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What is a drone?

Simon Gibson-Poole

Leading the way in Agriculture and Rural Research, Education and Consulting

What is a drone?

- A Drone is a flying robot that is defined as:
  - *"An aircraft (or aircraft system) that is flown from a remote location without a pilot located in the aircraft itself."*
- They make use of an on-board auto pilot, and can be made to follow a series of waypoints and commands.
- Lots of different acronyms used (UAV/UAS etc.):
  - The term RPAS (Remotely Piloted Aircraft Systems) is the preferred term to use.

(The Taranis, a stealthy combat drone)

(The Black Hornet, a nano drone)

Multi-rotor drones

- Multi-rotors are some of the most popular types of drone as they are mechanically simple and powered using batteries.
- Can take of and land vertically but have a short flight endurance, so better for field scale monitoring (10~20 ha per flight).
- They come in a variety of sizes and combinations of motors:
  - Quadcopters (4 motors) are the most efficient but no redundancy.
  - Hexacopters (6 motors) and octocopters (8 motors) are often preferred if expensive sensors are being used.

(A dji Phantom 4 quadcopter)

(A custom built Vulcan octocopter)

Fixed wing drones

- Fixed wing drones have much better endurance due to the lift generated by their wings so can be used for farm scale monitoring (up to 1 km^2 per flight).
- Mechanically more complicated and more difficult to fly manually, but better at handling higher wind speeds (typically also uses batteries).
- Come in a range of sizes, with smaller systems being hand launched, but larger ones requiring launching systems and more space in which to land.

(A Sensefly eBee)

(A Quest Q200)

How are they controlled?

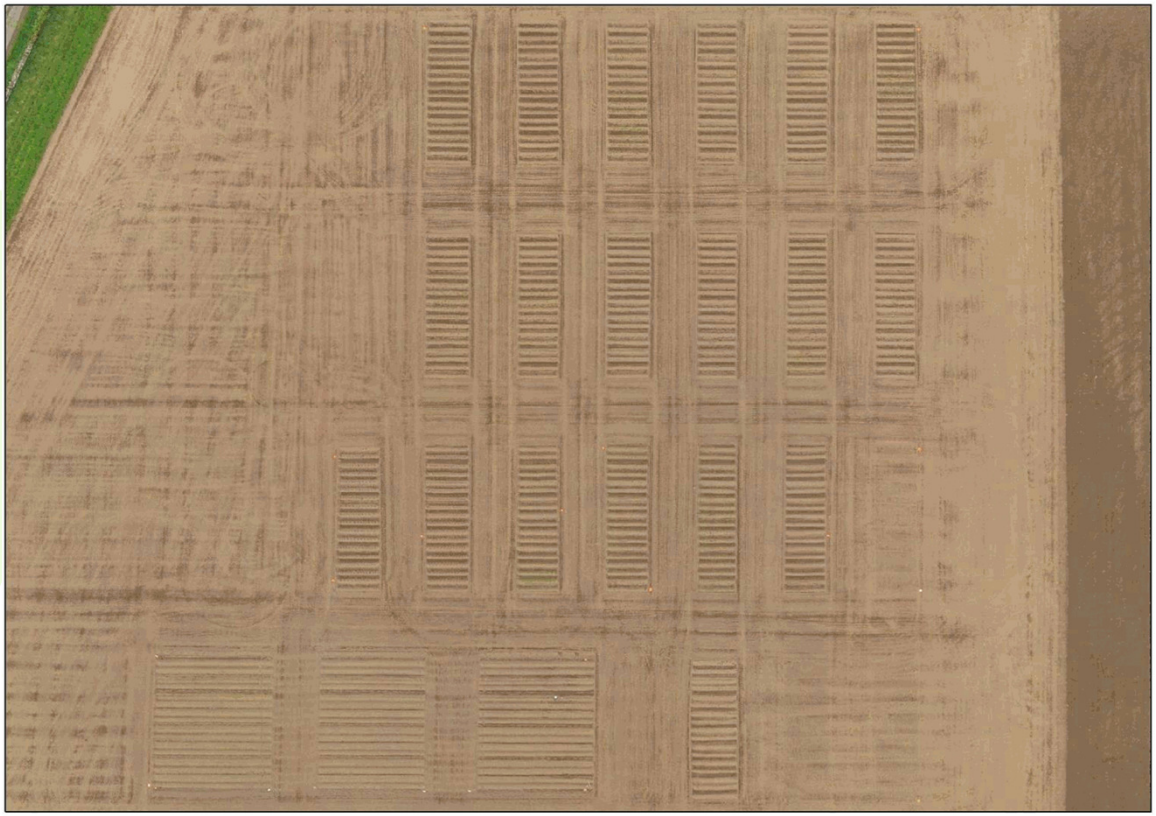
- They can be controlled manually using a radio transmitter, or fly autonomously using a given a set of waypoints to follow.
- Autonomous surveys use waypoints or specific positional commands which are transmitted to the drone via the use of wireless telemetry from a ground control station running specialised software.

(The blue line denotes the path the drone took during the survey)

(The yellow line is the intended flight path with waypoints along the way – the green markers)

Advantages of UAVs

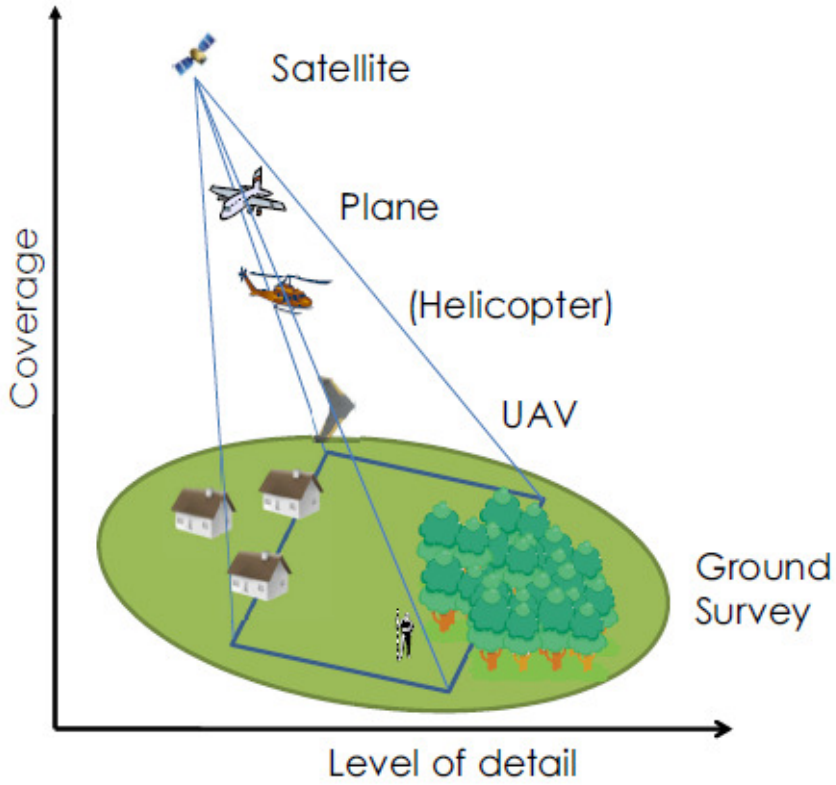
- They can collect very high resolution imagery at a lower cost than manned aircraft or commercial satellites.
- They can also operate below cloud cover, increasing availability.
- You can repeat the exact same survey time and again to build up a history of your crop over a growing season.
- That history can then inform the management decisions of the following seasons.



(An example of repeated data collection of a potato trial).

Drones, planes or satellites – Which is best to use when?

