Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

Data basis for a decision support system for split fertilization in spring wheat

(Datagrunnlag for beslutningsstøtte for delgjødsling i vårkorn)

Jakob Geipel, Maximilan Pircher, Håvard Lindgaard, Audun Korsæth (NIBIO)

Underlag för ett webbaserat beslutssystem för smart växtodling

Slutkonferens 5-6 december 2018
Naturbruksskolan Uddetorp, Skara

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Innovationer för hållbar växtodling

Objectives

Goal

Develop methods to obtain precise in-season information on bio-physical plant properties utilizing multi- and hyperspectral imaging systems on air- and spaceborne platforms.

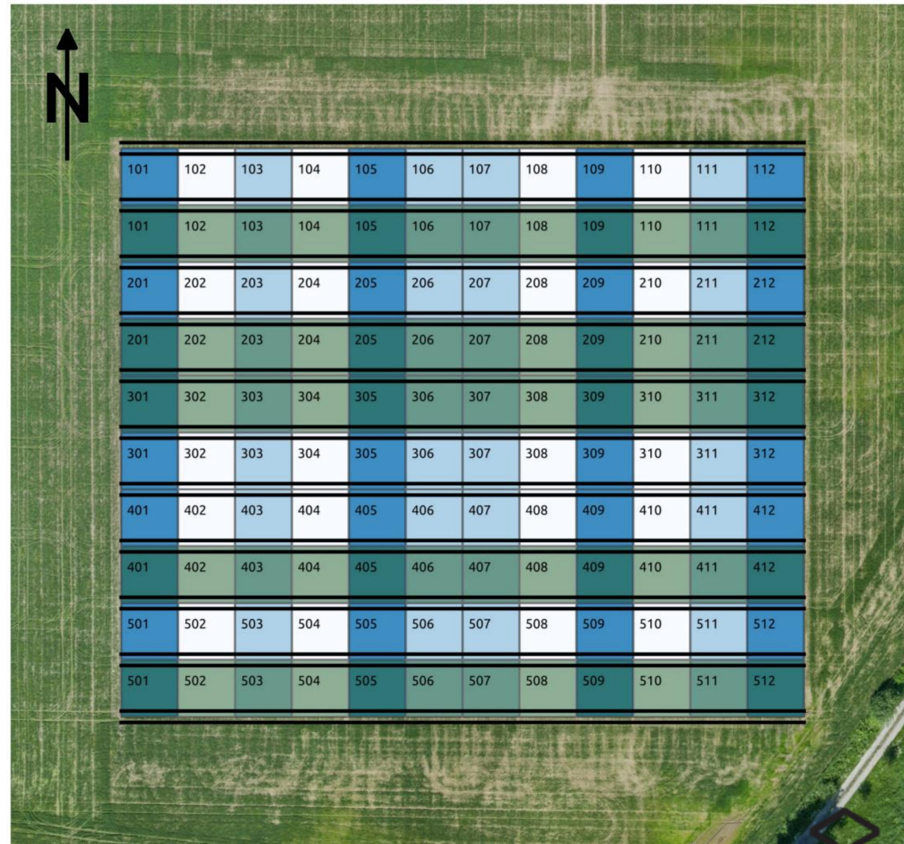
1. Basis for a decision support in forage production in terms of yield and quality estimation (not shown today)

2. **Basis for a decision support in grain production in terms of variable rate fertilization in spring wheat**

Spring wheat field trial

2017 & 2018

- Spring wheat (cv. Bjarne)
- Relative homogeneous soil organic matter content
- 120 plots (10 x 10 m each)
- 3 N-levels at sowing (40, 70, 100 kg N ha^{-1})
- Uniform N treatment around GS 39 (50 kg N ha^{-1})
- 3 destructive samples per plot
  - Biomass around GS 39
  - Yield at harvest



Sensor measurements

2017 & 2018

- Measurements around GS 39 before biomass sampling
- Unmanned aerial vehicle (UAV) together with an RGB and hyperspectral imager (Sony a5100, Rikola HSI)
- Ground spectrometer for irradiance measurements (ASD FieldSpec 3)
- Sentinel 2 satellite data

