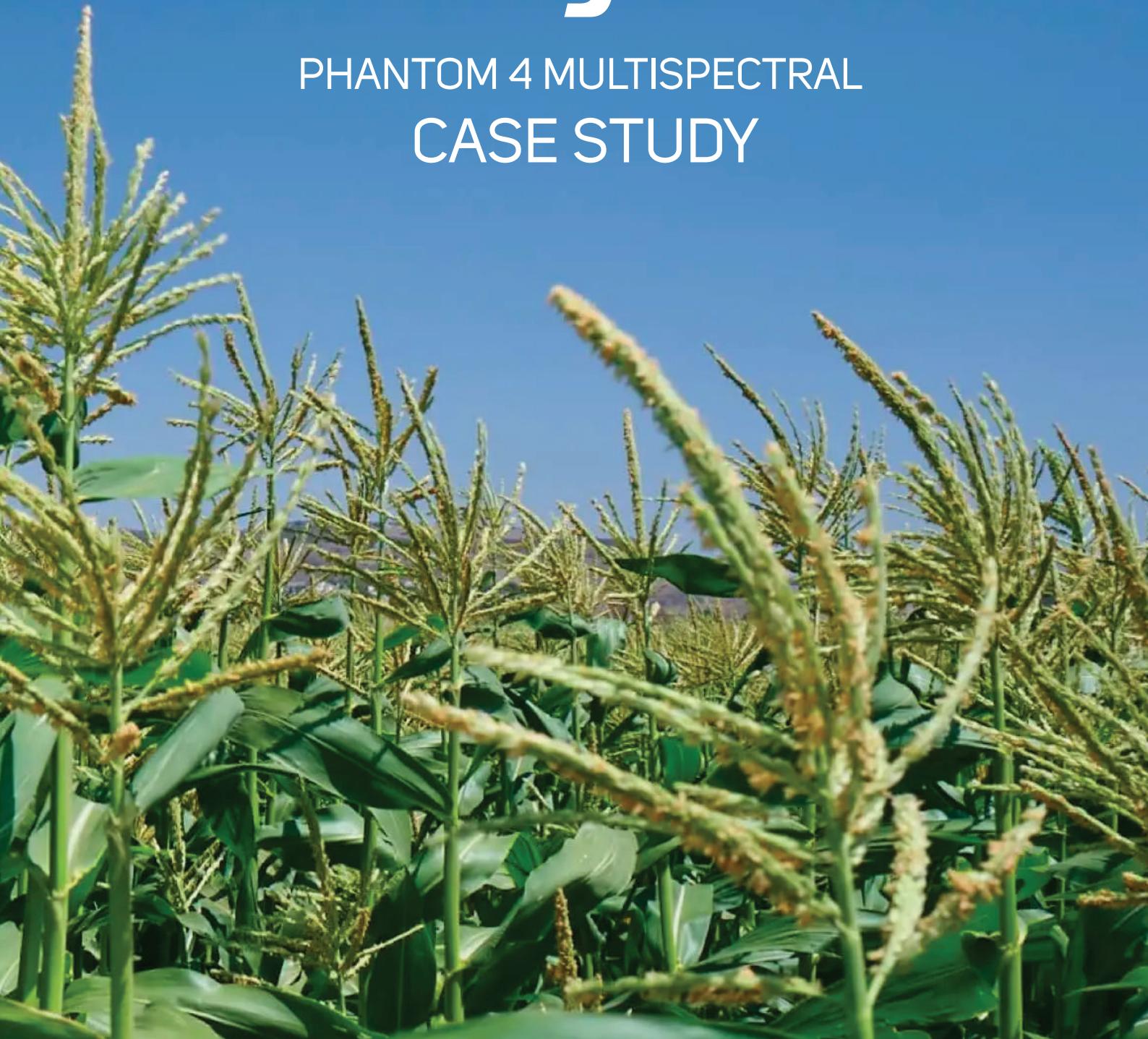




PHANTOM 4 MULTISPECTRAL CASE STUDY



DJI Phantom 4 Multispectral case study

Introduction

Practical and affordable UAVs with great cameras have been around for perhaps five years now, starting from the Phantom 3. NDVI and multispectral sensors for UAVs have also been available since then too. Yet while crop analysis has been slowly but steadily gaining commercial traction and, by early 2020 it remains an “early adopter’s” tool.

This may be about to change with the release of DJI’s Phantom 4 Multispectral (P4M): a new, big, brash and bold participant to the sector, an entry that will significantly boost the whole process of plant analysis.

The Phantom4M combines the outstanding Phantom 4 Pro frame with an RTK system and includes one RGB sensor for visible light imaging and five monochrome sensors for multispectral imaging. Mission planning and post-flight data analysis is taken care of by DJI’s Ground Station and Terra photogrammetry software, respectively. One manufacturer, an integrated process from end to end and a price tag of NZ\$9,129 + GST (includes 12-month subscription to DJI Terra and Enterprise Shield). But will it work for end users?

DroneMate have been ploughing the crop analysis furrow since 2015. Partnered with Sentera, a US manufacturer of NDVI and multispectral sensors, we know the Sentera solutions and, thanks to DJI Ferntech, had access to the Phantom4M for a couple of weeks.

Our task was to answer the following question: knowing what we know, is the Phantom4M a “game changer” for the sector and will it be adopted by end users [usually farmers, contractors or agronomy consultants]? We’ll let you decide.

What is a “Solution”?

A solution solves a problem: the problem here is to get advanced notice of problems in a field of crops and to be able to quickly take action. Owning a drone may be fun but won’t solve any problems unless you can do something with the data it collects.

We’ve split the solution process into five steps:

1. Planning and executing the UAV flight
2. The UAV and sensor hardware (data gathering)
3. Photogrammetry: turning the data into maps
4. Crop analysis: being able to manipulate the map to create either an electronic file for use in equipment (tractor, sprayer, spray-drone etc) or to be able to help someone in the field
5. Feeding data/info into other equipment systems or end user applications

The UAVs and our processing were geared to relative, not absolute, NDVI. This ties in with our practical approach to surveying: survey conditions change a lot over time due to weather, sun position, plant changes and more. What matters to most users is the difference across a field at that one survey moment in time so they can take action. Gaining an accurate absolute NDVI value can be tricky and unnecessary for most of the surveys these systems were designed for.

Planning and Execution

Mission planning and flight dispatch was conducted through one of two software systems:

1. P4M: can only use DJI's Ground Station Pro. P4M will likely be compatible with other apps soon
2. P4A and P4: Sentera's FieldAgent on tablet or smartphone. Other compatible systems are MapPilot, Drone Deploy, GS Pro and others

UAVs

We compared three UAV systems:

1. Phantom 4M
2. Phantom 4A with a Sentera Double 4K NDVI/NDRE
3. Phantom 4 with a Sentera Gen 1 NDVI Single Sensor

The P4M is an integrated unit, while the Sentera sensor is an add-on to the P4. Installation requires a little electronic surgery which invalidates DJI's one-year warranty on the UAV. This is a drawback. Mounted on the back of the UAV and not gimballed, the sensors have little or no effect on the UAV's operation and the UAV retains the original RGB camera.



The table below summarises the units' capabilities:

Unit	RGB	NDVI	NDRE	RTK	Gimballed?	Year
Phantom 4M	2.12MP	2.12MP	2.12MP	Yes	Yes	2020
P4A / D4K	20MP (DJI camera)	12.3MP	12.3MP	No	Yes RGB No D4K	2017
P4 / Single Sensor	12.4MP (DJI camera)	1.2MP	None	No	Yes RGB No D4K	2016

Please see the appendix for the full specifications sheet for the units.

Photogrammetry Software

Four software packages were used for photogrammetry, which converts images into a cohesive field map. While creating similar looking maps, they vary on a spectrum from fully orthorectified maps (Pix4Dmapper, the most accurate but slowest method) through to direct-to-orthomosaic processing in Pix4Dfields optimized for fast processing.

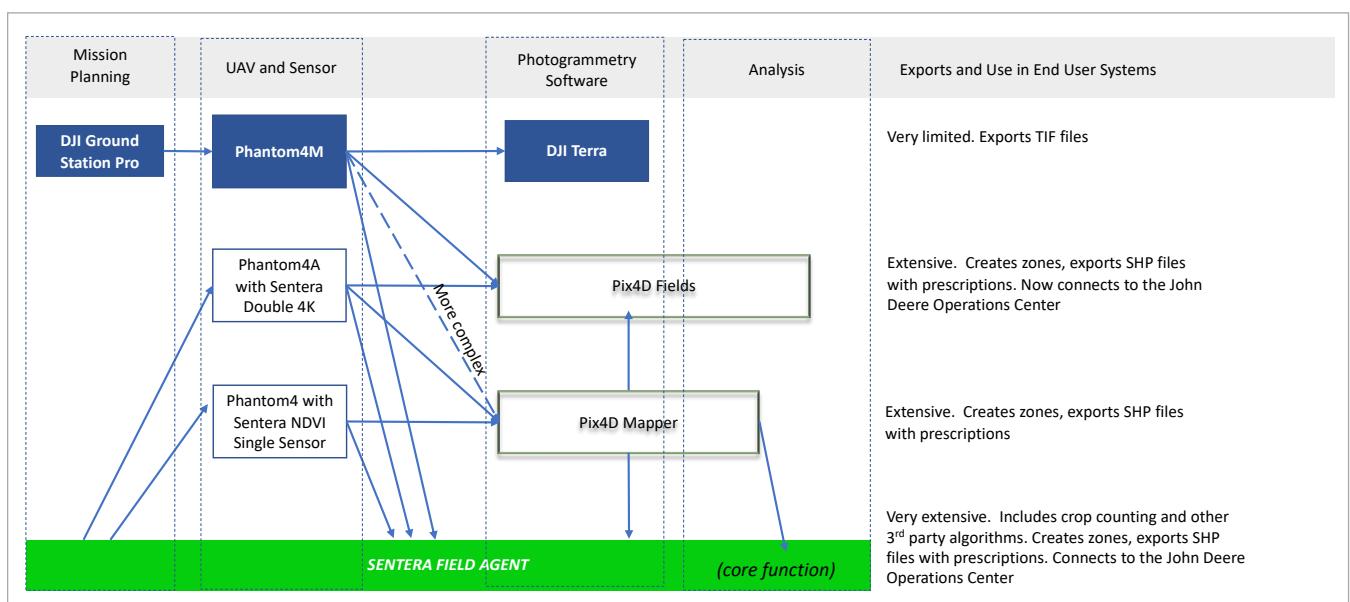
- **Terra:** DJI's data processing software, which is fast and now compatible with the P4M
- **Pix4Dfields:** For agricultural mapping, fast direct to ortho processing
- **Pix4Dmapper:** Pix4D is heavy duty, multipurpose photogrammetry software
- **FieldAgent:** Sentera's data management and analysis software that has a quick stitching feature. It can order orthomosaic maps (12hr or so turnaround) from the cloud. FieldAgent includes a free full orthorectified processing module on fast PCs, but this is complicated to set up and is very slow compared to other software

