Perspectives of predicting grass growth by modelling and measuring grass yield

Workshop NVWV

Sept 18th 2019, Idse Hoving, Johan van Riel, Gertjan Holshof and Gerbert Roerink

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Questions to answer, what are we searching for?

- How many grass is available?
- How much will grow in the coming days?
- When do I have to mow or graze?

➢"Grip on grass"; more control over the entire roughage process

Objectives?

To know the actual yield and nutritional value of grass

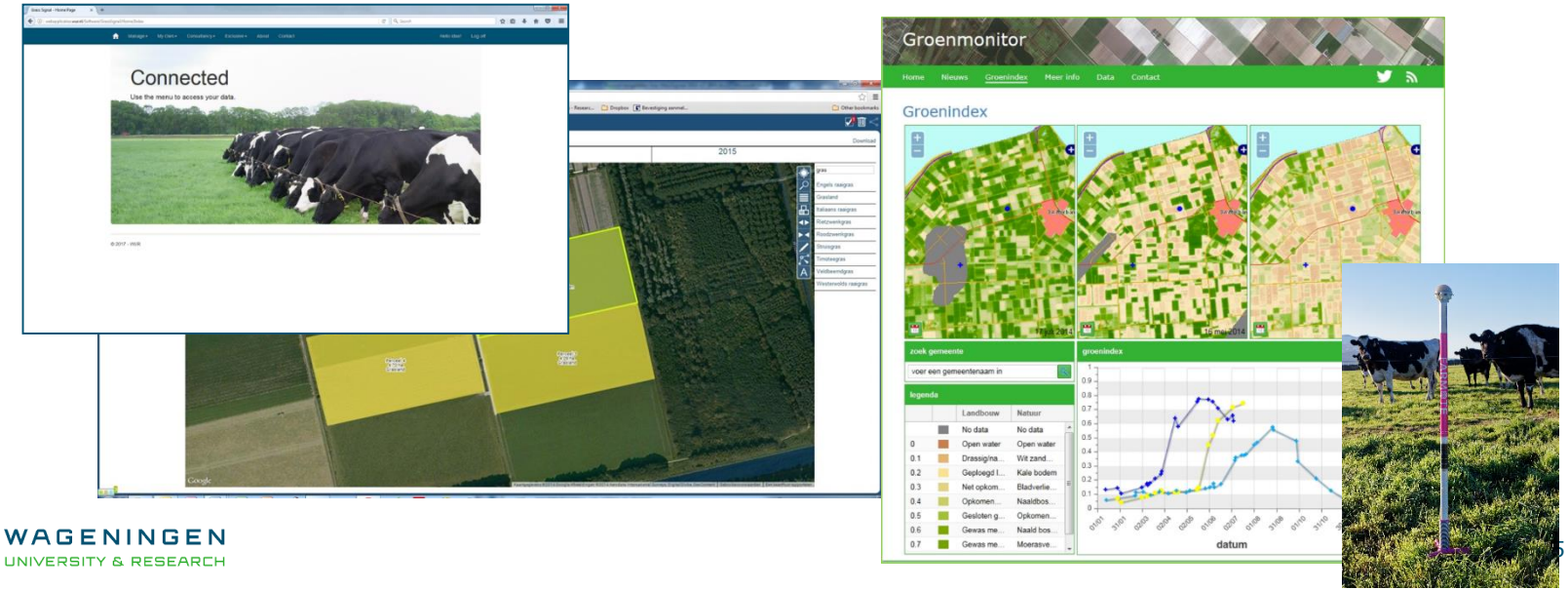
- Higher fresh grass uptake by cows during grazing
- Realizing the desired feed quality (mowing)
- Overview at company level (how much and where)
- Good grassland planning (predicting growth)

Ambitions

1. Advice on parcel level and local spots
2. Advice on a daily basis
3. Based on current measurements and predictions (near future)

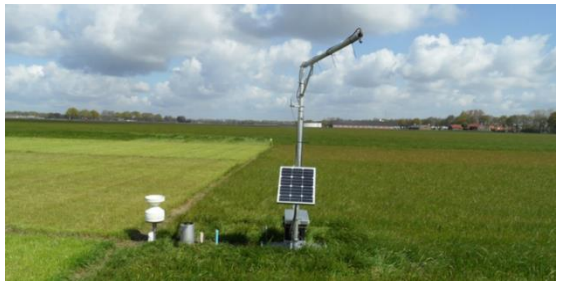
Approach

1. Grass growth prediction as a basis
2. Refinement with sensor measurements



Different projects, one research route

- Predicting grass growth
  - (Amazing Grazing)
- Measuring grass yield
  - (Precision farming 2.0)
- Measuring and predicting N-delivery soil and protein content of grass
  - (PPS DISAC N-sensor)



