Nordic silage production development by remote sensing, crop growth models and artificial intelligence in CyberGrass I project

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Contents of presentation: Background info and work packages

WP 1. Test sites , satellite and drone measurements and estimations

WP 2. Developing prediction models for yield quantity and quality estimation

WP 3. Decision Support System for grass silage sward management

WP 4. Dissemination

(WP 5. Project Management)

The provinces in Interreg Botnia Atlantica region:

In Sweden the areas in BA are:

Västerbottens län (Övre Norrland)

Västernorrlands län (Mellersta Norrland)

Gävleborgs län (Norra Mellansverige)

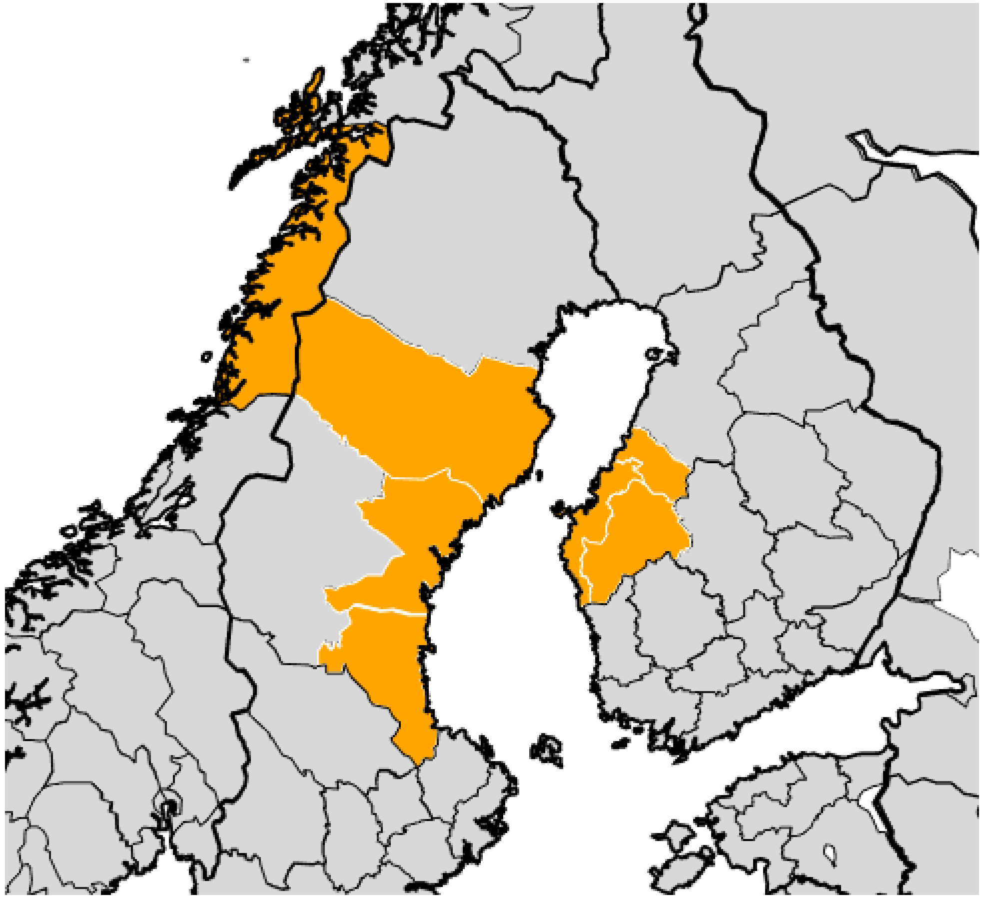
All areas are in NORRA SVERIGE.

In Finland:

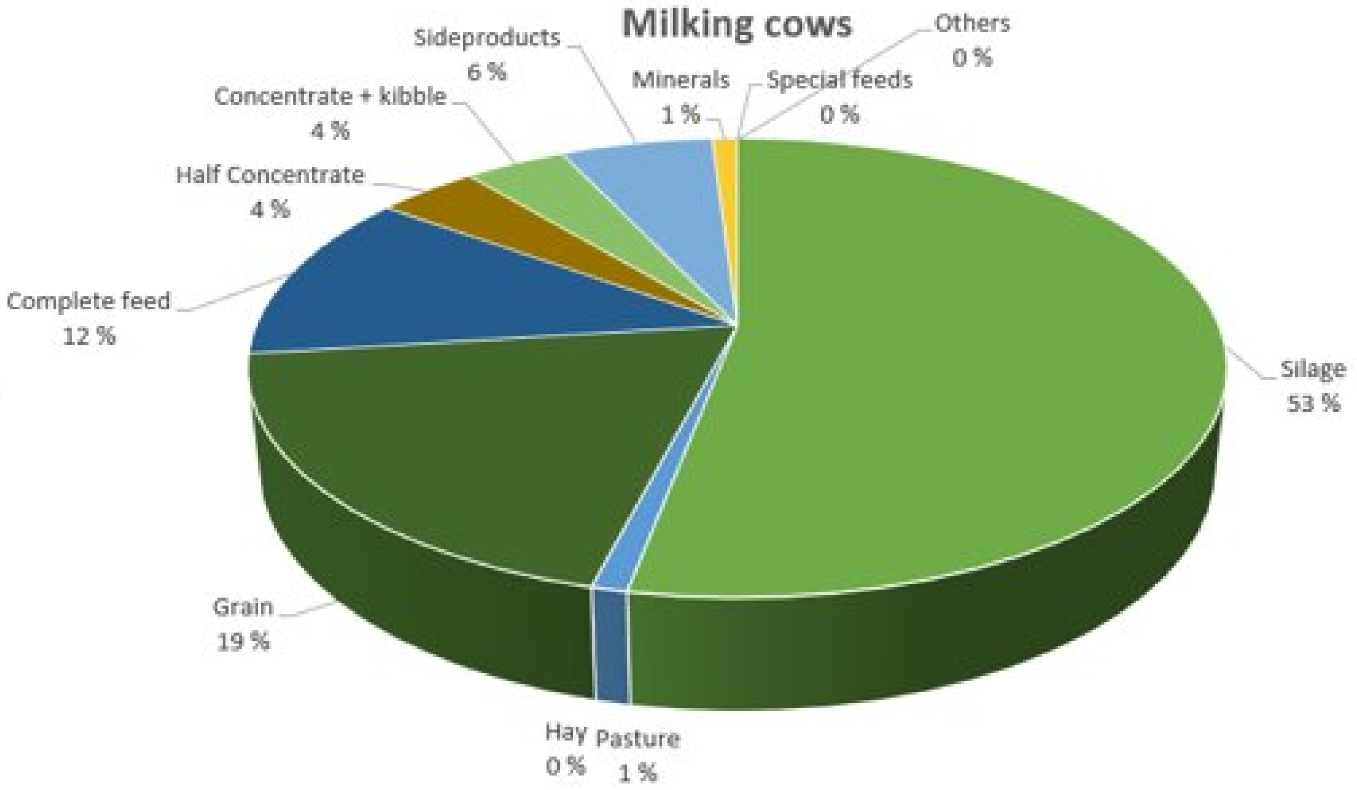
Pohjanmaa (Ostrobotnia)

Etelä-Pohjanmaa (South Ostrobothnia)

Keski-Pohjanmaa (Middle Ostrobothnia



Silage is the most important constituent of ruminant diets in the study region



Problem and how to solve it

The silage swards is growing fast and the quality is changing rapidly, especially in the spring