- For field scale areas (10~20 ha) multi-rotor drones are a very cost effective solution giving very high resolution data (0.5~10 cm per pixel).
- For farm scale areas (1~5 km^2) fixed wing drones would be better solution but also imagery from manned aircraft could be a better option, giving high resolution data (3~50 cm per pixel).
- Where high resolution is so not important, satellite data can be used (if its not cloudy!), giving regional coverage at coarser resolutions but with a wide range of spectral bands (10~20 m per pixel is free, less than 10 m can be expensive).



(The difference between extent of coverage and level of detail from different aerial platforms).

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Regulations

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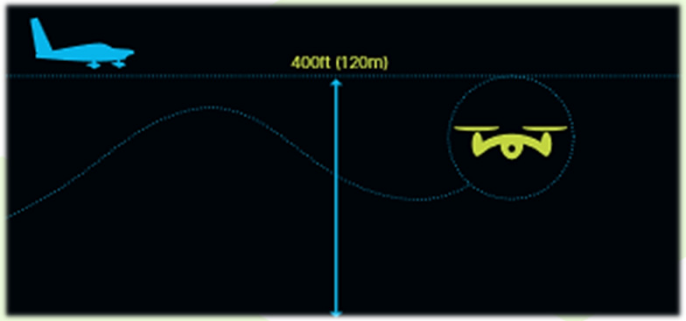
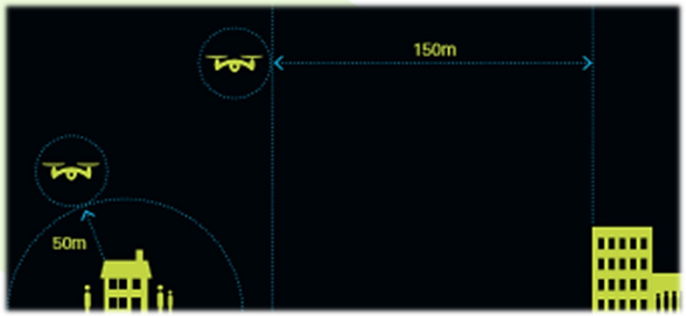
Drone regulations – How to fly a drone safely?

- Drones share airspace with other aircraft and people don't like to be intruded upon, so follow the Civil Aviation Authorities (CAA) Drone Code to ensure you are not breaking the rules.
- The regulations around drone and their use will be changing this year when a new "Drone Bill" is completed and comes into force (expected at some point this spring).
- The new rules will require everyone to register their drone and complete a safety awareness test (possibly online).
- Use of specific software to monitor drone flights and the use of geofencing are also in the pipeline.

Drone regulations – Follow the Drone Code!



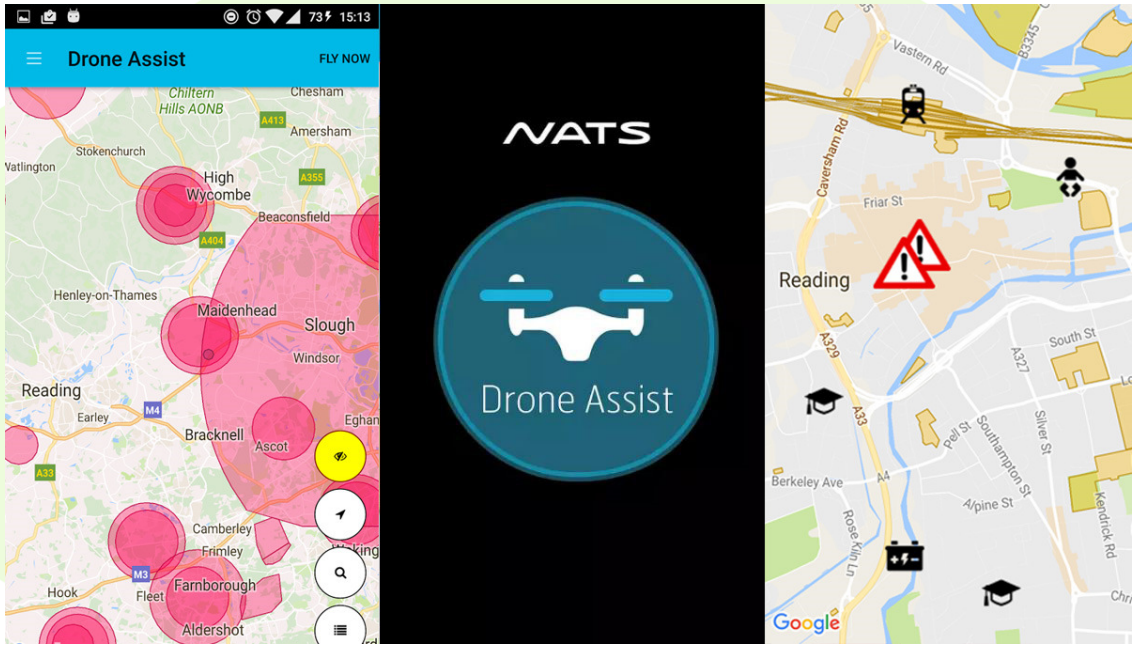


- The CAA have general safety guidelines called the “Drone Code”, which has six main points.
- 1 – Always keep the drone within line of site.
- 2 – Stay below 400ft (120m).
- 3 – Follow the manufacturers instructions.
- 4 – Keep 50 m away from people and buildings and 150 m away from urban areas and large crowds of people (1000 or more).
- 5 – You are legally responsible for each flight you make.
- 6 – Stay well away from airport, airfields and other aircraft.

Drone regulations – How to check its safe to fly?

- Always check the weather before you fly and especially the wind speed (its worth getting an anemometer to check it when you get to the field as well).
- Know the limitations of your aircraft, especially its maximum wind resistance (typically less than 22 mph).

DRONE **SAFE**
dronesafe.uk



- Make use of online applications to check if you are flying in a safe area (www.dronesafe.uk/safety-apps/).
- Always watch out for random members of the public blundering about (remember to stay 50 meters away from them)!

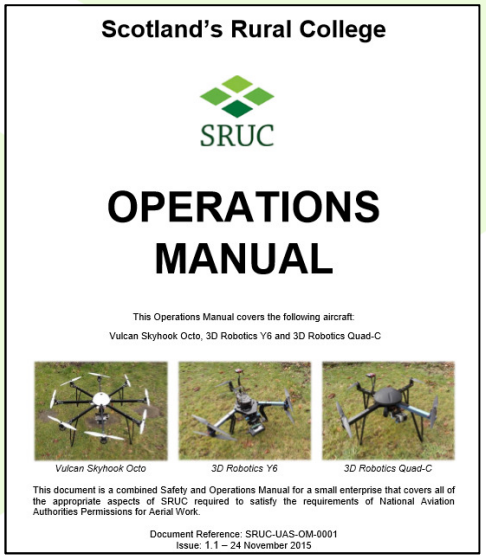
Drone regulations – Size matters!

(DJI AGRAS M1: 20~25 kg)

(A Yamaha R-Max: Approx. 60 kg)

- When people talk about drones they usually think of relatively small multi-rotors, but the weight of a drone effects how it is regulated.
- A Small Unmanned Aircraft (SUA) is up to 20kg, however this is split between 0-7 kg and 7-20 kg.
- Sub 7 kg SUA have the lightest regulation and can operate more easily in controlled airspace.
- 7~20 kg SUA require permission to operate in controlled airspace and have tighter rules when working in more congested areas.
- Light UAS are between 20-150 kg and full UAS > 150 kg. These require airworthiness certificates, registration and are generally much more heavily regulated.

Drone regulations – What is aerial work?



