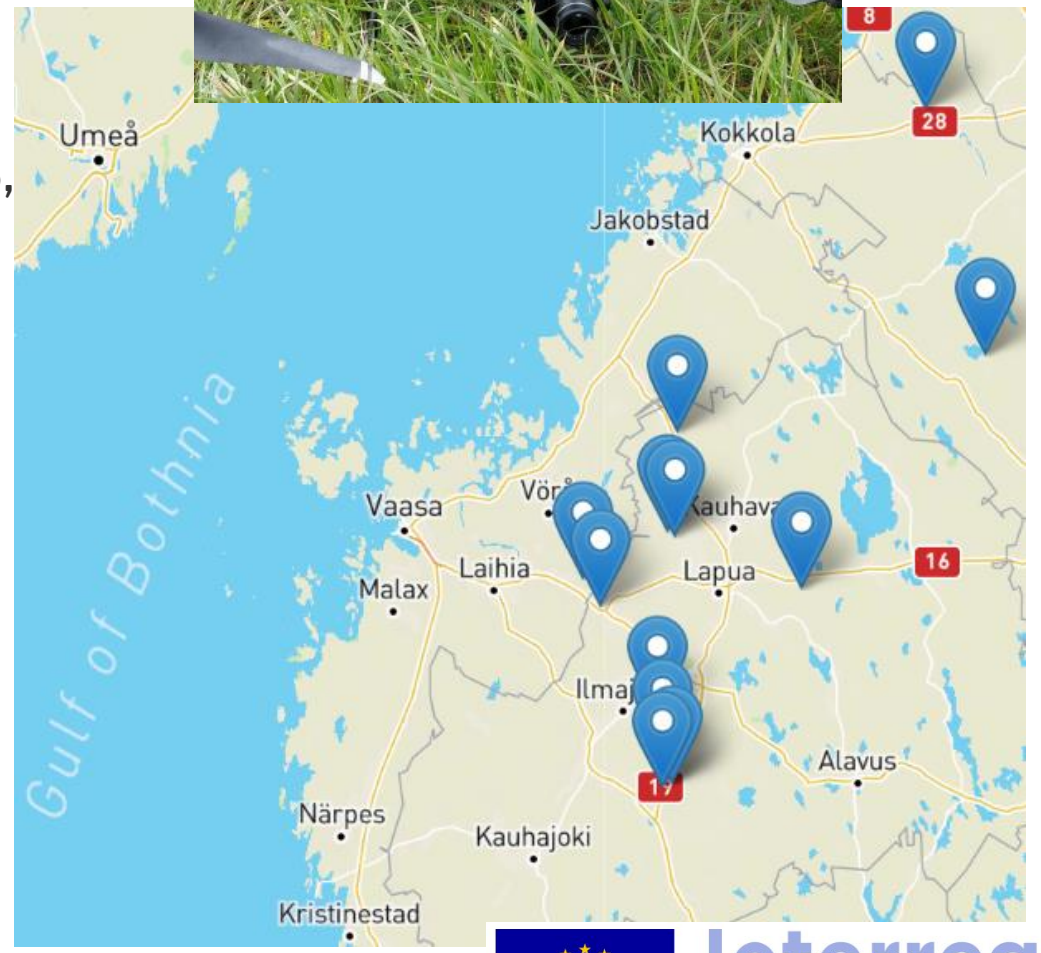
Drone data collection 2022

-44 flights

-Drones were flying 168km in the project

-19 datasets from 8 different farms (RGB, MS)

-Full time series from Isokyrö and Ylistaro trials (RGB, MS, HS)



Date 2022				
6.6		Farm	Koskenoja Jalasjärvi, 164	RGB
				MS
6.6		Farm	Koskenoja Jalasjärvi, 164	RGB
				MS
6.6		Farm	Savunen, Ilmajoki, 14503	RGB
				MS
6.6		Farm	Heikkilä, Ilmajoki, 14507	RGB
				MS
7.6		Farm	Aspila, Alahärmä, '00408	RGB
				MS
7.6		Farm	Sillanpää, Ylihärmä, 971	RGB
				MS
7.6		Farm	Sillanpää, Ylihärmä, 004	RGB
				MS
7.6		Farm	Kotala, Lapua, 40825339	RGB
				MS
10.6.		Farm	Aspila, Alahärmä, '00408	RGB
				MS
10.6		Farm	Patana, Veteli	RGB
				MS
10.6		Farm	Isohanni, Kannus	RGB
				MS
16.6		Plot trial	Boreal Isokyrö Jauri	RGB
				MS
				AFX10
				AFX17
16.6	Primary growth (1)	Plot trial	Boreal Ylistaro Pelmaa	RGB
				MS
				AFX10
				AFX17

18.7.2022		Farm	Koskenoja Jalasjärvi, 164	RGB
				MS
18.7.2022		Farm	Koskenoja Jalasjärvi, 164	RGB
				MS
18.7.2022		Farm	Heikkilä, Ilmajoki, 14507	RGB
				MS
19.7.2022		Farm	Sillanpää, Ylihärmä, 971	RGB
				MS
19.7.2022		Farm	Sillanpää, Ylihärmä, 004	RGB
				MS
19.7.2022		Farm	Aspila, Alahärmä, '00408	RGB
				MS
19.7.2022		Farm	Kotala, Lapua, 40825339	RGB
				MS
20.7.2022		Farm	Savunen, Ilmajoki, 14503	RGB
				MS
25.7.2022		Plot trial	Boreal Isokyrö Jauri	RGB
				MS
				AFX10
				AFX17
25.7.2022	Regrowth (2)	Plot trial	Boreal Ylistaro Pelmaa	RGB
				MS
				AFX10
				AFX17
7.9.2022		Plot trial	Boreal Isokyrö Jauri	RGB
				MS
				AFX10
7.9.2022	Regrowth (3)	Plot trial	Boreal Ylistaro Pelmaa	RGB
				MS
				AFX10