Crop Analysis

We used a simple framework for crop analysis for this case study:

1. Seeing a field as “zones” (number of zones determined by the user) so effort can be focused on specific areas/zones
2. Creating files where a prescription/rate can be applied to a zone, for use in a sprayer, for example
3. Exporting field maps as data that can be used in analysis software. Exporting a map as a picture (.TIF) only is not much use
4. Access to various algorithms for crop counting, nitrogen analysis, moisture analysis, weed identification etc. Terra only does #1 of these four criteria. The Pix4D products do 1, 2 and 3. FieldAgent does all four but it is not really a good photogrammetry tool. FieldAgent is designed primarily as a data manager and analysis tool, incorporating third party algorithms in its suite for many types of crops and analytical needs

The diagram below attempts to plot the compatibility of hardware and software while the data was being processed for this case study. Since then, Pix4Dfields has become compatible with the Sentera single sensor.



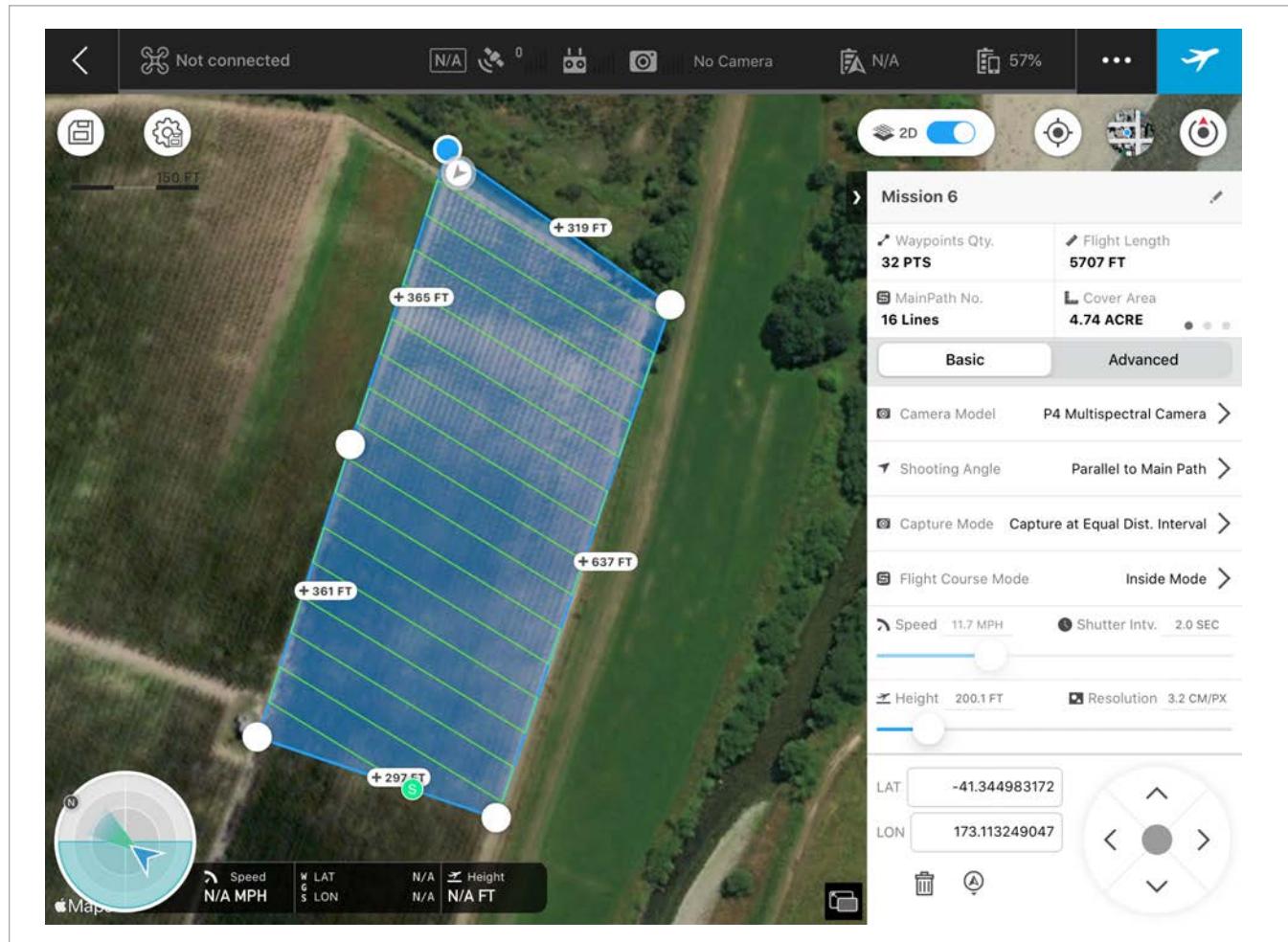
Field Work

We surveyed a 5 acre section of a hop garden near Nelson, NZ in January 2020. Hops are an excellent crop for NDVI analysis because they are leafy and dense. From the ground, the grower can't get a good idea of how the garden looks as a whole and a UAV perspective is brilliant.

Flights were done at 400ft with a couple at 200ft. The 200ft flights took approximately 25 minutes (2 batteries needed) while the 400ft flights were around 11 minutes (1 battery each). All the UAVs were launched minutes apart and flown at similar speeds (see the settings on the screenshots below and later). This case study focuses on the 400ft flights only, referring to the 200ft flights to make key points about UAV surveying.

Mission Planning

The P4M's mission and flight used Ground Station Pro (settings for 200ft flight below):

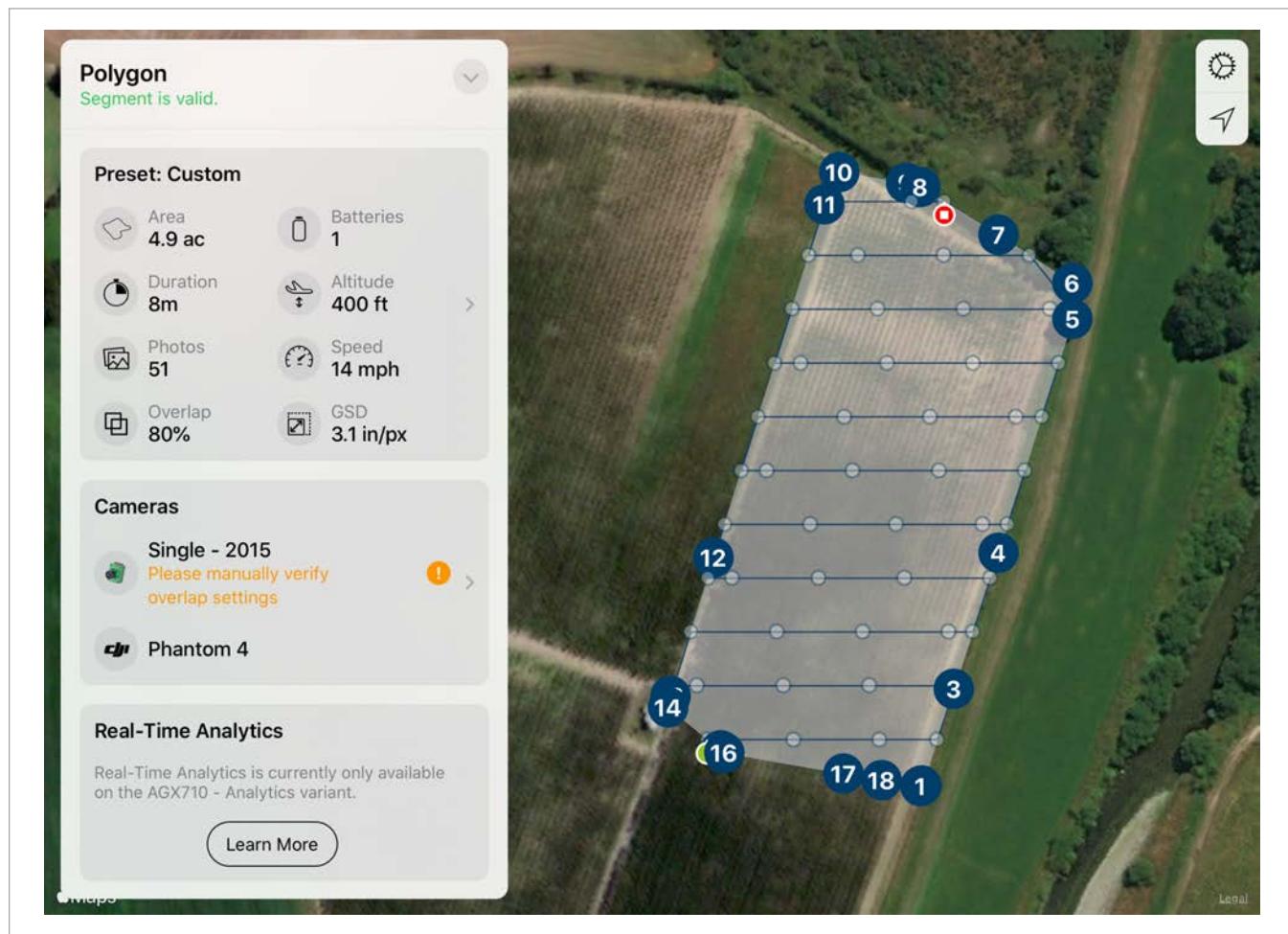


GS Pro is easy to use: the screen has a good menu and it only takes a couple of minutes to set up a flight. The default settings needed to be changed for our flights, which we talk about later.