- Essentially if you are being paid for the data captured by the drone then this is aerial work and you will need a Permission for Commercial Operations (PfCO) from the CAA.
- This can be quite expensive (~£1,500 per pilot) and requires keeping up with regulations (paperwork) and renewal each year (£130).
- If you are paying someone else to fly for you then make sure they have a PfCO!
- Do you need a PfCO to fly over your own farm?
  - This is still a bit of a grey area, but if you are serious about using drones on your farm then it would be best to get one.
- Get insurance, organisations such as the British Model Flying Association (BMFA) can provide effective insurance for non-commercial flights.

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What can you do with a basic drone?

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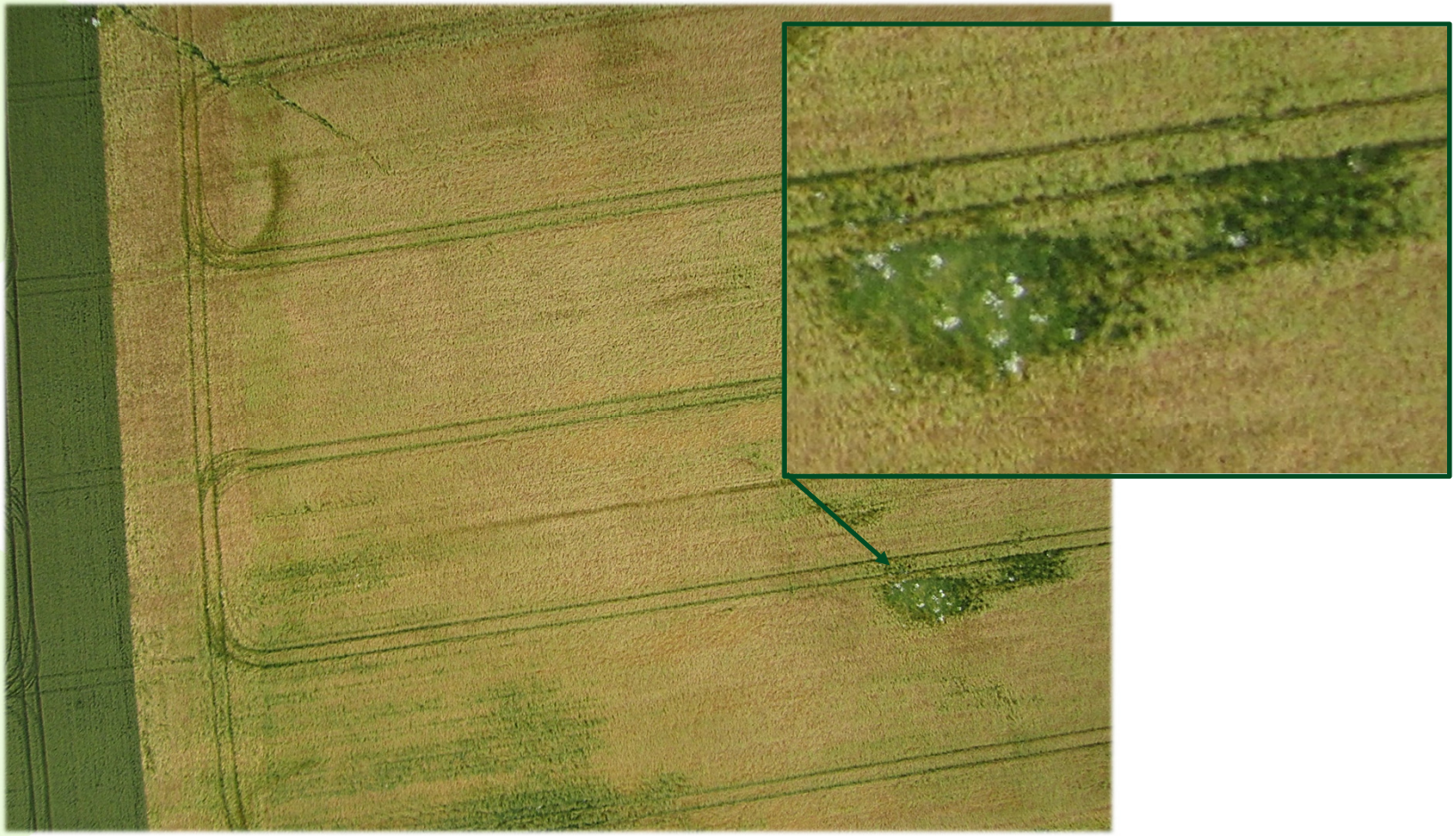
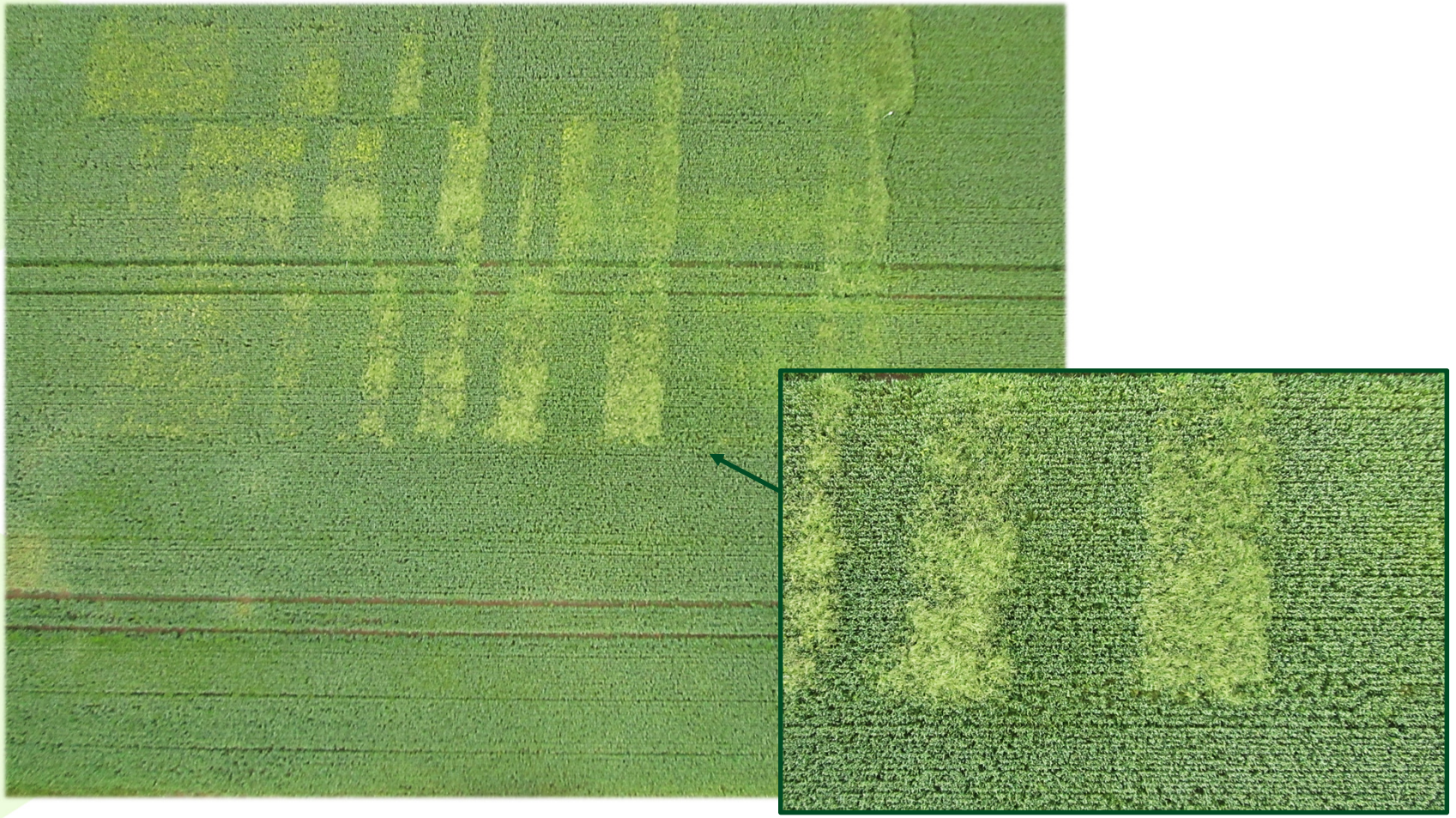
Identifying issues in field to inform your field walk