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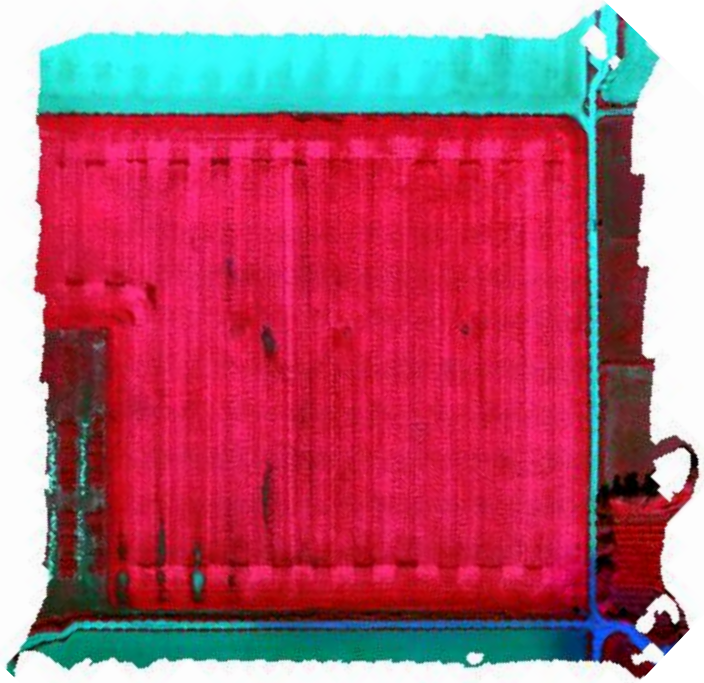
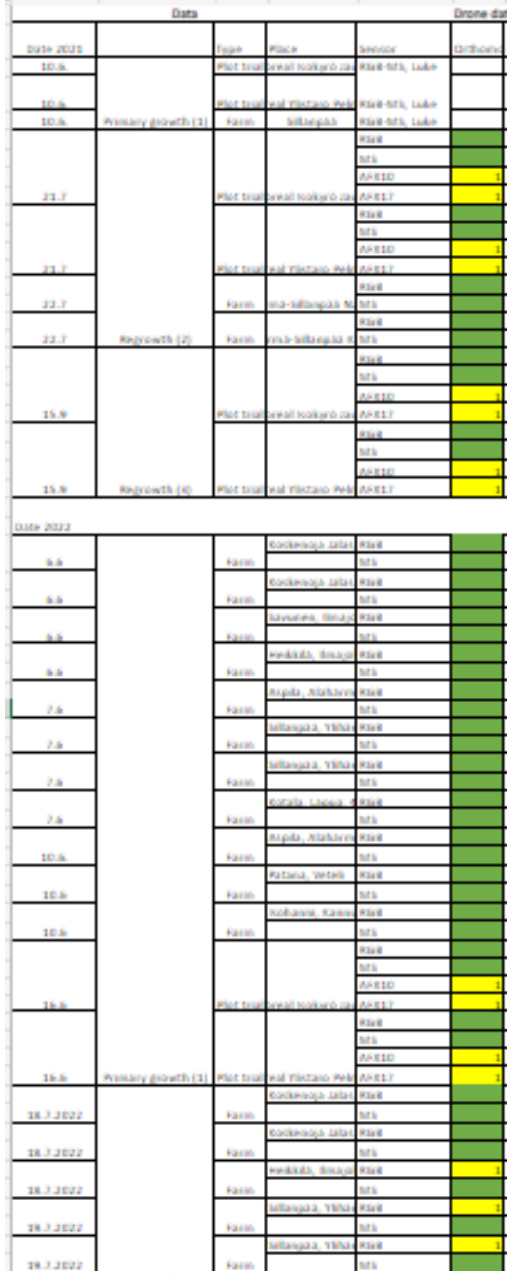
Data processing to orthomosaics

-85% in total of real farm datasets and 100% of multispectral datasets of those has been processed
-Efforts to standardize data collection and processing in Finland and Sweden
-Swedish data was processed in Finland



A multispectral orthomosaic from Sweden

Data processing of FGI data, green indicates the ready mosaics



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Estimating grass parameters - results

- Cases 1 and 2
  - Experimental trials
  - Multispectral data
  - Handcraft features and machine learning
- Case 3
  - Experimental trial
  - Comparison of different data sources
    - RGB, MS, HS-VNIR, HS-SWIR, CHM
  - Handcraft features and machine learning
- Case 4
  - Experimental trial
  - Novel deep learning methods
- Case 5
  - Real farm parcels

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Experiences of grass stand yield and quality estimation by **multispectral** drone data 2021 - trial (case 1)

-Boreal (tall) fescue trial in Isokyrö

- 240 plots
- No separate nitrogen levels - > low variation
- Regrowth (3rd cut) imaging date 15.9.2021

-Regression results using machine learning algorithm (random forest) and 10-fold cross validation repeated 10 times.