Assessing the quantity and quality of the yield per hectare is difficult because

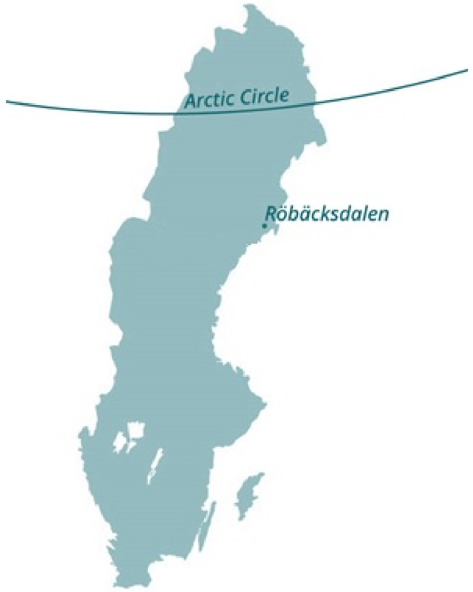
- the dry matter content has a large effect on the dry matter yield
- crop sampling is laborious and sample processing is laborious

The quantity and quality of the silage yield is of great importance to the economy of livestock farms

->there is need to develop methods for estimating the yield from growing grass stands. Remote sensing and growth modeling make it possible.

In CyberGrass I we have done sampling and drone imaging and satellite follow up on pilot farms and experiments in 2021 and in 2022 and developed grass growth modelling. Collaboration with pilot farmers, Boreal Plant Breeding and ValioArtturi is highly appreciated by the project.

Sampling in Sweden



2021

- 2 fields
- Harvest 1, two sample dates
- Harvest 2, three sample dates
- Harvest 3, one sample date

2022

- 3 fields
- Harvest 1, three sample dates
- Harvest 2, two sample dates
- Harvest 3, four sample dates

