



Tracking the Wheat Traits of Tomorrow

What can drones tell us?



Andrew Riche



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Introduction – research needs



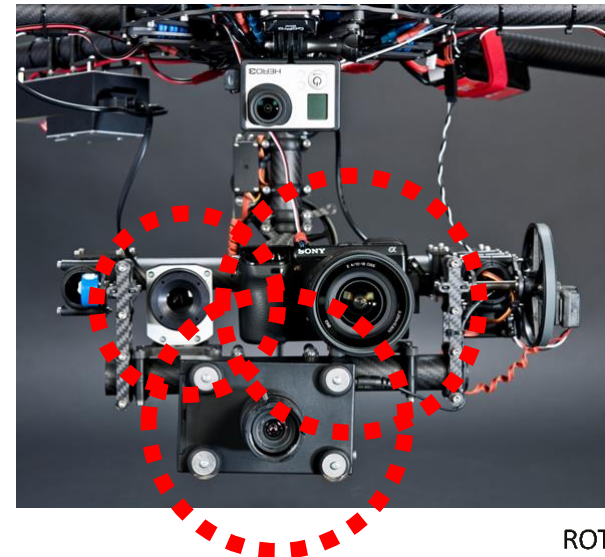
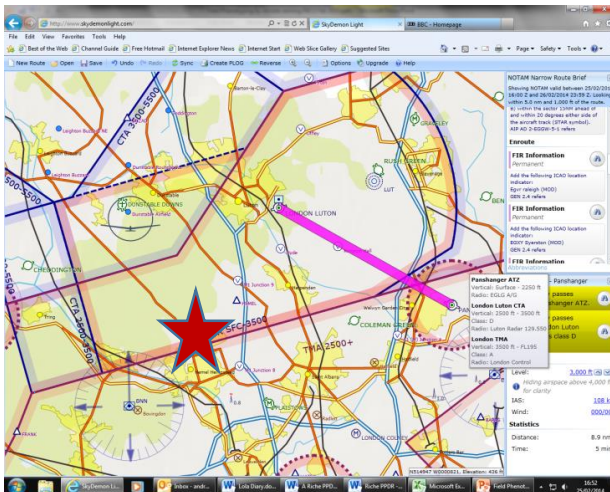
- Increasing number of field experiments
- Increasing demand for phenotyping
- Requires cost-effective High throughput Phenotyping

Field measurement solutions:

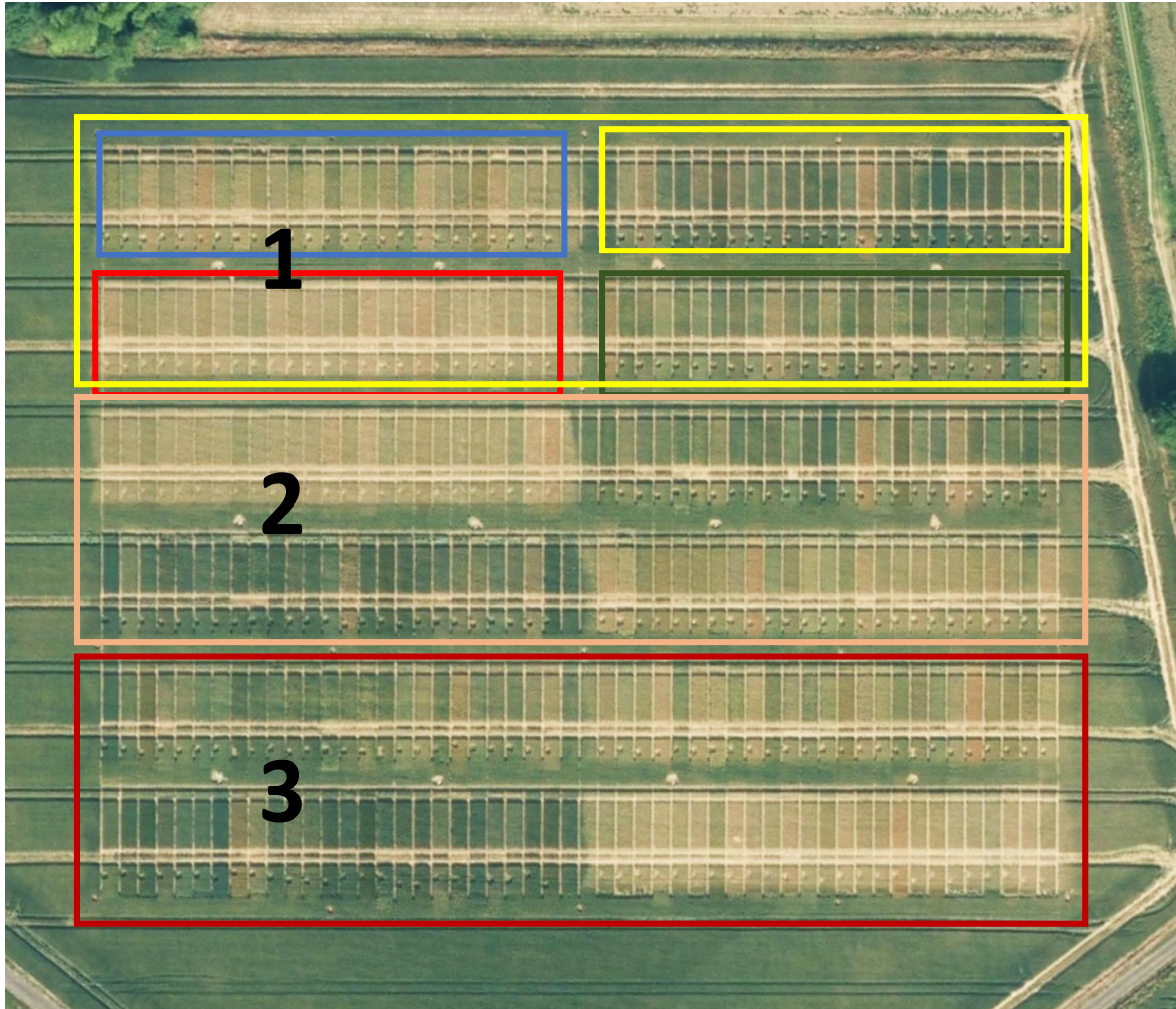


Rothamsted UAV - background

- Regulations – CAA, Insurance, flight clearance
- Allowed up to 120m altitude, 500m from operator
- Fly by GPS
- Carry up to 3 sensors



