Weed detection for targeted weed management and control

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Image based weed detection

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Computer vision could offer the potential to **discriminate weed plants from crops** in-field. A growing body of work is attempting to **develop this technology** and **apply it to precision weed management**.

Precision weed management might deliver both **economic** and **ecological** benefits via reduced herbicide use – **provided weeds can still be controlled simply and effectively**

- Weed detection using Drones
- Weed detection using on-farm machinery

Example: the Crop and Weed dataset - https://paperswithcode.com/dataset/cropandweed-dataset

Blackgrass: *Alopecurus myosuroides*

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- An outcrossing, predominantly autumn germinating annual species.
- Increasing distribution and abundance in the UK and NW Europe.
- Can it be detected and mapped autonomously via images?

Case study 1: Using UAVs

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__AiScope__

Using **UAVs** (drones) to capture imagery in-field, and train algorithms to recognise weeds

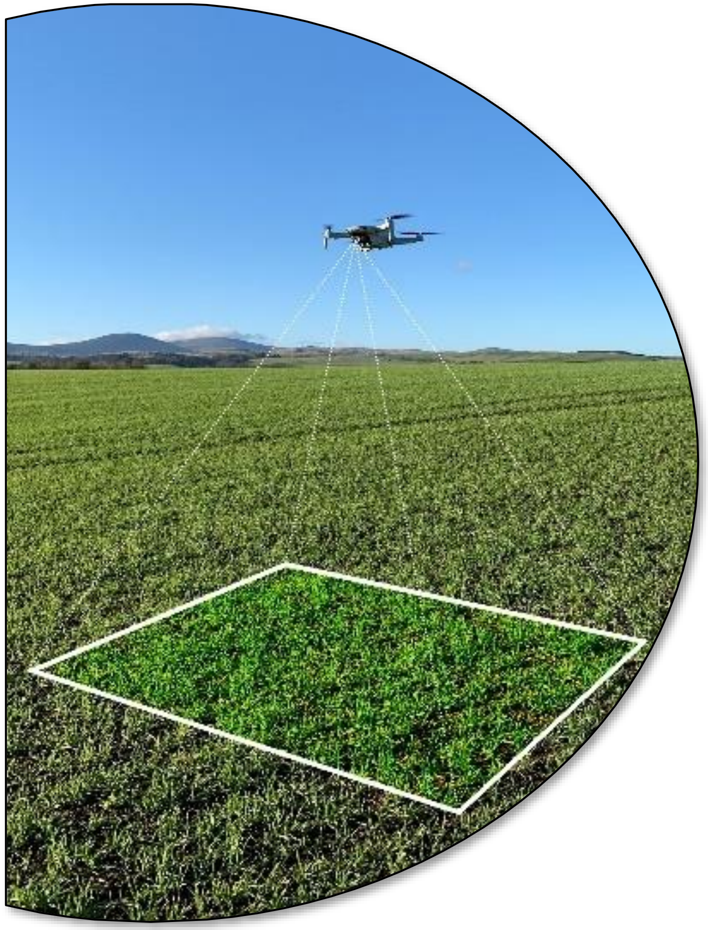
In this case, Blackgrass at the flowering stage

The University Of Sheffield.

IBM

Hummingbird Technologies

Precision Decisions
DRIVING FARMING FORWARDS



Mapping Blackgrass using UAV imagery

Hummingbird Technologies

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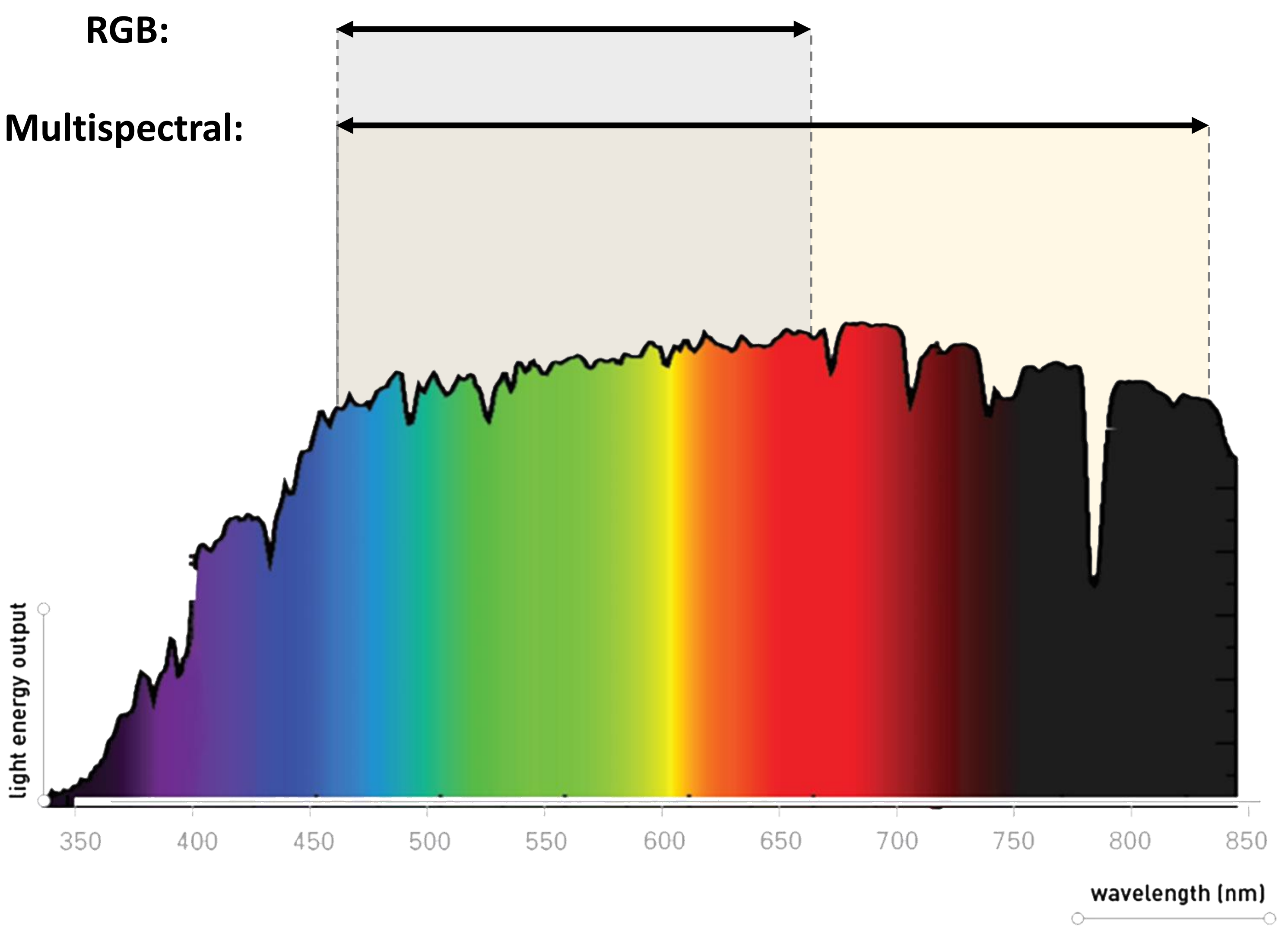
Attempt to map Blackgrass (*Alopecurus myosuroides*) at flowering using drones