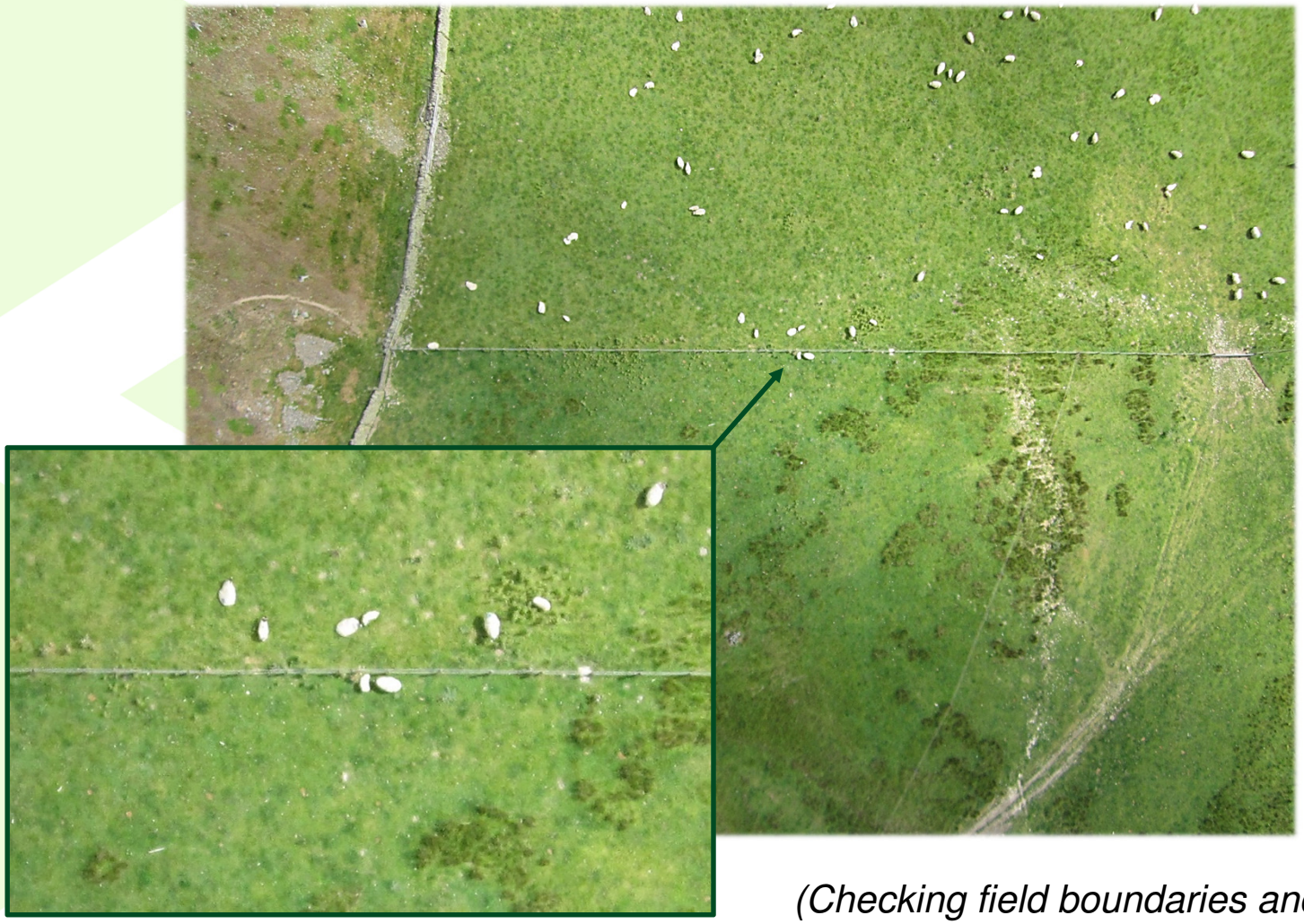
(Identifying issues within a field)

Pick out outbreaks of disease or weed issues



(Identifying onset of disease or weeds)

Check boundaries, irrigation and livestock



(Checking field boundaries and livestock)

Making promotional videos and other novel uses

(Video or stills of farm machinery in action)

(Turn your drone into a bird scarer by adding a siren)

(Could this be the end of the sheep dog?)

How much would a basic drone cost?

- The below gives an indication of the costs required to get a good basic setup.
- There are a few alternatives, however these may not be as capable or as easy to use.
- If you like DIY then you can also build your own, which can work out a bit cheaper.

(DJI Phantom 4: Easy to use platform with an excellent camera)

Total Cost	Cost	Qty	Notes
£1,360	£1,360	1	DJI Phantom 4 Advanced (this includes a good RGB camera on a gimbal, some spare propellers)
£516	£172	3	Extra batteries (to allow 4 batteries), enabling multiple flights (~ 1 hour 20 minutes total flight time ∴ ~50 ha coverage)
£41	£41	1	Extra charger to speed up battery charging
£190	£190	1	Backpack carry case
£420	£420	1	iPad Mini or Android equivalent
£2,527			**TOTAL**

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What if you want to make in field measurements?

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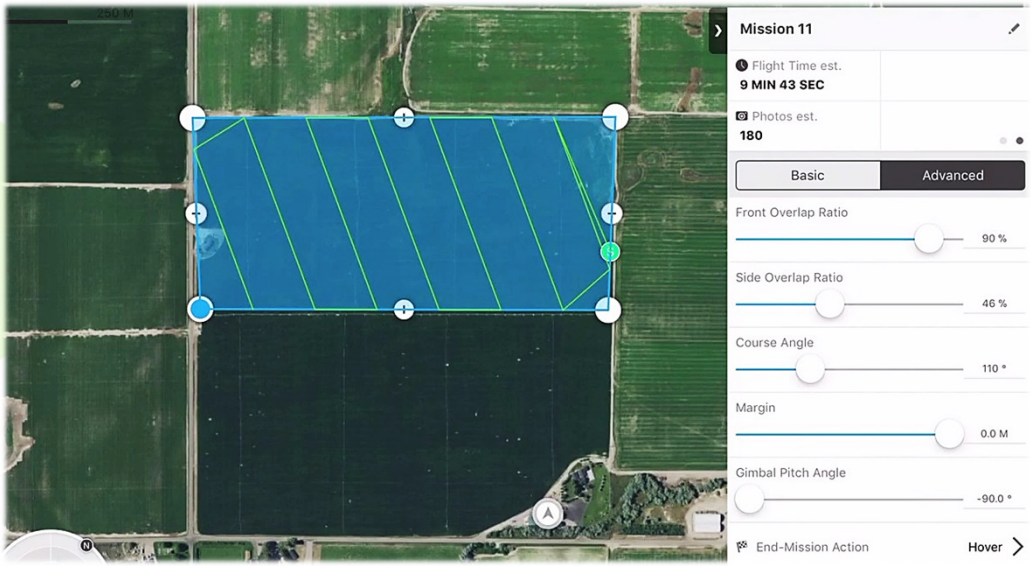
Use waypoints and automatic flight options

- To take measurements from aerial imagery (photogrammetry), the images need to be orthorectified and stitched together into an orthomosaic (a flat map of the entire area surveyed).
- To be able to do that then you need to use the drones automatic flight to collect imagery at a constant height and with sufficient overlap.
- Typically an image overlap of at least 80 % (forward) and 60 % (side) is required to get enough imagery to create a good quality orthomosaic.