Experiment (mowing trial)

- Focused on both growth prediction and reflection measurements
- Targeting for ‘ground truth’ measurements. The aim was to have a broad measuring range on one specific moment to relate spectral images to DM yield
- Grass height measurements as reference (known in practice)

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Experimental design

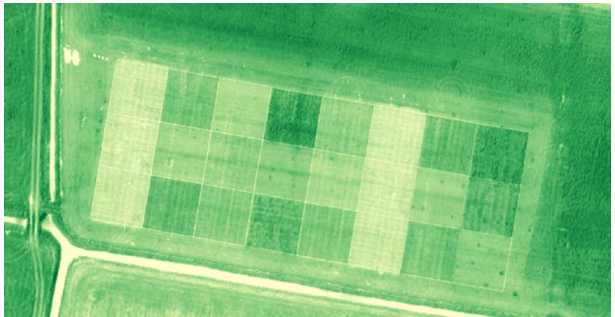
- The experiment was setup on a Dutch clay, sand and peat soil.
- A factorial combination of **nitrogen** fertilization (0, 180 and 360 kg ha.$^{-1}$jaar^{-1}) and **grass growth intervals** were provided to create various yield stages.
- The total number of plots was 24 per location (3 nitrogen levels * 4 growth intervals per cut * 2 repetitions).
- The 4 growth intervals existed of 3 interim trimmings (weekly, each on 6 plots) and a 'final' cut of all 24 plots.

Cut/week	1	2	3	4	5	6	7	8
Cut 1	T1	T2	T3	T1 – T4				
Cut 2					T1	T2	T3	T1 – T4
Etc.								

- The number of final cuts per location was 5 (clay and peat) to 6 (sand) and covered the entire growing season.

Measurements

- At the moment of final cut (T4), a day before harvest, light reflectance was measured with a calibrated Cropscan Multispectral Radiometer (MSR87, MSR16R).
- The clay (2016 - 2017) and peat (2017) locations were measured in 16 bands between 460 - 1080 nm.
- The sand location was measured in 8 bands between 460 and 810 nm, whereby 5 bands were corresponding with bands of the 16 bands Cropscan.
- On clay location additional measurements with an eBee drone were carried out
- Grass height (Jenquip EC09)



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Grass growth model

- GRAS2007, a stochastic model of Wageningen Livestock Research
- N-uptake prediction from different N-sources:
    - delivery of the soil
    - chemical fertilizer
    - manure
    - unutilized nitrogen from a previous cut
- Correction for soil moisture availability. The relative crop yield (Yact/Ypot) is set equal to relative transpiration (Tact/Tpot)
- Use of Irrigation Signal of ZLTO with soil moisture balance model of WLR

Reflection measurements

- Images in different bands (blue, green, red, nir) for incoming and reflected light.
- Translation to crop reflection per band (%).
- Red gives the most absorption and near infrared (NIR) gives the most reflection.
- Crop indexes such as NDVI or WDVI are calculated from the ratio between reflections.
- These can be a measure of biomass or crop characteristics such as nitrogen content

Translation reflection measurements

- Which vegetation index has the best relationship with yield and N content?
- Mostly developed for grain or potatoes
- How accurate is the relationship for grass?
- Vegetation indexes
- Individual wave lengths?
- Many indexes ...