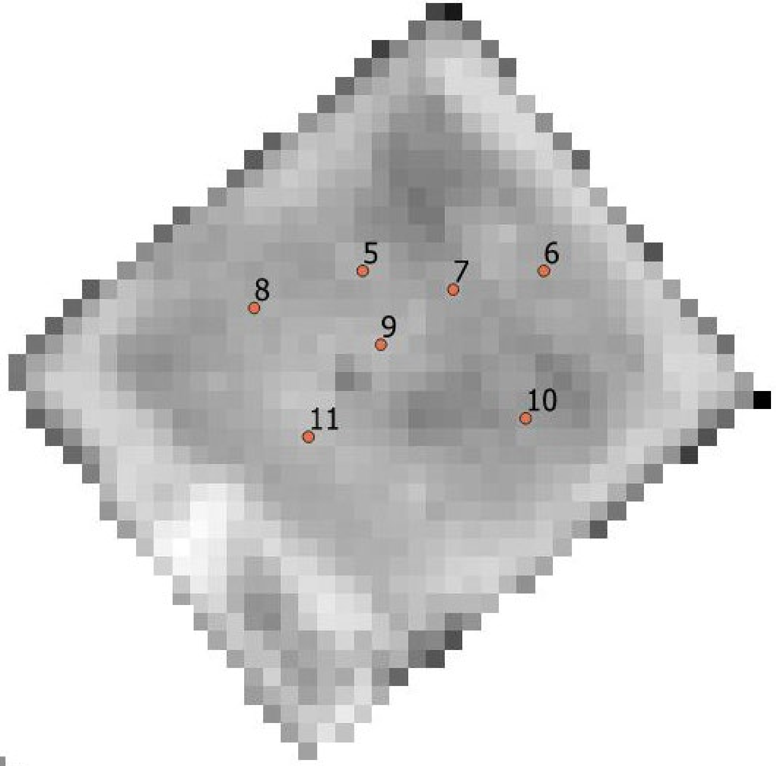
Choosing pixels for sampling

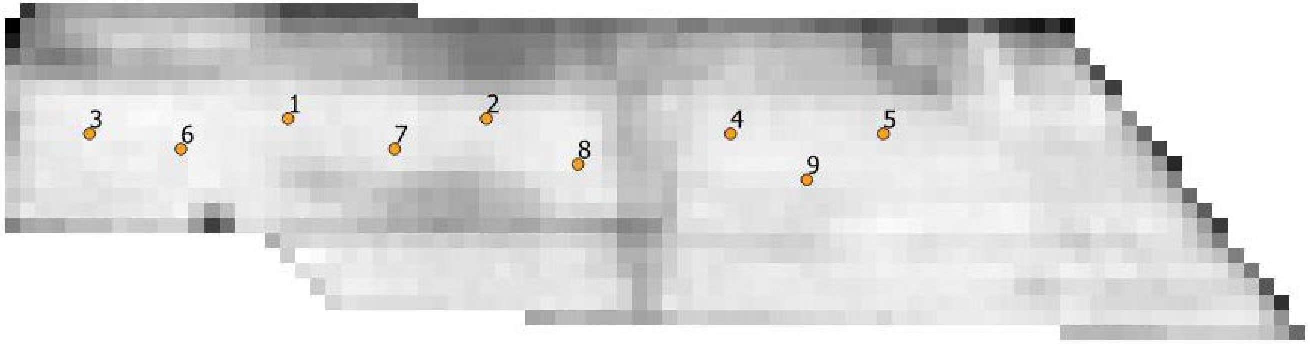
NDVI using satellite images

- 10x10 m

Two pixels sampled per field and sampling date

- Three quadrats per pixel



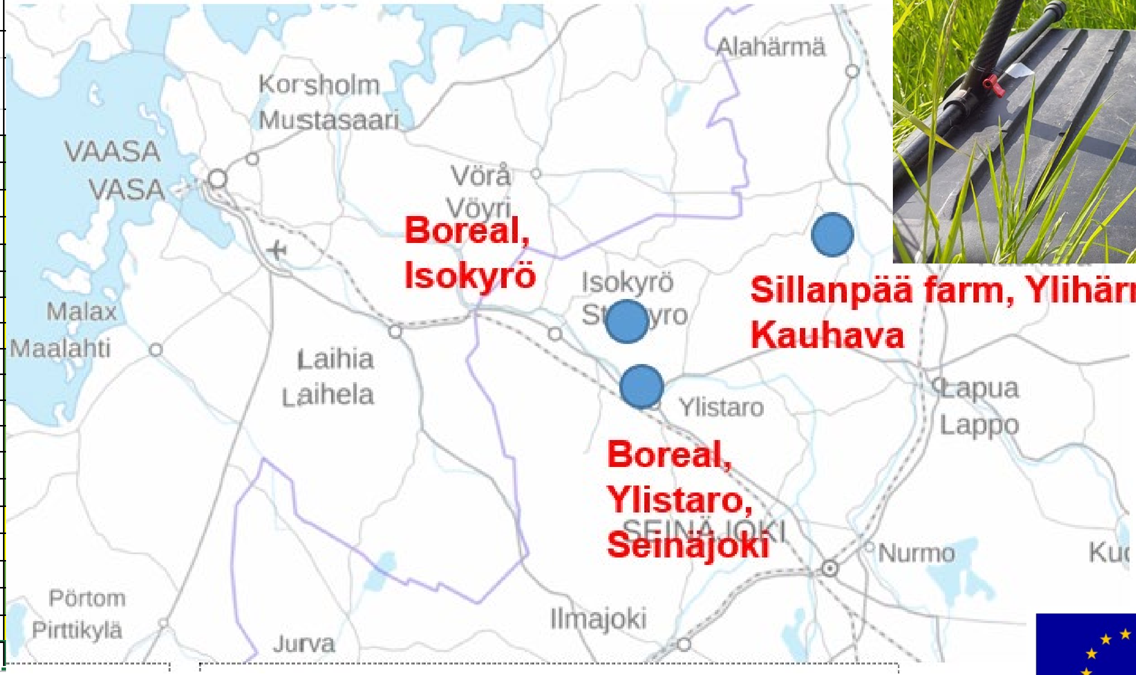


Drone data collection 2021 by FGI

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

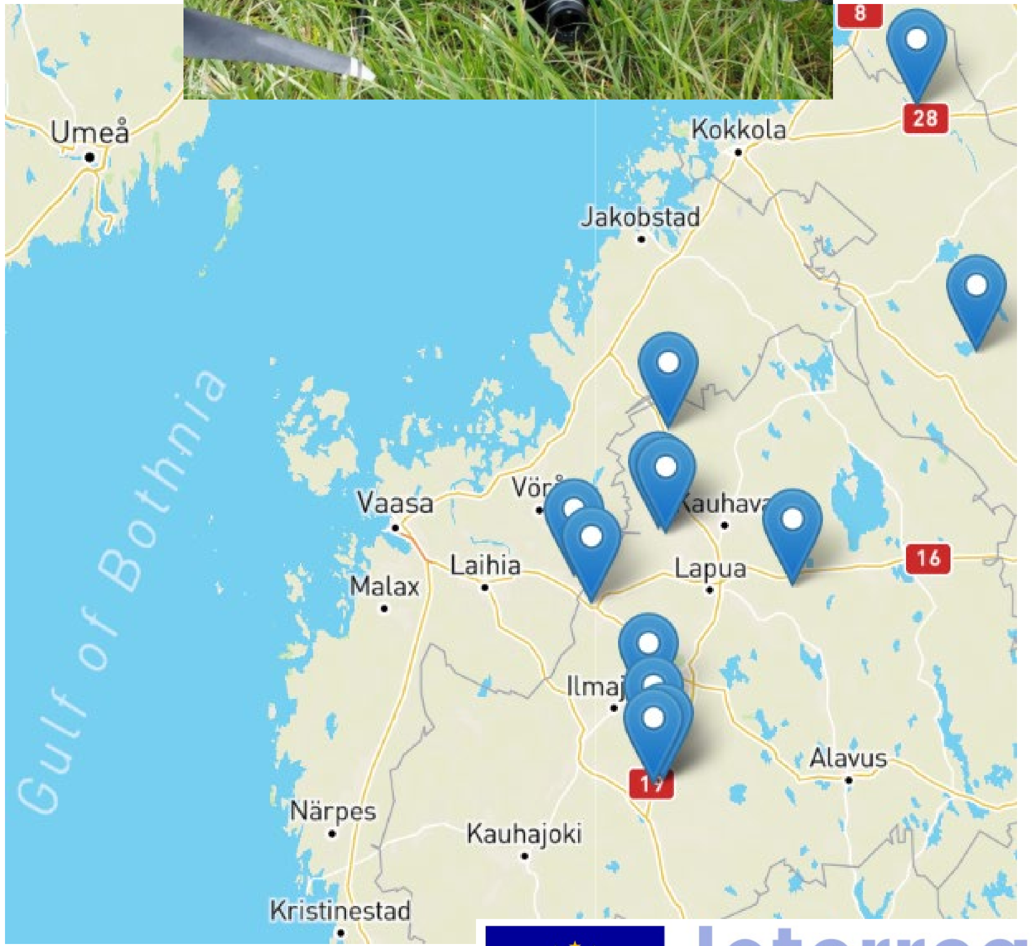


Drone data collection 2022 by FGI

- 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				
			Koskenoja Jalasjärvi, 164	RGB
6.6		Farm		MS
			Koskenoja Jalasjärvi, 164	RGB
6.6		Farm		MS
			Savunen, Ilmajoki, 14503	RGB
6.6		Farm		MS
			Heikkilä, Ilmajoki, 14507	RGB
6.6		Farm		MS
			Aspila, Alahärmä, '00408	RGB
7.6		Farm		MS
			Sillanpää, Ylihärmä, 9710	RGB
7.6		Farm		MS
			Sillanpää, Ylihärmä, 0040	RGB
7.6		Farm		MS
			Kotala, Lapua, 40825339	RGB
7.6		Farm		MS
			Aspila, Alahärmä, '00408	RGB
10.6.		Farm		MS
			Patana, Veteli	RGB
10.6		Farm		MS
			Isohanni, Kannus	RGB
10.6		Farm		MS
				RGB
				MS
				AFX10
16.6		Plot trial	Boreal Isokyrö Jauri	AFX17
				RGB
				MS
				AFX10
16.6	Primary growth (1)	Plot trial	Boreal Ylistaro Pelmaa	AFX17

			Koskenoja Jalasjärvi, 164	RGB
18.7.2022		Farm		MS
			Koskenoja Jalasjärvi, 164	RGB
18.7.2022		Farm		MS
			Heikkilä, Ilmajoki, 14507	RGB
18.7.2022		Farm		MS
			Sillanpää, Ylihärmä, 9710	RGB
19.7.2022		Farm		MS
			Sillanpää, Ylihärmä, 0040	RGB
19.7.2022		Farm		MS
			Aspila, Alahärmä, '00408	RGB
19.7.2022		Farm		MS
			Kotala, Lapua, 40825339	RGB
19.7.2022		Farm		MS
			Savunen, Ilmajoki, 14503	RGB
20.7.2022		Farm		MS
			Boreal Isokyrö Jauri	RGB
				MS
				AFX10
25.7.2022		Plot trial		AFX17
			Boreal Ylistaro Pelmaa	RGB
				MS
				AFX10
25.7.2022	Regrowth (2)	Plot trial		AFX17
			Boreal Isokyrö Jauri	RGB
				MS
7.9.2022		Plot trial		AFX10
			Boreal Ylistaro Pelmaa	RGB
				MS
7.9.2022	Regrowth (3)	Plot trial		AFX10



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Sampling data prior to 1st cut and prior to 2nd cut in Finland. In total 11 fields in first cut and six fields for 2nd cut.

1st cut (6-10.6.2022)	Mean	Min	Max
Dry matter yield (kg DM/ha)	3176	1680	3945
Protein (g/kg DM)	193	130	223
D-value	741	722	758
Fresh Yield (kg/ha)	19140	9440	25200
2nd cut (18-19.7.2022)	**Mean**	**Min**	**Max**
Dry matter yield (kg DM/ha)	3843	2561	5443
Protein (g/kg DM)	178	123	207
D-value	695	641	731
Fresh Yield (kg/ha)	18170	10900	24520

Four sub sample quadrats on each field each (0,5 m by 0,5 m with area 0,25 m^2). Pooled sample 1 m^2. On some fields big difference in sub sample yields observed.