FieldAgent is also very easy and can dispatch any DJI UAV at almost any speed or overlap. There is one complexity related to the sensor integration, though. The sensors only receive power and GPS from the UAV; they are triggered (overlap settings mostly) by their own computer's overlap settings which are fed from the sensor's SD card with their own program on it. This means the sensor could be set to a 25% overlap on the SD card while the FieldAgent flight could have dispatched the UAV with, say, a 75% overlap, which would result in missing sensor images.

Note: Recently Sentera have released a new blue tooth connection from the app to the sensors.

The photo below shows the FieldAgent screen for a single sensor flight.



Flights

All the UAVs performed flawlessly, as expected for a Phantom 4. Flight data was recorded on the P4M's single SD card with some live feed NDVI and RGB during the flight. On the other two UAVs, there was no live feed and data was recorded on both the UAV's and the sensor's SD cards. Both Ground Station and FieldAgent dispatched the UAVs as expected.

Photogrammetry software

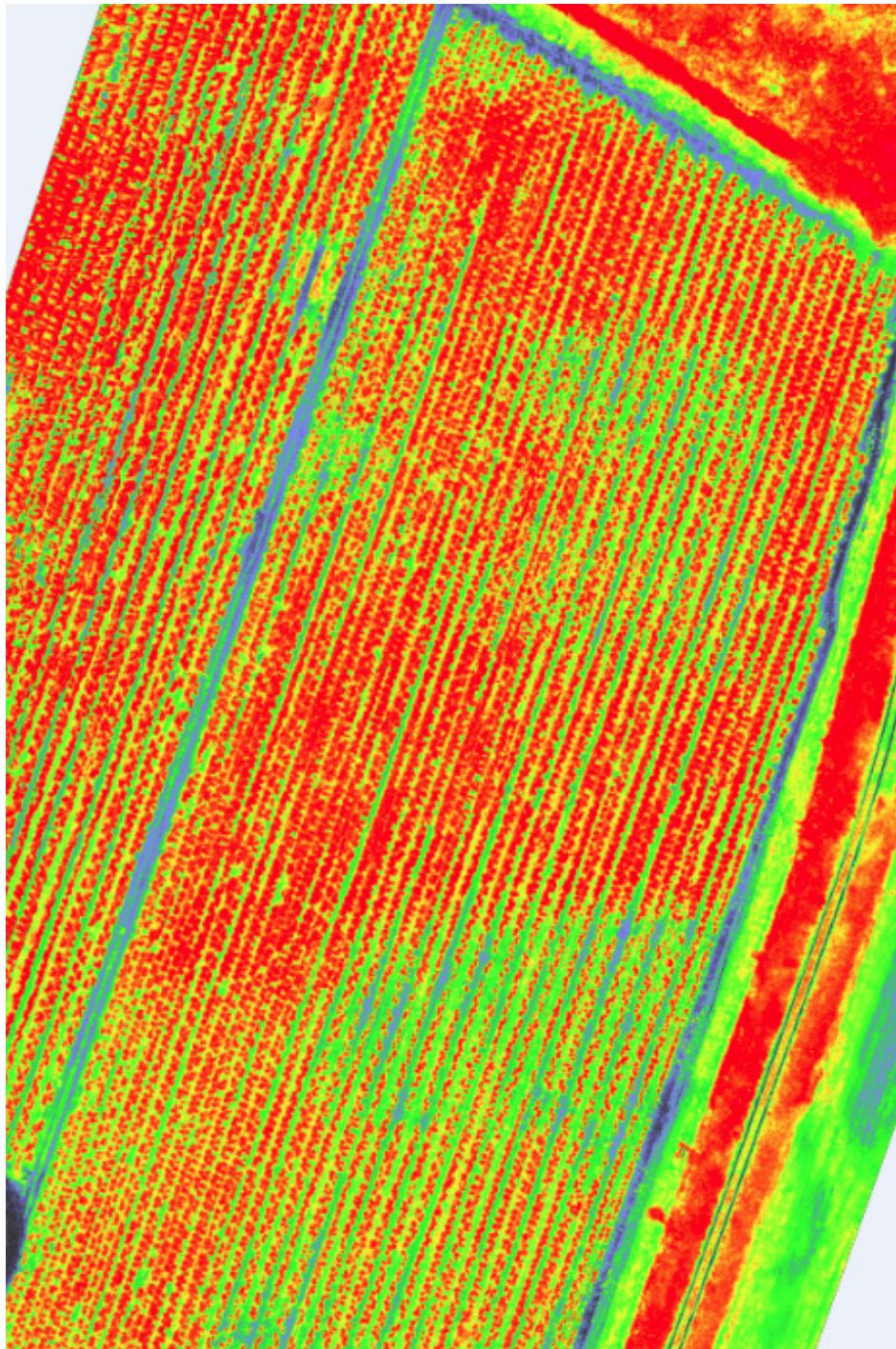
Now we have the data, it's time to process it into information.

Terra

The imagery from the P4M's SD card was transferred onto a PC and DJI Terra opened. Uploading the images is very easy and processing completed within seconds, giving great looking RGB and NDVI maps.

The RTK on the P4M and the integrated sensor mean the maps perfectly overlay each other. Sentera sensors and the UAV's RGB data can have a small mis-overlay typically between .2m and 1m. This mis-overlay can be corrected through ground control points, but that's another complication.

Terra doesn't provide any processing options but the NDVI map appears extremely quickly on screen and looks terrific. Curiously, it initially scales the NDVI to have red as a value of 1 and green as -1. Most other software has the default setting the other way around.



Above is an NDVI map produced in DJI Terra from the P4M

Pix4Dfields

Pix4Dfields looks like a modified version of Pix4Dmapper dedicated to ag surveying. It's pretty simple to use, the D4K and P4M data enters easily and an NDVI and NDRE map is available within minutes. Pix4Dfields has pre-loaded templates for various sensors, including the P4M but it was not compatible at that time with the Sentera single sensor. We were able to process the SS in Pix4Dmapper and then import the finished .TIF file into Pix4Dfields and FieldAgent for analysis. The latest update for Pix4Dfields (1.7) on 10 March 2020 has now made the software compatible with the Sentera single sensor.

Pix4Dmapper

Pix4Dmapper is the mothership of processing systems with near infinite options and flexibility. Having many more options makes it more complex and specific training is highly desirable.

Sentera currently has templates for the D4K and SS sensors for upload into Pix4Dmapper which allows for easy data processing. We didn't have a template for the P4M and we used the standard Ag Multispectral template to start with and then made some slight changes. The results using Pix4Dmapper were almost identical to Pix4Dfields.

FieldAgent

FieldAgent uploaded the images from all the UAVs and sensors easily and is great tool for viewing images. We didn't ortho-process any maps in it, instead importing the orthos from Pix4D.

Summing up: it all depends on the quality of the map you want and the tools you need for analytics.

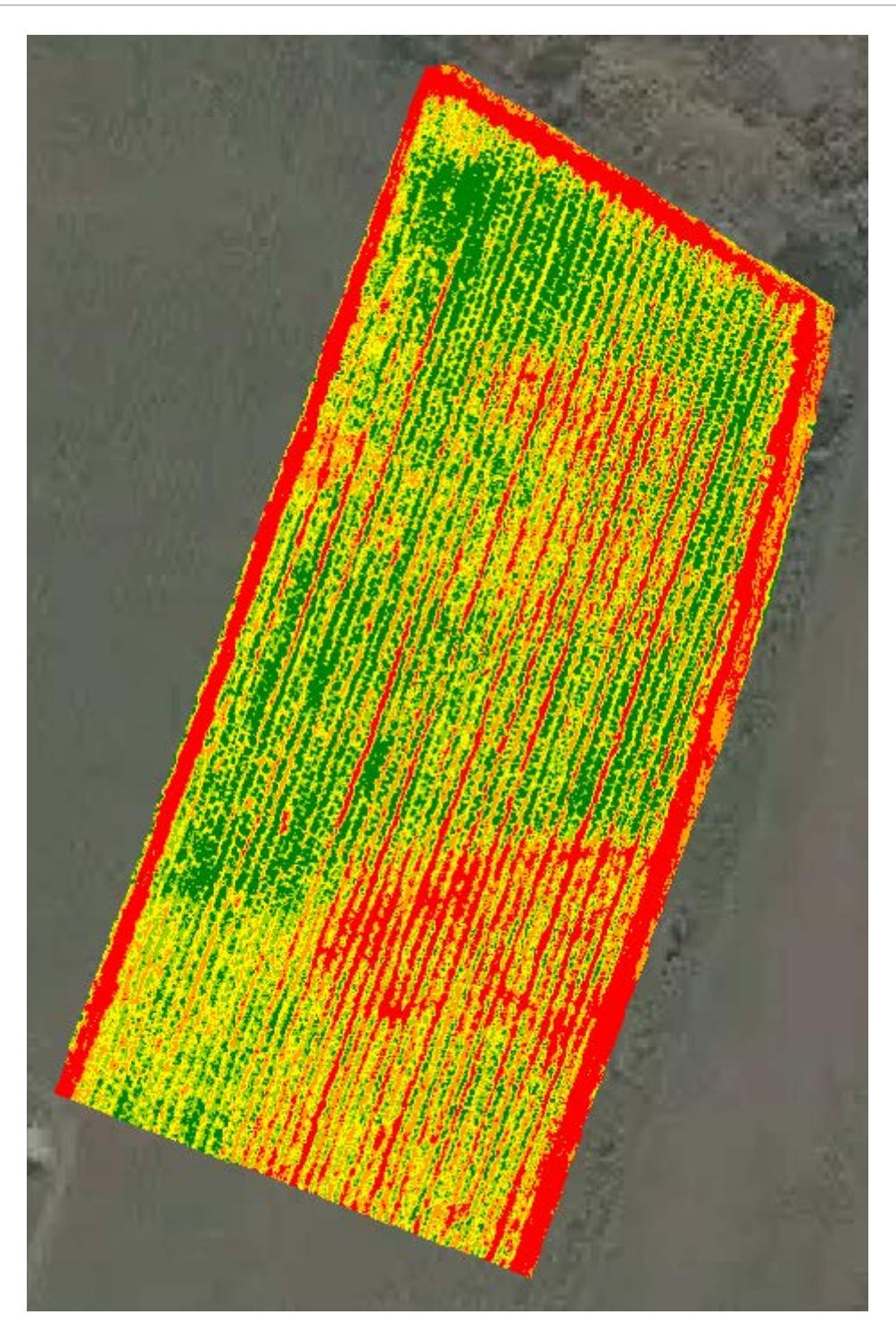
- Terra is fast and good but offers no tools
- Pix4Dfields is also fast, provides accurate results and has analysis tools
- Mapper is slow but creates the best index map and offers variable rate prescription outputs
- FieldAgent is great for data management and prescriptions but doesn't really process maps

What Did We Find?