- Created **high quality dataset** of 34 imaged wheat fields in 2021

- Images at 1cm resolution using a DJI M210 UAV, with X7 sensors

Lesson 1: *Resolution and timing of imagery collection is supremely important*

Imagery types:



Captured images with two different camera types:

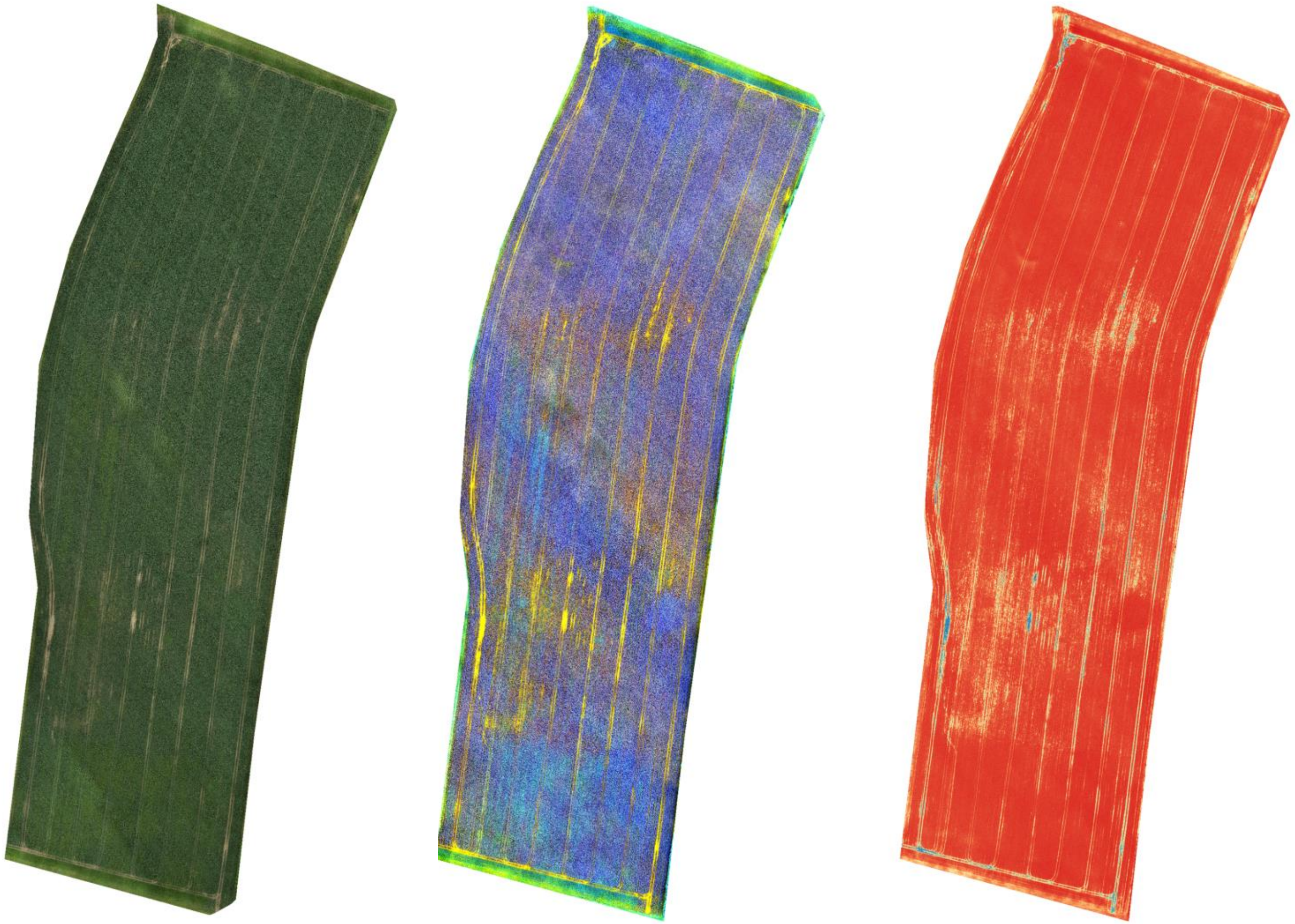
- Standard RGB images using the visible light spectrum.
- Multispectral images collecting data at wavelengths 475, 560, 668, 717, and 840nm

Normalized Difference Vegetation Index (NDVI)

RGB
(Red, Green, Blue)

MS
(Multispectral)

NDVI
(normalized difference vegetation index)



$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

- Provides a measure of "greenness"
- Standard measure in assessment of crop health and development