	NRMSE (%)	PCC	R^2
DMY	8.48	0.64	0.40
FY	7.00	0.58	0.34
D-value	1.65	0.17	-0.02

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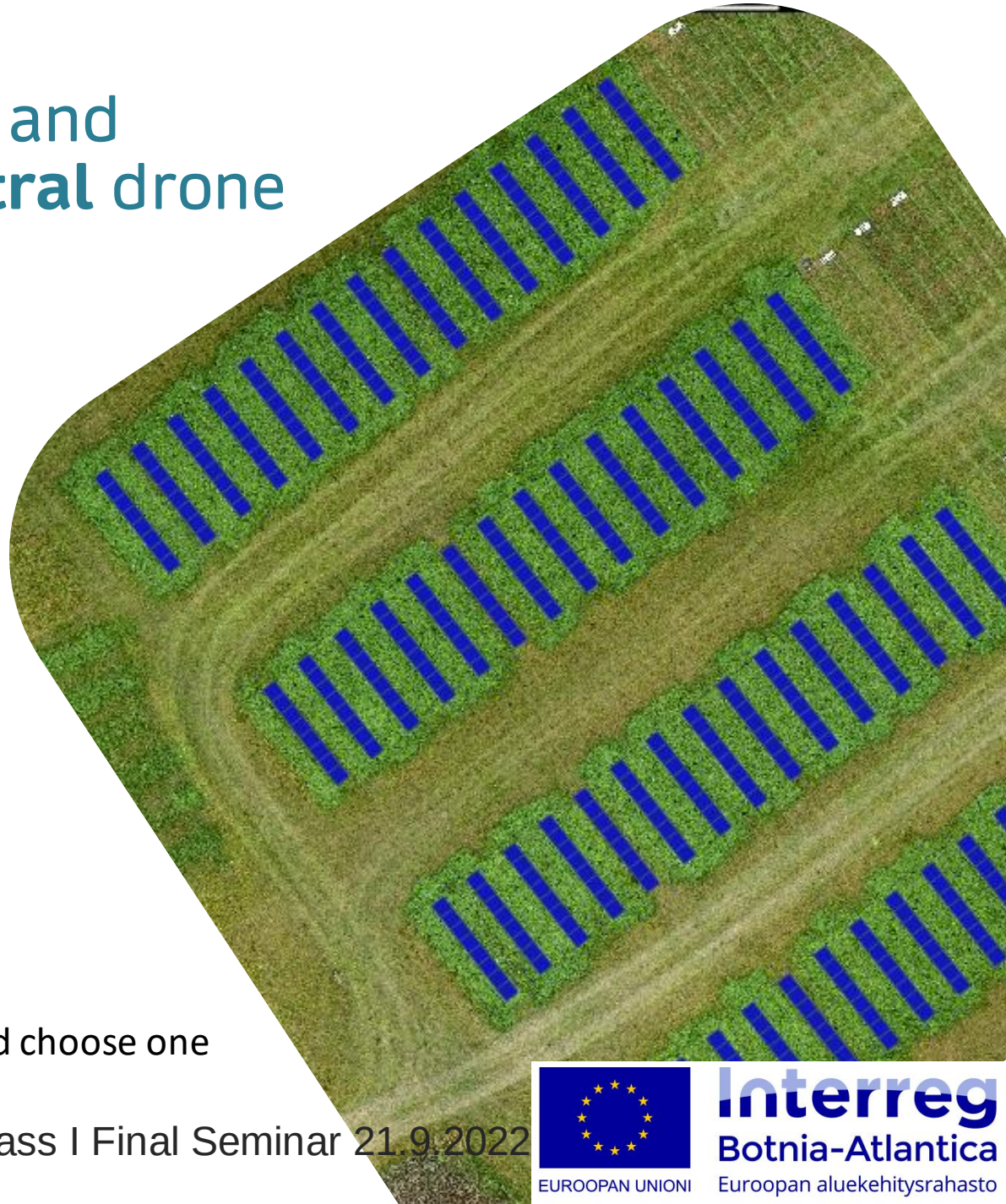
Experiences of grass stand yield and quality estimation by **multispectral** drone data 2021 - trial (case 2)

- Nitrogen trial at Luke Maaninka research center (outside of Cybergrass area)
  - 60 reference plots
  - Nitrogen vary from 0-200 kg/ha for the first cut
  - Primary growth:
    - Imaging date 9.6.2021
    - Harvesting date 10.6.2021

	NRMSE	PCC	R^2
DMY	8.11	0.92	0.84
FY	7.66	0.95	0.89
D-value	1.61	0.55	0.30



Regression results using random forest, which used 500 trees and choose one third of the features at each split.

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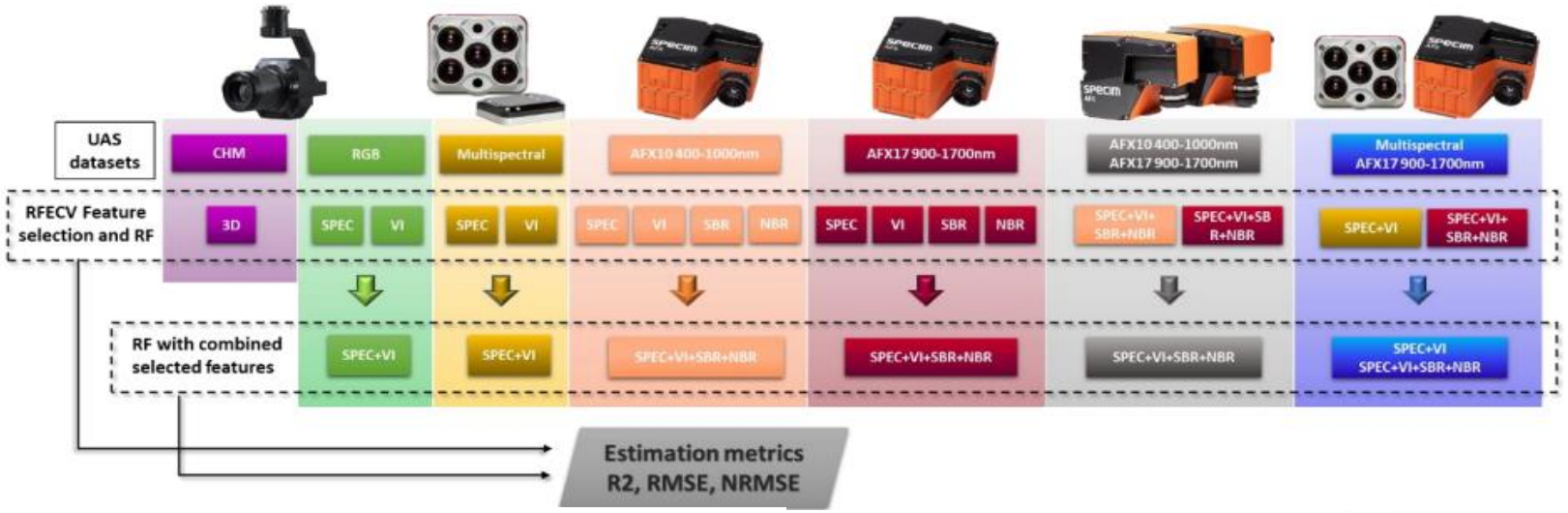
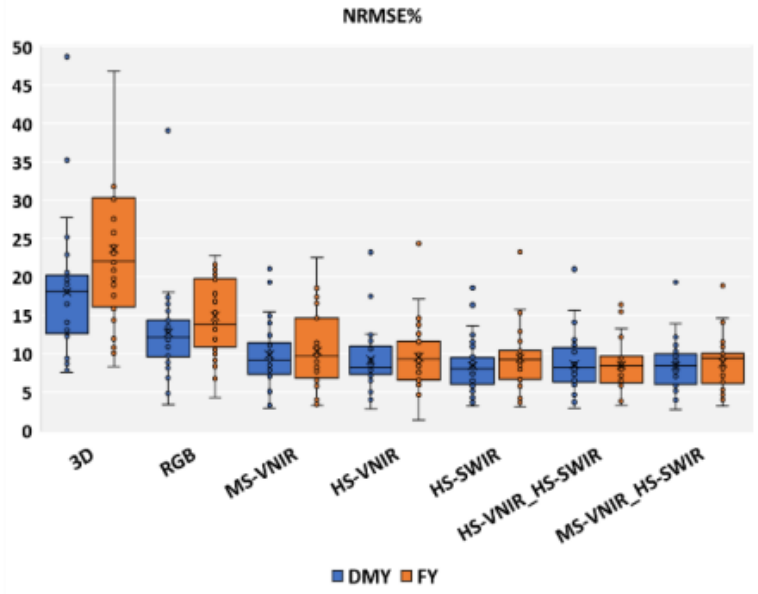
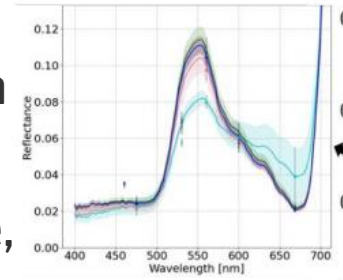
Experiences of grass stand yield and quality estimation by drone data 2021 - comparison of different data sources (case 3)