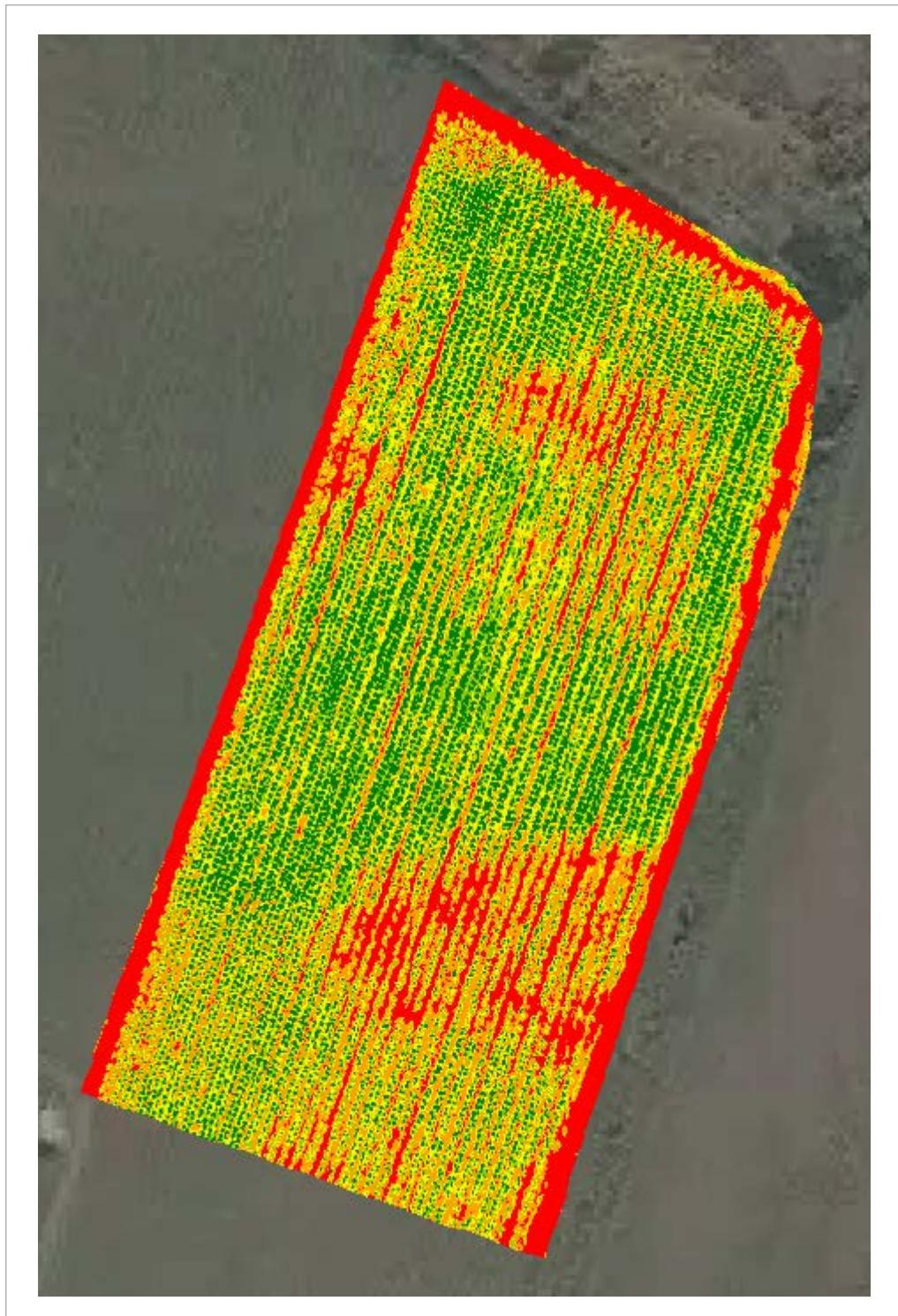
Below are 3 NDVI maps produced from the 3 different set ups and they are very similar. They clearly show areas of concern and areas with more vigour. We have ground truthed many NDVI maps from Sentera sensors over the years and have always found the information coming from the maps to represent very well what we are seeing on the ground.

The P4M NDVI maps mirrored what we were seeing from the Sentera sensors, which gives us high confidence in the sensor.