Index	Formulation	Reference
REP	$(((R_{670} + R_{780})/2 - R_{700})/(R_{740} - R_{700}))*40 + R_{700}$	(Guyot and Baret 1988)
MTCI	$(R_{754} - R_{709})/(R_{709} - R_{681})$	(Dash and Curran 2004)
MCARI/OSAVI	$(((R_{700} - R_{670}) - 0.2*(R_{700} - R_{550}))*(R_{700}/R_{670}))/(1.16*(R_{800} - R_{670})/(R_{800} + R_{670} + 0.16))$	(Daughtry, Walthall et al. 2000)
MCARI/OSAVI RE	$(((R_{750} - R_{705}) - 0.2*(R_{750} - R_{550}))*(R_{750}/R_{705}))/(1.16*(R_{750} - R_{705})/(R_{750} + R_{705} + 0.16))$	(Wu, Niu et al. 2008)
TCARI/OSAVI	$((R_{700} - R_{670}) - 0.2*(R_{700} - R_{550})*(R_{700}/R_{670}))*3/(1.16*(R_{800} - R_{670})/(R_{800} + R_{670} + 1.16))$	(Haboudane, Miller et al. 2002)
TCARI/OSAVI RE	$((R_{750} - R_{705}) - 0.2*(R_{750} - R_{550})*(R_{750}/R_{705}))*3/(1.16*(R_{750} - R_{705})/(R_{750} + R_{705} + 1.16))$	(Wu, Niu et al. 2008)
CI red edge	$(R_{780}/R_{709}) - 1$	(Gitelson, Keydan et al. 2006)
CI green	$(R_{780}/R_{550}) - 1$	(Gitelson, Keydan et al. 2006)
NDNI	$(\log(1/ R_{1510}) - \log(1/R_{1680}))/(\log(1/ R_{1510}) + \log(1/R_{1680}))$	(Serrano, Penuelas et al. 2002)
SIPI	$(R_{800} - R_{445})/(R_{800} - R_{681})$	(Penuelas, Filella et al. 1995)
DCNI	$(R_{720} - R_{700})/(R_{700} - R_{670})/(R_{720} - R_{670} + 0.03)$	(Chen, Haboudane et al. 2010)
NDRE	$(R_{790} - R_{720})/(R_{790} + R_{720})$	(Tilling, O'Leary et al. 2007)
NDRE1	$(R_{740} - R_{705})/(R_{740} + R_{705})$	(Gitelson and Merzlyak 1994)
NDRE2	$(R_{780} - R_{705})/(R_{780} + R_{705})$	(Barnes, Clarke et al. 2000)
NDVI	$(R_{800} - R_{670})/(R_{800} + R_{670})$	(Rouse, Haas et al. 1974)
CCCI	$((R_{790} - R_{720})/(R_{790} + R_{720}))/((R_{800} - R_{670})/(R_{800} + R_{670}))$	(Barnes, Clarke et al. 2000)
WDRVI	$(0.2*R_{800} - R_{670})/(0.2*R_{800} + R_{670})$	(Gitelson 2004)