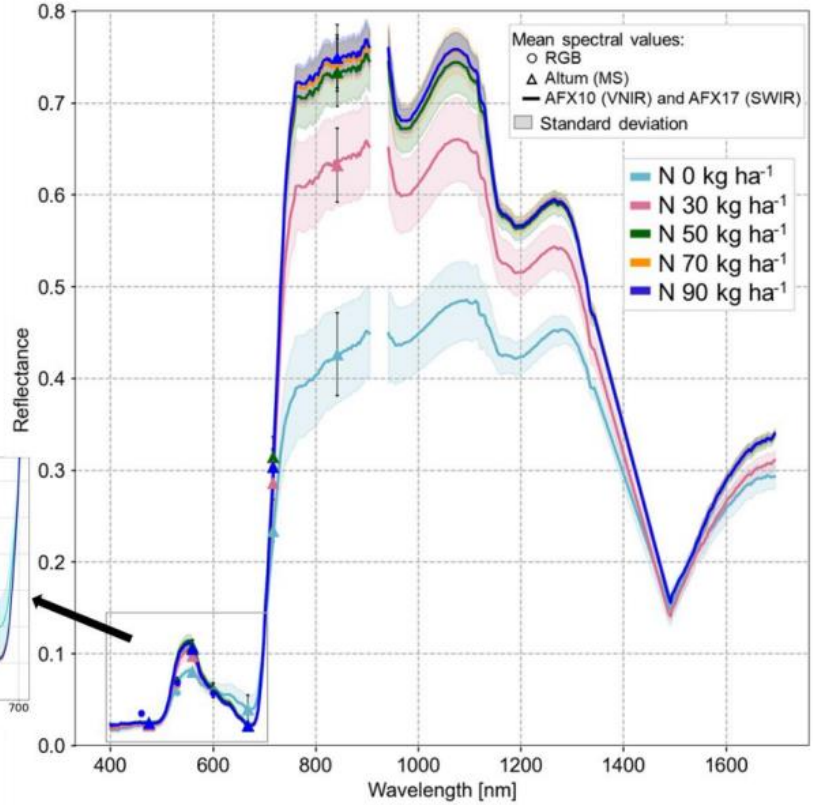




-Maaninka nitrogen trial, 3rd cut

-New spectal range, SWIR (AFX17), was boosting the accuracy of many parameters





Oliveira et 2022. Submitted manuscript: High-precision estimation of grass quality and quantity by using UAS-based VNIR and SWIR hyperspectral cameras and machine learning

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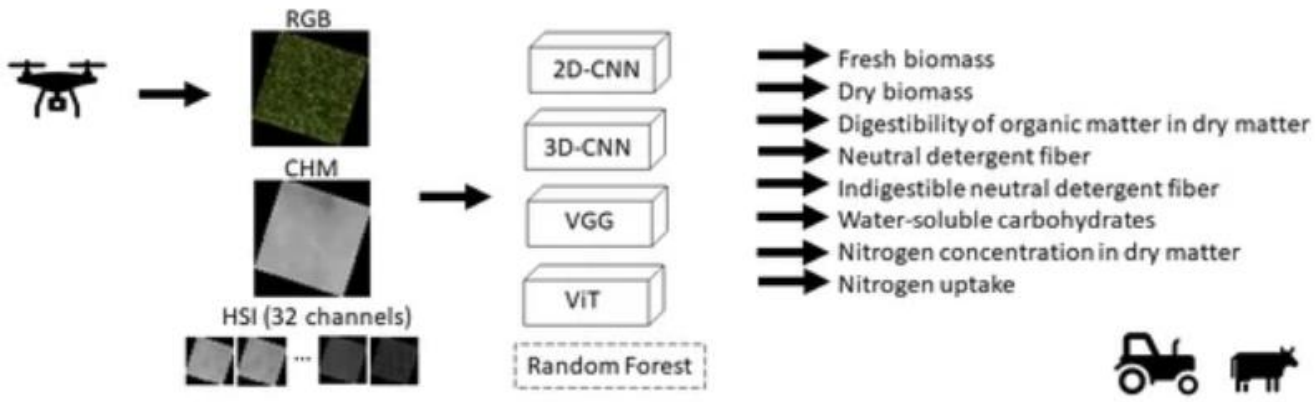
A study to analyze if enhanced deep neural networks could still improve the estimation accuracies (case 4)