NDVI provides little improvement for flowering plants

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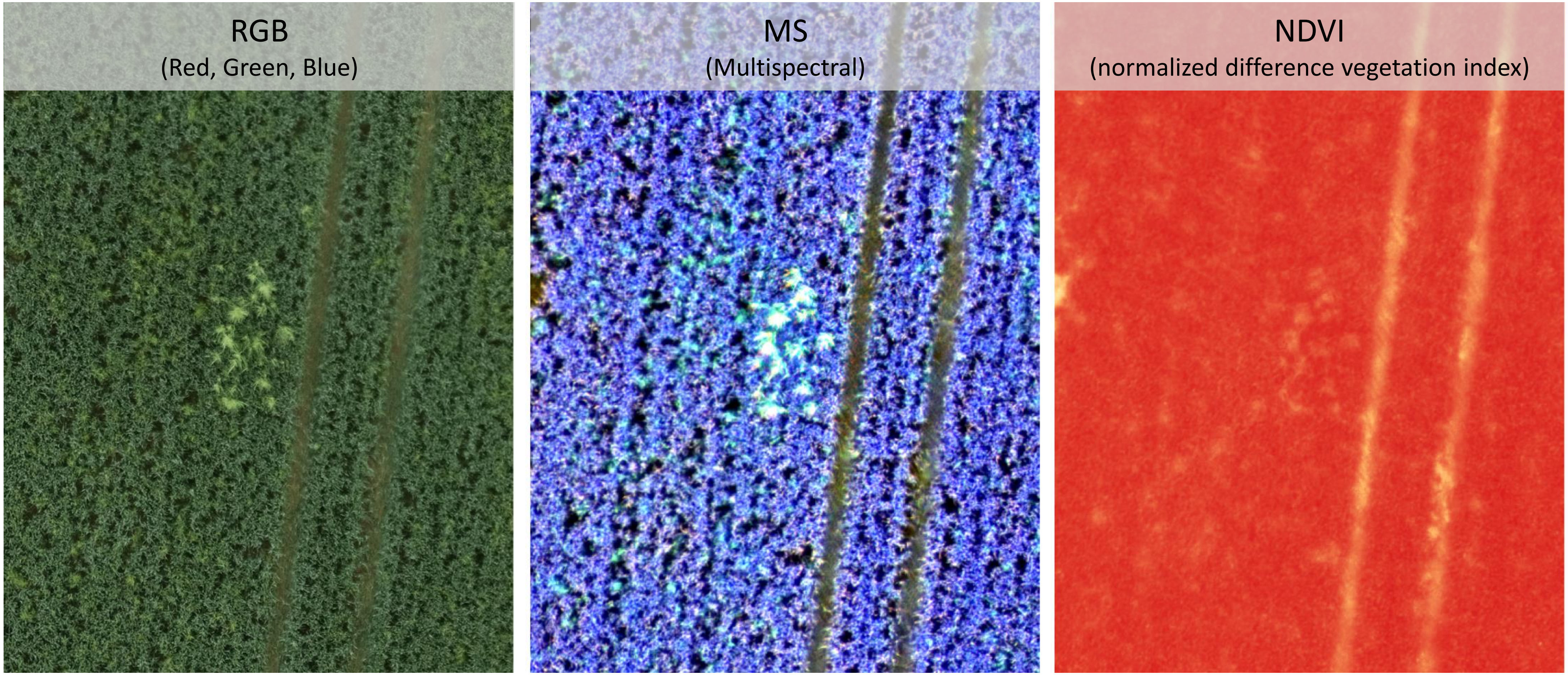
Lesson 2: *NDVI was no help for detecting Blackgrass at flowering*



Validation of the model

- Images annotated and two models trained: RGB only, and RGB + Multispectral data
- **Accuracy and recall was generally high:** the model found most of the weed labelled pixels correctly
- Precision was low: The model overpredicted around patches, and identified un-annotated weeds

Lesson 3: *Including multispectral data did not improve model performance*

RGB only

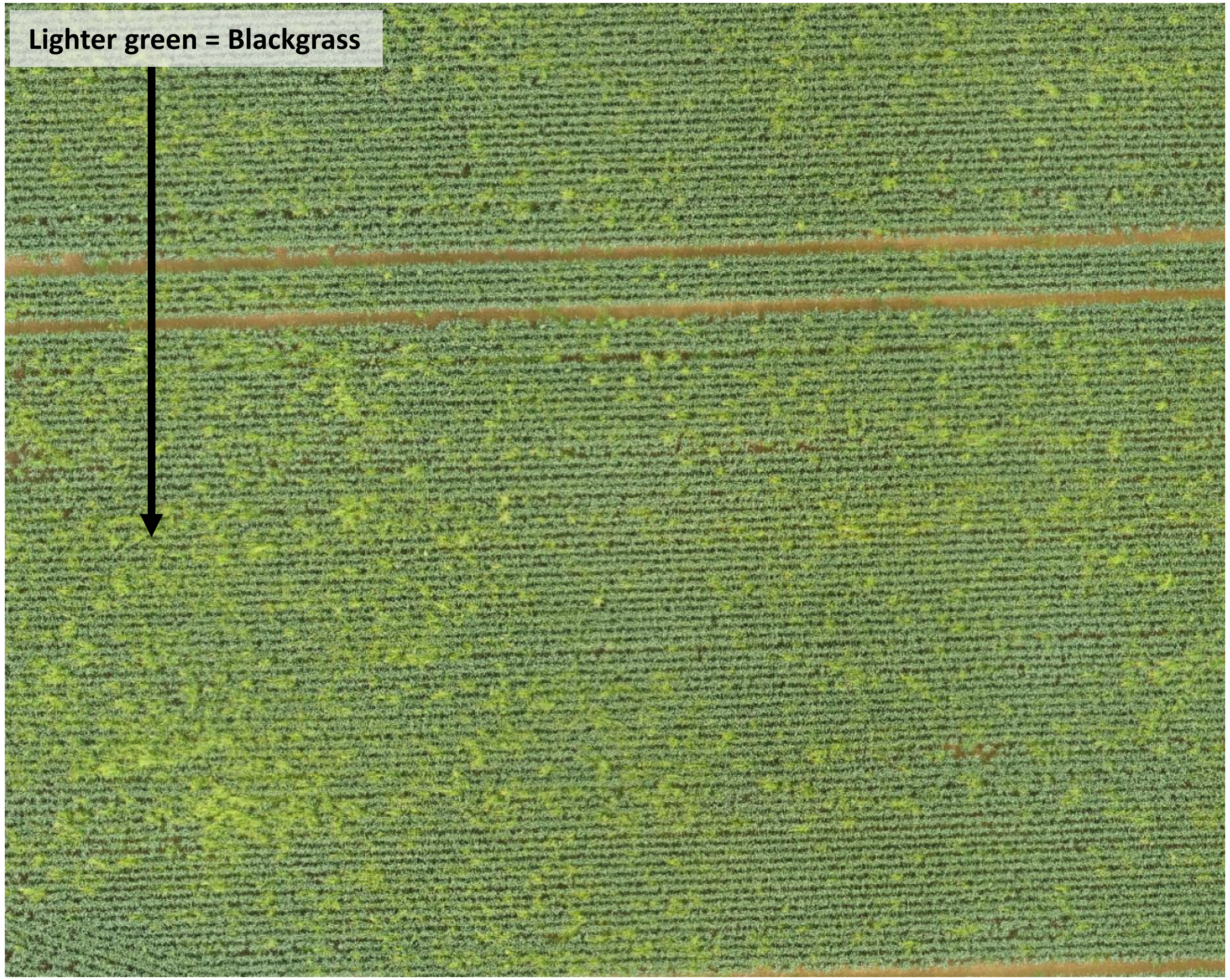
Dataset	Metric	Value (SD)
Test data	Accuracy	0.92 (0.01)
	Recall	0.89 (0.02)
	Precision	0.41 (0.03)
Unseen fields (out-of-bag)	Accuracy	0.91 (0.05)
	Recall	0.72 (0.23)
	Precision	0.35 (0.06)