Results reflection measurements and translation to vegetation indices

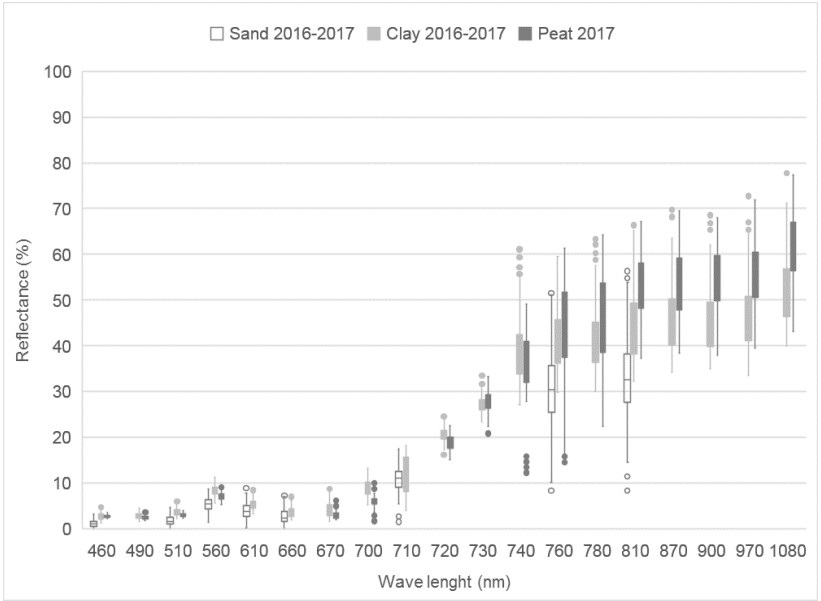

Figure 1. Percentage of light reflection per wave length per location

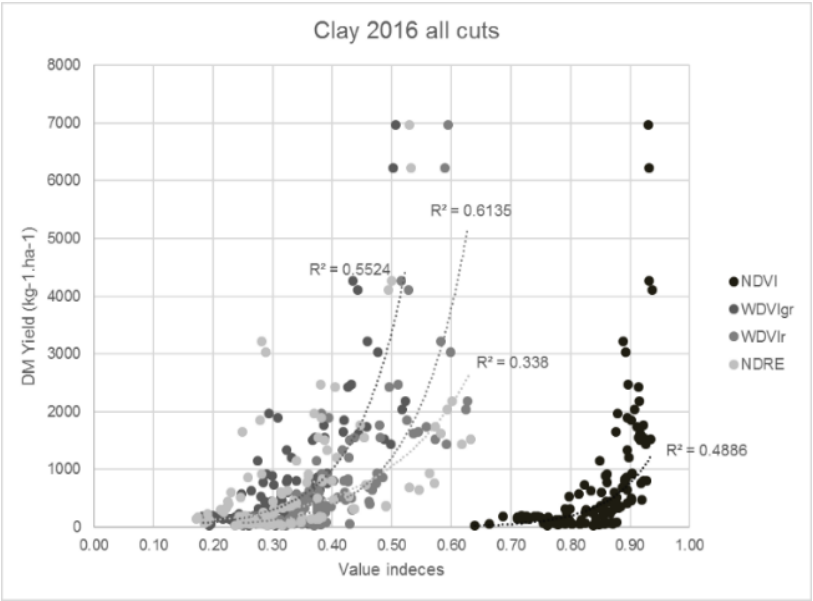

Figure 2. NDVI, WDVI green, WDVI red and NDRE plotted against DM yield for all cuts of the clay location in 2016

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Variation in correlations between locations and cuts