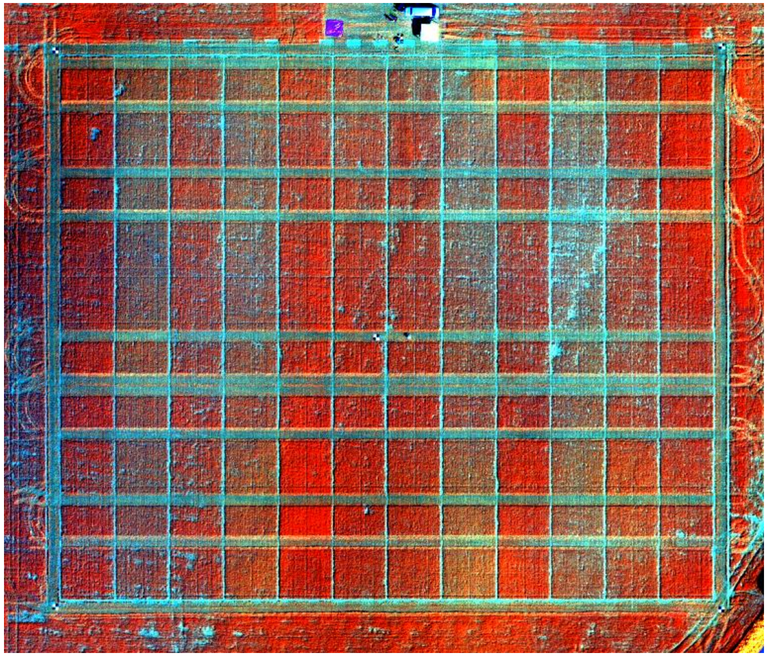
Biomass samples

Sample analysis

- Fresh and dry matter biomass (gravimetric)
- Protein and N concentration (NIRS)
- N uptake calculated from dry matter biomass and N concentration

Pre-processing (UAV / HSI)