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

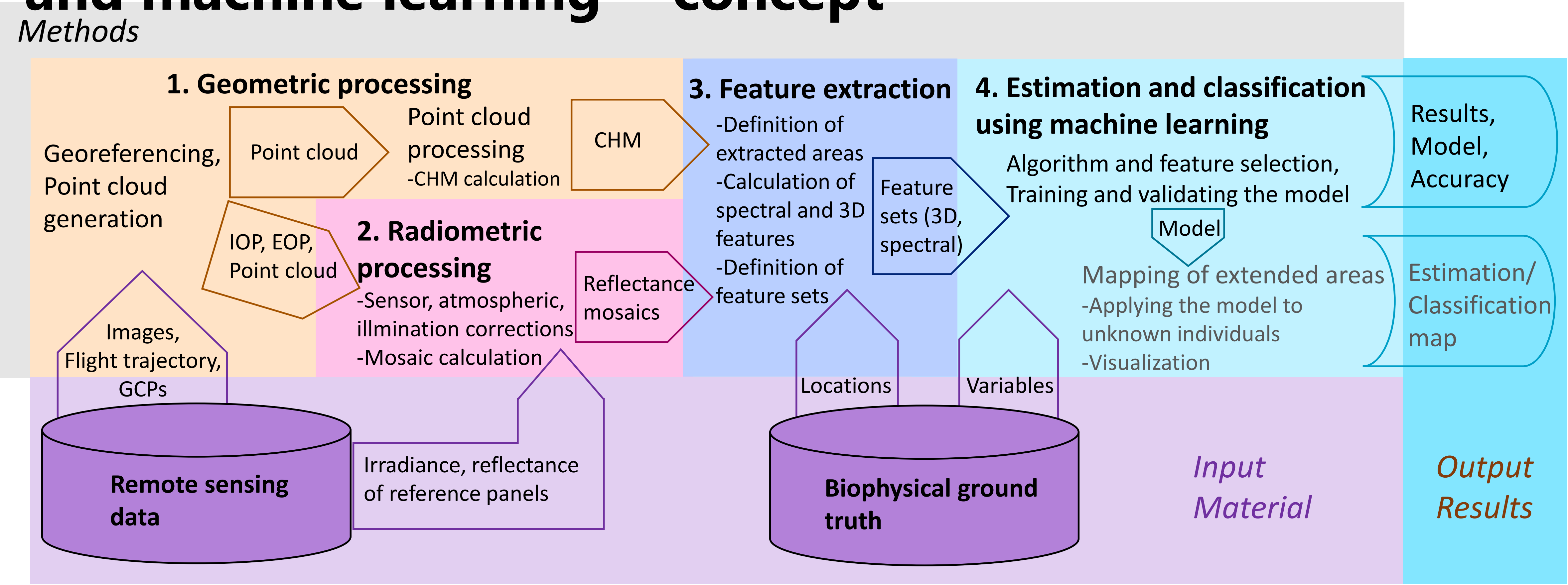

Figure: Näsi, R. (2021). Drone-based spectral and 3D remote sensing applications for forestry and agriculture. Doctoral Dissertation, Aalto University, School of Engineering. http://urn.fi/URN:ISBN:978-952-64-0613-8

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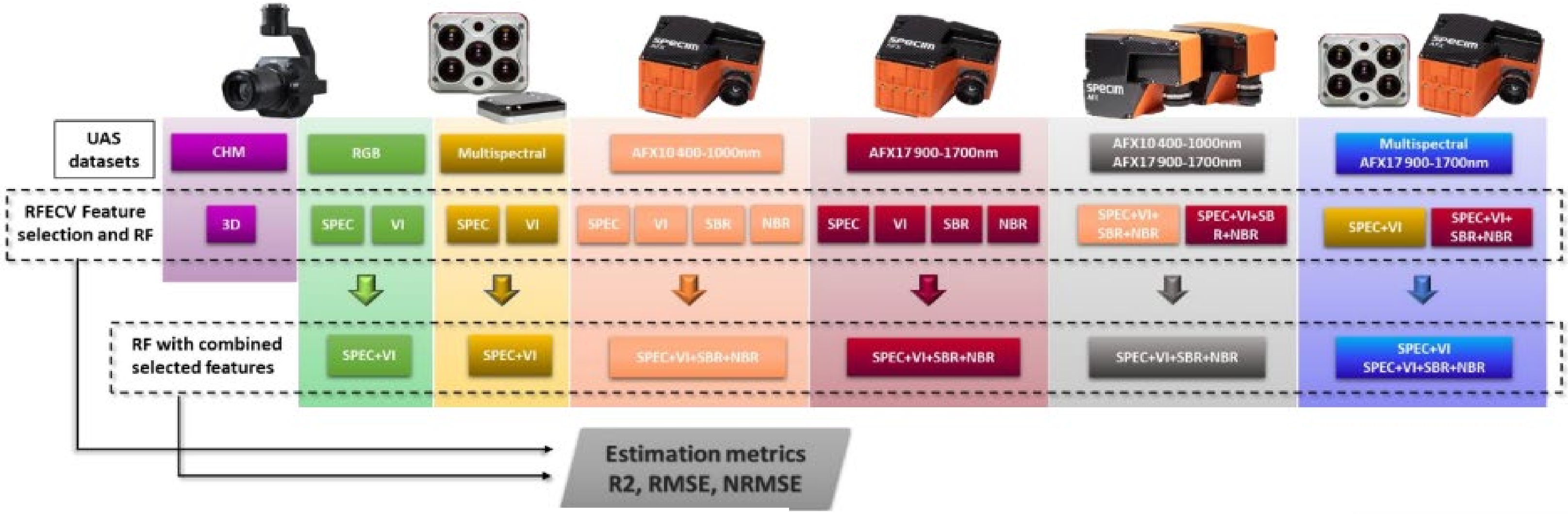
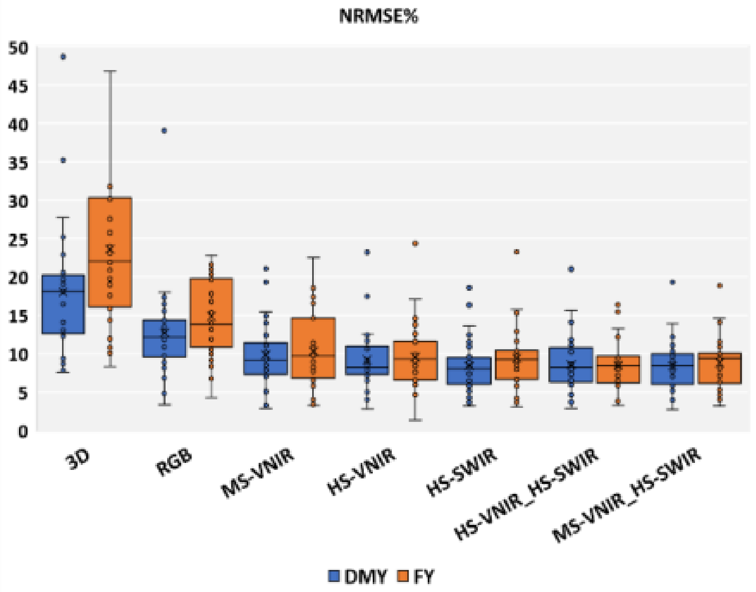
Estimating grass parameters
in the project results of five cases