RGB+Multispectral

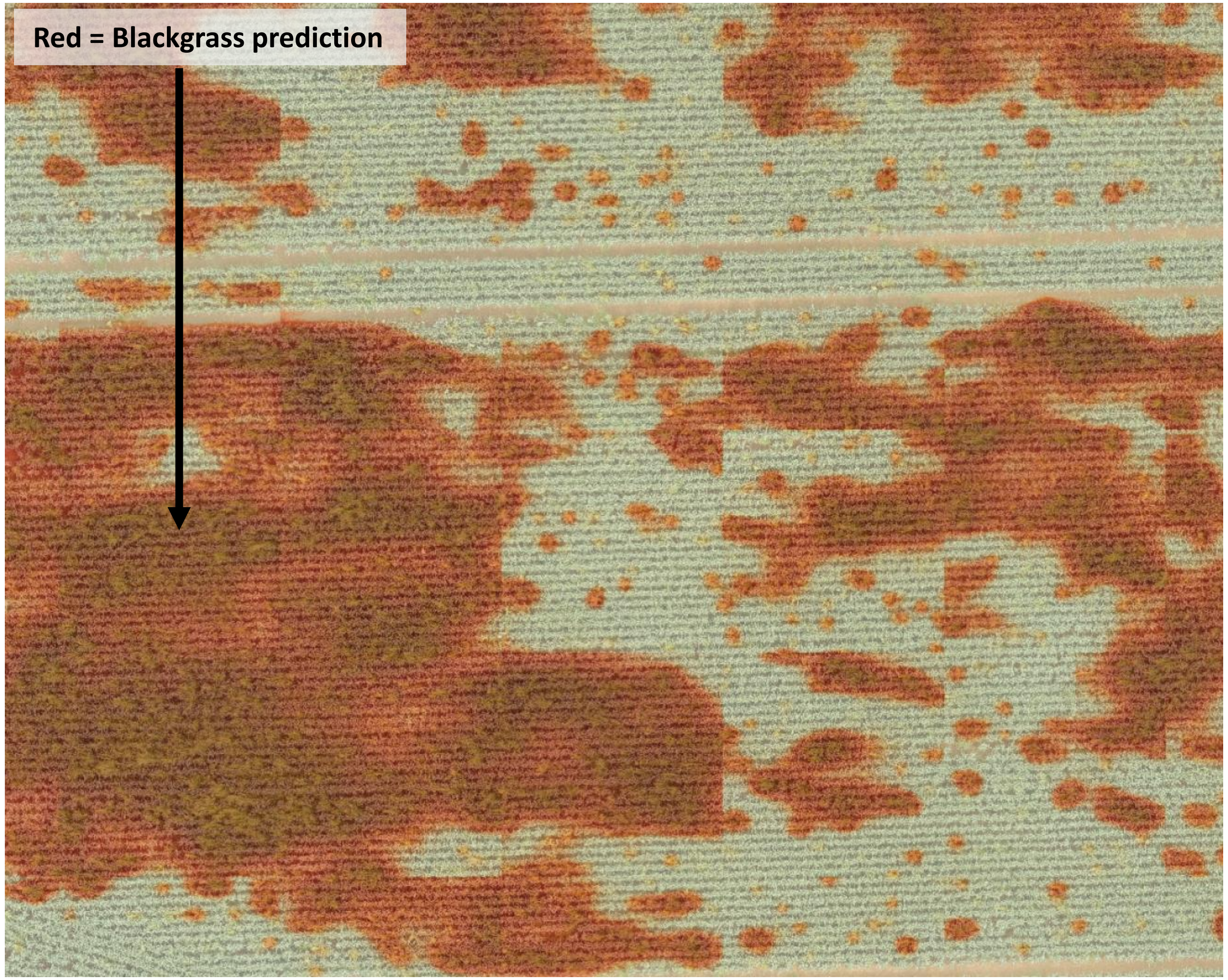
Dataset	Metric	Value (SD)
Test data	Accuracy	0.92 (0.01)
	Recall	0.88 (0.04)
	Precision	0.42 (0.02)
Unseen fields (out-of-bag)	Accuracy	0.91 (0.03)
	Recall	0.72 (0.27)
	Precision	0.35 (0.11)