WGIN Diversity trial



- 25 varieties
- 4 levels of N fertiliser:
 - 0 kg/ha
 - 100 kg/ha
 - 200 kg/ha
 - 350 kg/ha
- 3 replicates

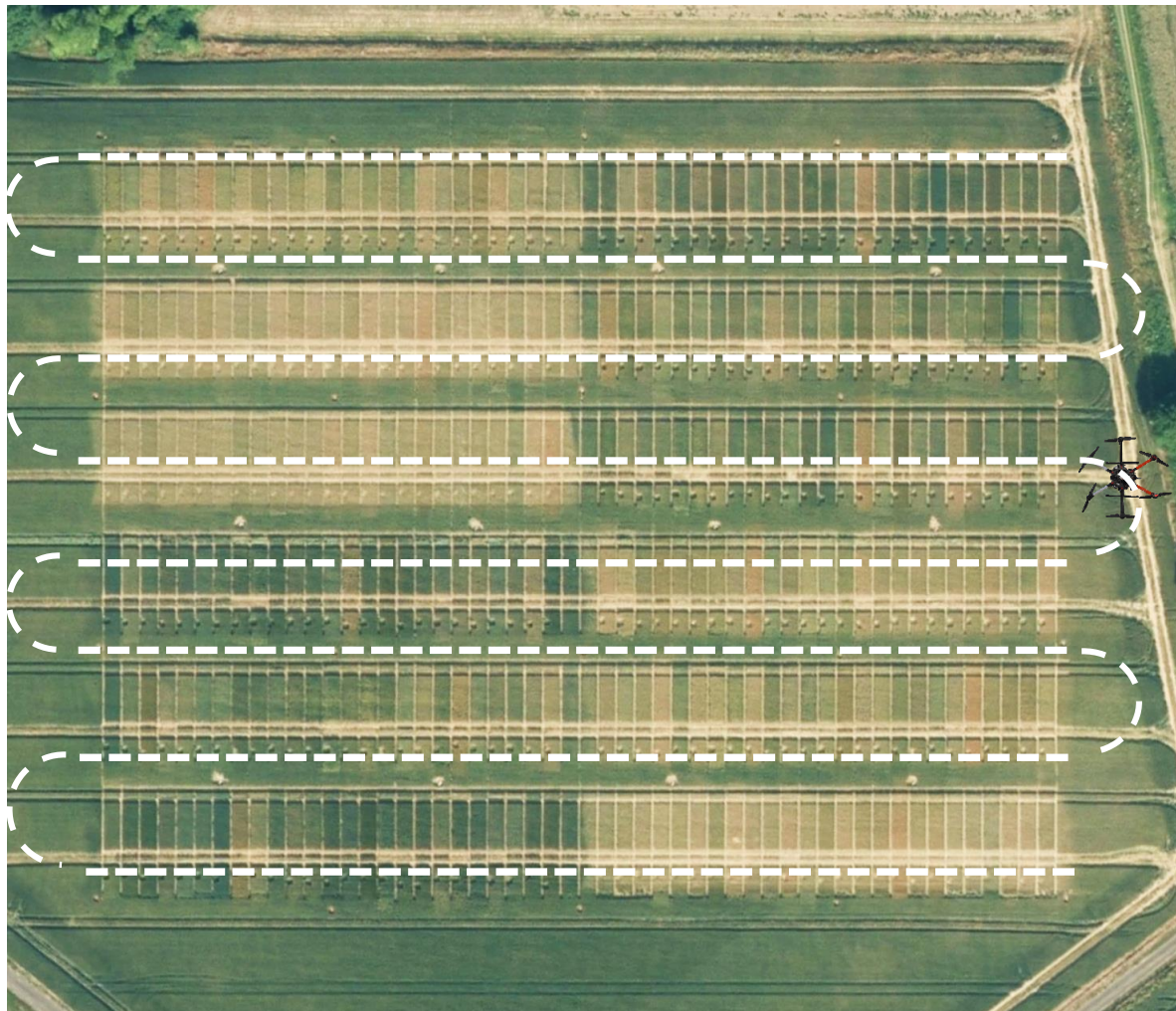


Pre-flight preparations

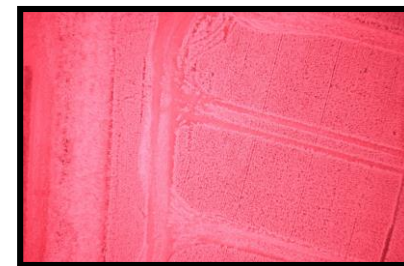


Ground control points

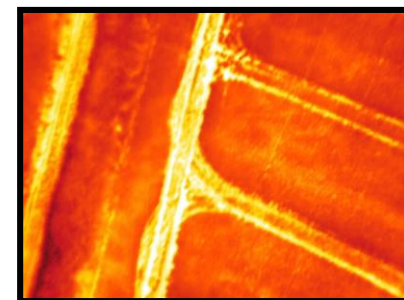