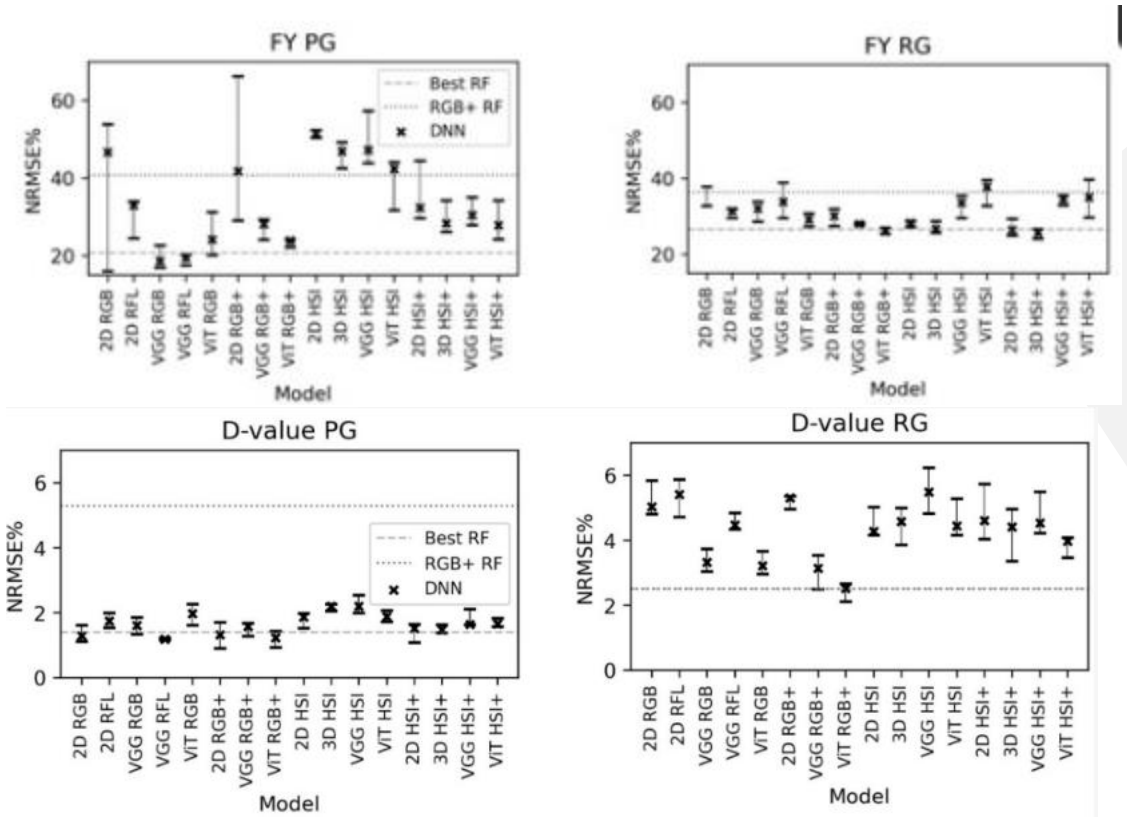
-Study to investigate the potential of novel neural network architectures for measuring the quality and quantity

-RGB, CHM and hyperspectral images

-Comparison of the results with the random forest (RF) method

-Improvements were seen especially using RGB data to many quality and quantity parameters





Karila K, Alves Oliveira R, Ek J, Kaivosoja J, Koivumäki N, Korhonen P, Niemeläinen O, Nyholm L, Näsi R, Pölönen I, Honkavaara E. Estimating Grass Sward Quality and Quantity Parameters Using Drone Remote Sensing with Deep Neural Networks. *Remote Sensing*. 2022; 14(11):2692. https://doi.org/10.3390/rs14112692