Comparison: Spatial distribution of Blackgrass

RGB UAV Image



AI model prediction

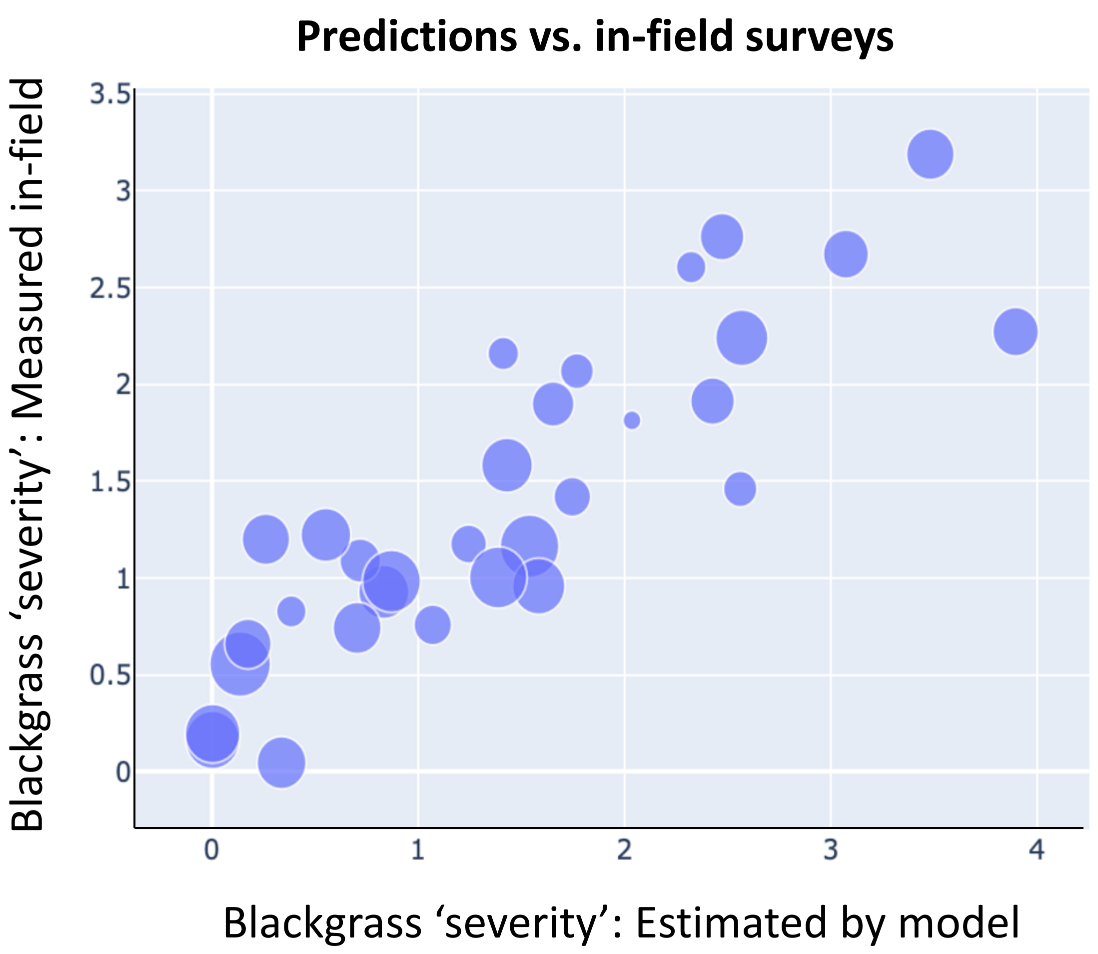


Comparison: Severity of Blackgrass infestation

The model predictions were converted to a format equivalent to our in-field weed survey data:

- **Spatial arrangement of Blackgrass patches conforms well with in-field mapping**

- **Strong positive correlation between model predictions and actual measured abundance**



A Deep Learning Application to Map Weed Spatial Extent from Unmanned Aerial Vehicles Imagery. (2022). *Remote sensing.* https://doi.org/10.3390/rs14174197

Taking weed detection and mapping further

Blackgrass management

UAV mapping

- UAV mapping was reasonably successful at blackgrass maturity
- But, most management occurs before this
- Can we detect and map Blackgrass earlier?

Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul

Case study 2: In-field machinery

Chafer

BASF
We create chemistry

BOSCH

xarvio™
Digital Farming
Solutions

<u>SmartSprayer</u>

Upgrading **farm machinery** to incorporate cameras / sensors to detect weeds

Again, focussed on Blackgrass detection

“Smart-sprayer” system

Chafer
BASF
We create chemistry
BOSCH
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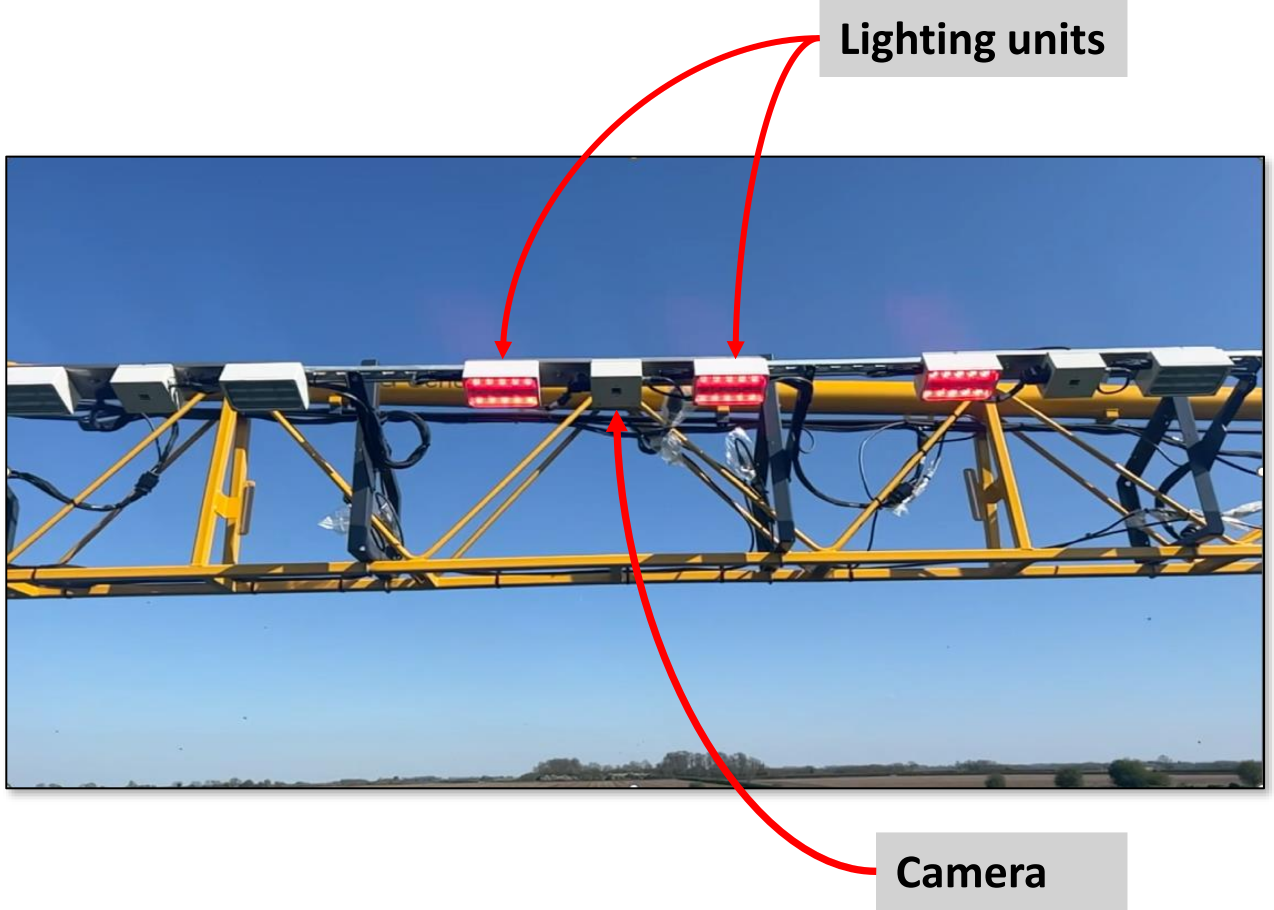
Bosch and BASF have jointly created a camera equipped **“smart” spraying system.** Current UK Innovate project is to build one of these (Chafer machinery), and trial it for detection of Blackgrass.