Flight pattern



Red Blue Green

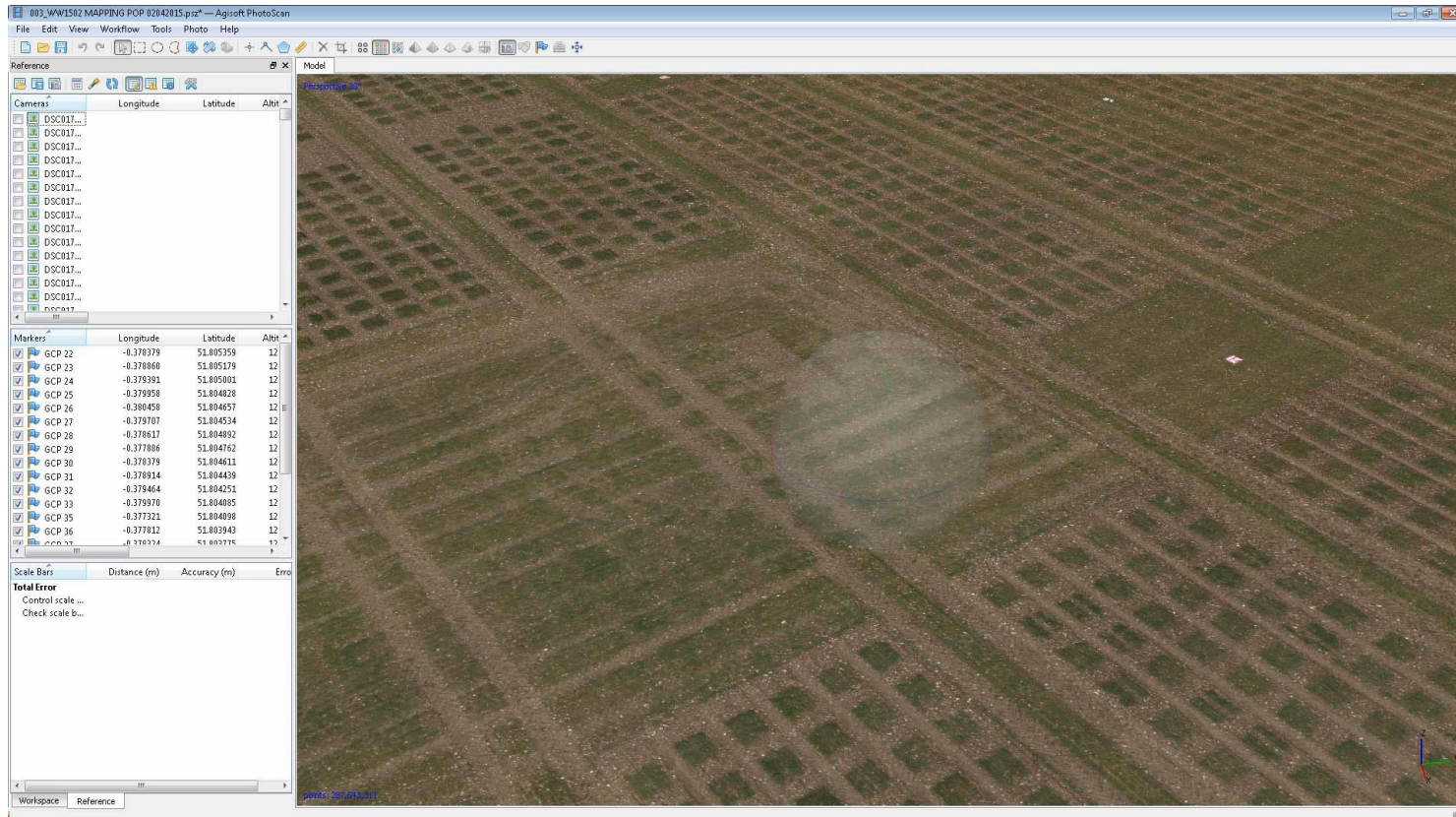
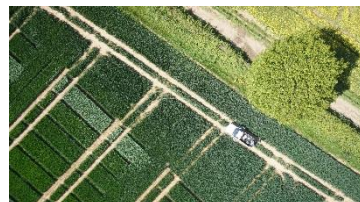


Near infrared



Thermal

WGIN Diversity trial

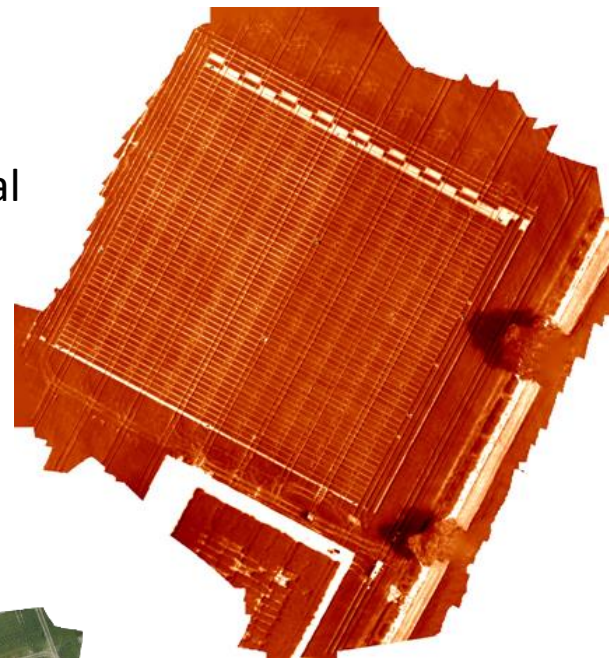


Ortho mosaics



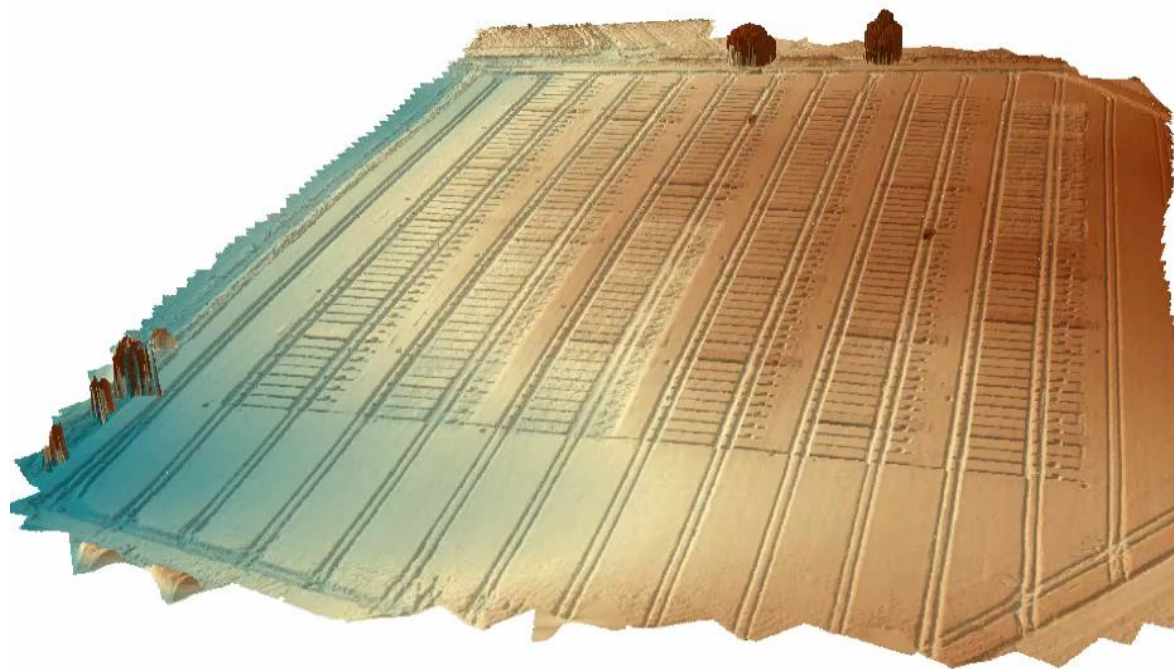
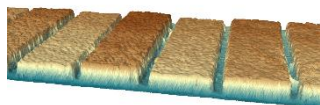
Near Infrared

