UPOV

International Union for the Protection of New Varieties of Plants

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Technical Working Party for Agricultural Crops

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TWA/52/7

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NEW TECHNOLOGIES IN DUS EXAMINATION

Document prepared by experts from Denmark and the United Kingdom

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The annexes to this document contain copies of presentations to be made by experts from Denmark and the United Kingdom, at the fifty-second session of the TWA:

Annex I “Drone imaging in winter wheat DUS trials”
Annex II “UAV-Based Field Phenotyping in the United Kingdom Agricultural DUS testing”

[Annexes follow]

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Drone imaging in winter wheat DUS trials

PREBEN KLARSKOV HANSEN

INNOVAR

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 818144

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InnoVar will

Use winter wheat as a test crop to devise and demonstrate improved and more efficient methods of

- Integrating new science into **DUS** and VCU testing processes
  - Genome Wide Association Studies
  - **Sensor based phenotyping**
  - Machine learning technology
- Combining DUS and VCU characters, and
- Incorporating variety information into descision-making on-farm
  - Varieties categorised into 'fit-for-purpose-groups' of High Performance Low Risk (HPLR - novel branding developed by *InnoVar*)

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Drone and sensor technology

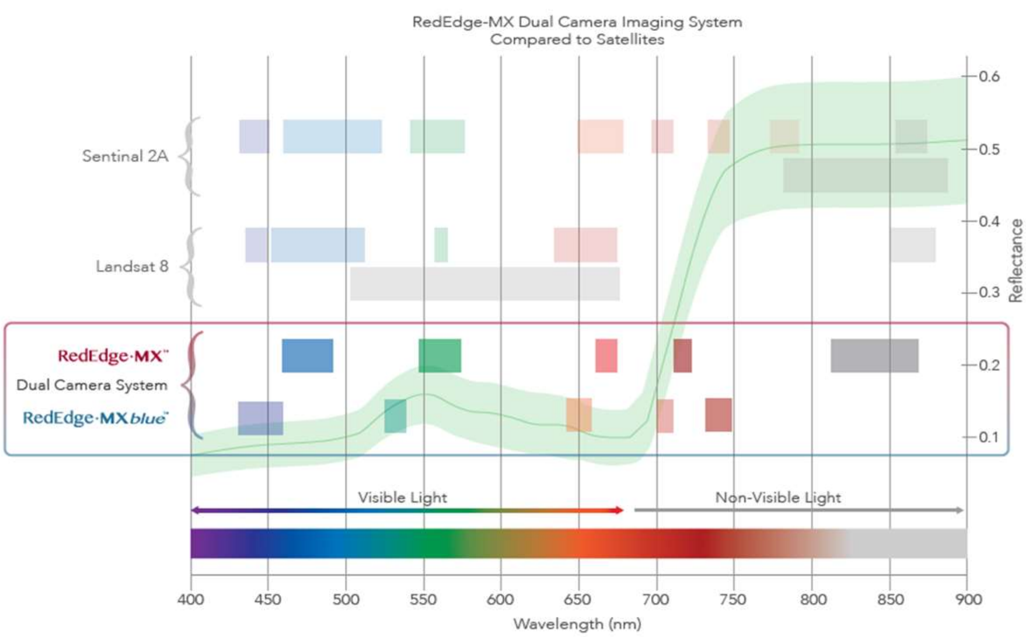


Table. Available indices in *FIELDimageR*. Any other index can be implemented using the option *myIndex* and the new formula (*FIELDimageR::fieldIndex*).