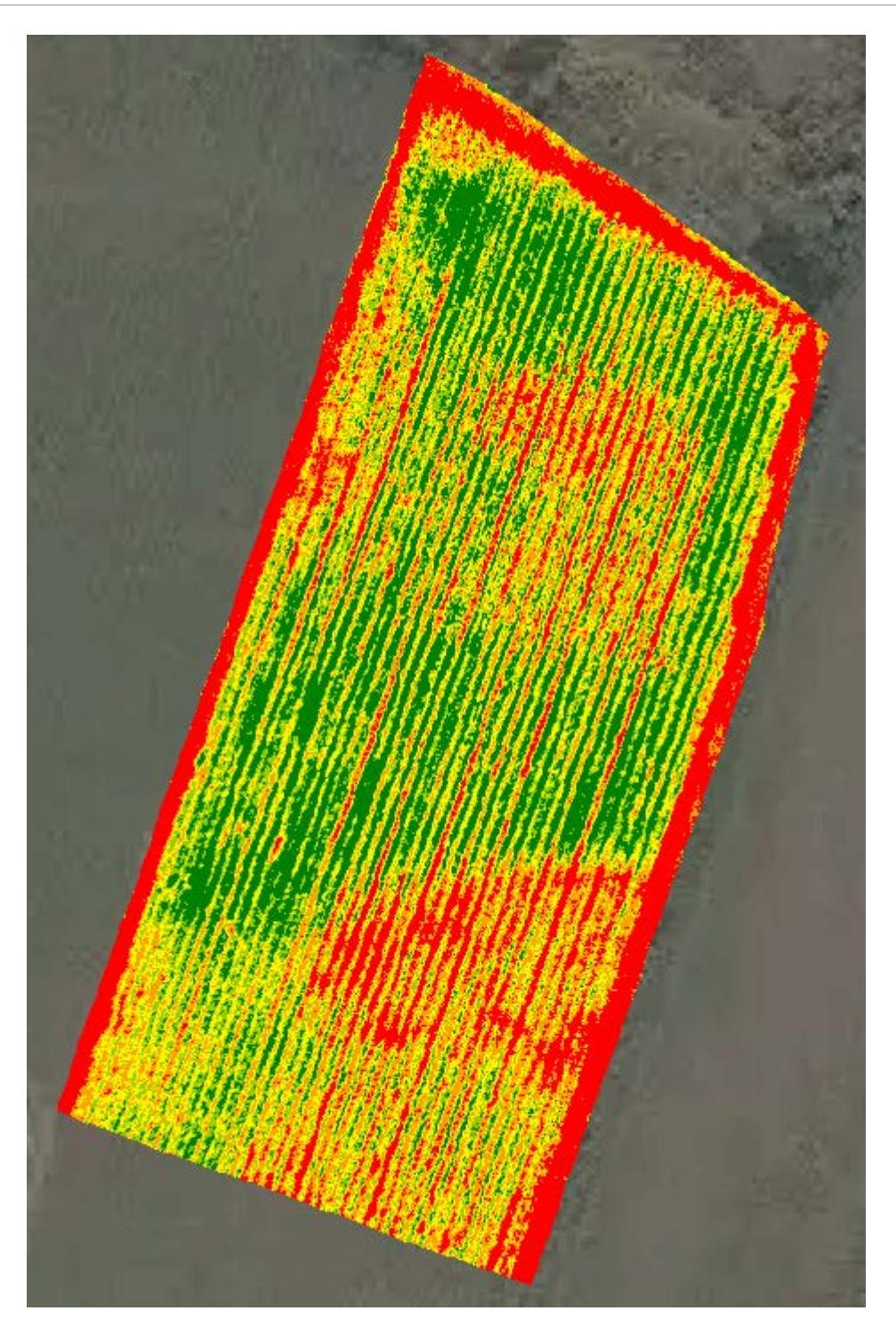
P4M 400ft NDVI Map



P4 SS 400ft NDVI Map



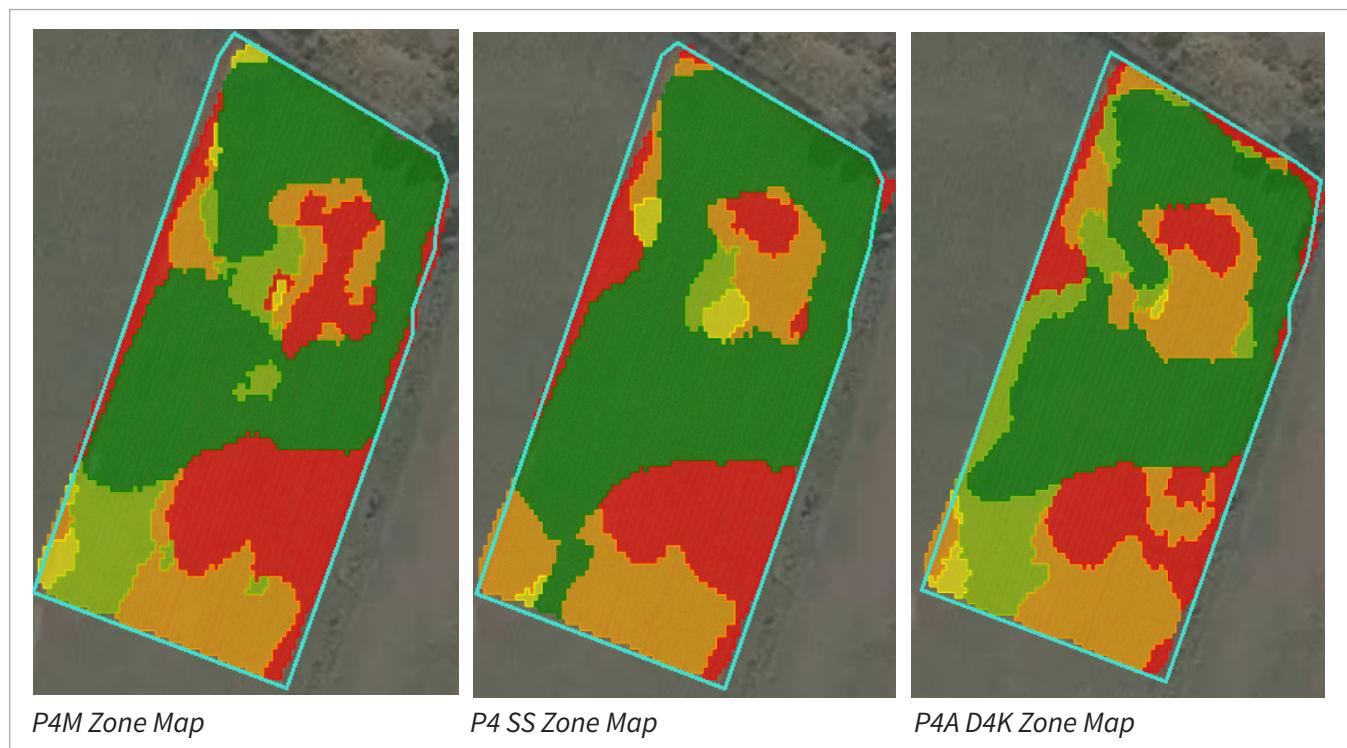
P4 D4K 400ft NDVI Map



Management Zones

After completing the NDVI maps, we pulled them into FieldAgent to create management zones, which are easier to understand than speckled maps. FieldAgent creates zones by looking at the NDVI range on the map and dividing it up into however many zones, or bins, requested by the user (5 in the case). There is also “detail” setting which is like granularity and sets the averaging over smaller or larger areas. We used a moderate setting below.

Below are the three zone maps we created in FieldAgent from the 3 different sensors. Red represents the lowest NDVI values going up to green being the highest.



We expected some small differences and, in general, we were directed to the same areas of the field from all three maps. The D4K and P4M provided us with the highest level of pixelation/granularity, but the single sensor seems to get similar zones with less complexity.

Management zones are also used to create variable rate zone maps for upload into automated systems like the John Deere variable rate sprayers. FieldAgent and Pix4Dfields are great tools for this as these prescription maps can be sent directly to MyJohnDeere, their data hub, and then into the machinery.

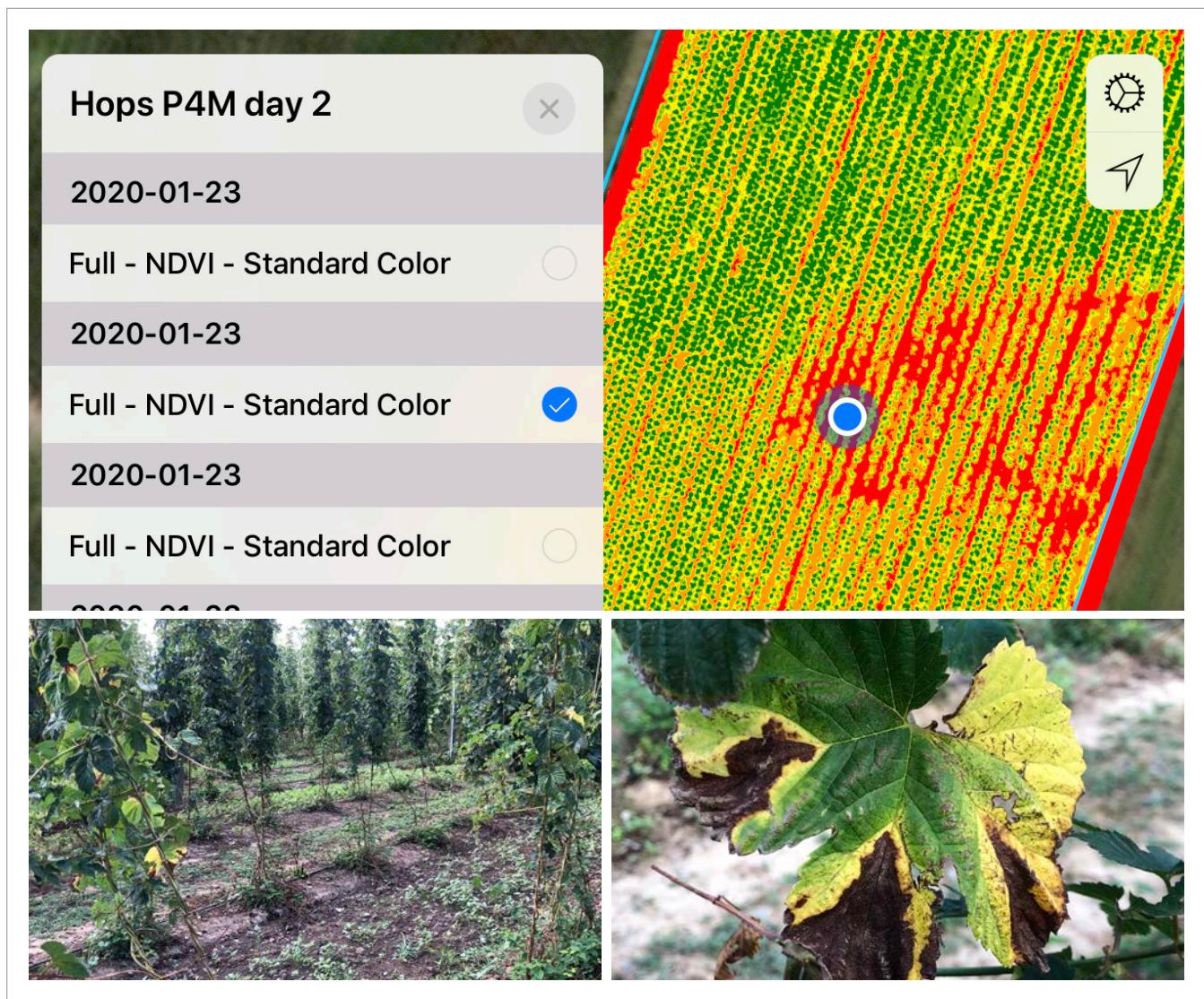
Ground truthing

We went back out to the hop garden to reconcile maps with hops. FieldAgent uploads maps to the cloud and makes them available on a smartphone. The blue dot on the maps below is the smartphone's position on the NDVI map as the user wanders through the crops. A pretty useful feature.

The following NDVI map images are screen shots from the FieldAgent mobile app. Each screen shot is followed by ground images taken at that location.

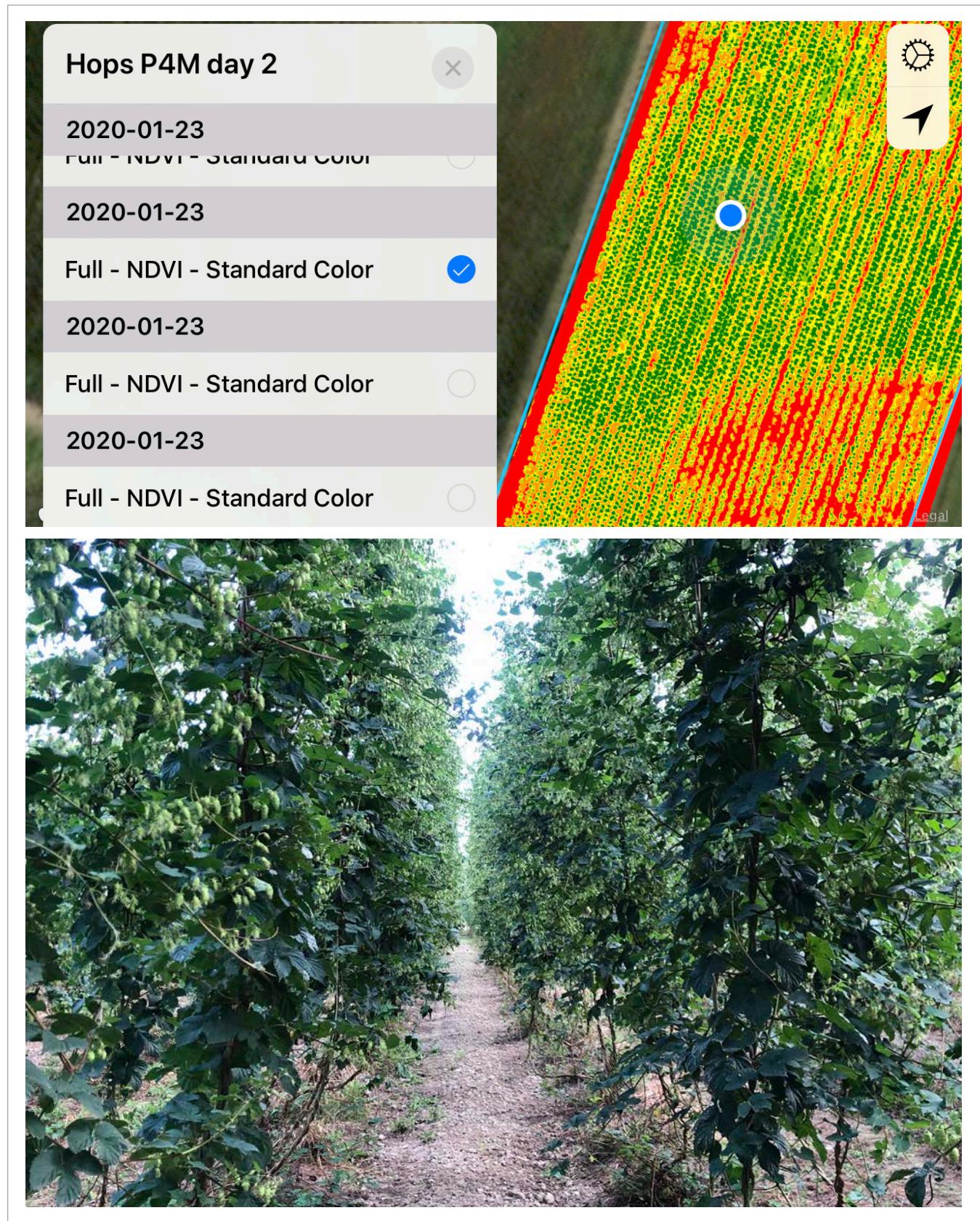
The first area we went to can be seen below. Being relative plant health maps rather than absolute, red does not mean dead; it means that it is at the lower end of that survey's NDVI range, i.e.. the least vigorous plants in the survey.