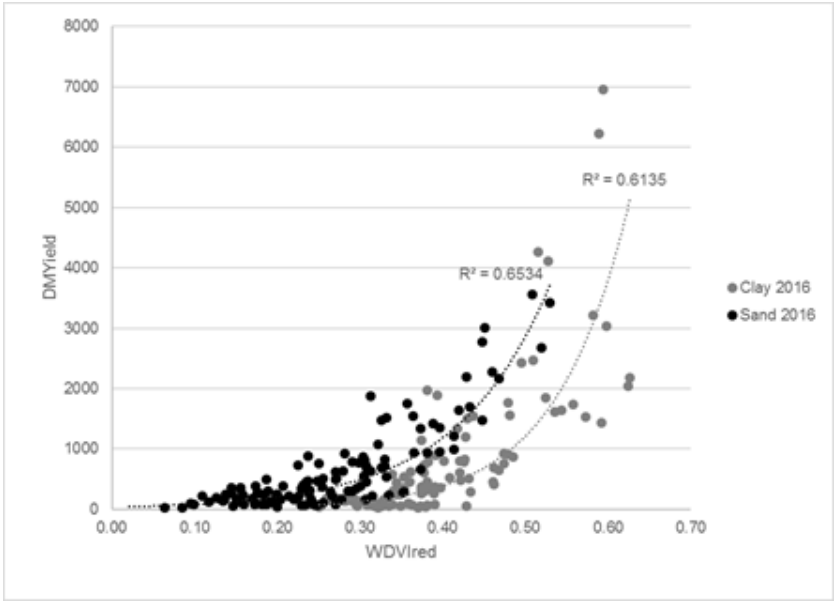


Figure 3. WDVI red plotted against DM yield for the clay and sand location

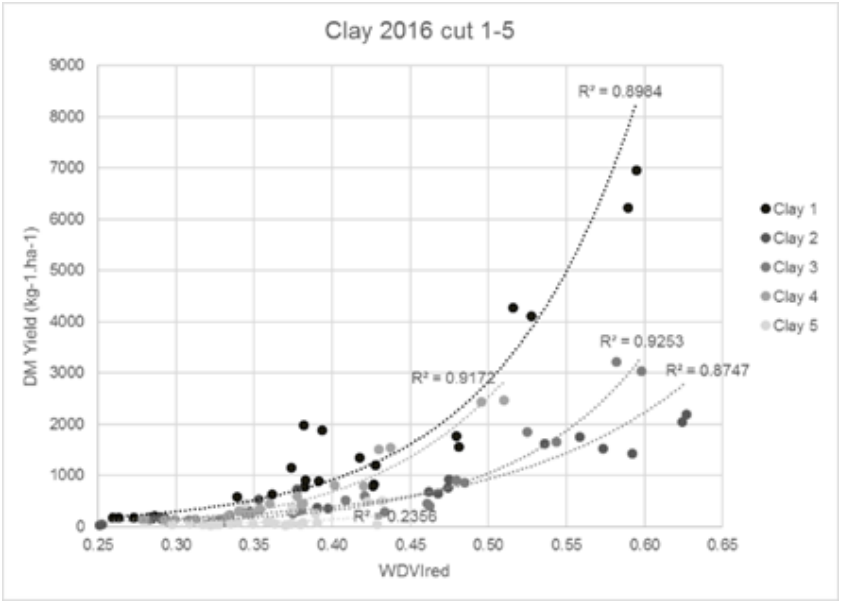
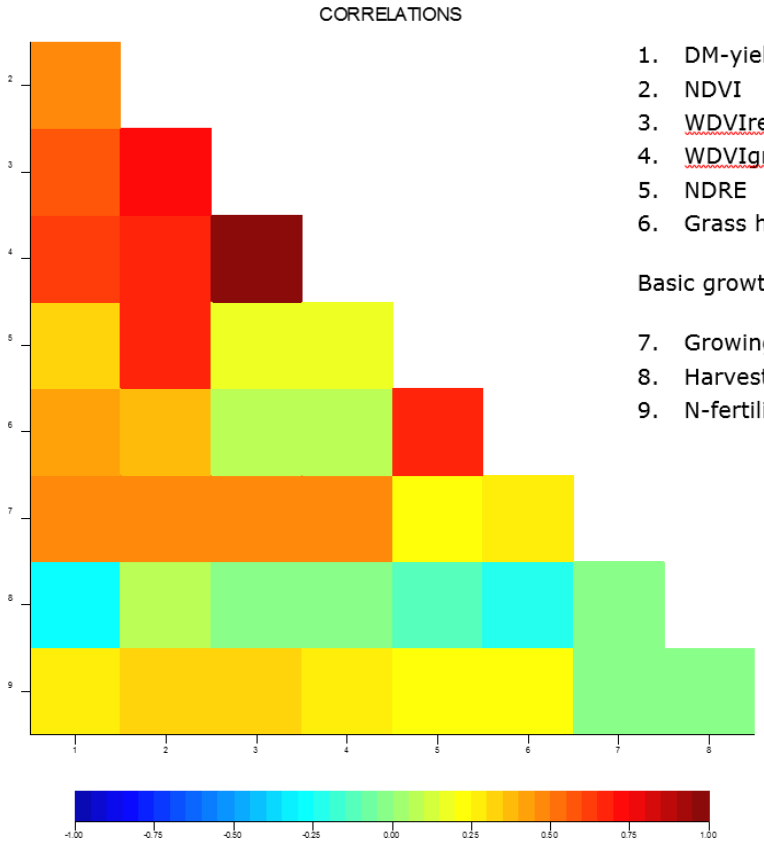


Figure 4. WDVI red plotted against DM yield per cut (1-5) for the clay location in 2016

Correlations



1. DM-yield
2. NDVI
3. WDVIred
4. WDVIgr
5. NDRE
6. Grass height

Basic growth information

7. Growing day
8. Harvest day
9. N-fertilisation level

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Statistical analyses

- Focused on explaining the absolute DM-yield and the N-content in fresh grass on the basis of the measurements and model-based predictions.
- The analysis was carried out on the data of the T4 harvest moments to generate separate predictive models for:
    1. reflection measurements
    2. grass height measurements
    3. model-based grass growth prediction
    4. basic growth data
- For the reflection measurements, the analyses focused on individual wavelengths and 4 general vegetation indices, namely NDVI, WDVI red, WDVI green and NDRE.

Predicting models for DM-yield and N-content

Predictor
Growth data
Growth model
Grass height
Reflection measurements
Grass height + Growth data
Grass height + Growth model
Reflection measurements + Grass height
Reflection measurements + Growth data
Reflection measurements + Growth model

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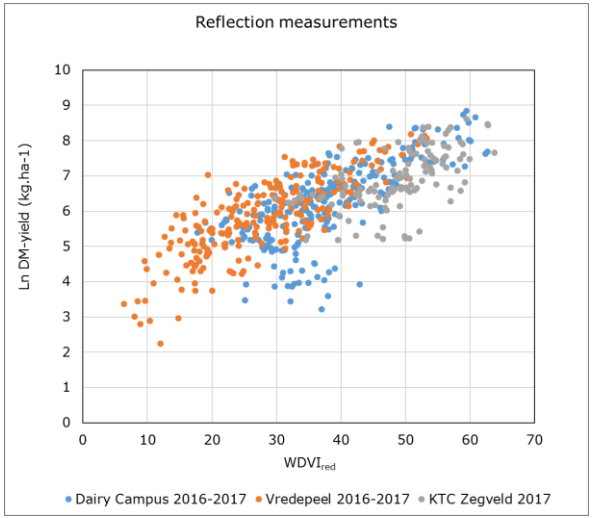
R^2 and P-values DM yield