Description	Index	Formula	Related traits	References
Brightness Index	BI	sqrt((R^2+G^2+B^2)/3)	Vegetation coverage, water content	Richardson and Wiegand (1977)
Soil Color Index	SCI	(R-G)/(R+G)	Soil color	Mathieu et al. (1998)
Green Leaf Index	GLI	(2*G-R-B)/(2*G+R+B)	Chlorophyll	Louhaichi et al. (2001)
Primary Colors Hue Index	HI	(2*R-G-B)/(G-B)	Soil color	Escadafal et al. (1994)
Normalized Green Red Difference Index	NGRDI	(G-R)/(G+R)	Chlorophyll, biomass, water content	Tucker (1979)
Spectral Slope Saturation Index	SI	(R-B)/(R+B)	Soil color	Escadafal et al. (1994)
Visible Atmospherically Resistant Index	VARI	(G-R)/(G+R-B)	Canopy, biomass, chlorophyll	Gitelson et al. (2002)
Overall Hue Index[#]	HUE	atan(2*(B-G-R)/30.5*(G-R))	Soil color	Escadafal et al. (1994)
Blue Green Pigment Index	BGI	B/G	Chlorophyll, LAI	Zarco-Tejada et al. (2005)
Plant Senescence Reflectance Index	PSRI	(R-G)/(RE)	Chlorophyll, nitrogen, maturity	Merzlyak et al. (1999)
Normalized Difference Vegetation Index	NDVI	(NIR-R)/(NIR+R)	Chlorophyll, LAI, biomass, yield	Rouse et al. (1974)
Green Normalized Difference Vegetation Index	GNDVI	(NIR-G)/(NIR+G)	Chlorophyll, LAI, nitrogen, protein content, water content	Gitelson et al. (1996)
Ratio Vegetation Index	RVI	NIR/R	Biomass, water content, nitrogen	Pearson and Miller (1972)
Normalized Difference Red Edge Index	NDRE	(NIR-RE)/(NIR+RE)	Chlorophyll	Gitelson and Merzlyak (1994)
Triangular vegetation index	TVI	0.5*(120*(NIR −G)−200*(R −G))	Green LAI, chlorophyll, canopy	Broge and Leblanc (2000)
Chlorophyll vegetation index	CVI	(NIR*R)/(G^2)	Chlorophyll	Vincini et al. (2008)
Enhanced vegetation index	EVI	2.5*(NIR −R)/(NIR + 6*R −7.5*B + 1)	Chlorophyll, biomass, nitrogen	Huete et al. (2002)
Chlorophyll index – green	CIG	(NIR/G) −1	Chlorophyll	Gitelson et al. (2003)
Chlorophyll index – red edge	CIRE	(NIR/RE) −1	Chlorophyll	Gitelson et al. (2003)
Difference Vegetation Index	DVI	NIR-RE	Nitrogen, chlorophyll	Jordan (1969)

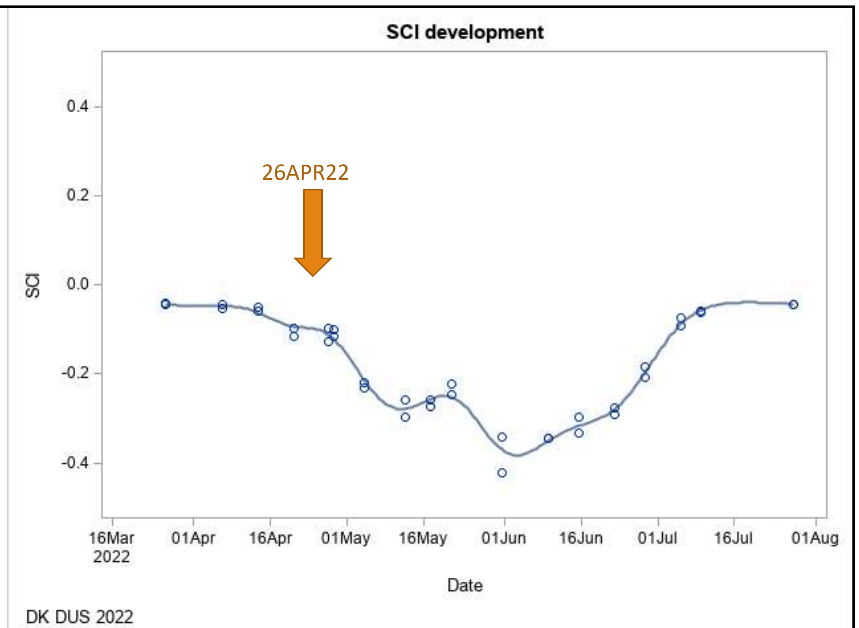
[#] Index HUE was modified to capture better the soil color. Original equation: "atan(2*(R-G-B)/30.5*(G-B))" (Escadafal et al., 1994)

Callobre

Plant:

growth habit

3 - semi erect

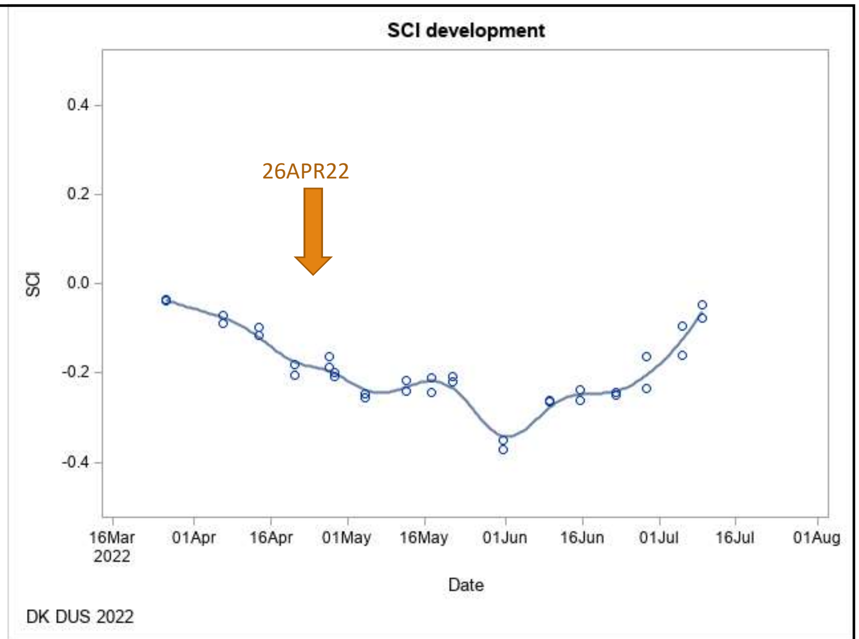


Stellarka

Plant:

growth habit

9 - prostrate



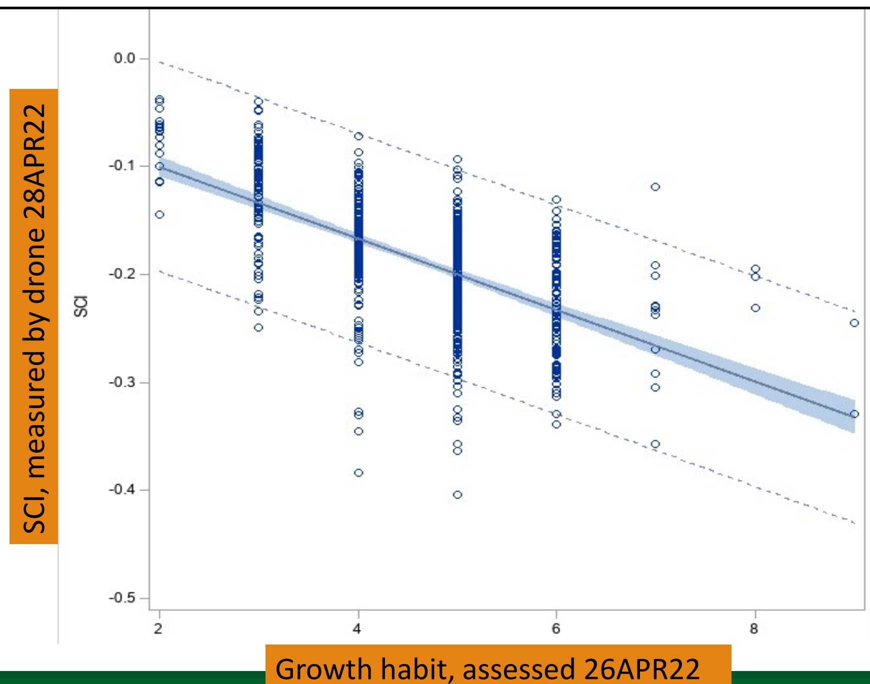
Growth habit

Drone measurements

vs

visual assessments

300 varieties, 2 reps

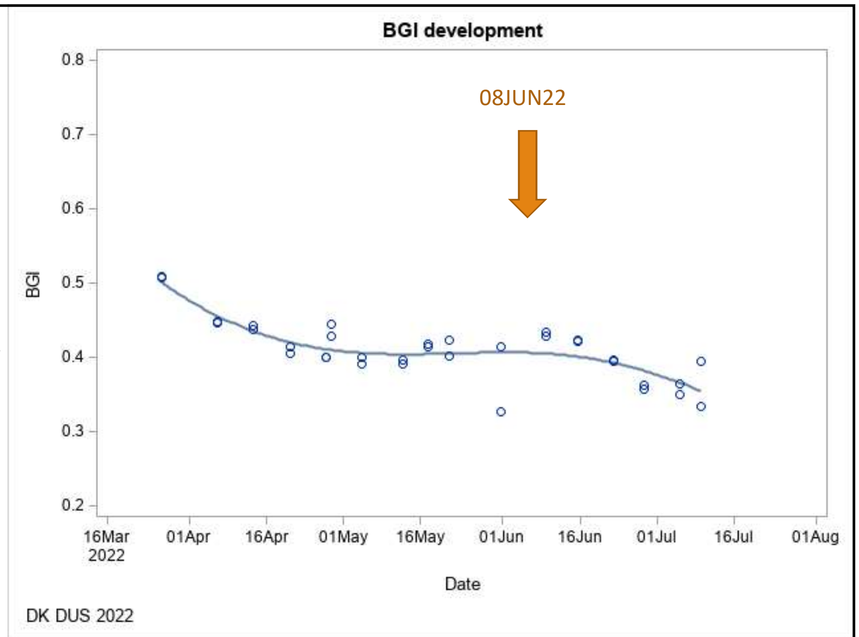


Basilio

Flag leaf:

glaucosity of blade

1 - absent or very weak

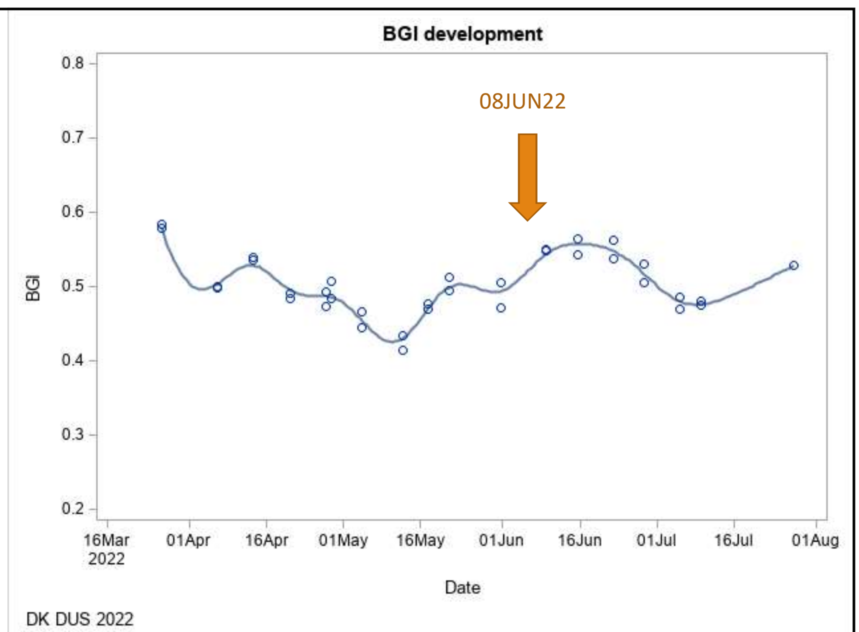


Waximum

Flag leaf:

glaucosity of blade

9 - very strong



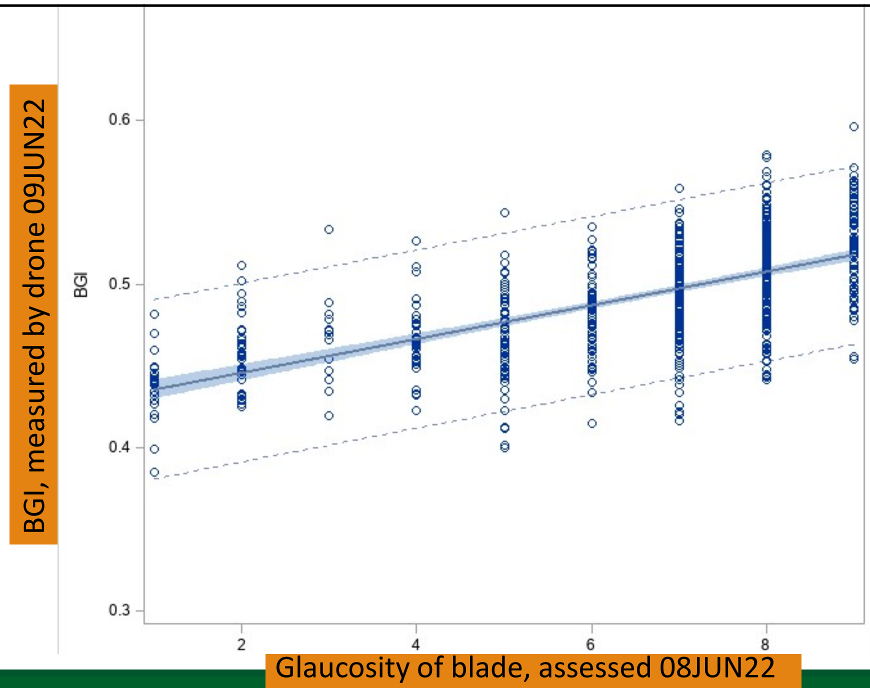
Glaucosity of blade

Drone measurements

vs

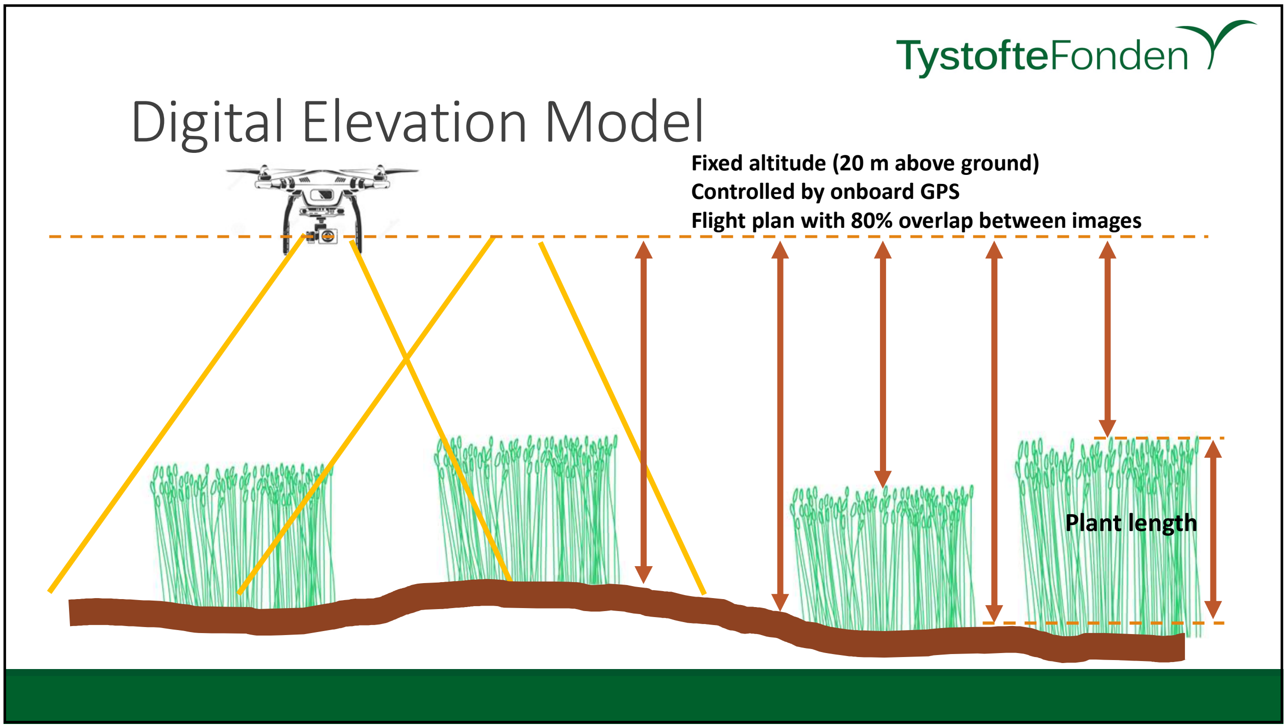
visual assessments

300 varieties, 2 reps



Materials and methods

- 2 years
- 300 winter wheat genotypes
- 2 replicates
- Plot size brutto 1,5*2m
- Manual plant length measurements
  - 24AUG21 + 28JUL22
  - 5 subsamples / plot
  - Stretched plants
- Drone images
  - 24JUL21 + 26JUL22
  - 2330 subsamples/plot (2,7 cm/pixel)
  - Digital elevation model from Agisoft Metashape v 1.8.1
  - Height above sea level of **Crop surface** = Clip 1*1,7 m (99% fraqtile)
  - Height above sea level of **Soil surface** = Clip 1,6*2,5 m (1% fractile)
  - Canopy height (plant length)= Crop surface – Soil surface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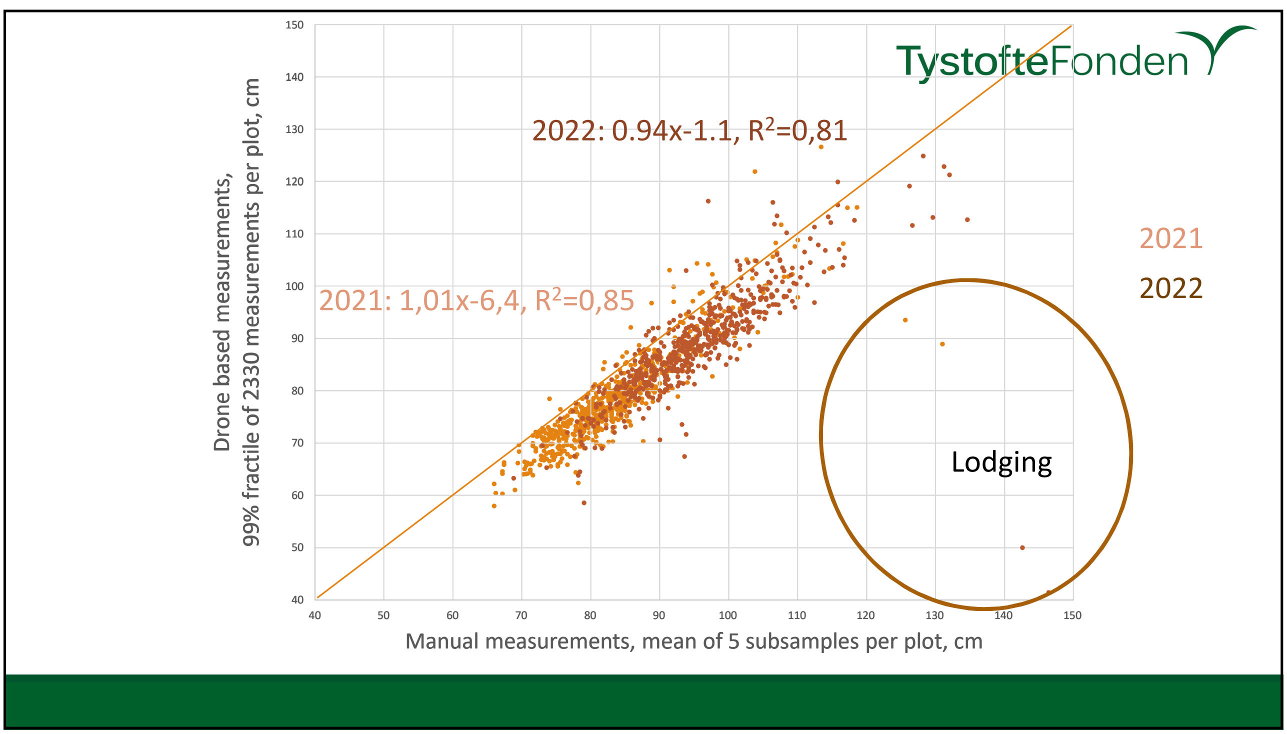
Digital Elevation Model
Fixed altitude (20 m above ground)
Controlled by onboard GPS
Flight plan with 80% overlap between images
Plant length