- 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

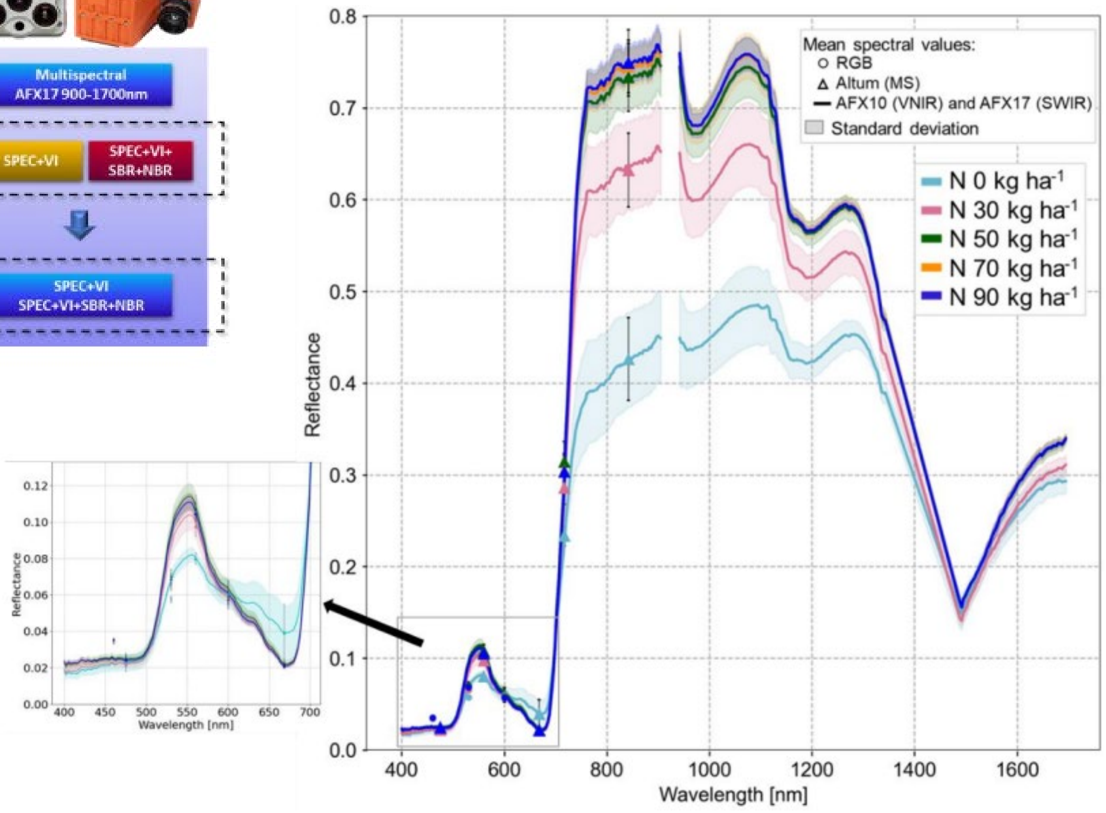
Experiences of grass stand yield and quality estimation by drone data 2021 - comparison of different data sources (case 3)





-Maaninka nitrogen trial, 3rd cut

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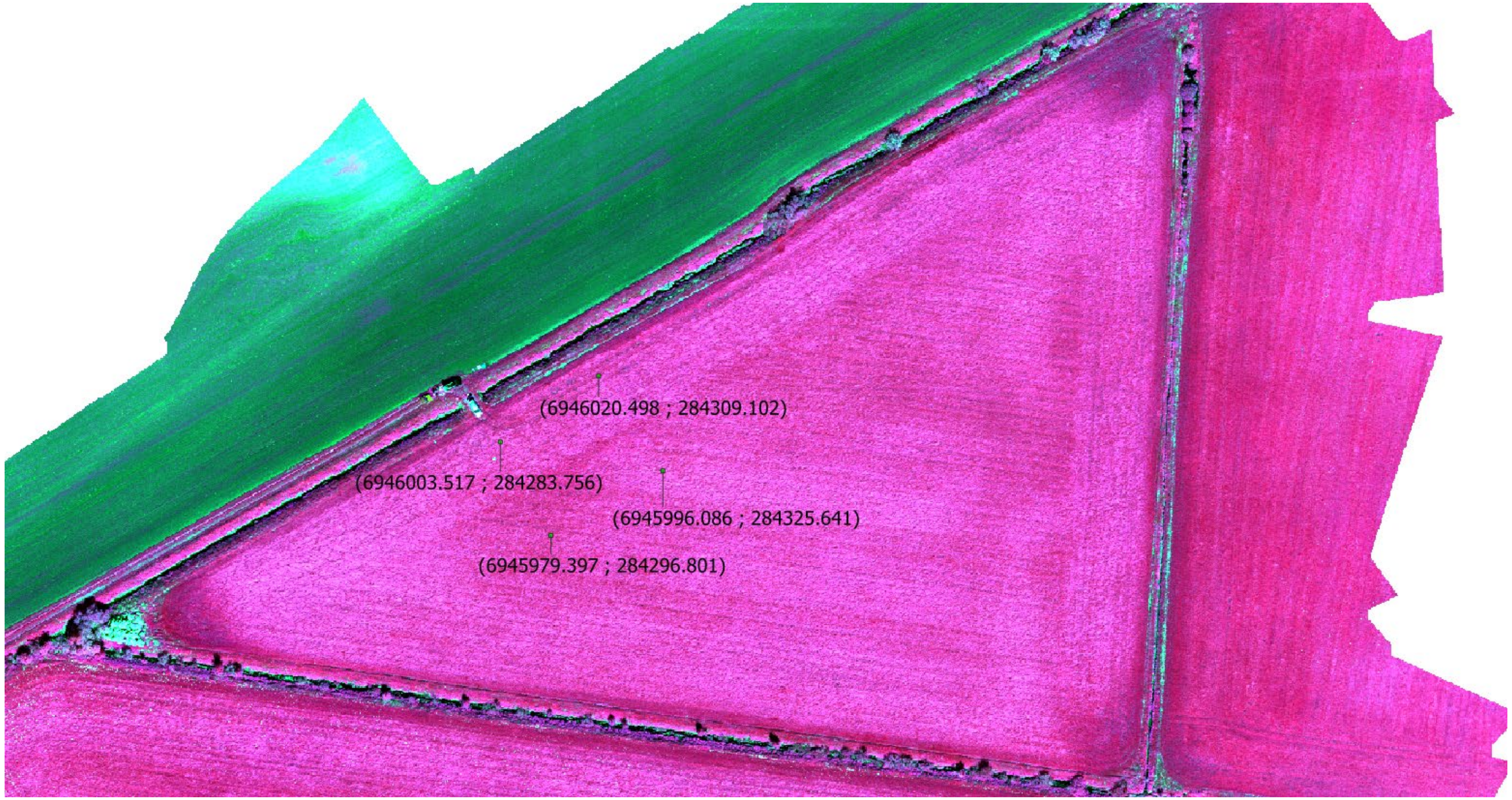
Estimation of fresh yield in real farm parcels (case 5A)



False-color composite image of parcel with sampling locations

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

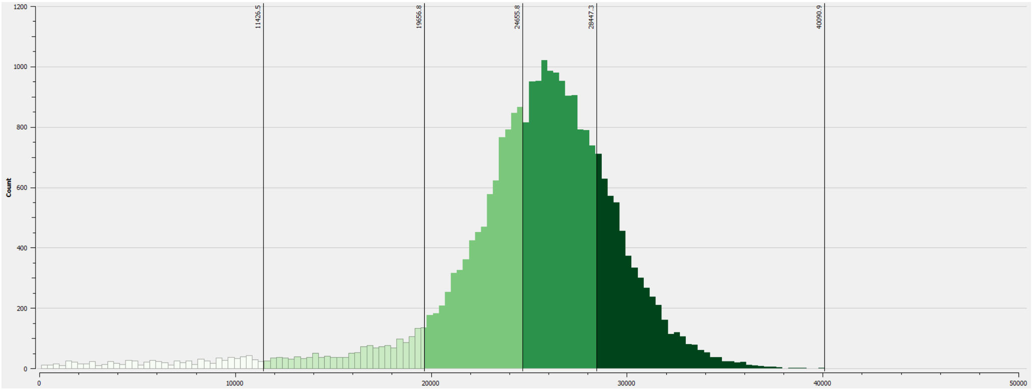
Fresh yield reference values from the topmost sample (kg/ha):