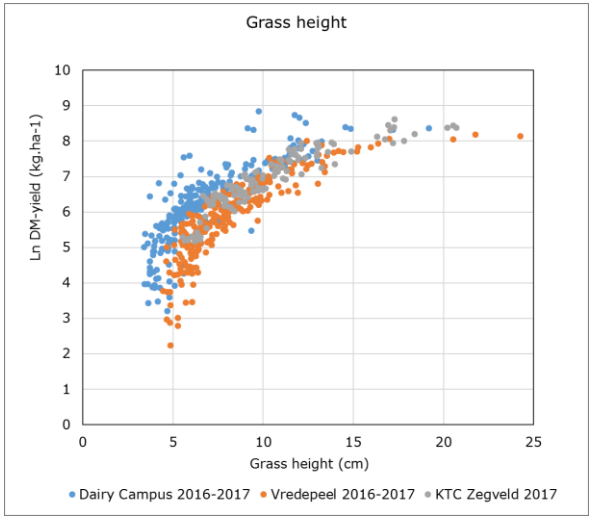
R^2	Df	560 nm	760 nm	810 nm	CIred	NDRE	NDVI	$WDVI_{gr}$	$WDVI_r$
Single predictor									
54.9	2	-	-	-	-	-	-	-	< 0.001
51.2	2	-	-	< 0.001	-	-	-	-	-
50.1	2	-	< 0.001	-	-	-	-	-	-
48.4	2	-	-	-	-	-	-	< 0.001	-
39.3	2	-	-	-	-	-	< 0.001	-	-
24.6	2	-	-	-	< 0.001	-	-	-	-
18.3	2	-	-	-	-	< 0.001	-	-	-
0.01	2	0.778	-	-	-	-	-	-	-
Combination with growth data									
78.0	12	-	-	-	-	-	-	-	< 0.001
77.5	12	-	< 0.001	-	-	-	-	-	-
77.5	12	-	-	< 0.001	-	-	-	-	-
75.3	12	-	-	-	-	-	< 0.001	-	-
74.6	12	-	-	-	-	< 0.001	-	-	-
74.5	12	-	-	-	-	-	-	< 0.001	-
72.4	12	-	-	-	< 0.001	-	-	-	-
70.5	12	0.259	-	-	-	-	-	-	-

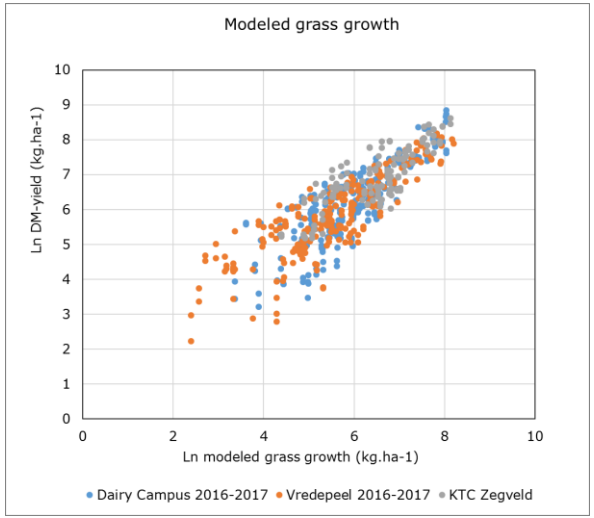
R^2 and P-values N content

R^2	Df	560 nm	760 nm	810 nm	CIred	NDRE	NDVI	$WDVI_{gr}$	$WDVI_r$
Single predictor									
7.4	2	< 0.001	-	-	-	-	-	-	-
6.3	2	-	-	-	-	-	< 0.001	-	-
4.1	2	-	-	-	-	< 0.001	-	-	-
3.4	2	-	-	-	< 0.001	-	-	-	-
2.4	2	-	-	-	-	-	-	-	< 0.001
1.7	2	-	-	-	-	-	-	0.002	-
0.8	2	-	-	0.028	-	-	-	-	-
0.7	2	-	0.049	-	-	-	-	-	-
Combination with growth data									
72.7	12	< 0.001	-	-	-	-	-	-	-
71.9	12	-	-	-	-	-	< 0.001	-	-
71.6	12	-	-	-	-	< 0.001	-	-	-
71.5	12	-	-	-	< 0.001	-	-	-	-
70.6	12	-	-	-	-	-	-	-	0.032
70.6	12	-	-	0.072	-	-	-	-	-
70.5	12	-	-	-	-	-	-	0.205	-
70.4	12	-	0.375	-	-	-	-	-	-