TystofteFonden
2022: 0.94x-1.1, R2=0,81
2021: 1,01x-6,4, R2=0,85
2021
2022
Lodging
Drone based measurements,
99% fractile of 2330 measurements per plot, cm
Manual measurements, mean of 5 subsamples per plot, cm
40 50 60 70 80 90 100 110 120 130 140 150

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Conclusions

Different vegetation indices can explain varietal differences in DUS characteristics

- Soil Cover Index [SCI; (R-G)/(R+G)], shows correlation with visual assessments of growth habit
- Blue Green Pigment Index [BGI; B/G)] shows correlation with visual assessments of glaucosity of blade

Plant length estimated from drone images showed a correlation with manual measurements

- R^2=0.85 in 2021 *and*
- R^2=0.81 in 2022

after exclusion of plots with lodging

A general under-estimation of 4-6 cm of plant length is found in the drone based plant length measurements

Further studies, including machine learning, will be conducted in InnoVar to increase accuracy

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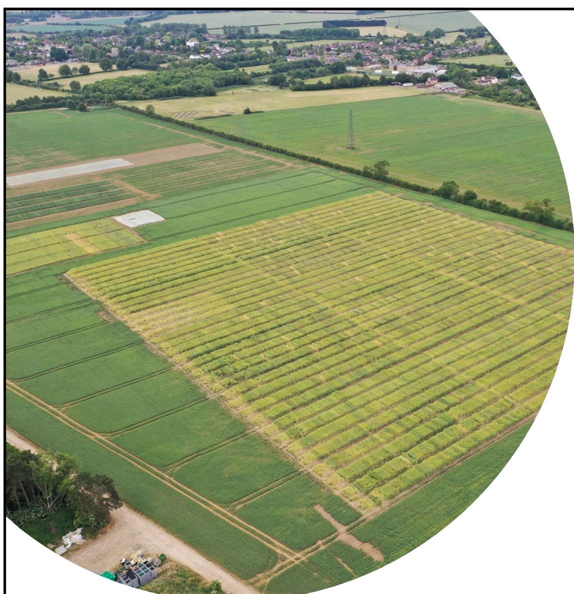
[Annex II follows]

NIAB

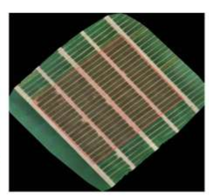
UAV-Based Field Phenotyping in the United Kingdom Agricultural DUS testing

UPOV TWA 52 (May 2023)