(Example flight planning using the DGI GS Pro application)

Processing the data into an orthomosaic

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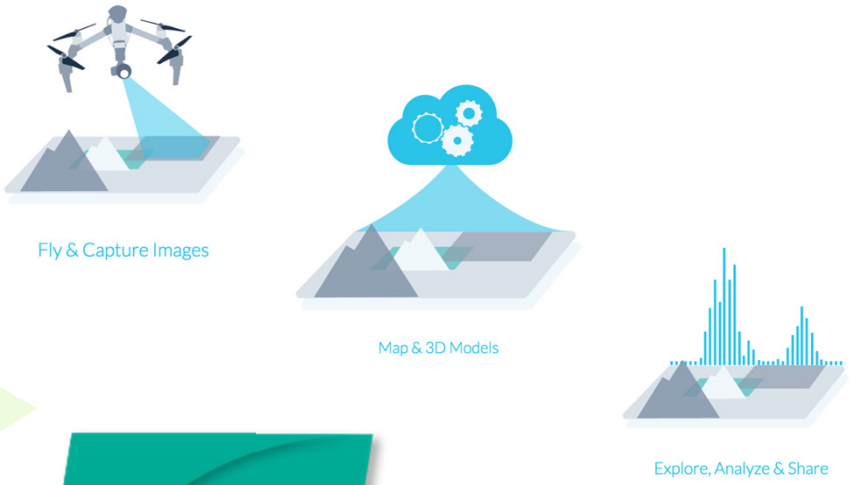
- Typically this is typical done using a technique called Structure from Motion (SfM), and requires a powerful PC (or a good internet connection) and expensive software (you can get trial versions of the software to test it out).



- Pix4D AG (Desktop + Online)
  - £2500 for perpetual license or
  - £1100 yearly subscription, or £340 every three months

PIX4D AG

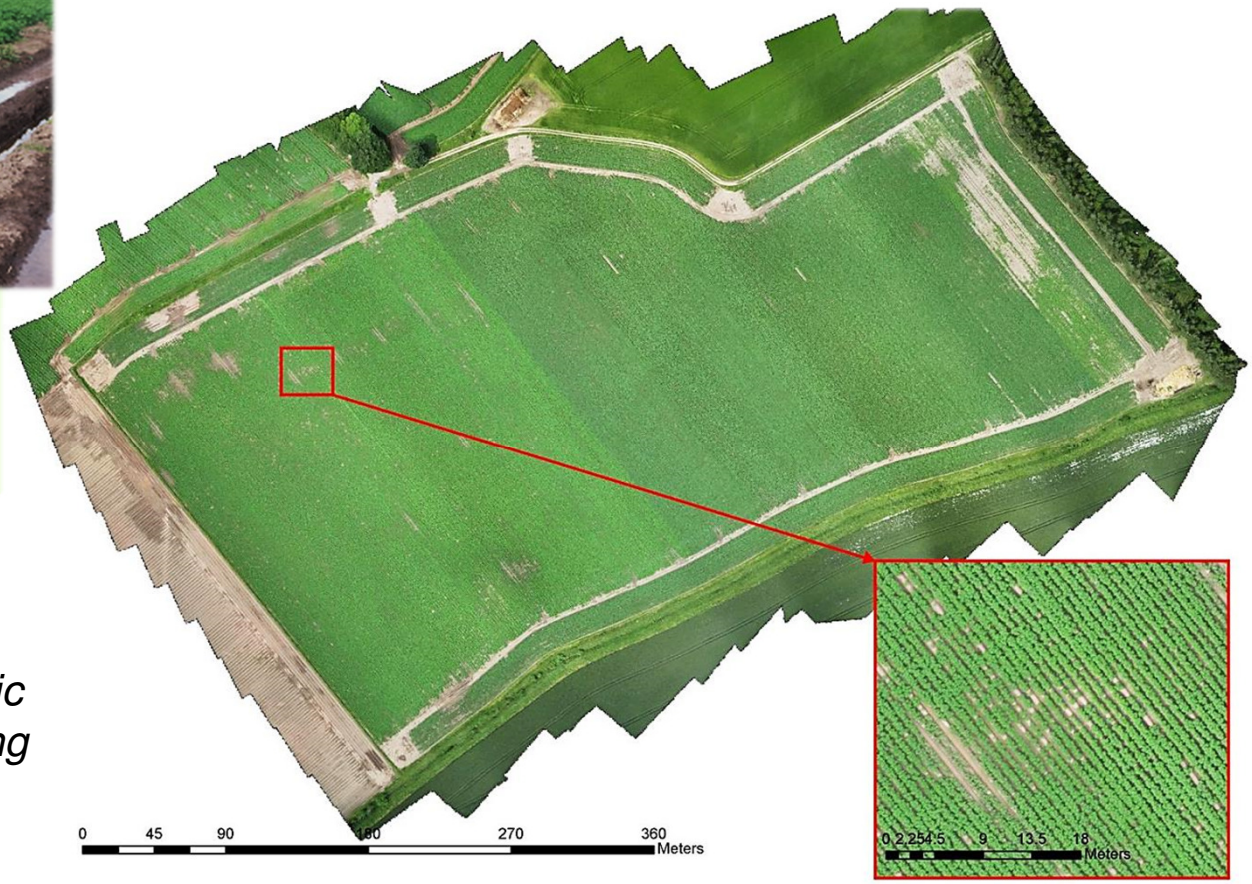
- Drone Deploy (Online only)
  - £75 (Pro) ~ £230 (Business) per month

DroneDeploy

- If your into DIY there are also some open source options but they are fiddley.

Basic RGB imagery – Orthomosaic example

(Viewed from the ground)