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

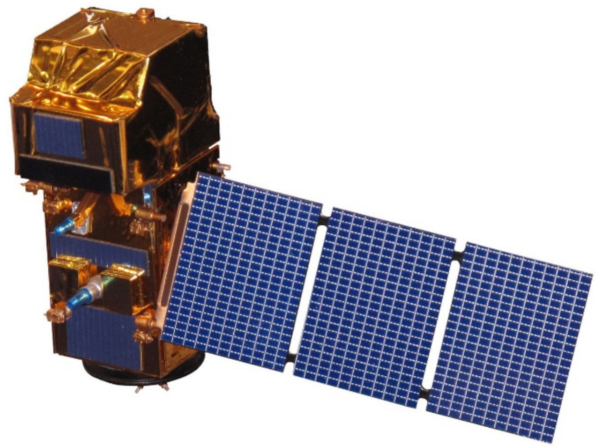
Satellites

Sentinel 1

- Active sensor (can be used at night)
- Microwaves (can see through clouds)

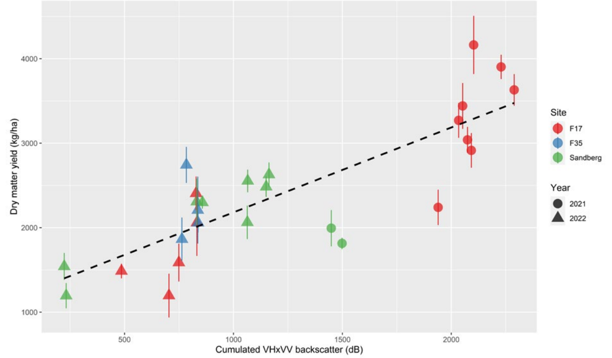
Sentinel 2

- Passive sensor
- Visible/NIR/SWIR spectral range
- Multispectral sensor (13 bands)



Workflow

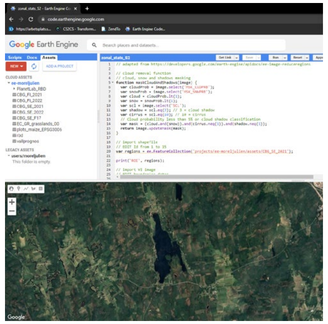
Sample dataset → Dry matter yields



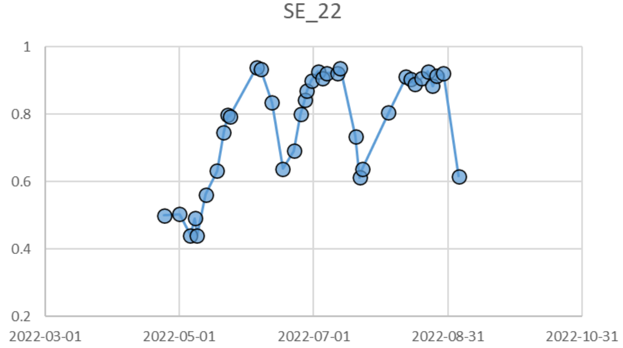
GPS coordinates

Regression models → Performance metrics

Extracting spectral values → VI/Time integrated VI/ML (Sentinel-2)
Time integrated backscatter (Sentinel-1)



Satellite dataset



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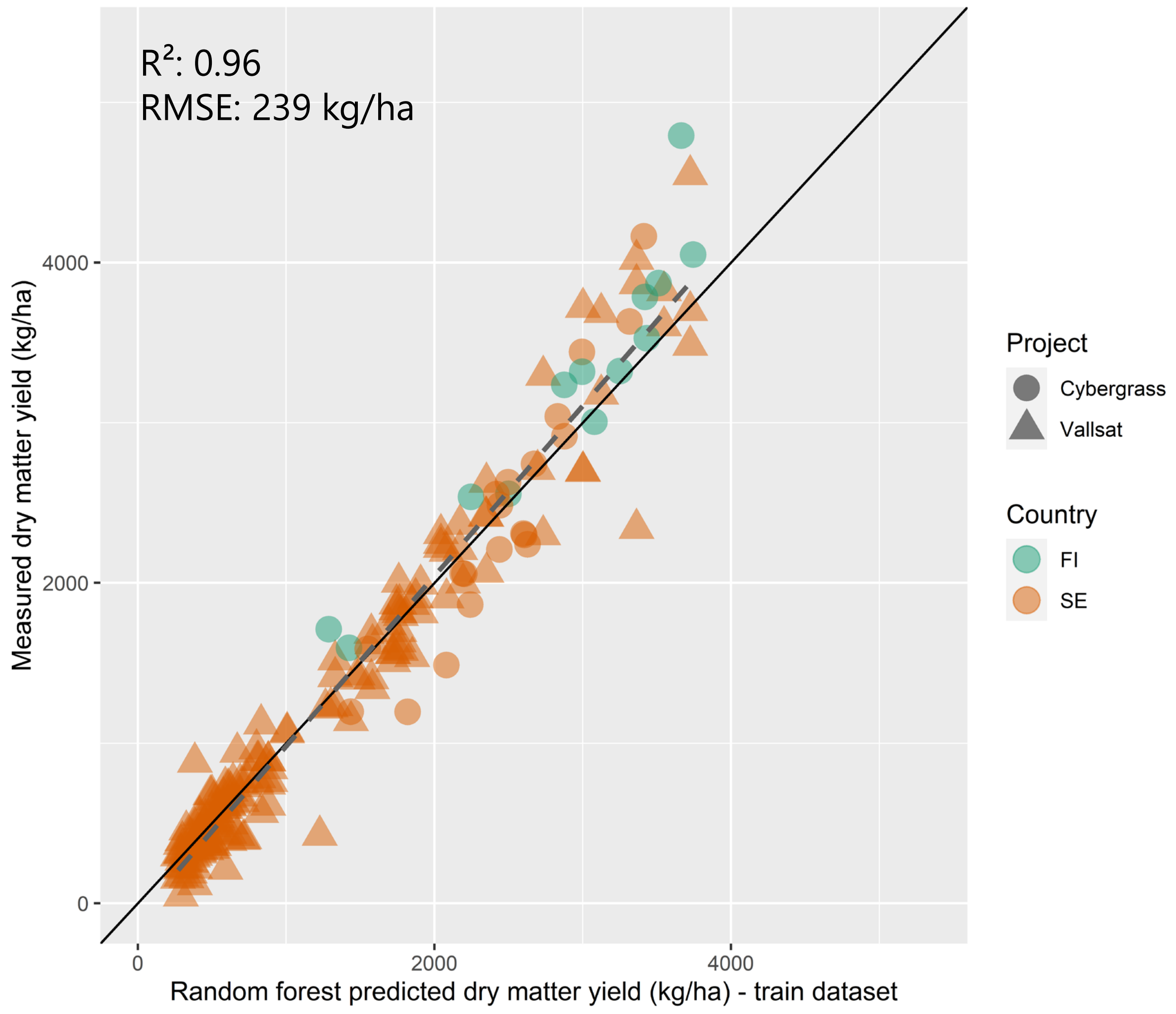
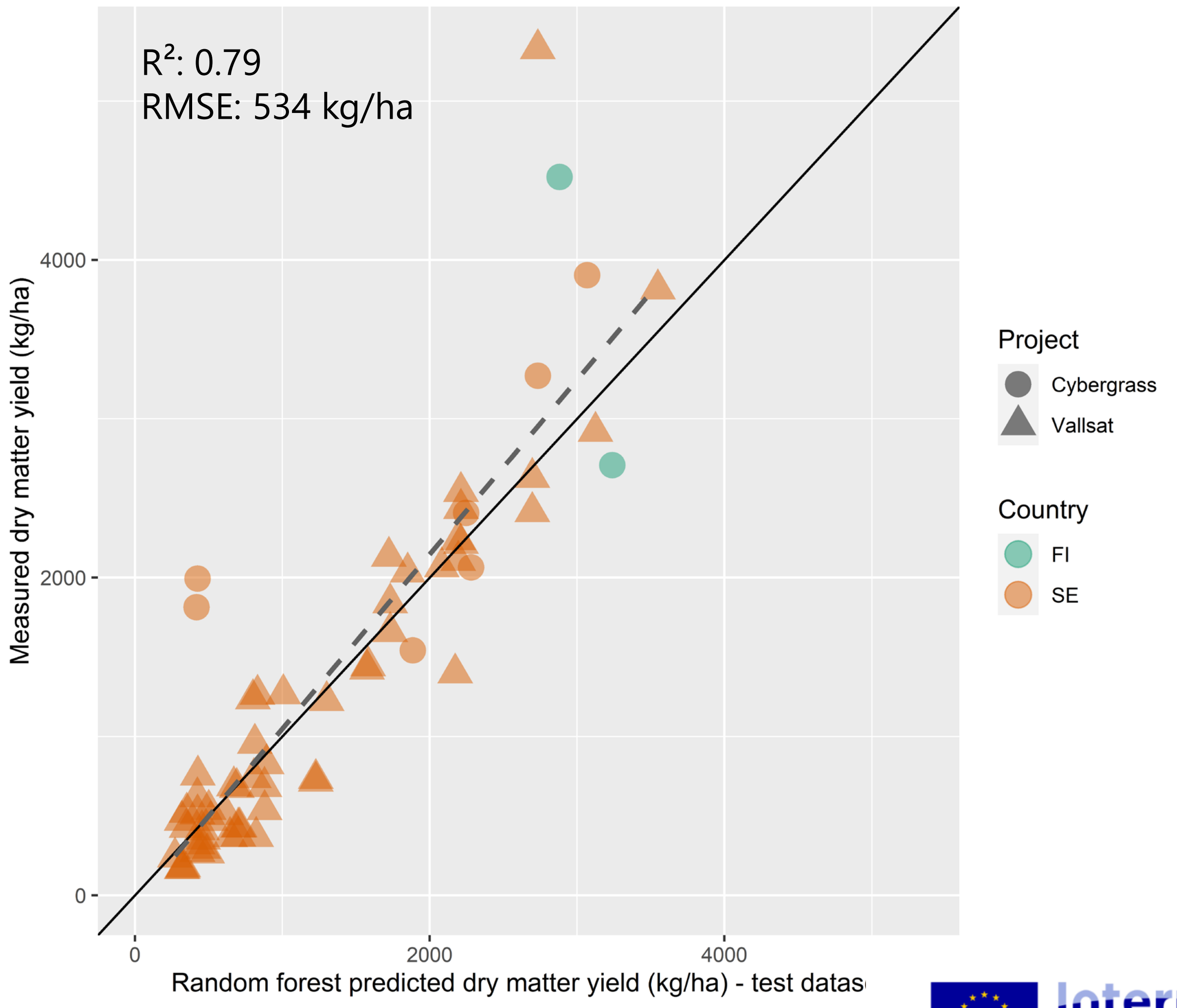
Sentinel-2 (Random Forest)