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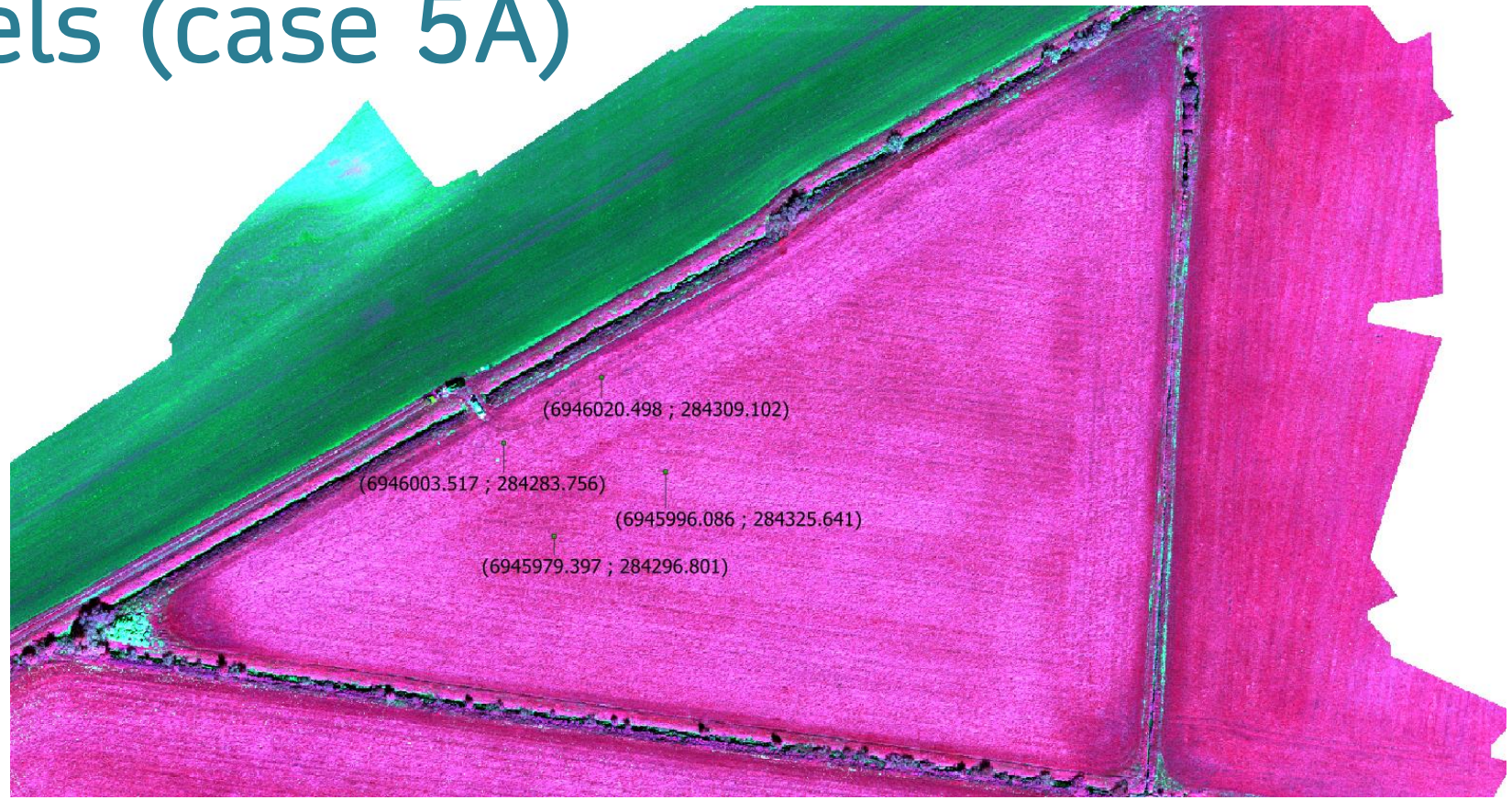
Estimation of fresh yield in real farm parcels (case 5A)



False-color composite image of parcel with sampling locations

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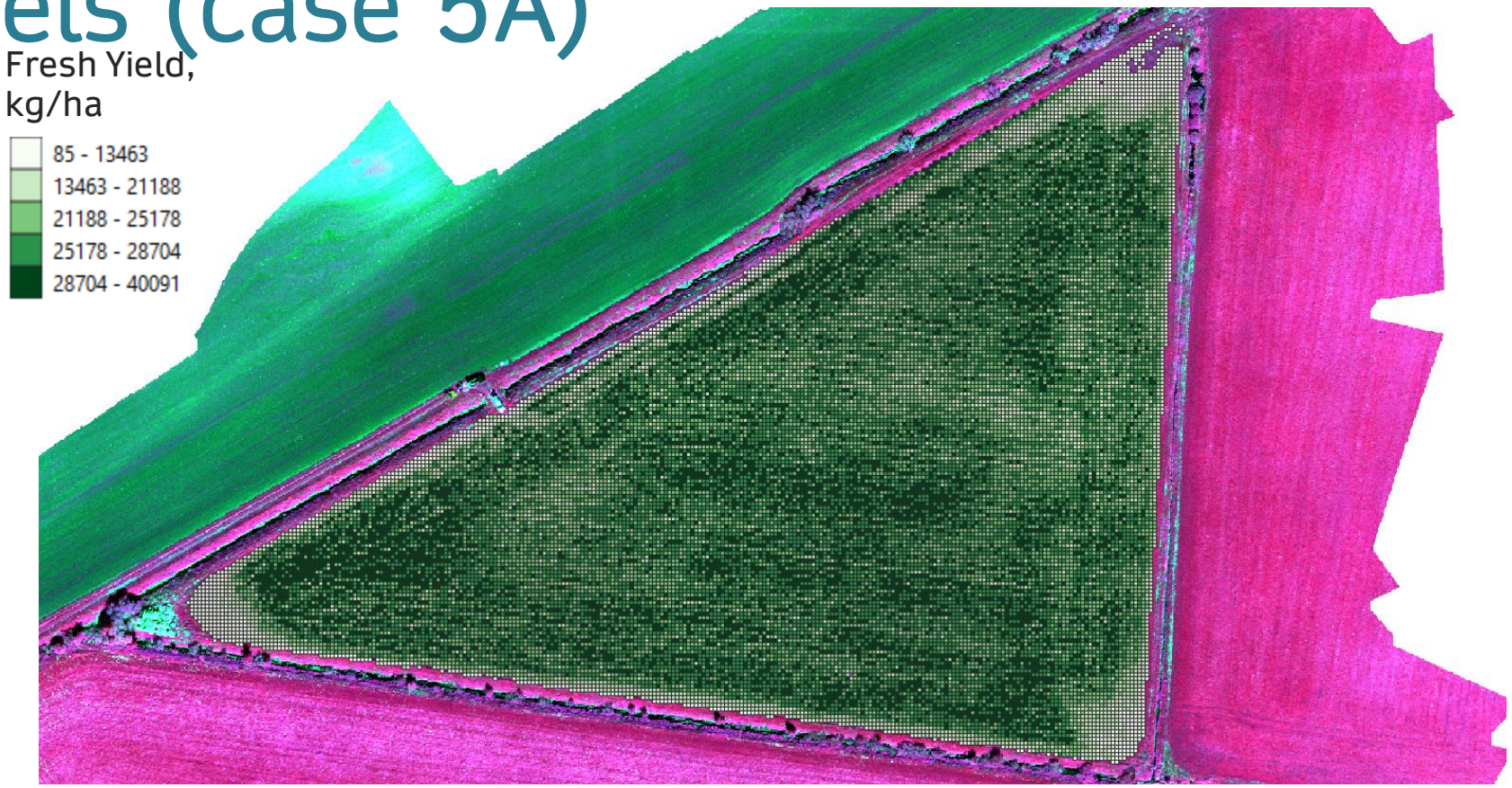
Estimation of fresh yield in real farm parcels (case 5A)