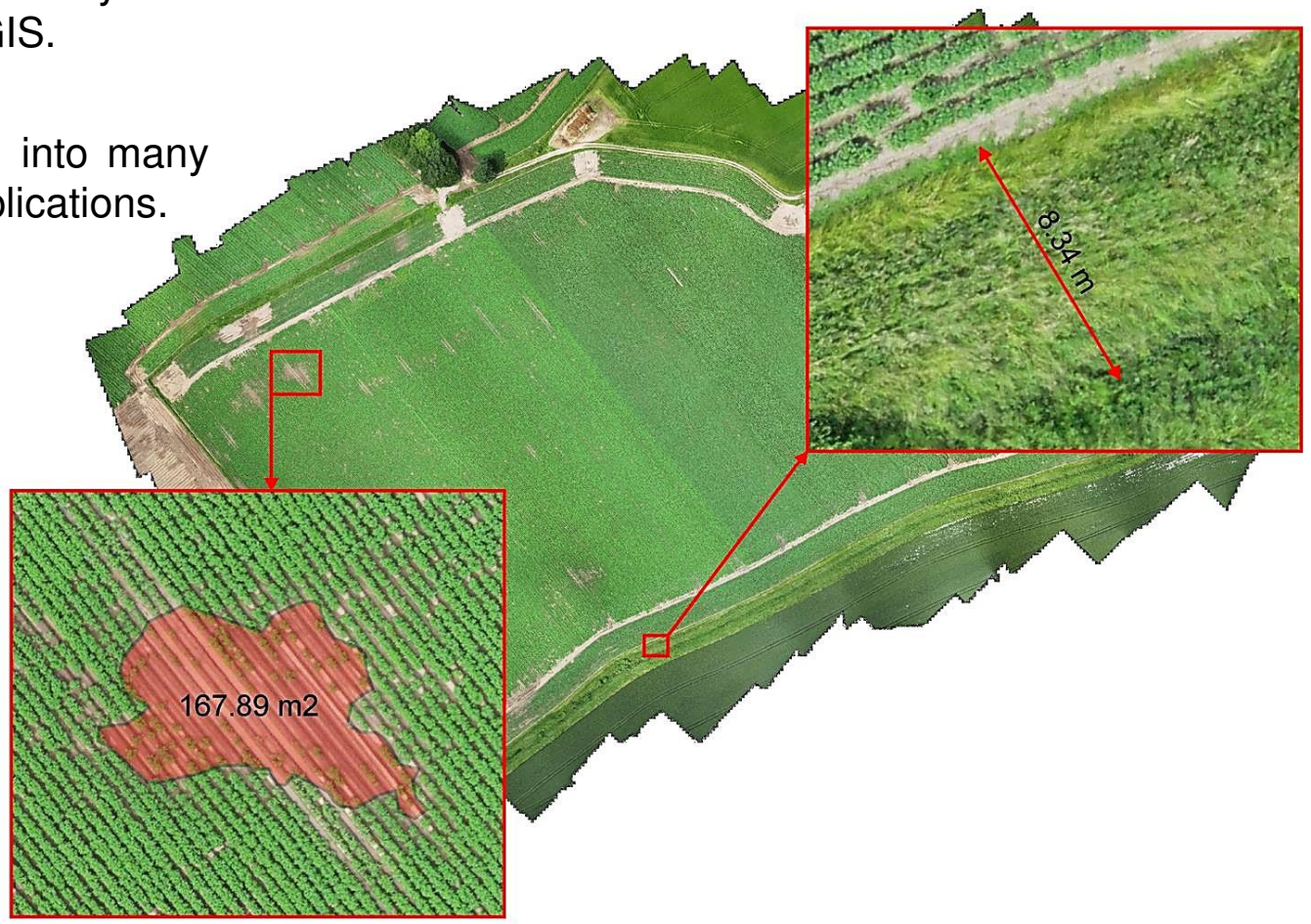


(An aerial orthomosaic of 153 images showing ~16 ha of potatoes)

Basic RGB imagery – Making measurements

- You can use measuring tools within the software, or free geographical information system (GIS) software like QGIS.
- Can also be imported into many farm management applications.

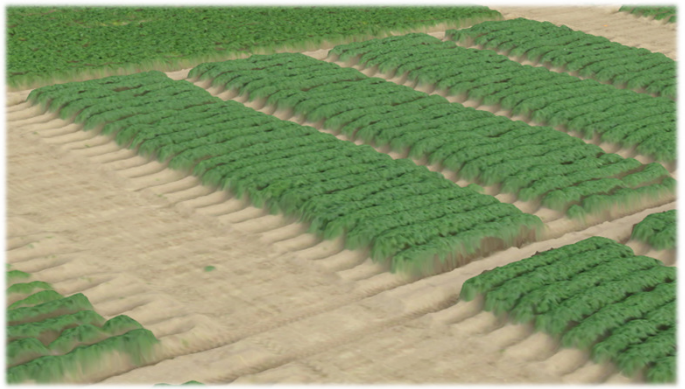
(Measuring the width of a buffer zone to a water course)



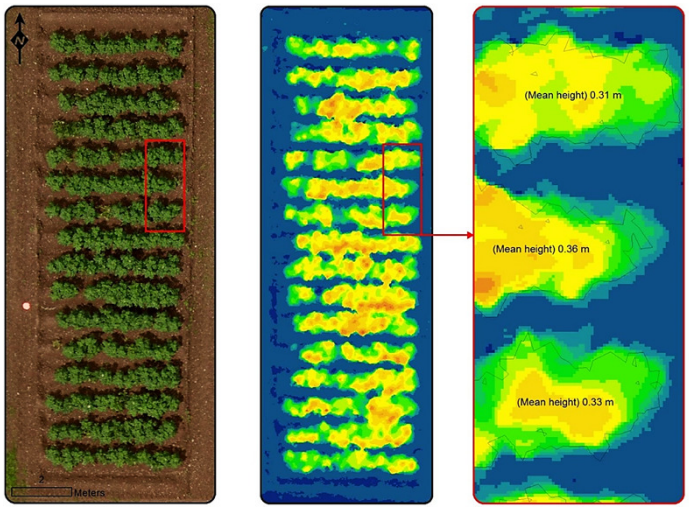
(Measuring the area of a poorly performing patch in the field)

Basic RGB imagery – Extras and processing time

- Depending on the software you use you can also produce other outputs including 3D models and elevation models (useful for looking at drainage or creating crop height maps).
- Processing on a desktop computer depends on the speed of that computer and the number of images, but if you are using an online service you need to account for data upload speeds.
- Example using a DJI Phantom 4 Advanced:
  - 73 images required to capture ~10 ha at 120 m above ground level (overlap 80/60, ~584 MB of data).
  - Less than 10 minutes to survey the field.
  - ~1.5 hours at 1 Mbps upload (an average ADSL connection upload speed).
  - Online processing speeds vary but would typically be within 24 hours or less.



(Example 3D model (above) and height (below) of a potato trial)



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Getting more from your drone by using multi-spectral sensors

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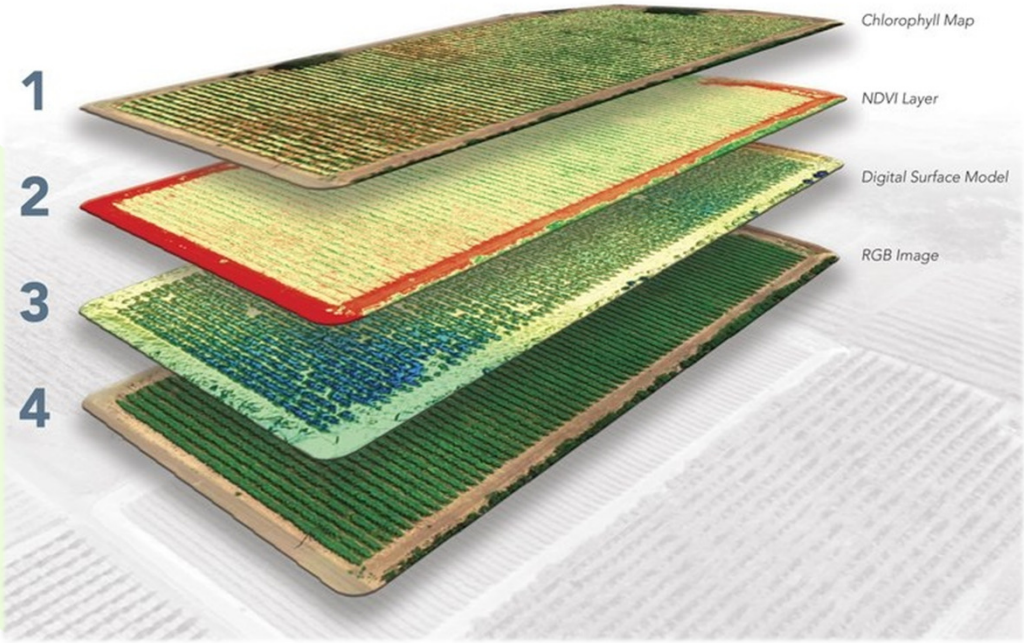
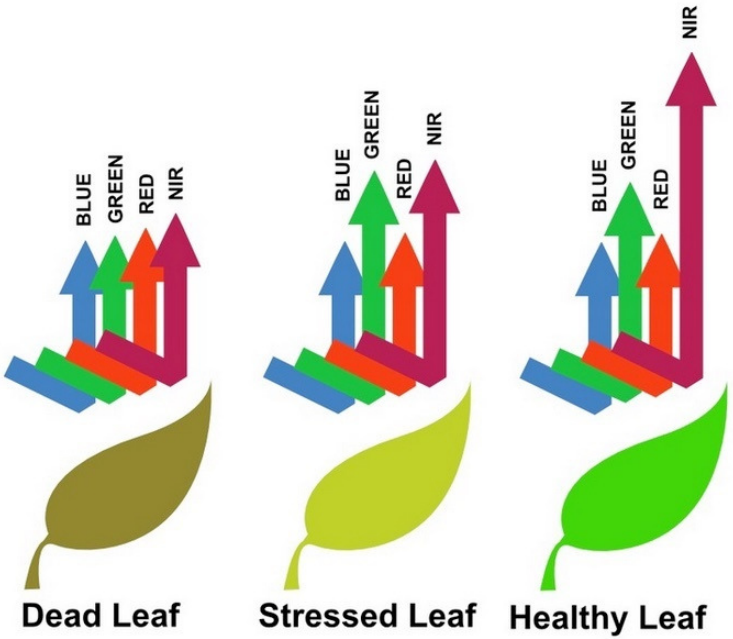
What is a multi-spectral sensor?