Training dataset



Test dataset



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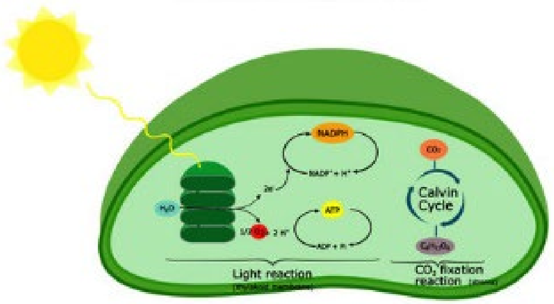
Solar radiation

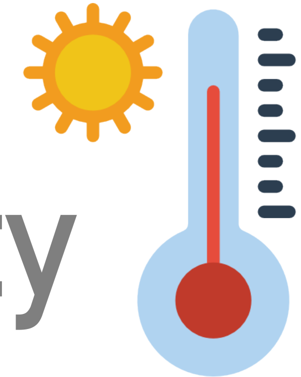
Photosynthesis

Biomass growth

Yield



Quality



Temperature

Phenological development

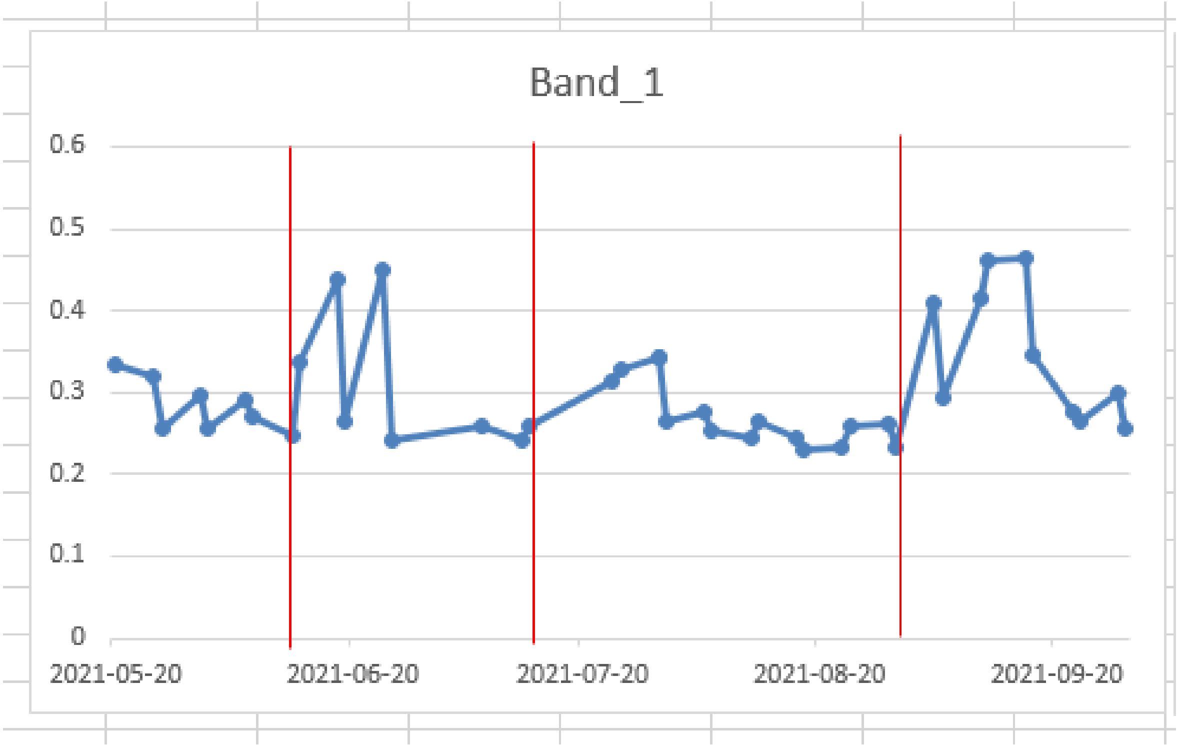
Forage quality

Types of models

Empirical	Simulation
Less mechanistic	More mechanistic
e.g. Vallprognos, Karpe	e.g. Basgra, Stics
Quality	Biomass, quality
Simple	Complex
Little information needed	Much information needed
Period: single cut	Period: whole season