False-color composite with fresh yield values

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Estimation of fresh yield in real farm parcels (case 5A) statistics

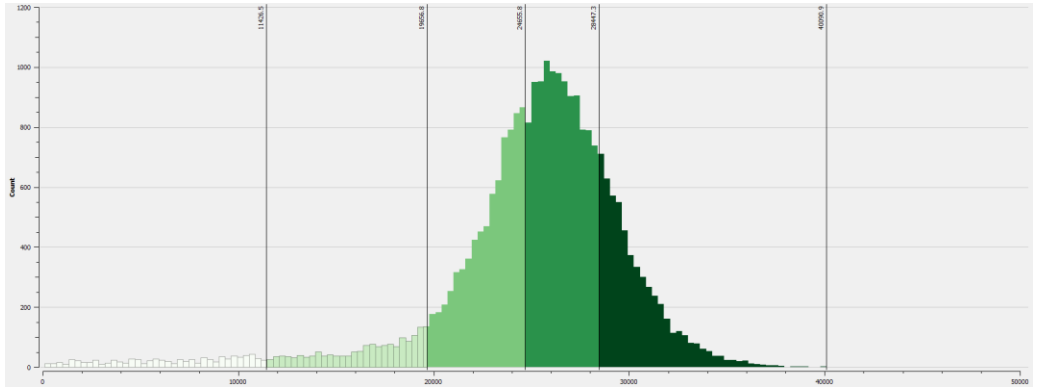
Fresh yield reference values from the topmost sample (kg/ha):

1. 23440
2. 19120
3. 18800
4. 25120

Avg. 21620

For the linear model the dark median spectra of 842 nm feature was used. The correlation between the samples was 0.936 with the used feature.

With that model we resulted an average fresh yield estimation of 25069 kg/ha for the whole field. The total fresh yield estimation for the whole field was **66.4 tkg**.



Histogram of full parcel fresh yield estimation data distribution

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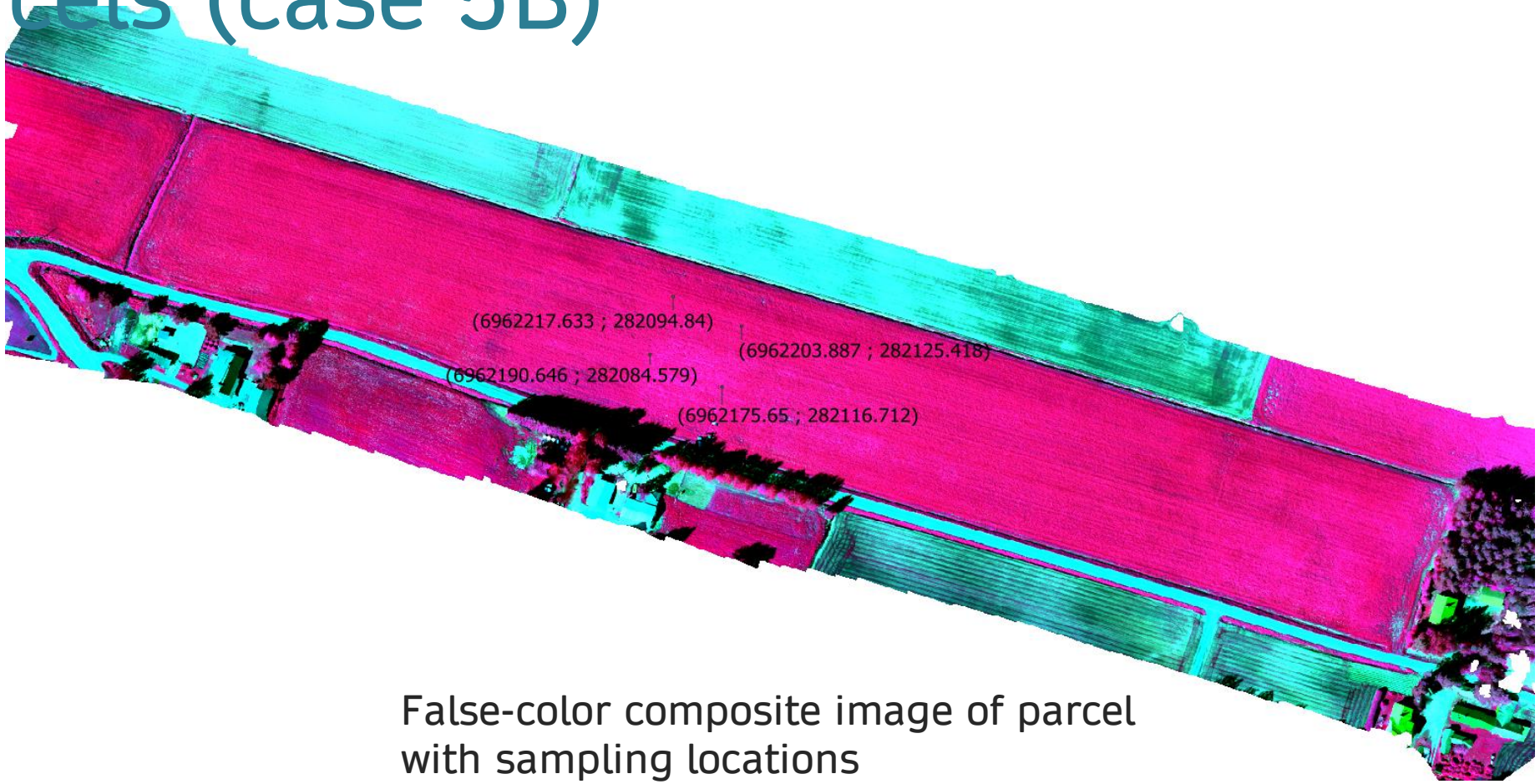
Estimation of fresh yield in real farm parcels (case 5B)