Thermal

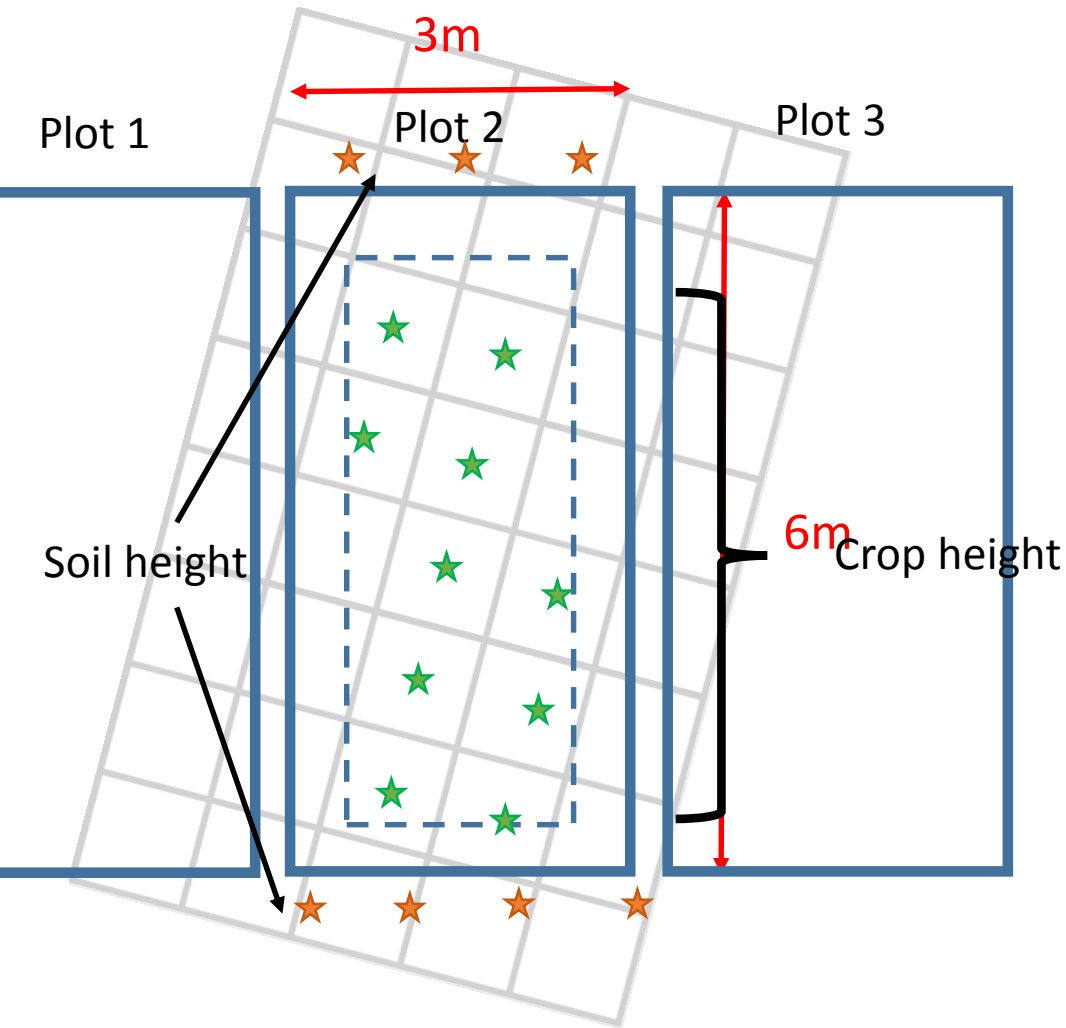


Red Blue Green

WGIN Diversity trial



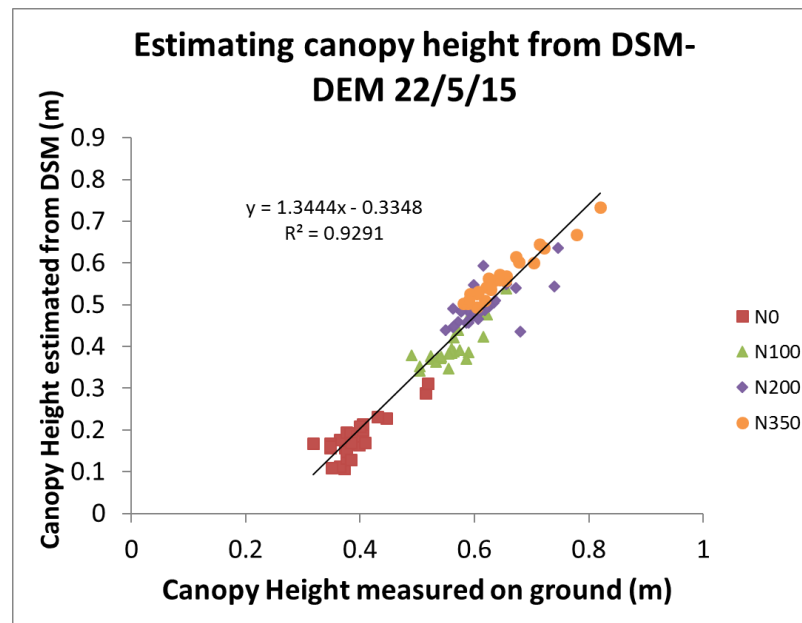
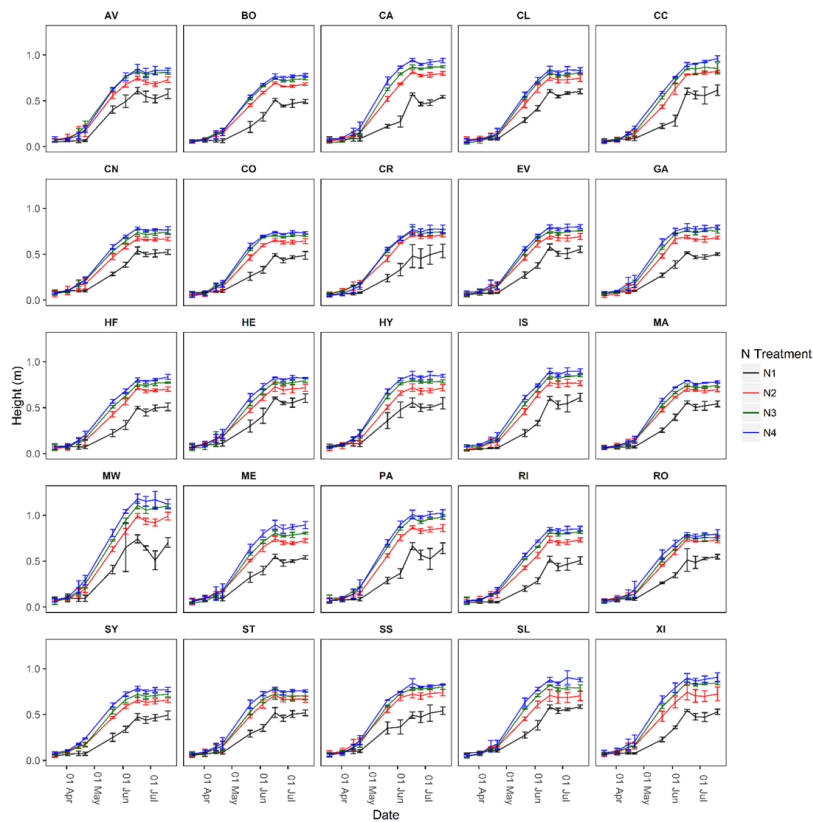
Data extraction: Crop height



- 50cm border excluded from analysis
- 100cm grid overlaid
- Crop and soil height data extracted