- Radiometric correction
- Geometric correction
- Structure from Motion

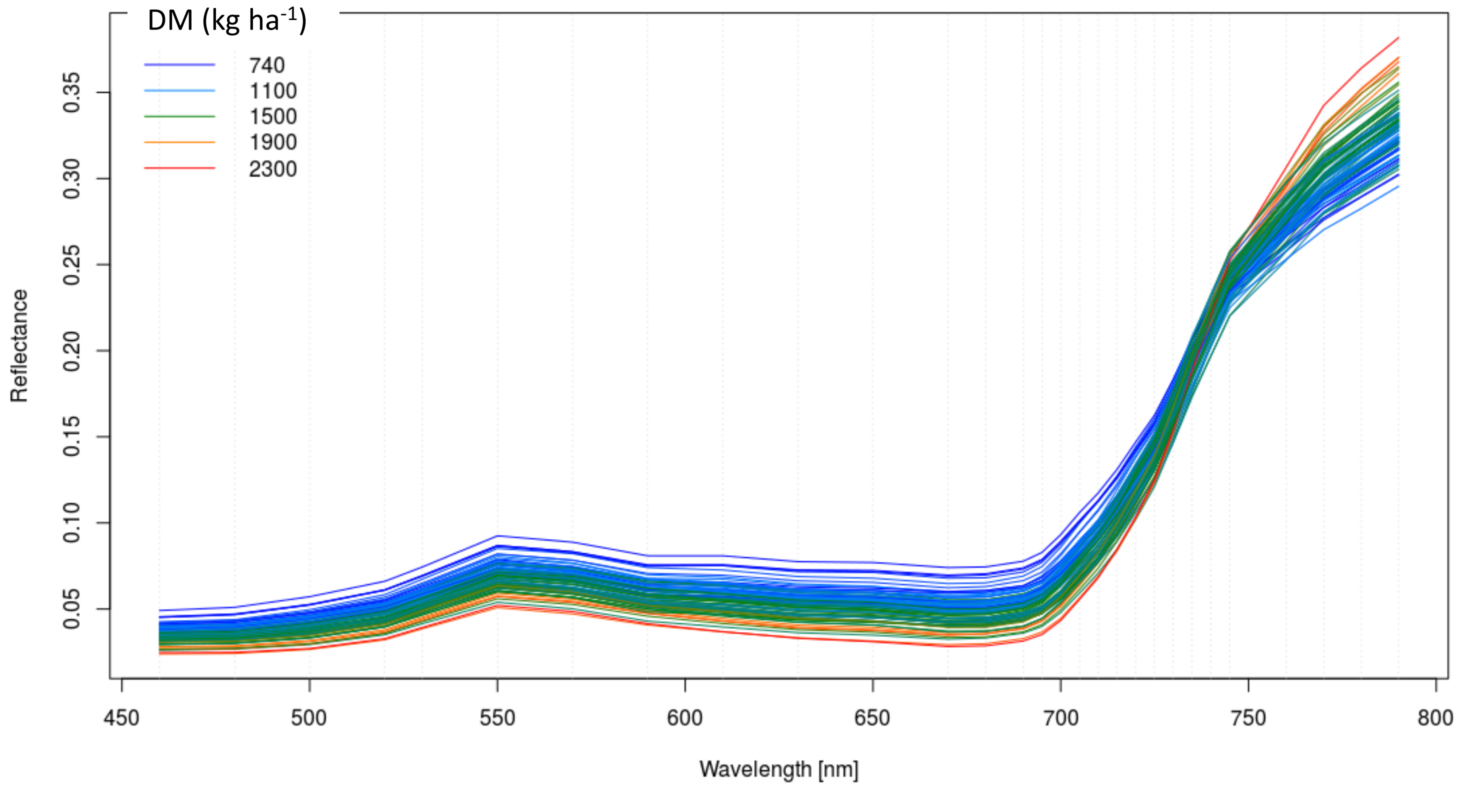


Innovationer för
hållbar växtodling

NIBIO
NORSK INSTITUTT FOR
BIOØKONOMI

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

Spectral response (UAV / HSI)



Modeling strategy (UAV / HSI)

Two different approaches

- **Powered partial least squares regression** (PPLSR) with all bands as predictor variables
- **Simple linear regression** (SLR) with some selected vegetation indices as predictor variables

Minimal Euclidian distance of spectral response used to split data into

- Calibration data set (50% = 180 samples)
- Validation data set (50% = 180 samples)

PPLSR model selection was based on Mevik & Wehrens 2007 and Indahl 2005 to avoid overfitting.

Outliers were not removed from the models.

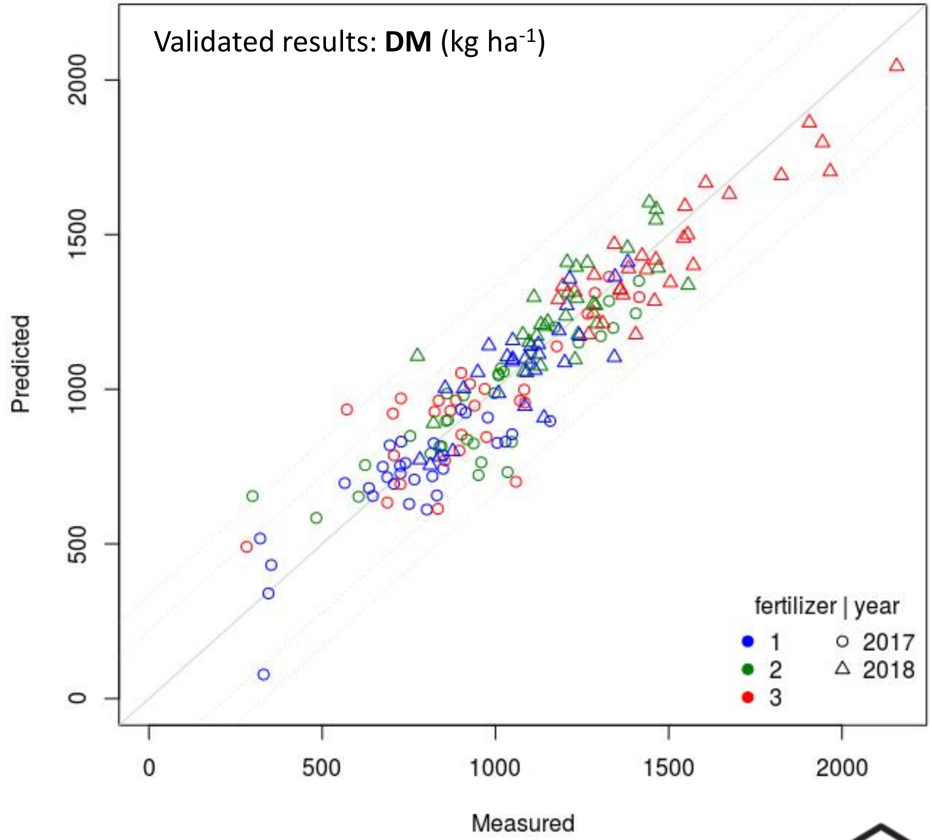
Dry matter (UAV / HSI)

Best performing model:

PPLSR

- R^2: 0.85
- RMSEP: 123 kg ha^{-1}
- RMSEP %: 11.5 %
- Nr. comp.: 7
- Gamma: 0.95

SLR prediction accuracy **not** acceptable!