We knew from the map, however, that this area was struggling because of gaps in the plants and very low vigour on the ones there. We found very low vigour on most plants, vines with no leaves at all, gaps in the rows and most plants had yellowing and deteriorating leaves.



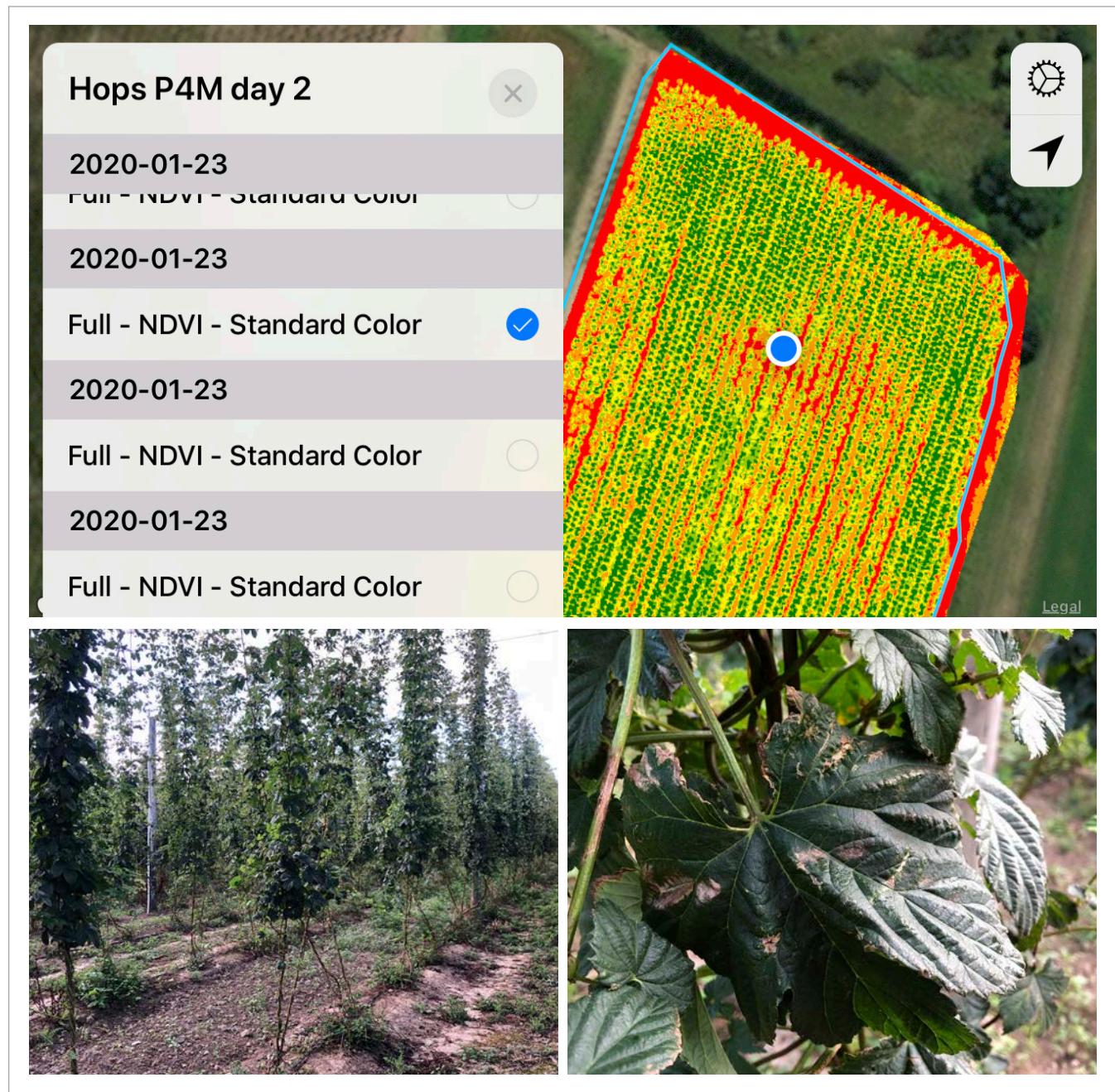
The field manager said the soil in this area is different from the rest of the field and has historically created under performing hops plants.

The second area showed high NDVI values and we didn't see any signs of problems. Lots of healthy hops with no signs of damage on the plants.



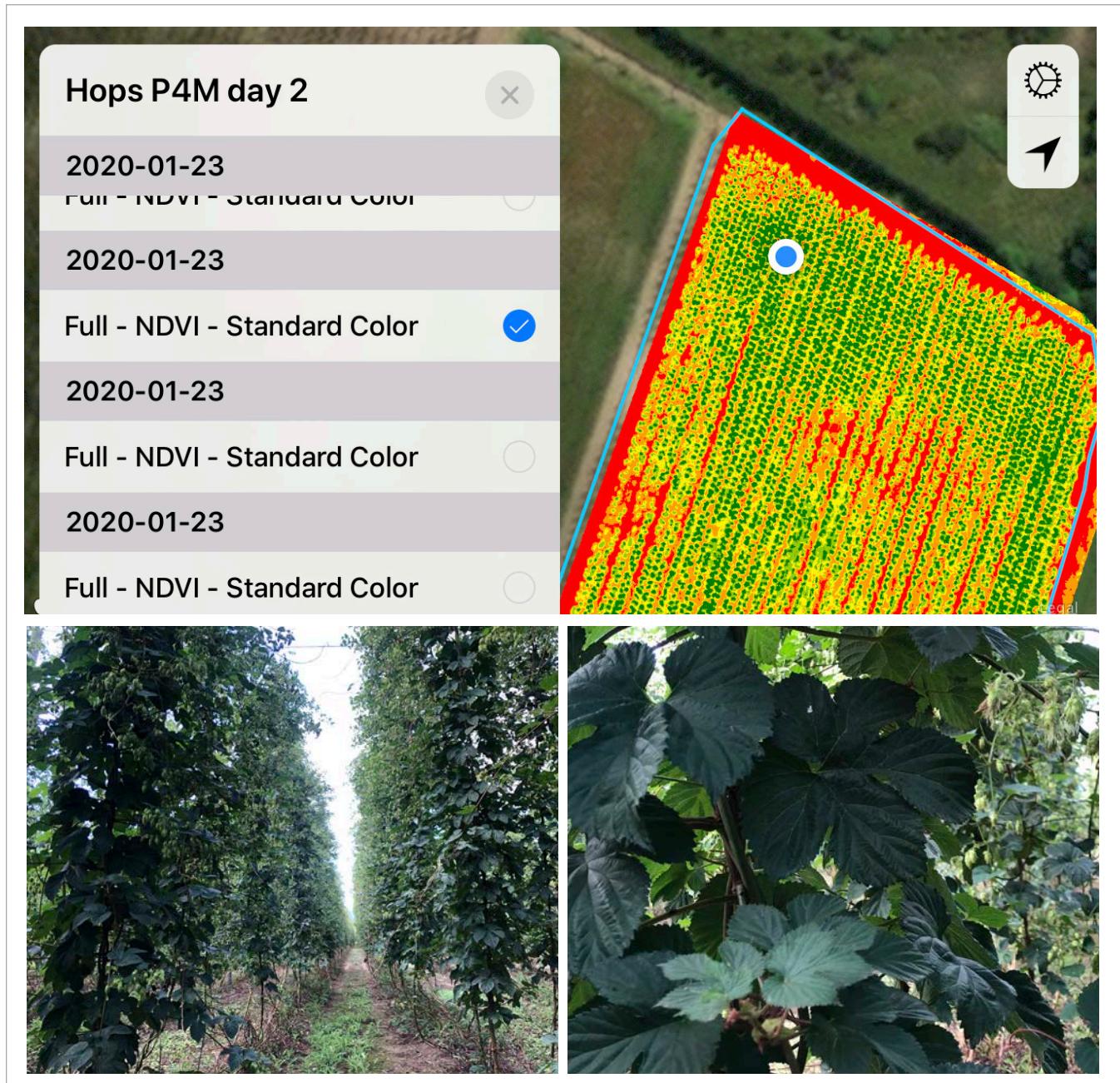
Area 3 was another area of concern on our NDVI maps. Lots of low values along with gaps in the plants. The ground truthing supported what the sensors said but the damage was not the same as the previous area of concern.

The plants were either missing or under-performing like in the first area but almost all of them had leaves with various stages of browning, through to being completely brown and dead.



The farm manager revealed the section was treated for Californian thistle 3 years ago and they think it was over treated. Every year since, the area has under-performed.