- Outliers excluded at the point cloud processing stage



Data extraction: Crop height (2)



Article

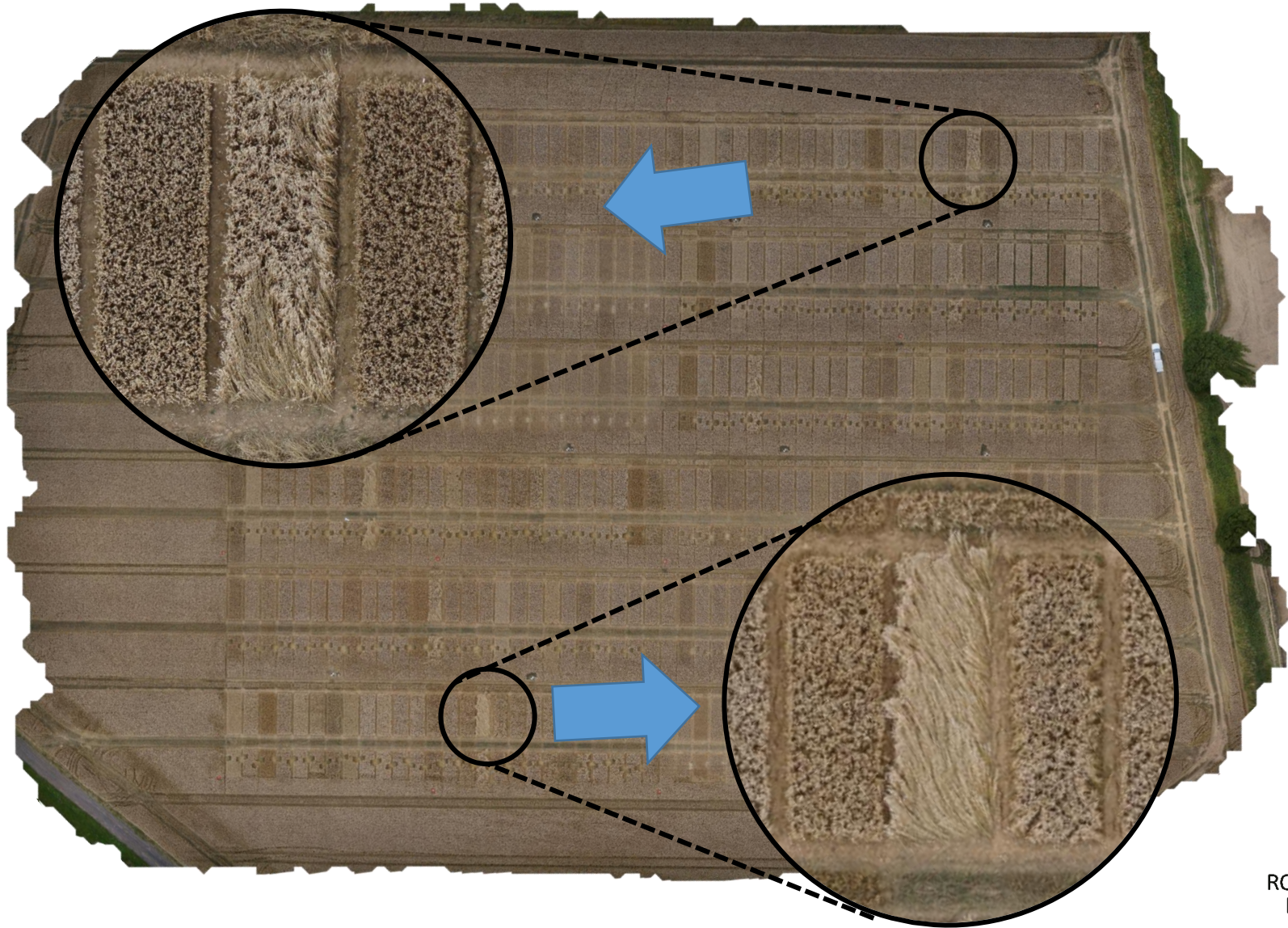
High Throughput Field Phenotyping of Wheat Plant Height and Growth Rate in Field Plot Trials Using UAV Based Remote Sensing