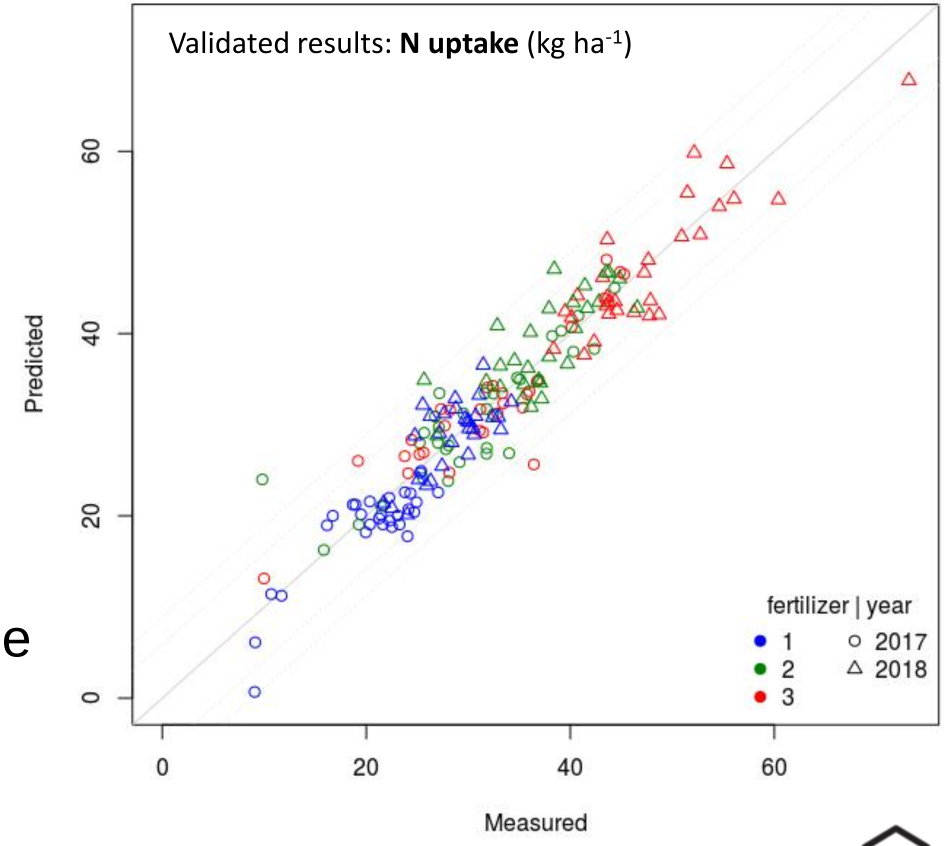


N uptake (UAV / HSI)

Best performing model:

PPLSR

- R^2: 0.89
- RMSEP: 3.4 kg ha^{-1}
- RMSEP %: 10.5 %
- Nr. comp.: 6
- Gamma: 0.94



NDRE prediction accuracy maybe acceptable?

(R^2 = 0.64, RMSEP = 6.3 kg ha^{-1})