Controlled imaging

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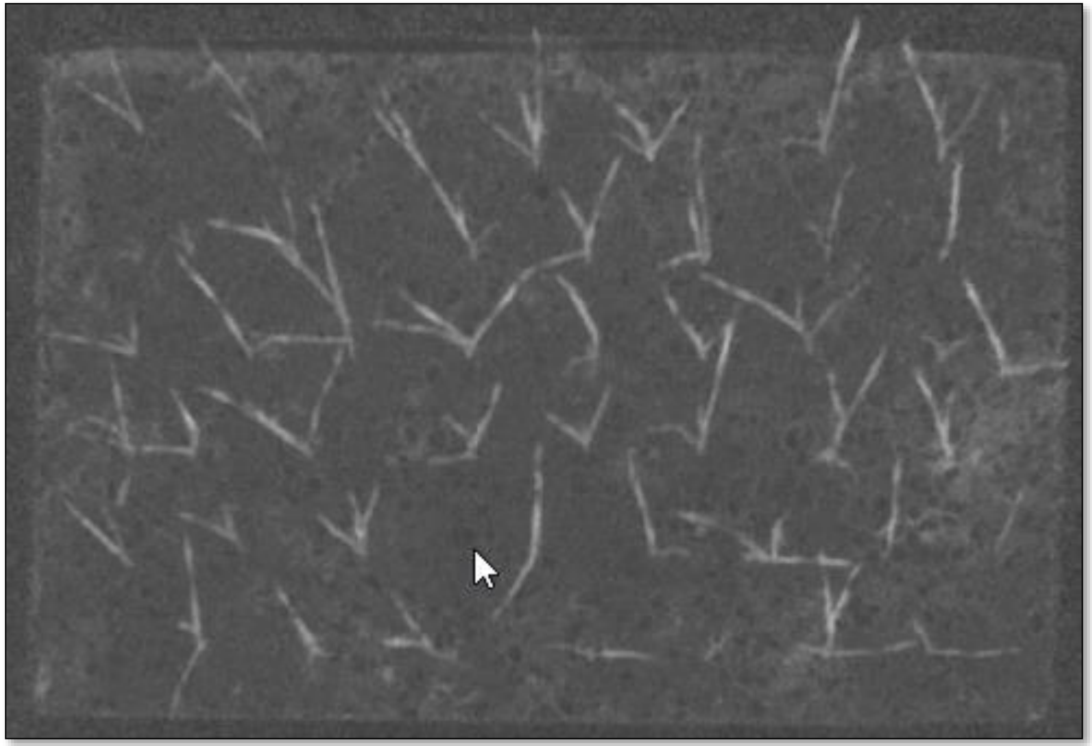
Before starting in the field, built a test-rig at Rothamsted mimicking the sprayer boom.

- Initial work has been to grow many Blackgrass and wheat seedlings in separate soil trays.
- Imaged over a range of growth stages from seedling to large vegetative plants