Fenner H. Holman ^{1,*}, Andrew B. Riche ², Adam Michalski ², March Castle ², Martin J. Wooster ^{1,3} and Malcolm J. Hawkesford ^{2,*}



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Data extraction: lodging



Data extraction: lodging



Data extraction: lodging



Plot	Variety	N Level	% Area Lodged	Lodging score
92	Maris Widgeon	N3	11	3
130	Maris Widgeon	N3	14	3
213	Maris Widgeon	N3	14	3
43	Maris Widgeon	N4	17	4
159	Maris Widgeon	N4	75	6
266	Maris Widgeon	N4	100	6
31	Paragon	N4	6	1
169	Paragon	N4	14	3
272	Paragon	N4	11	3

Lodging score

0 = No lodging

5 = lodged 45°

10 = lodged 90°

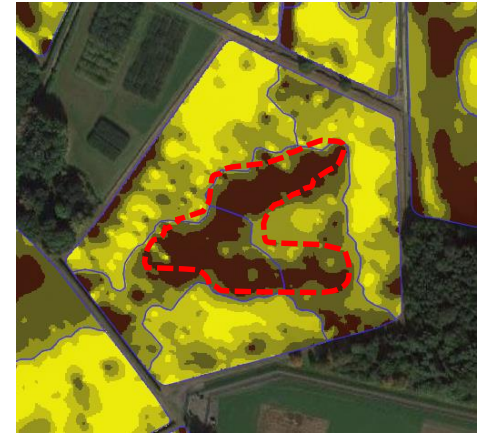


Vegetation classification

Diversity 08/04/15

$$\text{ExGR} = (2 \times G - R - B) - (1.4 \times R - G)$$

ExGR (Excess green – excess red)



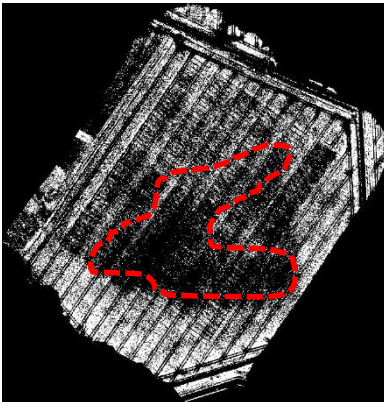
Variation in canopy development

Also seen in bare earth image

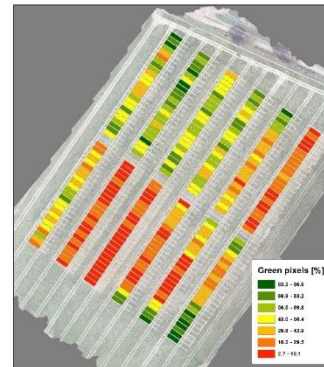
Same area picked up by shallow conductivity scan

This area of soil has a higher clay content

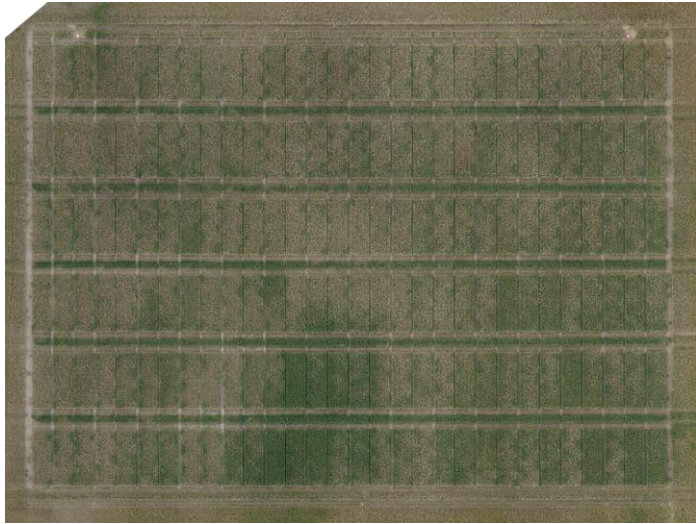
Mask built by ExGR pixel filtration



Canopy data extracted



Disease assessment by VC

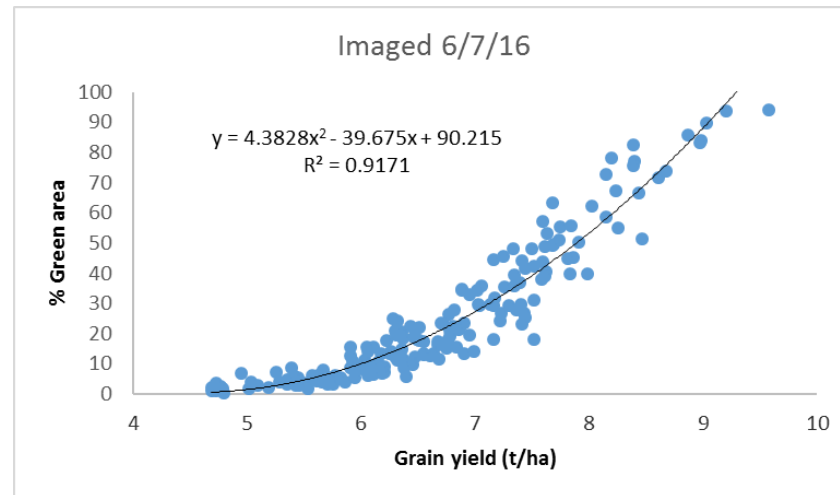


2nd wheat, common variety, over sown first wheat variety trial.