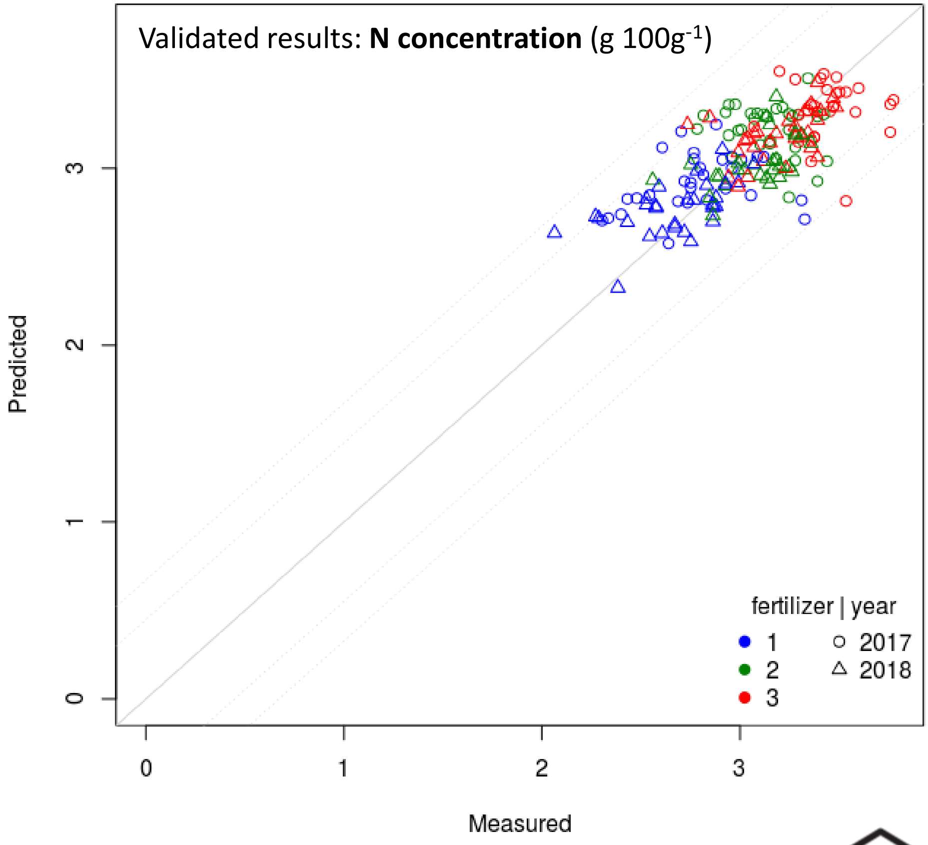
N concentration (UAV / HSI)

Best performing model:

PPLSR

- R^2: 0.50
- RMSEP: 0.23 g $100g^{-1}$
- RMSEP %: 7.5 %
- Nr. comp.: 3
- Gamma: 1

SLR prediction accuracy **not** acceptable!



Innovationer för hållbar växtodling

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

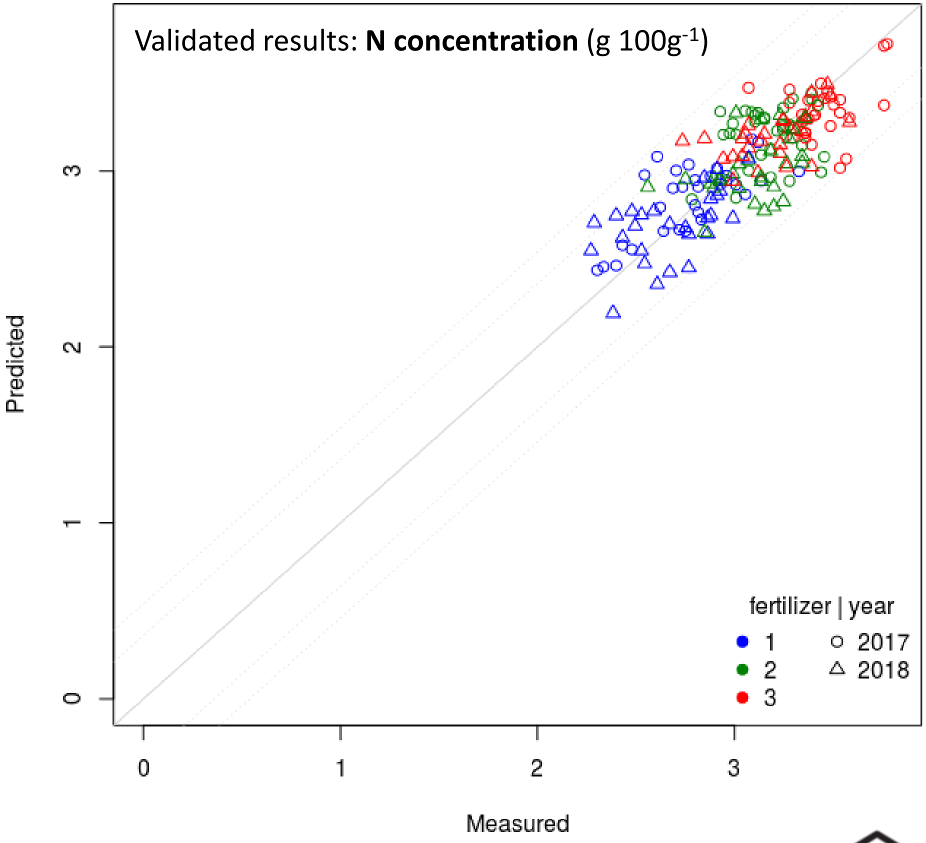
N concentration (UAV / HSI)