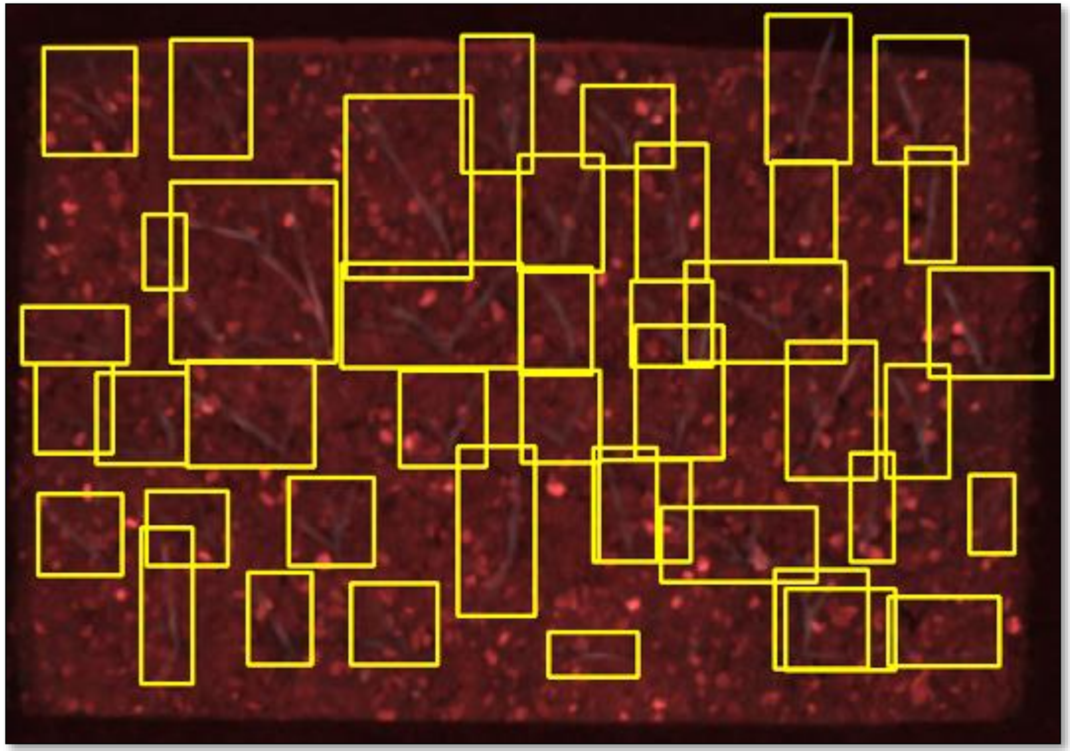
Controlled imaging

Building up a large library of Blackgrass and Wheat imagery. Captured using the same camera and lighting equipment deployed in the field. **Creating an imagery database to aid algorithm development**