- Using calibrated multi-spectral sensors you can gain much more insight into the health of your crops.
- This is primarily through the use of wavelengths of light beyond human visual site; Near infra-red (NIR) and the red edge (between red and NIR).



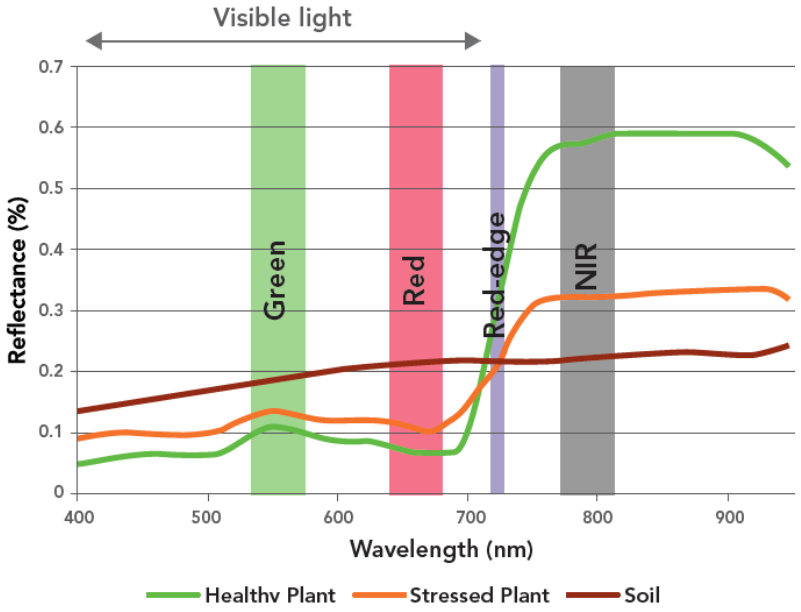
(Example maps obtained from a multi-spectral sensor)



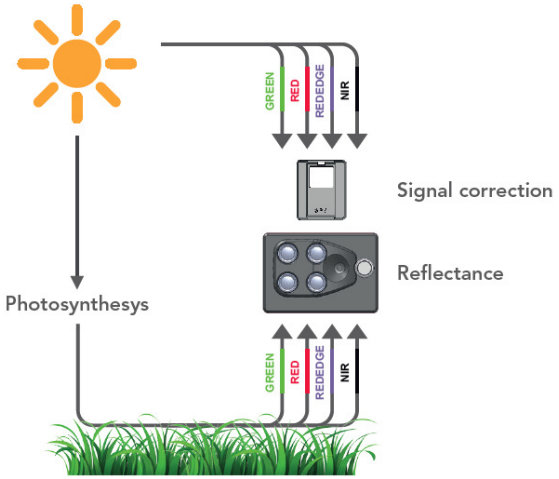
(Vegetation indices such as NDVI make use of NIR to identify plant vigour, but you cant always be sure of what is stressing a crop)

Example multi-spectral sensor for agriculture use

- The Parrot Sequoia Multispectral sensor is just one brand of a new breed of sensors that are designed for agricultural drones.
- It is a calibrated sensor that has discrete and narrow bands to capture areas important to plant development.
- They are GoPro sized and can fit on small drones but it will reduce your flight time and have a typical cost of ~£3,250.



(Parrot Sequoia)

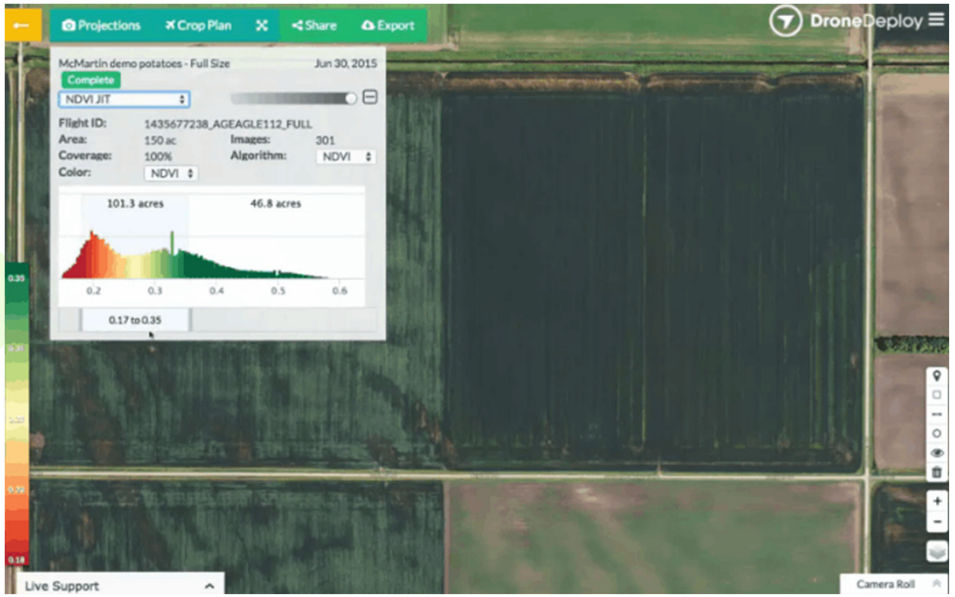


Using software to display multi-spectral data

- Produce calibrated quantitative data:
  - Identify crop vigour or stress
  - Estimate nitrogen & chlorophyll content
  - Variability in soil moisture
  - Estimate dry biomass

- Generate application maps to use as variable-rate prescriptions for applying fertilizer (this will still need ground truthing to identify the best rate).

- Some processing applications (e.g. SlantView for SlantRange sensors) also include algorithms that enable:
  - Plant population assessment
  - Weed density analysis
  - Yield potential



(An example of the visual representation using Drone Deploy)