Best performing model after image classification:

PPLSR

- R^2: 0.63
- RMSEP: 0.20 g 100g^{-1}
- RMSEP %: 6.4 %
- Nr. comp.: 8
- Gamma: 0.97

PPLSR prediction accuracy increases due to removal of soil- and mixed pixels (NDVI < 0.6)



Comparison Sentinel 2 vs. UAV

Comparison of air- and spaceborne data is **not** straight-forward due to differences in e.g.:

- Radiative transfer through atmosphere
- Irradiance (measured vs. modelled)
- Spectral resolution (central wavelength and bandwidth)
- Spatial resolution (ground sample distance)
- Radiometric resolution (sensitivity)
- …

Comparison Sentinel 2 vs. UAV

Approach

Compare the model prediction accuracy for the most common vegetation indices as predictors in simple linear regression models

Samples

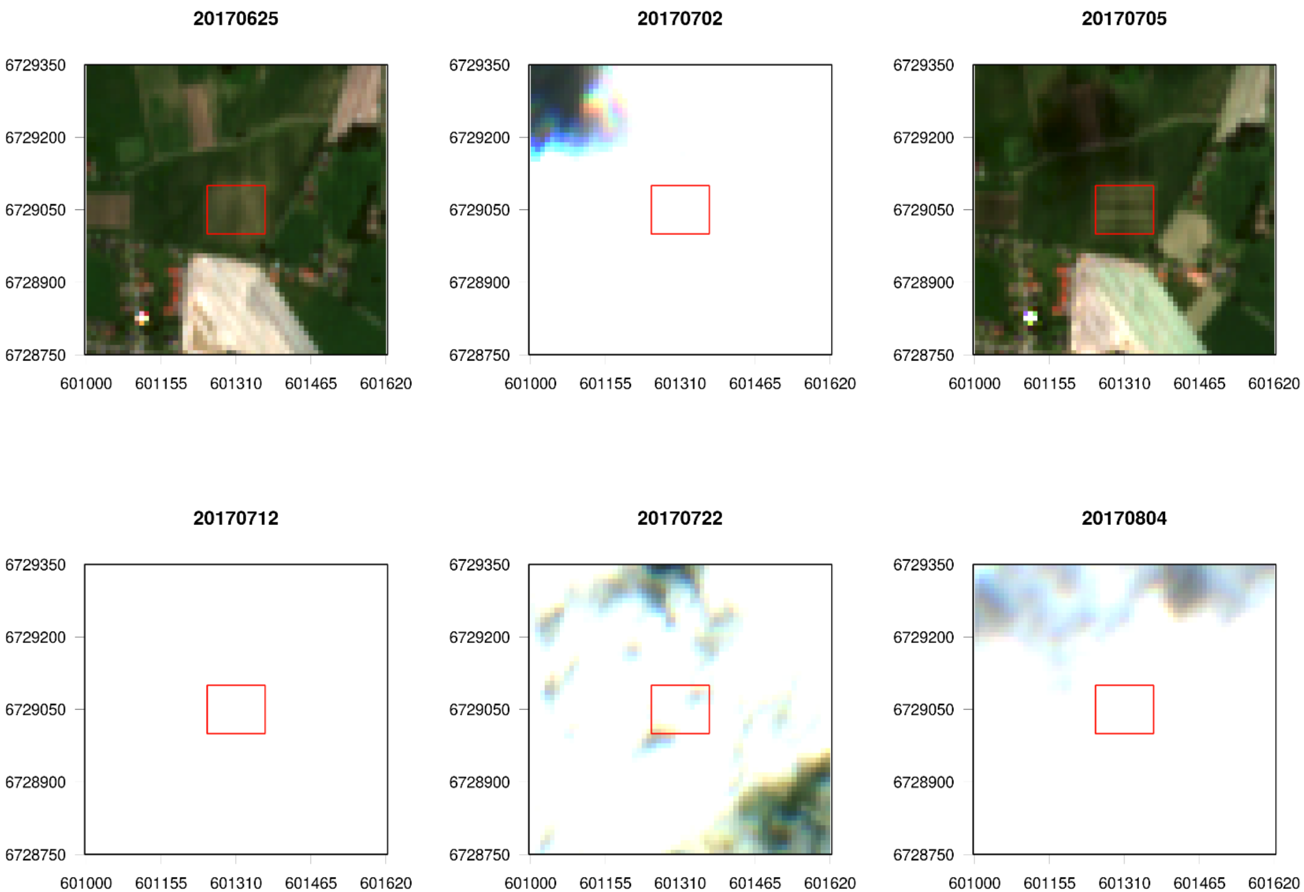
- Samples are aggregated to match the spatial resolutions of the S2 satellite (10 and 20 m GSD)
- Due to the aggregation, only smaller number of samples available