UAV Image Capture

a. Low-cost UAV



b. Flight Plan c. 2D orthomosaic d. Detail image

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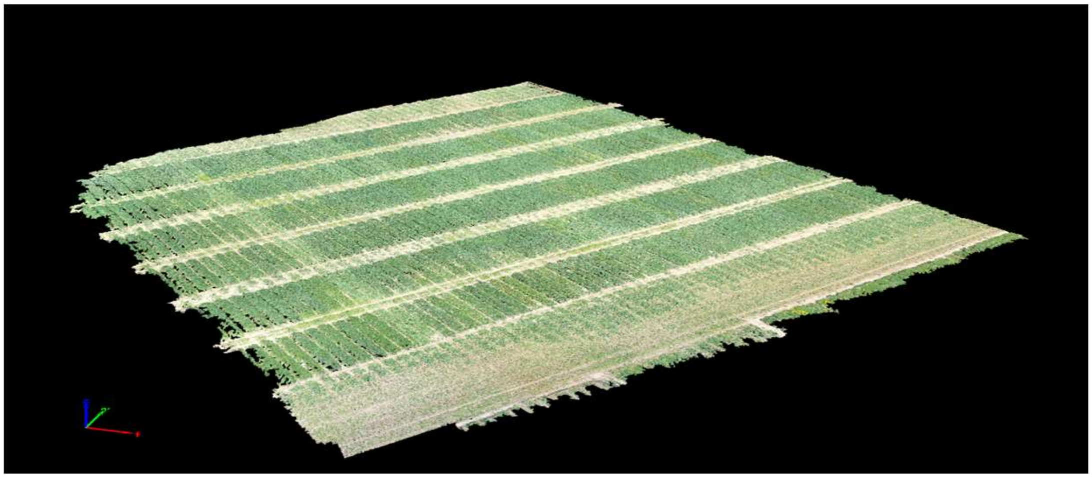
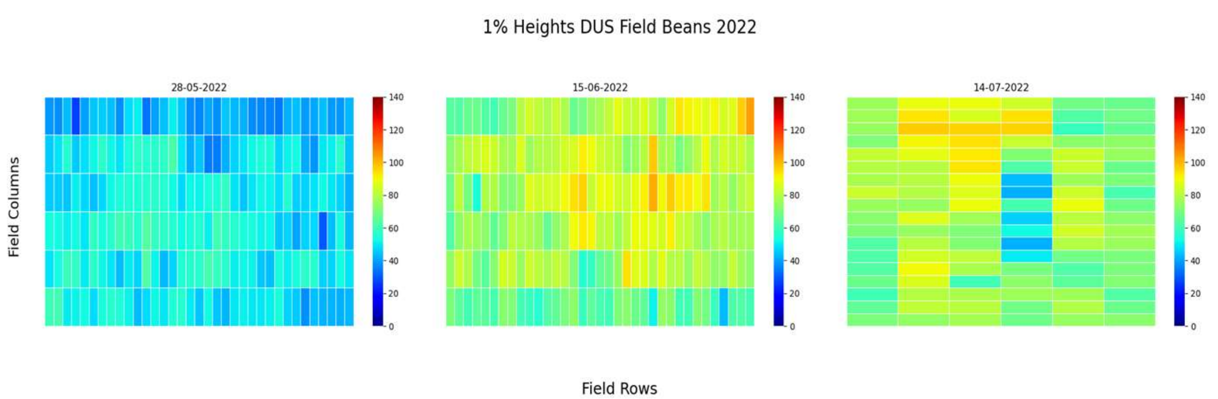
3D field-level representation

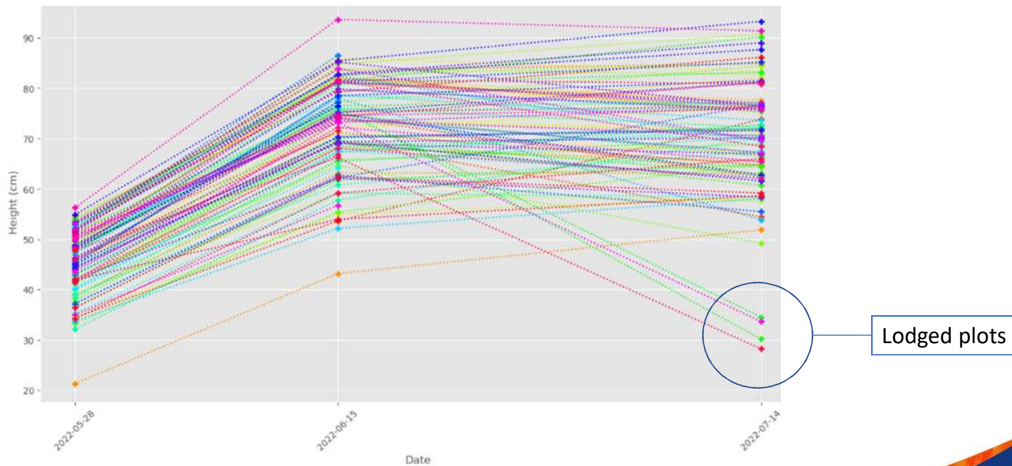


Plot based heatmaps showing crop height differences



Vicia faba L.

Variety based UAV plant height comparisons



109 varieties; 2 replicates

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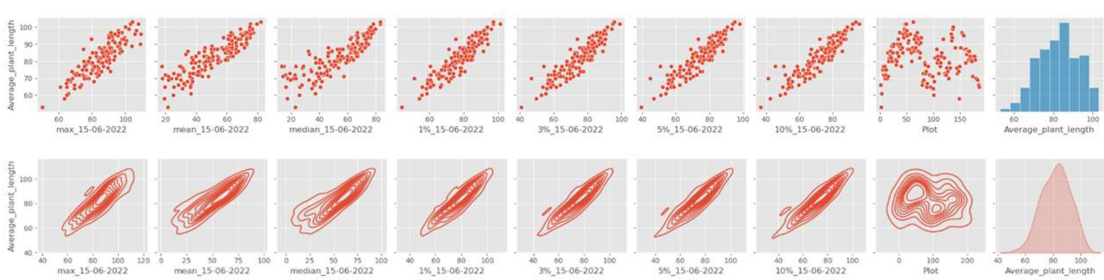
Vicia faba L. (Field Bean)

Correlation between UAV plant heights and manually measured plant lengths (cm)



Manual measurements (20 individual measurements) – 12th July 2022
Flight data – 15th June 2022