Take-all infected roots

Vegetation classification data from UAV imagery correlates well with grain yield at final harvest

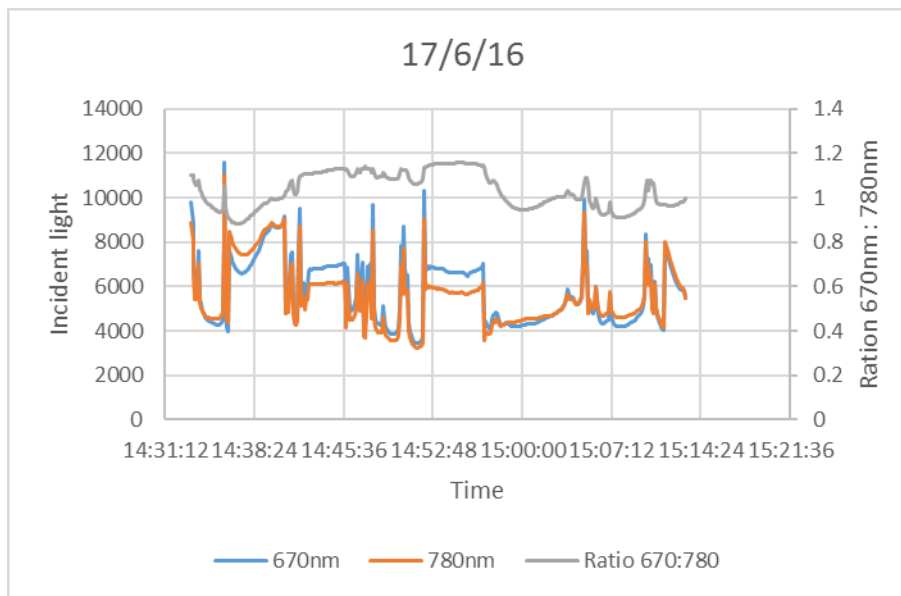
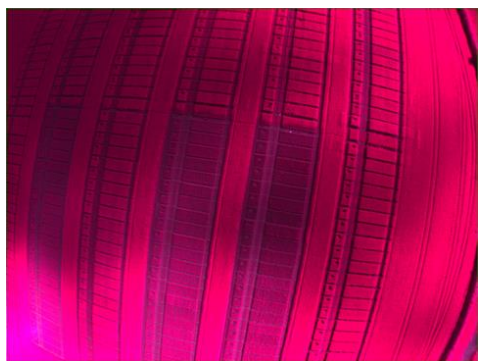


Crop Indices

Index	NIR	Red	Green	Formula
Sum Green Index		R	G	$SGI = \text{avg}(500:600)$
Green Normalized Difference Vegetation Index		R	G	$VARI = (550 - 680) / (550 + 680)$
Visible Atmospherically Resistant Index		R	G	$VARI = (550 - 680) / (550 + 680 - 470)$
Red difference vegetation index	N	R		$RDVI_{900} = 900 - 680$
red simple ratio	N	R		$SRa_{800} = 800 / 680$
green difference vegetation index	N		G	$gDVI_{800} = 800 - 550$
green simple ratio	N		G	$gSRa_{800} = 800 / 550$
Normalized Difference Vegetation Index	N	R		$NDVI_{800} = (800 - 680) / (800 + 680)$
Green Normalized Difference vegetation Index	N		G	$GNDVI_{800} = (800 - 550) / (800 + 550)$
Infrared Percentage Vegetation Index	N	R		$IPVI = 800 / (800 + 680)$
Modified Simple Ratio	N	R		$MSR = [(800 / 680) - 1] / [(\text{sqrt}(800 / 680) + 1)]$
Non-Linear Index	N	R		$NLI = (800^2 - 680) / (800^2 + 680)$
Renormalized Difference Vegetation Index	N	R		$RDVI = (800 - 680) / \text{sqrt}(800 - 680)$
Soil Adjusted Vegetation Index	N	R		$SAVI = 1.5 * (800 - 680) / (800 + 680 + 0.5)$
Optimized Soil Adjusted Vegetation Index	N	R		$OSAVI = (800 - 680) / (800 + 680 + 0.16)$
Transformed Difference Vegetation Index	N	R		$NDVI_{800} = \text{sqrt}(0.5 + [(800 - 680) / (800 + 680)])$
Modified Non-Linear Index	N	R		$MNLI = (800^2 - 680) * (1 + 0.5) / (800^2 + 680 + 0.5)$
Green Atmospherically Resistant Index	N	R		$GARI = [800 - (550 - 1.7 * (470 - 680))] / [800 + (550 - 1.7 * (470 - 680))]$
Enhanced vegetation index	N	R		$EVI = 2.5 * (800 - 680) / (800 + 6 * 680 - 7.5 * 470 + 1)$
Leaf Area Index	N	R		$LAI = 3.618 * EVI - 0.118$