Indices

- UAV / HSI indices are narrowband and lack the B8/8a bands at 835/865 nm → 790 nm used instead

Scene selection Sentinel 2

Problems with scene selection due to clouds



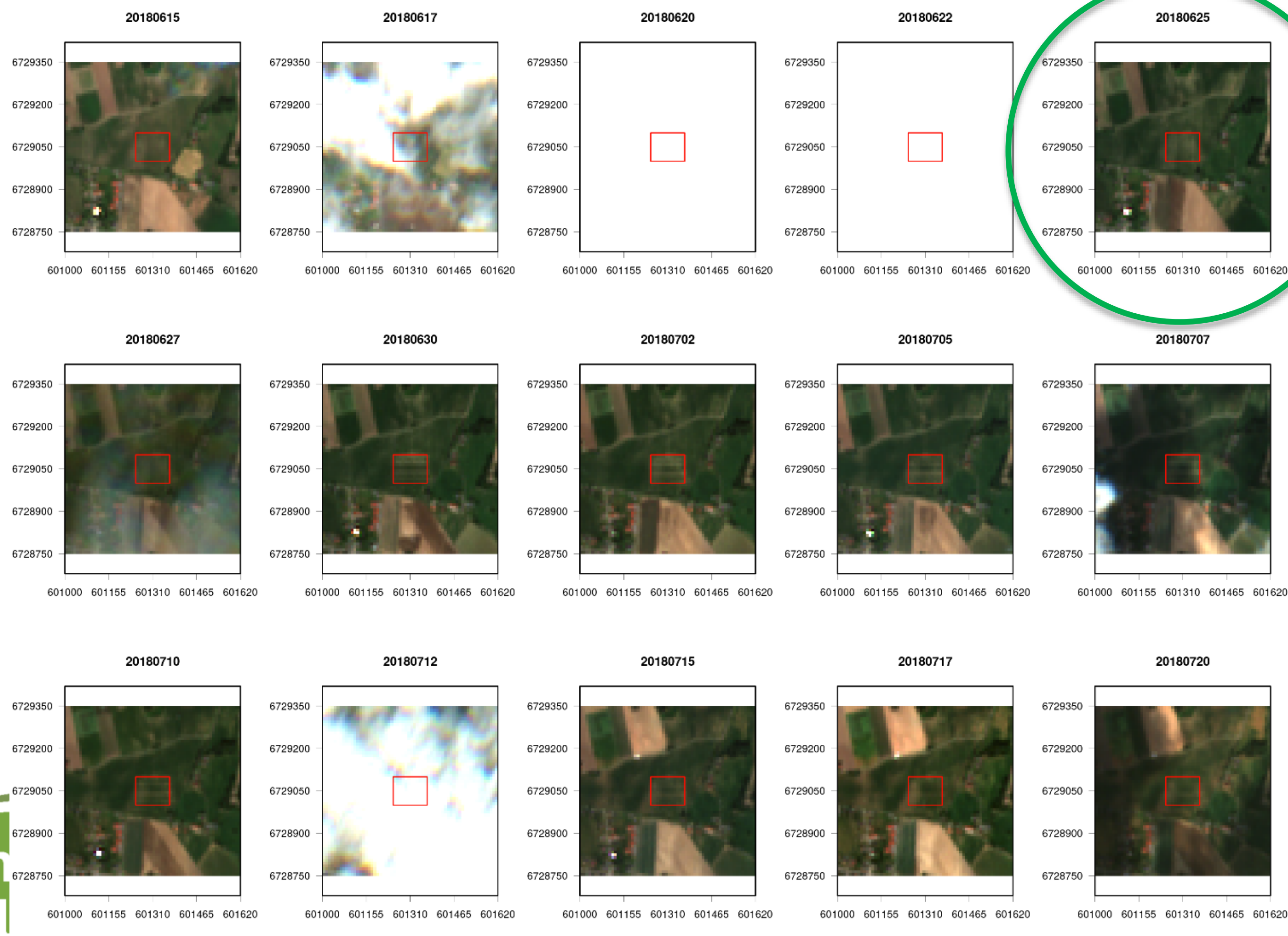
Sample date:
04.07.2017

No scene available!