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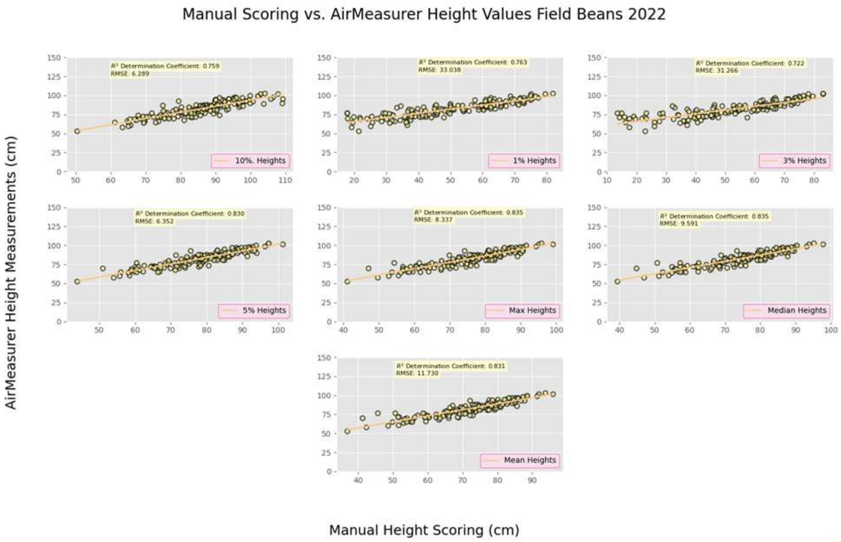
Vicia faba L. (Field Bean)

Correlation between UAV plant heights and manually measured plant lengths (cm)



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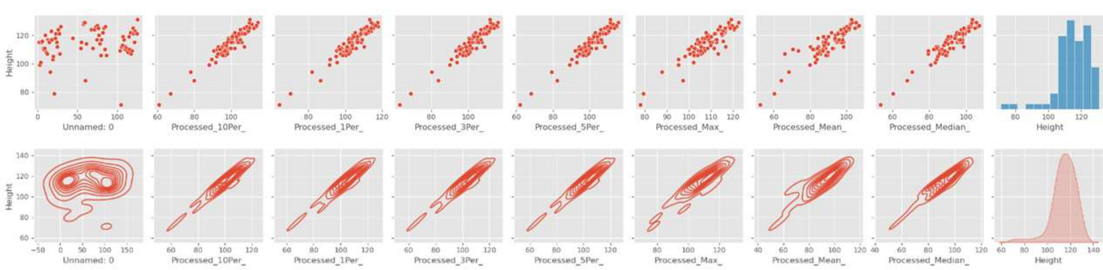
Avena sativa L. (Oats)

Correlation between UAV plant heights and manually measured plant lengths (cm)



73 varieties; 2 replicates
Manual measurements (3 individual measurements) – 30th June 2022
Flight data – 6th July 2022

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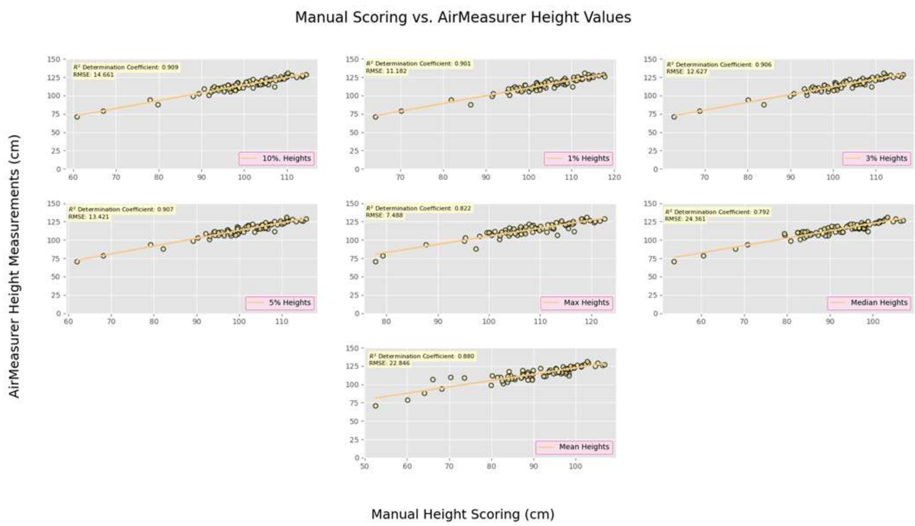
Avena sativa L. (Oats)

Correlation between UAV plant heights and manually measured plant lengths (cm)



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Conclusions

- Both cases showed good correlation but must determine suitable thresholding of data points appropriate to the species measured.
- Timing and number of flights needs to be considered to factor in lodging of plots and/or "shrinkage" to plants.
- Data storage and costs involved can be high.
- Potential for additional assessments.
- Maybe not appropriate for all species (Oilseed rape, Barley)

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[End of Annex II and of document]