Crop Indices – Ambient light

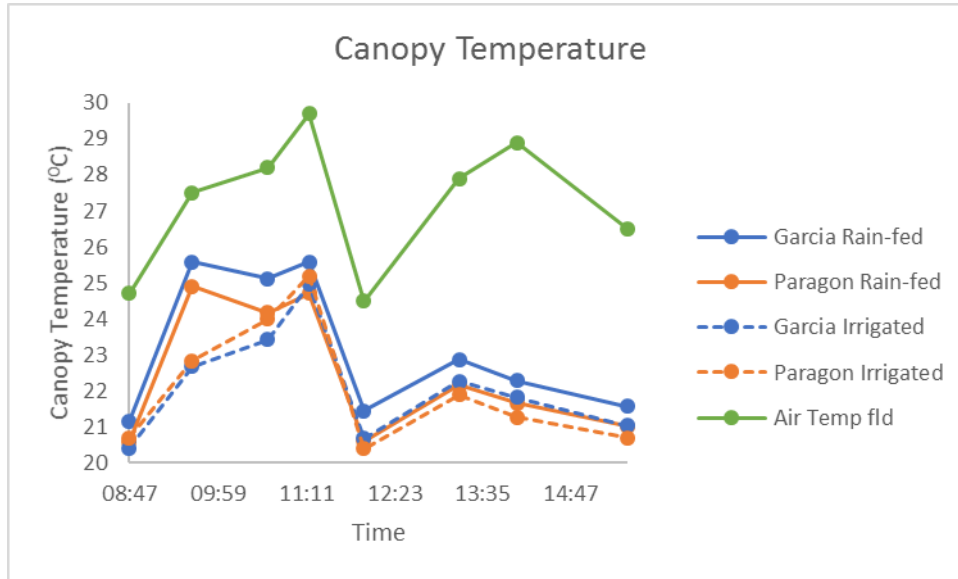


Spectrometer

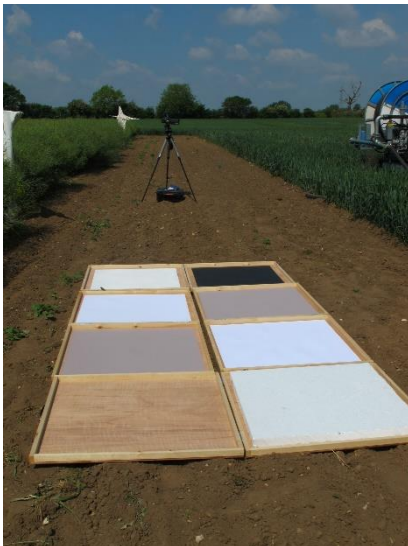


UAV mounted sensor

Canopy temperature



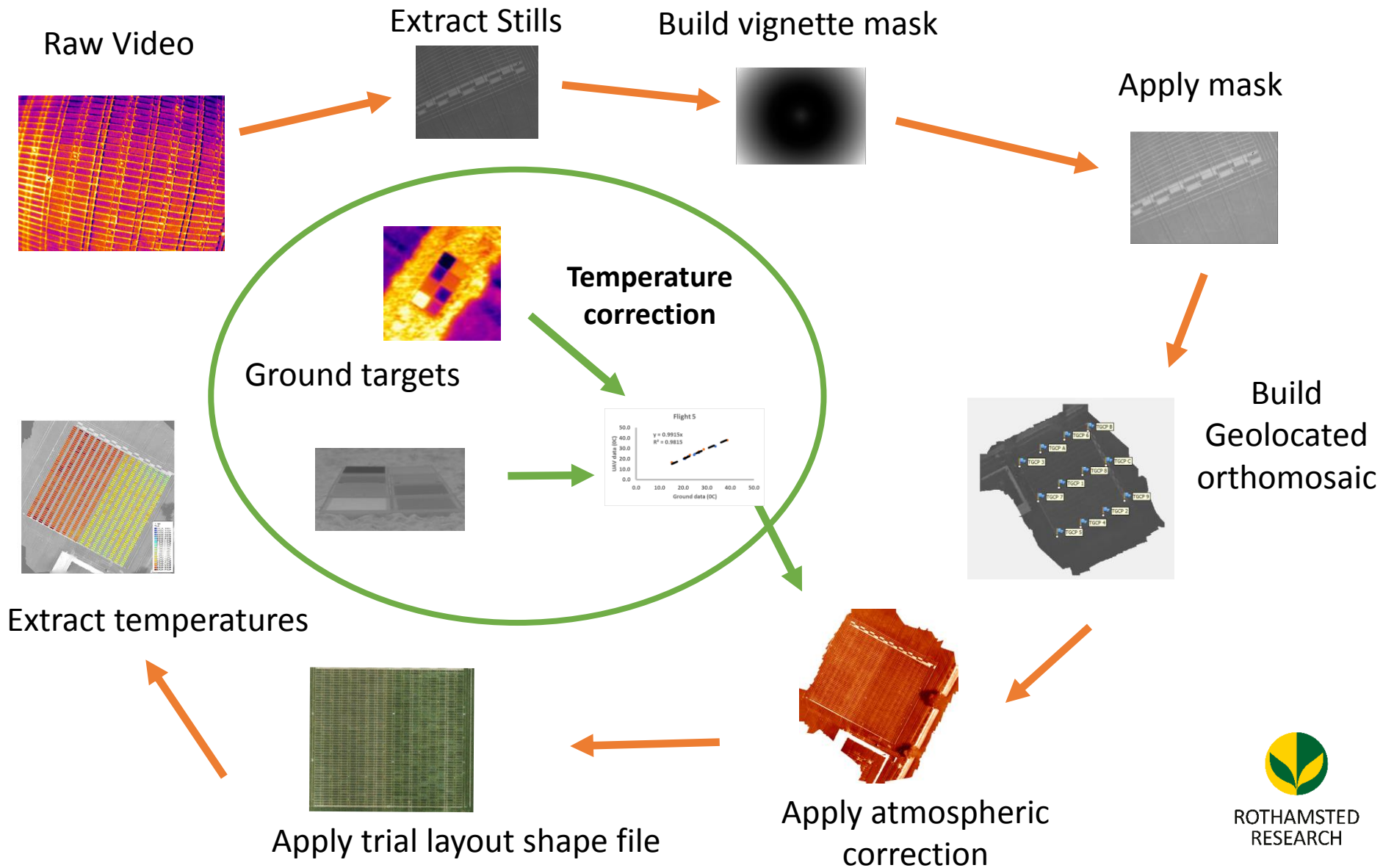
Canopy temperature tracked air temperature, but was lower, and on average about 1 degree lower on irrigated plots compared with rain-fed.



Ground control point – aluminium foil and black paint on wood



Thermal image processing



Future work



RTK GNSS
Base station



5m altitude with 45mm lens

Aims:

- Automated plant counts
- Automated ear counting
- Anthesis detection
- Insect pest/weed/disease identification



Conclusions

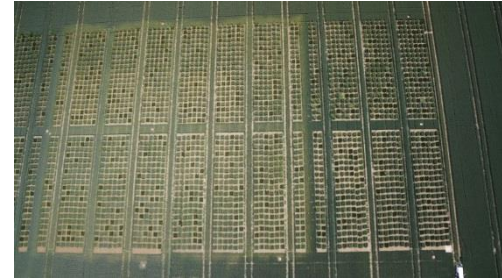
Crop traits measurable from UAV imagery:

- Crop height
- Lodging
- Vegetation classification (measures senescence, disease, canopy development)
- Crop Indices (biomass growth, LAI, N uptake, senescence)
- Canopy temperature

Measuring traits, also gaining a better understanding of spatial variability

Data processing takes time

Hi-resolution imaging will take the UAV work into new territory – work in progress



Acknowledgments

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Nicolas Virlet

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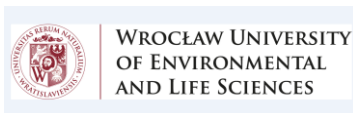


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