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

Scene selection Sentinel 2

Problems with scene selection due to clouds



Sample date: 27.06.2018

Situation improved with S2B!

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Modeling strategy (S2 vs. UAV)

Simple linear regression (SLR) with all common vegetation indices as predictor variables (2018 data only)

10 m GSD:

Minimal Euclidian distance of spectral response used to split data into

- Calibration data set (50% = 30 samples)
- Validation data set (50% = 30 samples)

20 m GSD:

Leave-one-out cross-validation due to small sample size (25 samples)

Outliers were not removed from the models.

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

Dry matter (S2 vs. UAV)

The UAV / HSI indices always outperform the S2 indices when used in SLR models to predict DM.

Only the NDI45 (20 m) shows a prediction accuracy in a similar range as the UAV / HSI indices.

	2018: 20 x 20 m GSD, N=25, CV					
	Sentinel 2			UAV / HSI		
BpIdx	R2	RMSECV		R2	RMSECV	
		kg ha-1	%		kg ha-1	%
NDI45	0.78	83	6.7	0.85	69	5.7
NDVI	0.65	105	8.6	0.77	85	6.9
GNDVI	0.62	109	8.9	0.69	98	8.0
SAVI	0.59	115	9.4	0.84	70	5.7
REIP	0.44	133	10.9	0.61	110	9.0
NDRE	0.28	153	12.5	0.61	110	9.0

	2018: 10 x 10 m GSD, N=60, 50/50					
	Sentinel 2			UAV / HSI		
BpIdx	R2	RMSEP		R2	RMSEP	
		kg ha-1	%		kg ha-1	%
SAVI	0.67	169	13.3	0.86	117	9.1
GNDVI	0.62	183	14.4	0.79	136	10.5
NDVI	0.60	190	15.0	0.81	135	10.5

Innovationer för hållbar växtodling

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

N uptake (S2 vs. UAV)

The UAV / HSI indices always outperform the S2 indices when used in SLR models to predict N uptake.

None of the S2 indices shows a prediction accuracy in a similar range as the UAV / HSI indices.

	2018: 20 x 20 m GSD, N=25, CV					
	Sentinel 2			UAV / HSI		
BpIdx	R2	RMSECV		R2	RMSECV	
		kg ha^{-1}	%		kg ha^{-1}	%
NDI45	0.71	3.16	8.8	0.77	2.70	7.5
NDVI	0.62	3.64	10.1	0.86	2.12	5.9
GNDVI	0.52	4.12	11.4	0.88	1.98	5.5
SAVI	0.48	4.24	11.8	0.88	1.92	5.3
REIP	0.32	4.88	13.5	0.84	2.25	6.2
NDRE	0.19	5.32	14.8	0.84	2.26	6.3

	2018: 10 x 10 m GSD, N=60, 50/50					
	Sentinel 2			UAV / HSI		
BpIdx	R2	RMSEP		R2	RMSEP	
		kg ha^{-1}	%		kg ha^{-1}	%
GNDVI	0.56	6.83	17.9	0.92	3.83	9.8
SAVI	0.54	6.98	18.3	0.90	4.54	11.6
NDVI	0.53	7.16	18.8	0.89	4.75	12.1

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Conclusion

- Airborne hyperspectral imagery combined with multivariate modeling techniques is best suited to predict above ground dry matter biomass, nitrogen uptake and nitrogen concentration.
- Uni-variate modelling techniques with vegetation indices performed generally worse and a prediction accuracy was within an acceptable range only for models built on single year data sets (2018).
- The comparison of airborne with Sentinel 2 satellite data revealed a general trend that regression models with indices that were based on airborne data showed always higher prediction accuracies than those which were based on Sentinel 2 data.
- Sentinel 2 images at 20 m resolution (including the red-edge bands) appeared to be better suited as predictors than images at 10 m resolution.

Interreg Öresund-Kattegat-Skagerrak European Regional Development Fund
EUROPEAN UNION
NIBIO NORSK INSTITUTT FOR BIOØKONOMI

Projektets finansiärer

Förutom Interreg Öresund-Kattegatt-Skagerack har projektet även följande finansiärer:

promilleafgiftsfonden
för landbrug

VÄSTRA GÖTALANDSREGIONEN
MILJÖNÄMNDEN