Measurements and fits







Results statistic analysis DM yield

	Locations overall 2016-2017			Dairy Campus (clay) 2016-2017			Vredepeel (sand) 2016-2017			KTC Zegveld (peat) 2017		
	R2	σ2	2S	R2	σ2	2S	R2	σ2	2S	R2	σ2	2S
Empty model	0	1.35	0.000	0	1.39	0.00	0	1.38	0.00	0	0.75	0.00
Growth data	71	0.39	3.509	72	0.37	3.40	71	0.40	3.55	64	0.27	2.83
Growth model	72	0.37	3.381	71	0.40	3.55	74	0.36	3.34	68	0.24	2.66
Grass height	65	0.47	3.940	74	0.35	3.28	83	0.23	2.60	91	0.07	1.68
Reflection measurements (WDVIred, clay 810 nm)	56	0.59	4.653	53	0.63	4.88	68	0.45	3.80	37	0.47	3.96
Gras height + Growth data	85	0.20	2.430	87	0.19	2.37	85	0.21	2.47	92	0.06	1.64
Grasheight + Growth model	80	0.27	2.816	80	0.28	2.86	86	0.19	2.39	91	0.07	1.68
Reflection measurements + Grass heighthoogte	77	0.32	3.073	77	0.31	3.04	85	0.20	2.45	92	0.06	1.64
Reflection measurements + Growth data	78	0.29	2.952	78	0.30	3.00	80	0.27	2.84	69	0.23	2.60
Reflection measurements + Growth model	77	0.30	3.007	76	0.33	3.16	84	0.22	2.56	69	0.23	2.61
Reflection measurements + Grass height + Growth data	87	0.18	2.325	87	0.17	2.29	87	0.18	2.35	92	0.06	1.62

Results statistic analysis N content

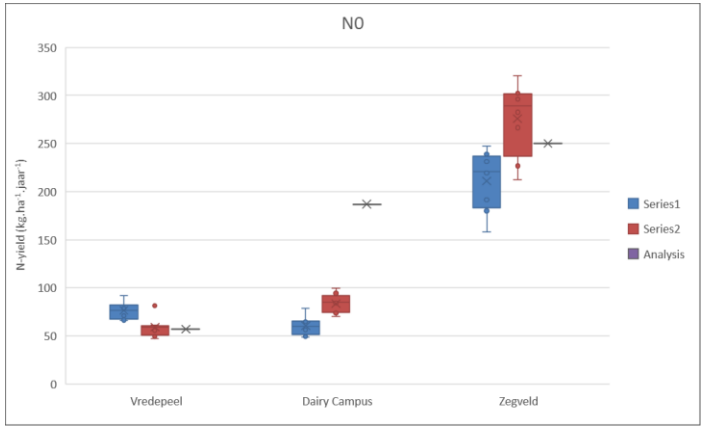
	Locaties gezamenlijk 2016-2017			Dairy Campus (klei) 2016-2017			Vredepeel (Zand) 2016-2017			KTC Zegveld (veen) 2017		
	R2	σ2	2S	R2	σ2	2S	R2	σ2	2S	R2	σ2	2S
Empty model	0	62.46	0.00	0	38.88	0.00	0	53.05	0.00	0	40.75	0.00
Growth data	71	17.92	8.47	72	10.92	6.61	60	21.18	9.20	49	20.70	9.10
Growth model	14	53.44	14.62	23	30.01	10.96	6	49.62	14.09	40	24.46	9.89
Grass height	5	59.60	15.44	24	29.55	10.87	12	46.78	13.68	40	24.45	9.89
Reflection measurements (WDVIred, clay 810 nm)	12	55.18	14.86	19	31.30	11.19	15	45.34	13.47	30	28.36	10.65
Gras height + Growth data	72	17.49	8.36	74	9.94	6.31	61	20.59	9.08	51	19.82	8.90
Grasheight + Growth model	14	53.53	14.63	30	27.04	10.40	12	46.59	13.65	44	22.75	9.54
Reflection measurements + Grass heighthoogte	16	52.18	14.45	35	25.30	10.06	25	39.99	12.65	42	23.55	9.71
Reflection measurements + Growth data	73	16.59	8.15	76	9.14	6.05	62	19.92	8.93	50	20.27	9.00
Reflection measurements + Growth model	22	48.76	13.97	33	26.12	10.22	21	42.13	12.98	44	22.84	9.56
Reflection measurements + Grass height + Growth data	74	15.95	7.99	81	7.57	5.50	63	19.50	8.83	52	19.73	8.88