Detecting cutting dates

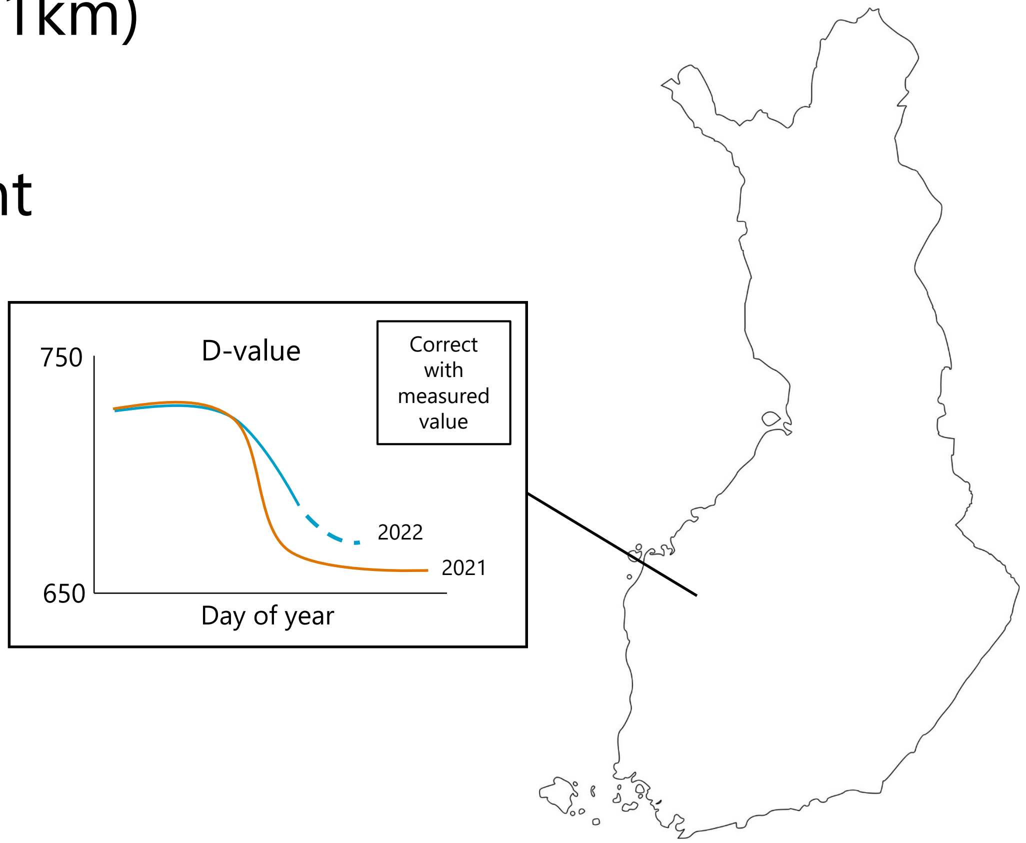
- Purpose: to develop an automated way to update mechanistic models
- Use Radar data from Sentinel 1 to detect cutting dates
- Unaffected by clouds, sensitive to biomass changes
- Amplitude of the complex correlation coefficient between two images



New version of D-value prediction model

Updates at 1st step:

- Weather data changed to gridded data (1 x 1km) with 5 day forecast
- Calculation of D-value estimates until current day and with 5 day forecast
- New UI under construction
    - Also map-based visualisation
    - Easier location selection
    - Mobile-friendlier approach
    - Will be published on Luke’s website



Draft estimate of readiness of different methods to be included as part of desicion support system.

Technology readiness level, Estimated attainable quality level, spatial data quality. Costs and benefits.

	Method		TRL	Quality	Eco. via.
Nutrient map	Free satellite	#	9	6	9
	Accurate satellite		7	7	6
	3D		4	4	3
	Close range sampling	#	4	9	6
	RGB		8	7	7
	Multispectral		7	8	6
	Sensor integration	#	6	9	6
	Hyperspectral		6	9	5
Anomaly map	Free satellite	#	9	6	9
	Accurate satellite		9	7	6
	3D		6	7	6
	Close range sampling		5	5	2
	RGB		9	6	7
	Multispectral		9	8	4
	Sensor integration		6	8	3
	Hyperspectral		7	8	3
Weed map	Free satellite		7	3	7
	Accurate satellite		7	4	5
	3D		6	7	6
	Close range sampling		6	5	6
	RGB		8	4	5
	Multispectral		6	7	5
	Sensor integration		6	9	5
	Hyperspectral		5	8	2

Quality map	Free satellite		7	6	6
	Accurate satellite		7	6	4
	3D		6	4	4
	Close range sampling		7	9	5
	RGB		7	4	4
	Multispectral		7	7	6
	Sensor integration		6	9	5
	Hyperspectral		7	9	4
Quantity map	Free satellite		6	6	6
	Accurate satellite		6	7	5
	3D	#	6	8	7
	Close range sampling		5	8	4
	RGB		8	6	5
	Multispectral		7	7	5
	Sensor integration	#	6	9	6
	Hyperspectral		6	8	4
Stack volume	Free satellite		3	1	2
	Accurate satellite		3	2	2
	3D	#	7	9	7
	Close range sampling		3	4	1
	RGB		3	3	3
	Multispectral		3	3	2
	Sensor integration		5	9	3
	Hyperspectral		3	2	1

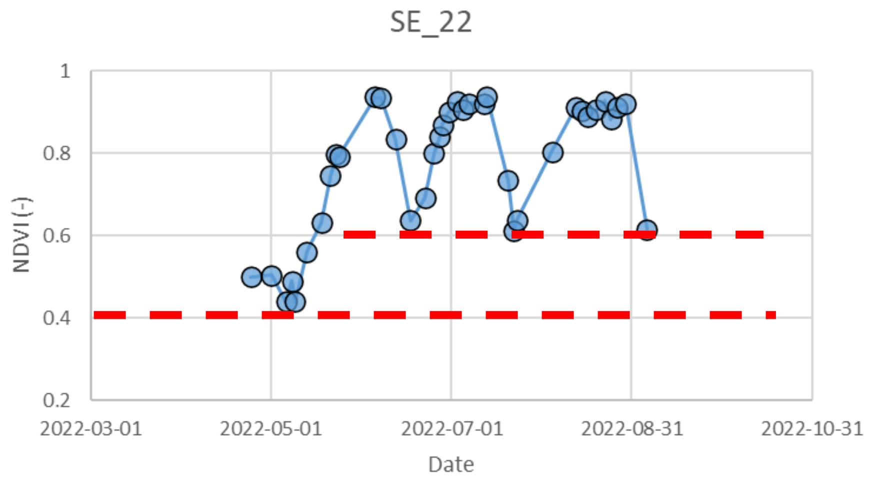
(by Jere Kaivosoja)

Future research in drone imaging

- Taking advantage of different data sources
  - Remote sensing data
  - Growth models, weather etc.
- Development towards more real-time or near-real-time solutions

Future research in satellites

- Quadrats- vs strips-estimated dry matter yield
- Refining hypotheses for time integration of signal (when to start the integration, baseline value, etc.)
- Sentinel-1: effect of the angle of acquisition?
- Combining Sentinel-1 and Sentinel-2
- More data!



Future research in prediction models

- Integration of data for correcting the estimates (to take into account regional variability due to factors not included in model)
- Inclusion of model-based yield estimates for the 2nd and 3rd cut
- More comprehensive use of weather data for assessing ”optimal harvest time”
- Improved flexibility and adaptability of the model to customers’ systems

Photo: agriland.ie

Thank you!

Collaborating farmers, ValioArtturi and Boreal Plant Breeding are warmly acknowledged for fruitful collaboration.

The project is funded by the European regional development fund with Region Västerbotten and Pohjanmaan liitto