Gray Scale Image after Processing the Raw Images



Blackgrass object detection



Testing in-field

Sprayer deployed in field over spring 2023 to collect imagery

Complemented by in-field surveys of the weed population

More imaging over the 2023-2024 season

Imaged a variety of crops and weeds

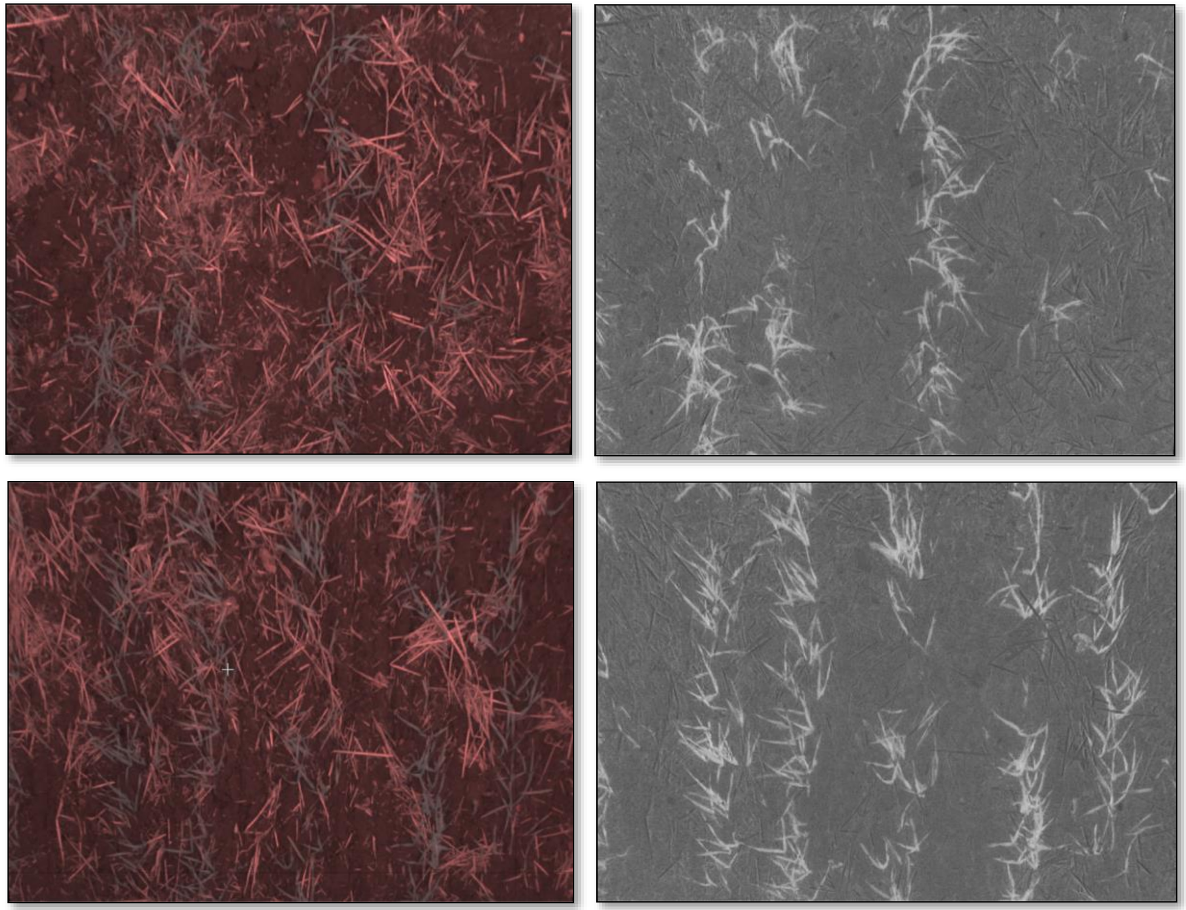
Early and late-stage Blackgrass

Volunteers and other weed species

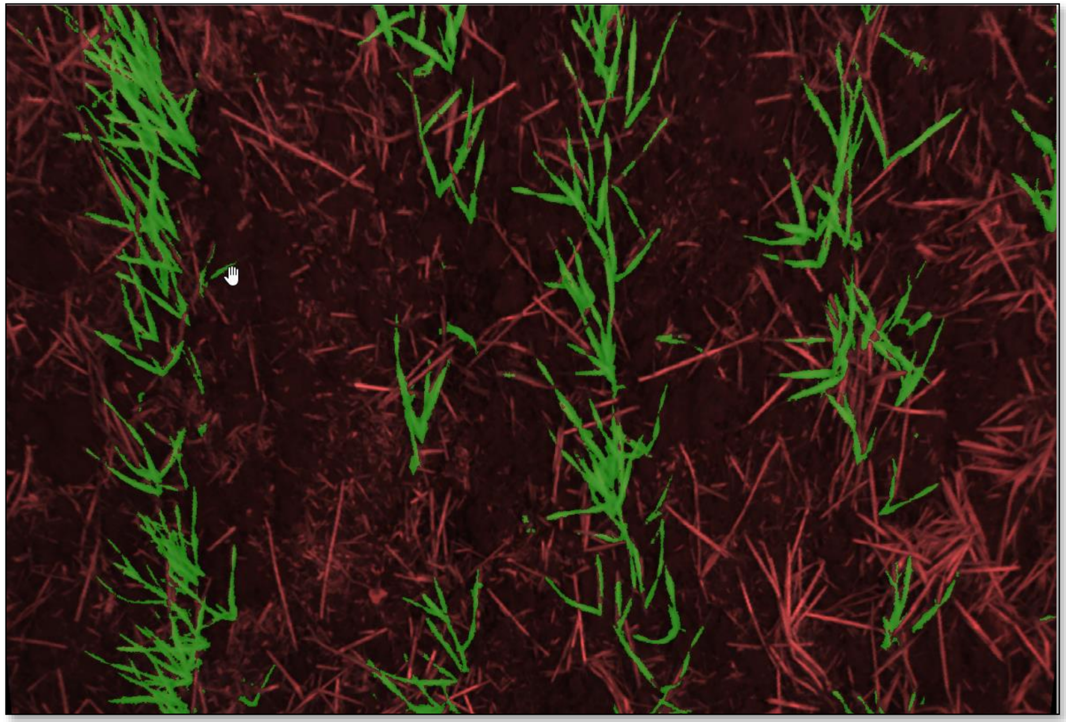
Broad-leaved crop

Image segmentation: To detect plants

Raw (left) and processed (right) imagery collected in-field



Object-detection allows segmentation of plants from the background, soil, straw etc.



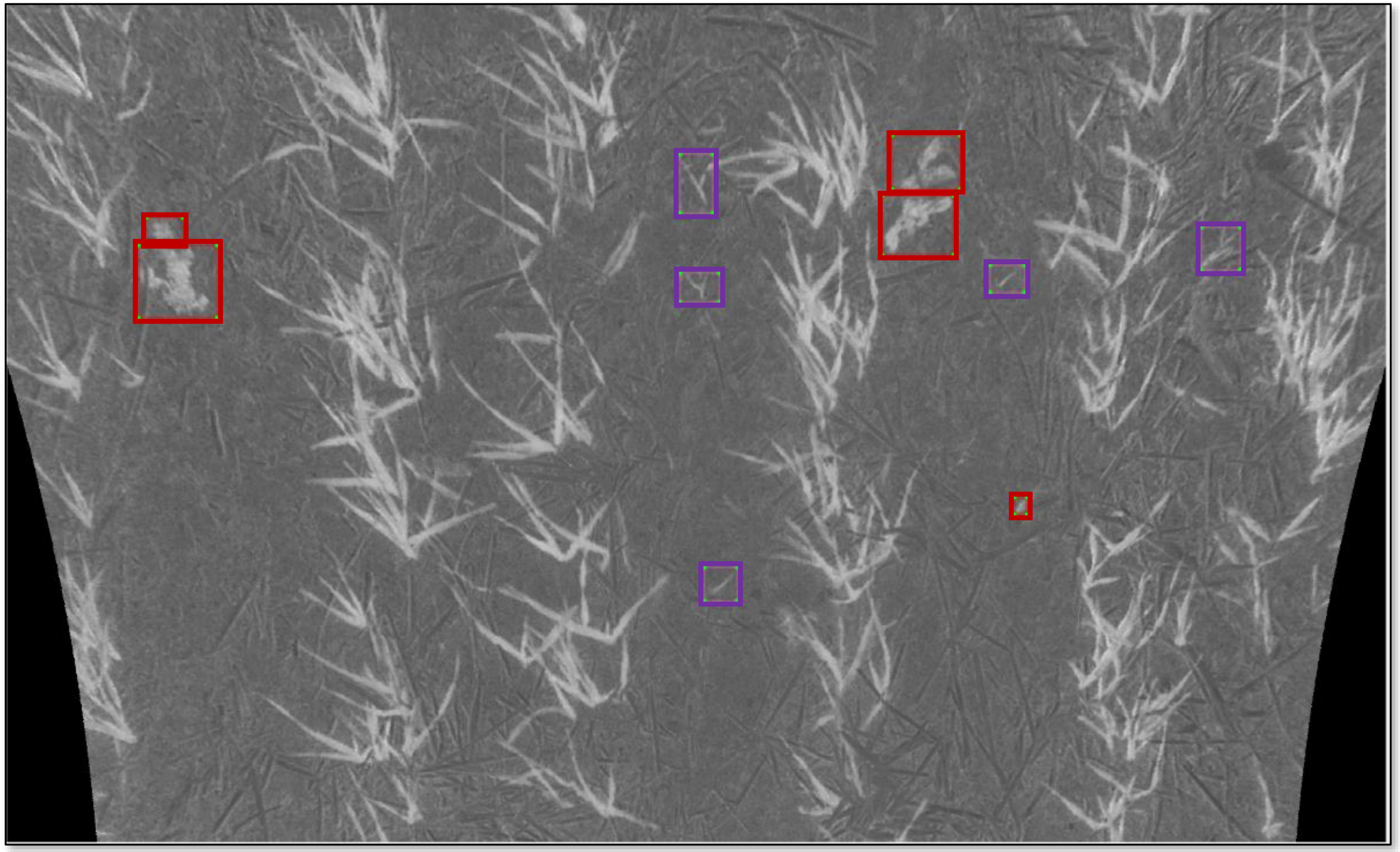
Object classification: To determine which are weeds

Lesson 4: *Weeds can be successfully detected at earlier stages, but the bottleneck is annotation of imagery*

An initial model has been trained, but only on a very limited training data-set

Algorithm **classifies detected plants as weeds or crop**. Detected weeds are currently grouped as Blackgrass (purple) or broad-leafed weeds (red).

Provides a proof-of-concept for image collection, processing, and algorithm development – but needs a lot more work!



Conclusions and lessons learned…

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- For UAV mapping, resolution was the most important aspect, followed by speed (slow!), lighting, and timing.
- Increased infrared data from the multispectral sensor did not aid model performance.
- NDVI was not helpful in detecting flowering blackgrass, but is useful in separating vegetative plants from background: soil, crop residues etc.
- The smart-sprayer system is allowing us to collect large amounts of crop-weed imagery.
- The real bottleneck now is finding ways to accurately and quickly annotate images for model training.

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Thanks for listening