Discussion reflection measurements

- Saturation of the signal at relatively high yields
- Influence of uncovered soil (effect unknown)
- Influence of the grass stubble that is not harvested (effect unknown)
- Under grazing conditions those effects possibly will be enhanced.
- Difference in atmospheric measurement conditions between measuring moments (noise)

Discussion growth prediction

- Incorrect estimate of the nitrogen delivery based on soil samples (DC).
- Corrected data was used for model input (N0 yield).
- Deviation in the model-based approach to nitrogen delivery (ZV).
- Large variation in measured grass yield between repetitions (VP).
- Inaccurate approach to the soil moisture status (saturated conditions).



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Conclusions

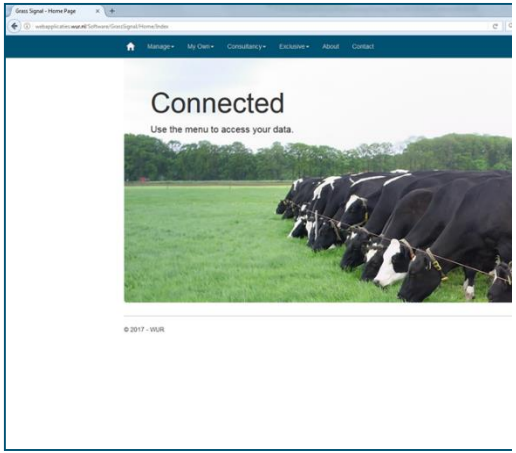
- Concerning reflection measurements WDVIred was the best estimator for DM
- Across locations and years, reflection measurements and grass height as single features were not very accurate in predicting dry matter yield. The growth model performed better at this level.
- With additional use of basic growth data, both reflection measurements and grass height give 5 to 10% extra explained variance.
- Grass height measurements improved the prediction of reflection measurements and the growth model.
- There was barely no prediction for N-content
- For hydrologically complex soils, a more advanced soil moisture model is needed

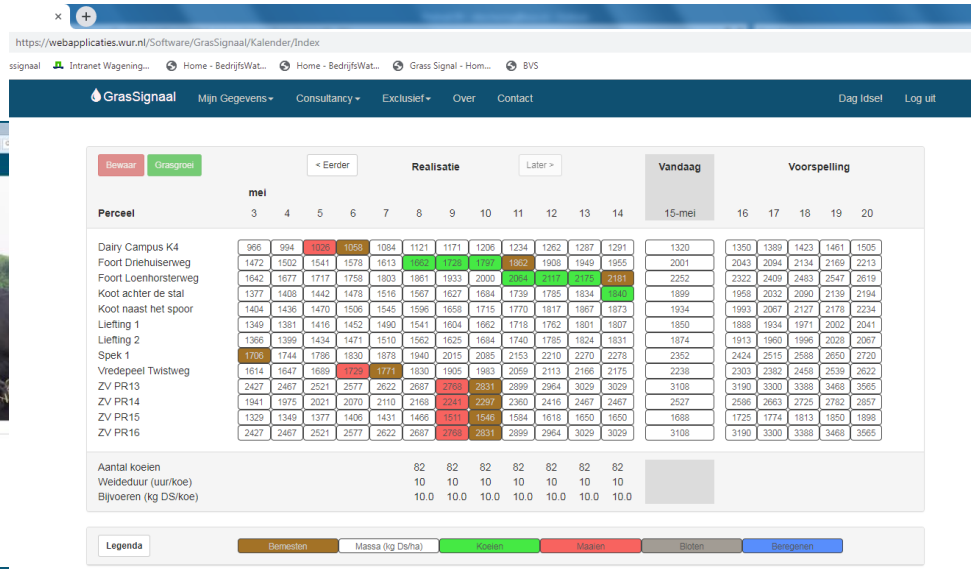
Continuation experiment 2018

- A continuation of the experiment has been carried out in 2018.
- How to get a better grip on the correlation between vegetation index and DM-yield and between vegetation index and N-content?
- Additional measurements
    - Hyper spectral camera with more bands in NIR
    - Canopy, fresh mowed and dry mowed (indoor)
    - Grass performance (flowering, sward density etc.)

Application Grass Signal

- Application based on GRAS2007 and soil moisture model
- Connection of data sources via internet platform Akkerweb





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Take home message

- Combination of data sources improves yield estimation!
- Confirmation of approach:
  - Grass growth prediction as a basis
  - Refinement with sensor measurements

Thanks for the attention!

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