False-color composite image of parcel with sampling locations

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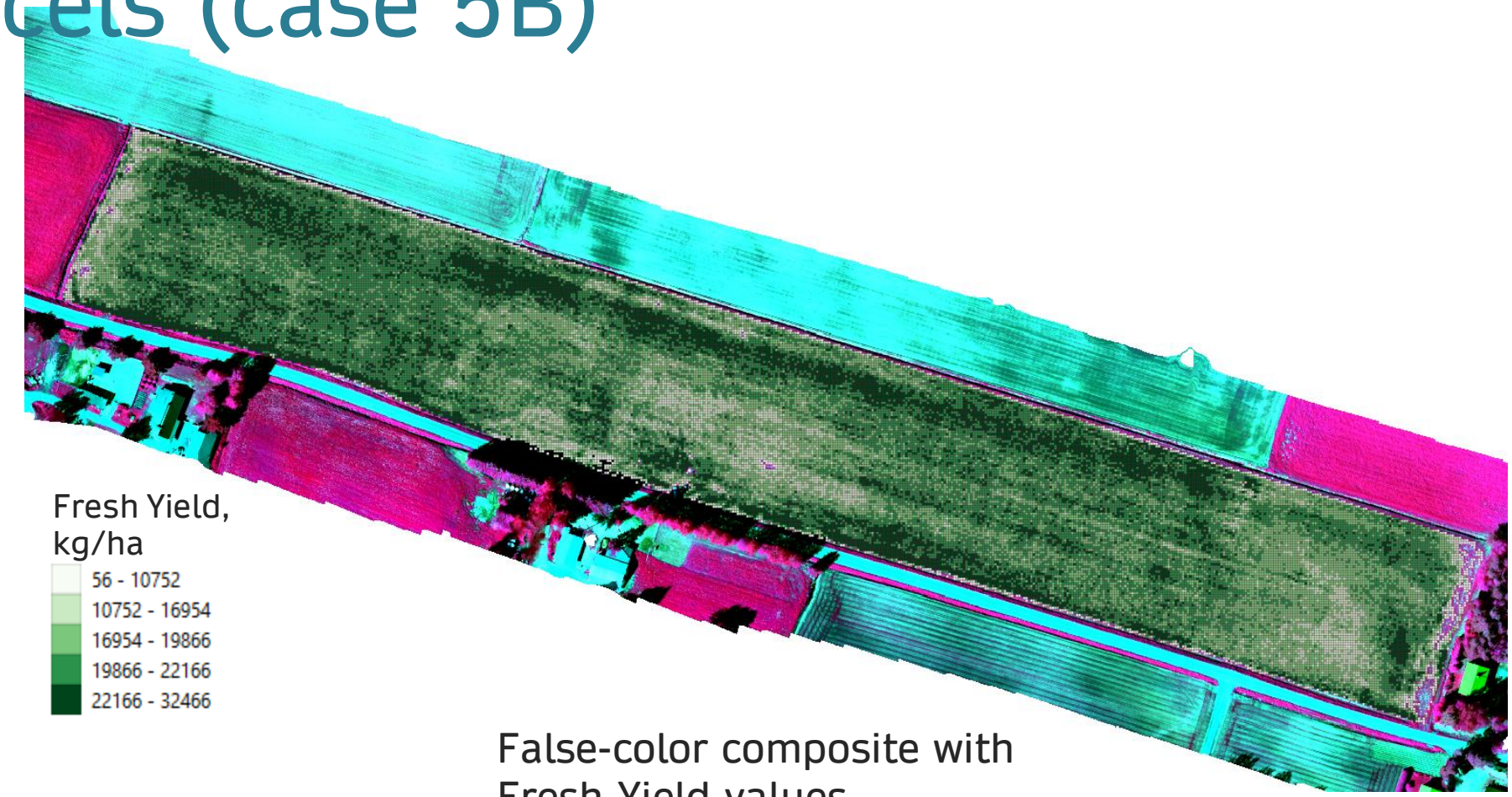
Estimation of fresh yield in real farm parcels (case 5B)



False-color composite with Fresh Yield values

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Estimation of fresh yield in real farm parcels (case 5B) statistics

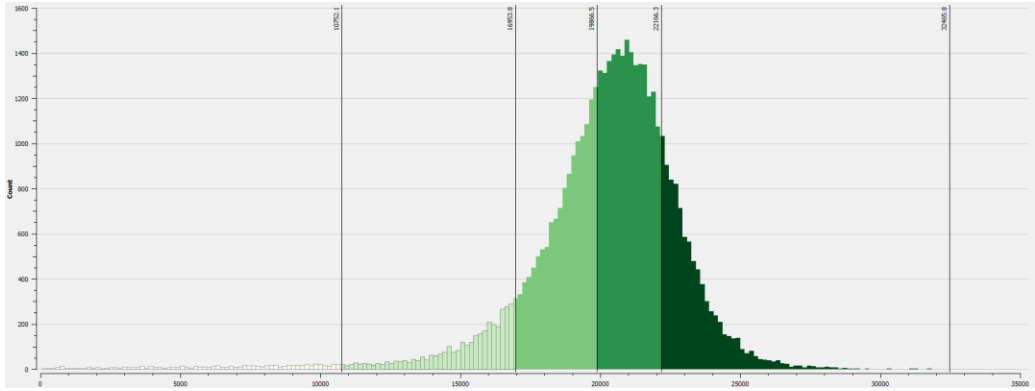
Fresh yield reference values from the topmost sample (kg/ha):

1. 24280
2. 16320
3. 20040
4. 17960

Avg. 19650

For the linear model the normalized mean spectra of 475 nm feature was used. The correlation between the samples was -0.931 with the used feature.

With that model we resulted an average fresh yield estimation of 20119,4 kg/ha for the whole field. The total fresh yield estimation for the whole field was **91,4 tkg.**



Histogram of full parcel fresh yield estimation data distribution

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Conclusions and future research

- Conclusions
  - New sensors and deep learning algorithms are boosting the estimation accuracies
  - Fresh and dry matter yields easier to estimate than quality parameters
- Future research
  - Taking advantage of different data sources
    - Remote sensing data
    - Growth models, weather etc.
  - Development towards more real-time or near-real-time solutions

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