To conclude

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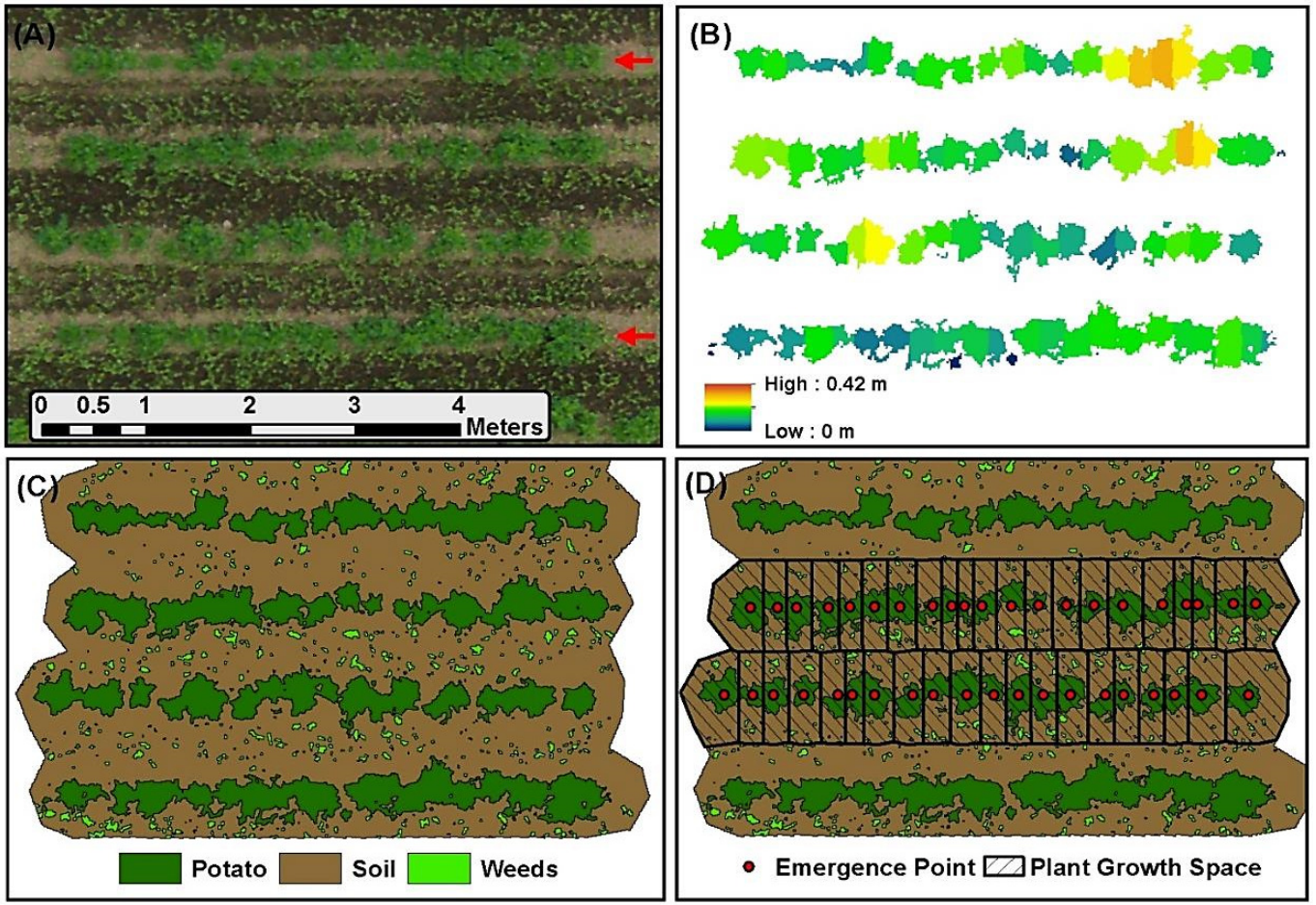
Case study:
Potato trials analysis



(Example results from a single plot.)

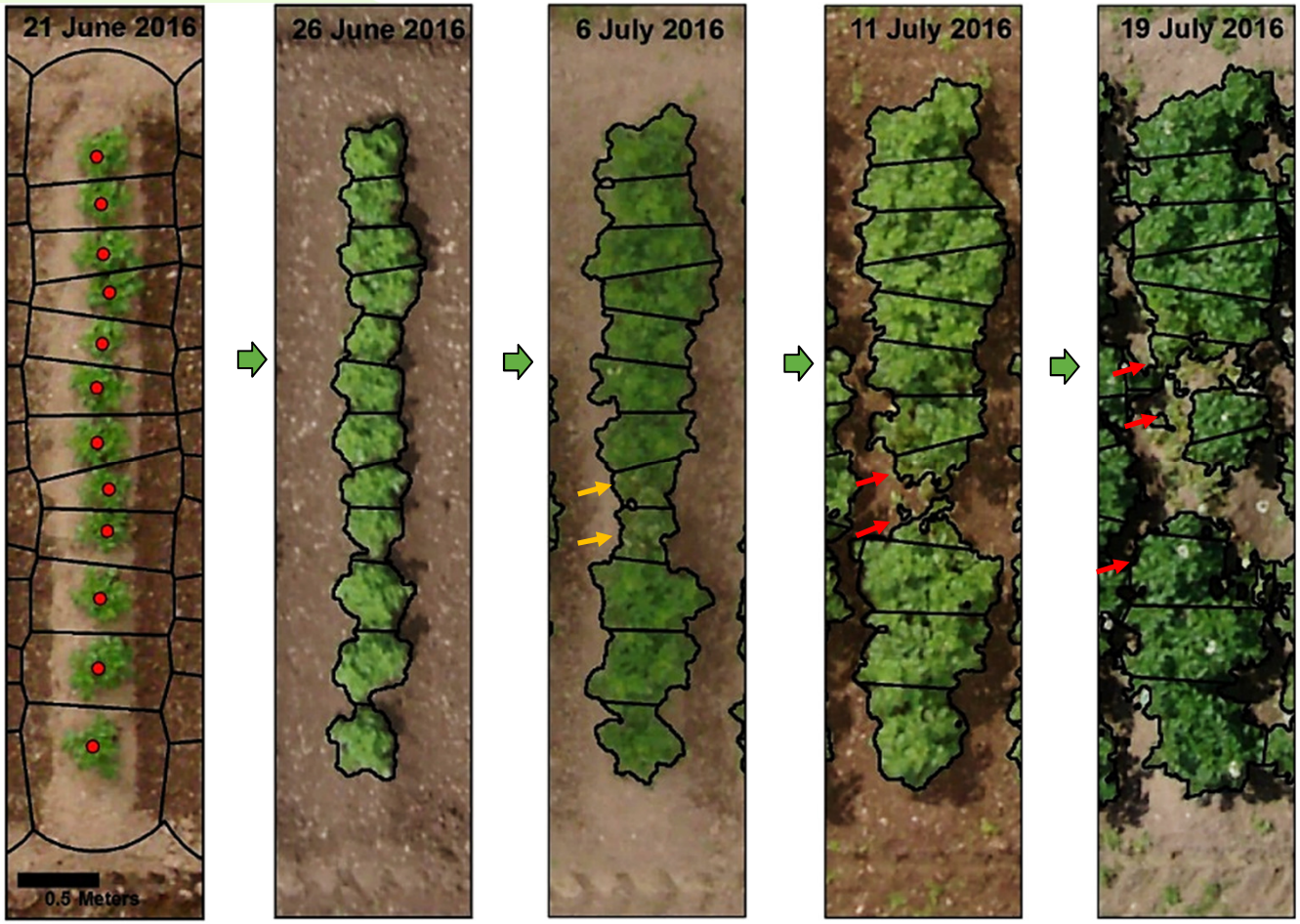
(A) RGB where weeds can already be seen between rows, showing guard rows (red arrows).

(B) Mean height of individual plants.

(C) Classification of plot.

(D) Detected emerged plant points and growth spaces allocated to each plant).

Case study:
Potato disease detection



(Example potato row showing signs of disease)

Red dots are emergence points.

Yellow arrows point to plants that have reduced growth.

Red arrows point to plants that are loosing foliage.

Drone use at SRUC

- Drones themselves are becoming cheaper and so are the multispectral sensors that can make them effective tools for precision agriculture.
- The use of drones at SRUC is now starting to increase, with more research projects and trials considering using them.
- We now have a small fleet of drones and range of sensors, so will be testing how best to use them with different sensor packages and for different crops.
- This should lead to more informed technical notes on how best to use this equipment, from flight planning through to analysis.

Future thoughts

(Drone taxis exist and may become a working reality quite soon – Daimler Volocopter)

(Heavy lift battlefield drones are also being developed - Urban Aeronautics AirMule, can carry 500 kg over a 50 km range)

(Will we one day see flying tractors?)

Any questions?

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