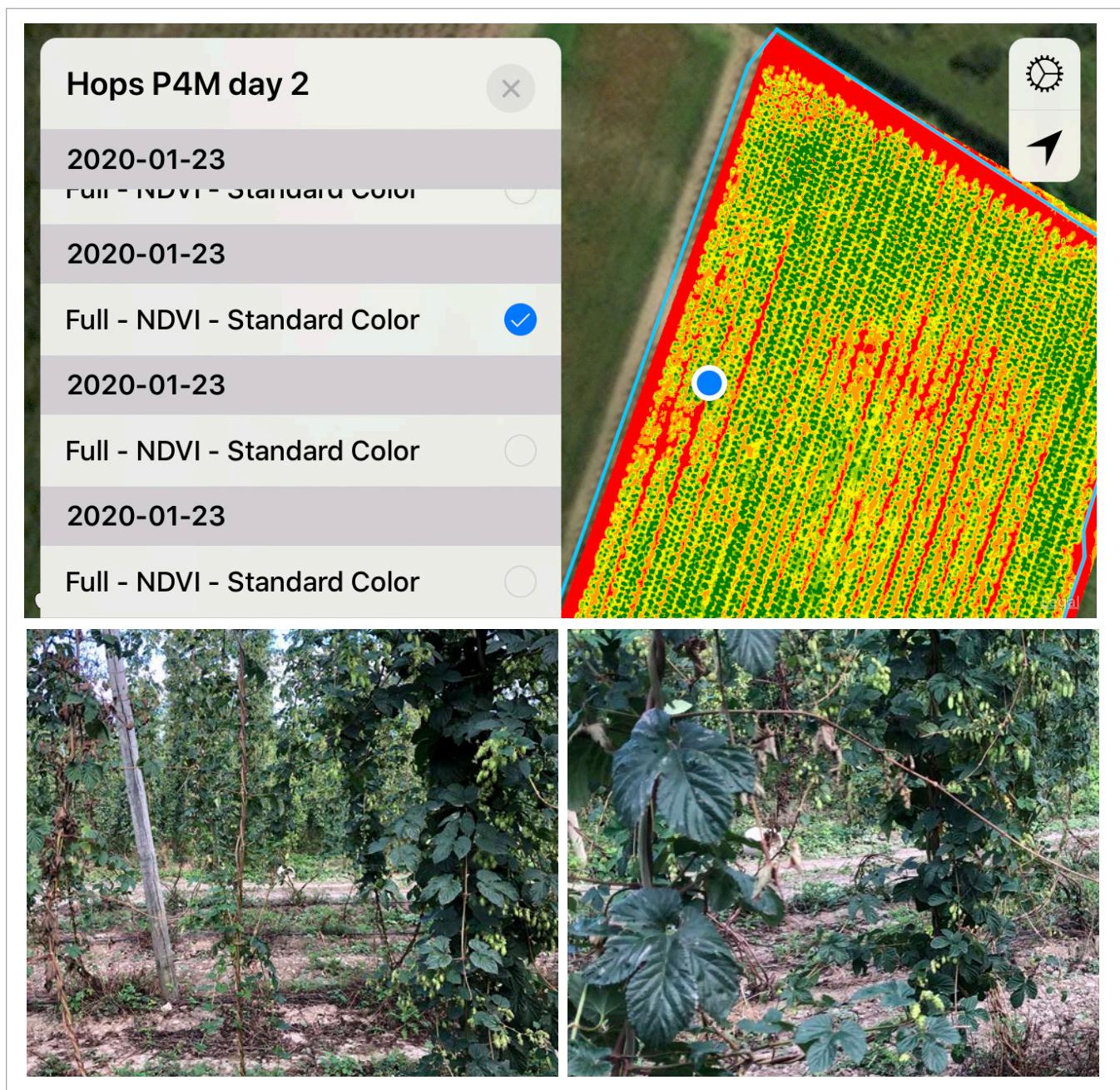
Area 4 was another section with high values, lots of plant vigour and no leaf damage which is exactly what's on the ground.



Area 5 had the most mixed values and plant vigour. The NDVI map has healthy plants next to plants with much lower health.

We thought there may be an issue with the irrigation in this area but that was not the case. The area had some replacement plants which explained why we saw some plants with high NDVI values but with less vigour than older plants in the area however we also found a similar browning of leaves on many of the plants. You can see in the ground images very healthy-looking plants right next to plants that seemed to be struggling a lot.

The field manager said some plants had been replaced here, with the older unreplaced plants being the most vigorous. The manager was unsure why they are starting to see so much browning on many of the leaves, prompting them to take samples and investigate further.



Summing up: the ground truthing was a success, showing the P4M is fully capable of providing good plant health information.

The NDVI maps from all three sensors were slightly different but they all lead us to the same findings. The higher granularity of the D4K didn't translate to any advantage over the low res SS here.



Overall System Observations

While the sections above go into some detail, they don't give a good picture of the overall system and its usability. So here goes:

P4M with DJI Terra

Set up, planning and flight is easy and it's a beautifully integrated system, right up to the production of the NDVI maps. At first use, it is amazing to be able to create such a great map so quickly. Being RTK and from a single gimballed camera, all the maps (RGB, NDVI, NDRE) overlay exactly. Very neat work.

Unfortunately, there are a few downsides. The low resolution RGB bands- 2.12MP- puts the P4M at a slight disadvantage. Often crop analysis is driven using RGB and high resolution is almost always better for spotting weeds, leaf shapes, blossom, stand counts and similar.

DJI Terra is excellent for saying "the NW corner bit of a field looks bad" but doesn't have much further use. You can't reconcile your ground position with the map, there are no custom algorithms or even a basic tool box to build zone maps. Also, Terra can't export the .TIF file with associated files needed to pull the NDVI maps into other software for analysis like FieldAgent or into farm management/equipment software like MyJohnDeere.

The P4M and Terra look great, but they're not a complete solution as such. Until DJI Terra starts releasing more features inside the software, the P4M will be a good drone that is still going to rely on other software to close the loop. Luckily until that time comes there are other great photogrammetry/analysis software compatible with the P4M.

The GS Pro/P4M/Terra solution is definitely the easiest system we have used for plant health mapping. The only complaints are minor and would not be a problem for anyone with a basic understanding of plant health mapping. So long as DJI keeps adding to its software, this will likely be the main reason DJI will pull ahead in Ag surveying.

There are a few points worth mentioning, though. Having lots of experience in UAV survey training, it was also important for us to fly the P4M as close to the default mode as possible, only changing the height between the surveys.

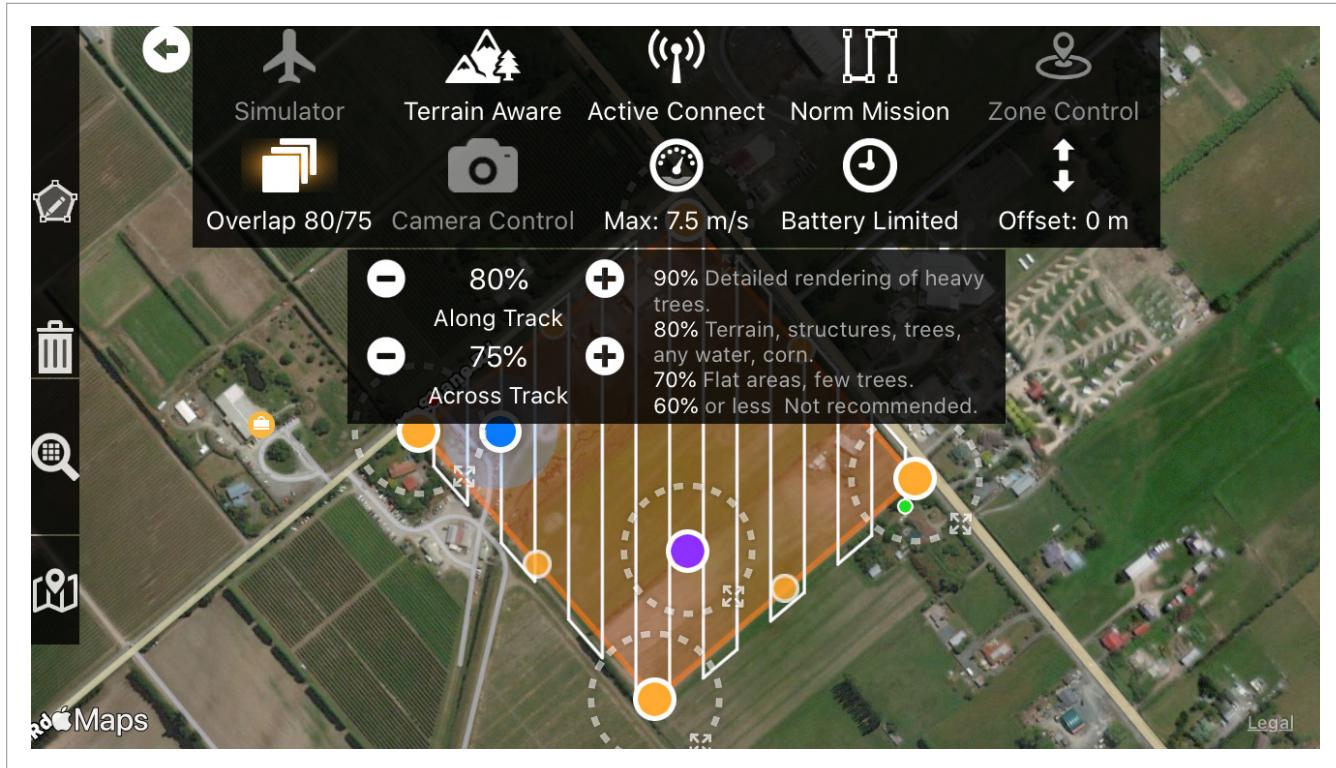
Most people we train are unaware of the basics of UAV surveying and don't understand why their maps aren't coming out right. The default settings are their starting point.

GS Pro default sets overlap to 75% forward and 60% side lap. Altering them requires the user to go into the Advanced settings. First of all, overlap settings are crucial to collecting a good survey and should not be looked at as an advanced setting.

If we used the default overlap settings it's very likely we would not have enough image overlap for good key point matching and could be left with holes in our survey or, at least, some distortion. We increased overlap to 75% 75% which is the minimum you would want to use for this terrain with this sensor.

Other apps, such as Map Pilot, do a great job of having the overlap setting out front with some very basic instruction on how to adjust the settings according to the terrain being surveyed.

Map Pilot image shows overlap setting menu in Map Pilot app:



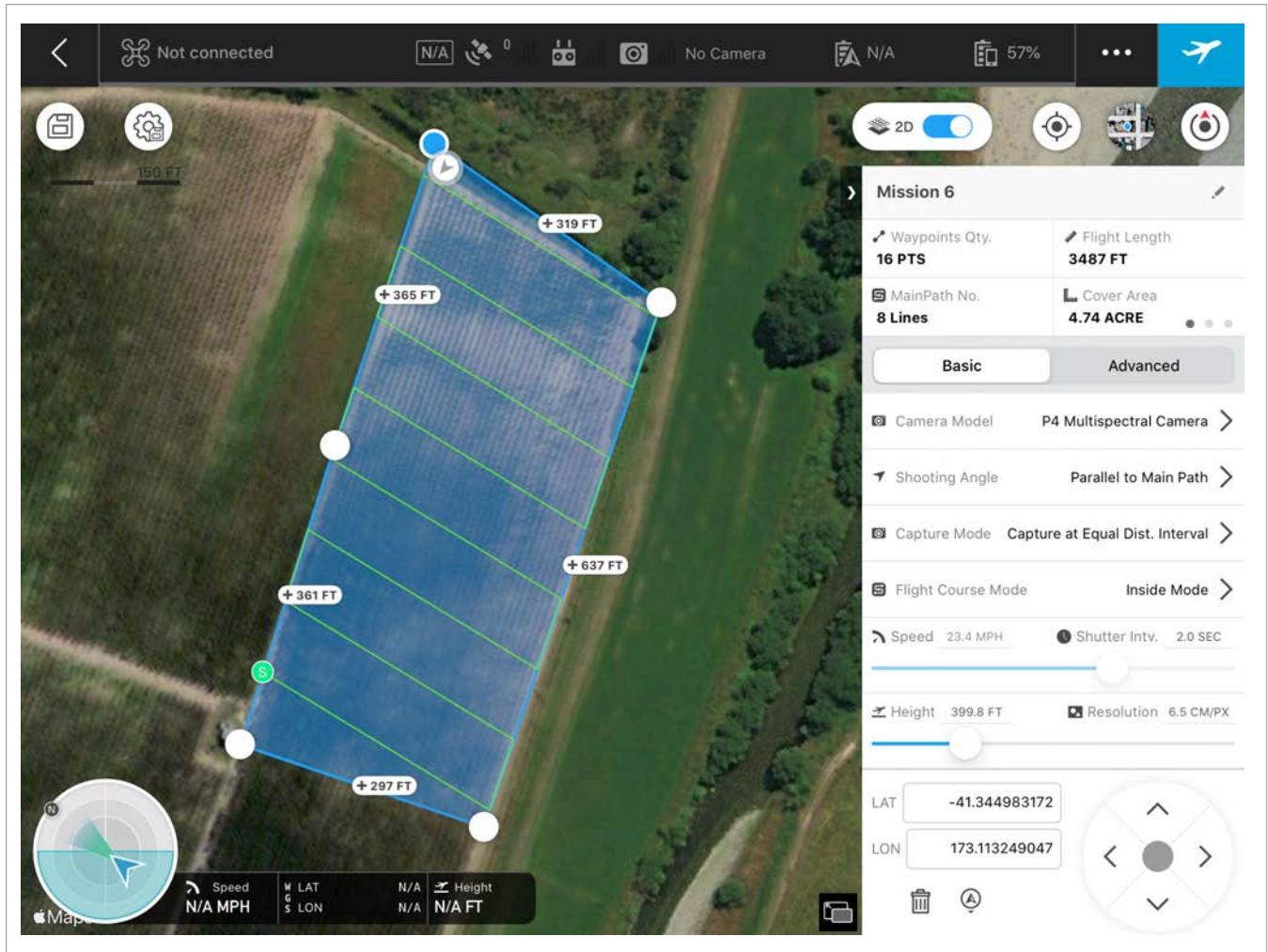
We altered other default settings that impacted the speed of the survey and how well the images could be quick tiled. We switched the shooting angle from “course aligned” to “parallel to main path”. This means now the UAV would never change the direction in which it captures the images from. This doesn’t matter to any photogrammetry software when going for an orthorectified map but software like FieldAgent has a quick tiling feature that almost instantly aligns the images into a quick map. This function has a harder time producing a good map when the images are taken from different directions.

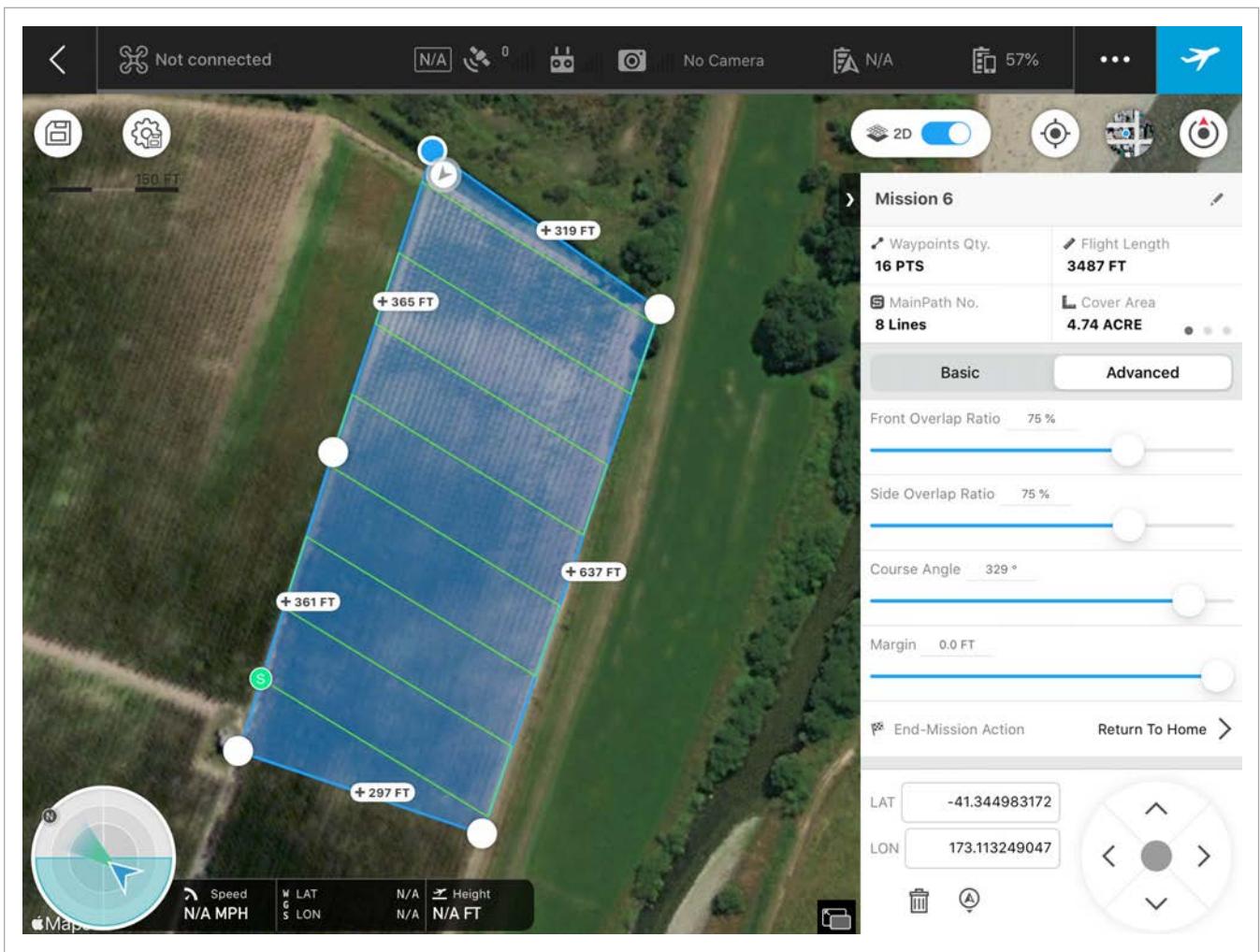
We also changed the capture mode from “hover and capture at point” to “capture at equal distance interval”. Leaving the setting in “hover and capture at point” drastically increases the time it takes to complete a survey. Instead of the drone flying at a consistent speed, it stops the drone to take every image and then moves to the next point. Having the drone stop to collect the images can sometimes be necessary depending on the weather conditions and height of the survey.

For example, flying too low or in low light can cause motion blur on the images which harms processing, giving distortion and gaps in the map.

We had a sunny day with a little bit of overcast and a flying height of 200ft and 400ft, which meant the risk of motion blur being more than double the ground sampling distance was low. Changing the settings to “capture at equal distance interval” no longer gave us the ability to choose what speed we wanted to fly at. Now, GS Pro dictated the speed based on the shutter interval which maxes out at every 2 seconds. This is a slow trigger rate compared to most sensors.

Below are images showing the settings we used in GS Pro for our 400ft flight.





Summing up The P4M gets an A for ease of use and, knowing DJI, it will only get easier to use. If DJI Terra provided all of the options available in other software such as FieldAgent, this would be a game changer as a complete solution provided by DJI.

P4A and D4K

Great camera, high resolution NDVI and NDRE and affordable; what's not to love? Well, a few things. FieldAgent is great as a dispatch tool and data management. At 12.3MP resolution with two lenses, the D4K creates gigabytes of data for every flight.

Frankly, we struggle to see the benefit of high resolution NDVI. To explain: as resolution gets higher, the NDVI values become a mass of colours. There is not much that can be done on a 2cm by 2cm patch of field that might have a weed or other problem. It is not practical. Pix4Dmapper aggregates the data anyway in many cases, creating value blending in nearby pixels which can give a lower resolution look to your index maps. In other words, the ortho-map is a dumbed down version of data to make it understandable and manageable.

We found that the best NDVI map- the clearest one with the most readily understandable resolution, came from the SS at 400ft. It has a pixel size of 10.6cms square which is pretty much around the size that can be investigated further and then treated.

All of the maps at 200ft had more pixel blending of values and gave an even lower resolution look to them. You'd expect resolution to increase as you are closer to the ground, of course. Even dramatically increasing overlap settings to combat perspective distortion doesn't improve map resolution in taller bushy crops. While this would not happen with all crops, with tall bushy plants like hops higher is better.

P4 and SS

The 2016 P4 has a standard DJI 12.4MP RGB camera. We didn't process this data as all new P4s are 20MP. As mentioned above, the Single Sensor NDVI map was easiest and clearest to understand even though it created the lowest detailed zone map.

Conclusions

This case study is long enough already and hasn't covered a lot of details. Many readers will want to get to the key recommendations, though, and here's what we think:

The P4M is a good integrated UAV and sensor. Not having a high resolution RGB camera can sometimes be an issue, but the RTK and overall quality of the product is good. Terra will undoubtedly have more features in months to come and software like Pix4Dfields has the P4M covered in the mean time or for the long run.

P4A and D4K is a practical high-resolution system. RGB, NDVI and NDRE all at high resolution. On the downside, the sensor needs managing (overlap and triggering settings on SD card) unless blue toothed to the sensor. The price is similar to the P4M, but there's no RTK.

A Sentera Single Sensor on a P4 is outstanding; good RGB and excellent NDVI, very reliable and affordable. A great combination for fast, good, affordable NDVI mapping but not as integrated as the P4M.



DJI P4 MULTISPECTRAL

(NZ price at time of going to print)

P4M: NZ\$9129 +GST, includes 12-month subscription to DJI Terra and Enterprise Shield
(see Ferntech for more details)

Terra: NZ\$1215 + GST per year (Free 12-month subscription with P4M)

P4Pro: NZ\$2350 +GST (see Ferntech for more details)

Sendera NDVI/NDRE Double 4K, installed on a P4A or Pro: NZ\$5500 +GST
(Price does not include the drone)

Sendera NDVI Single Sensor, installed on a P4A or Pro: NZ\$3650 +GST
(Price does not include the drone)

Sendera FieldAgent: US\$49/mth

Pix4Dfields: US\$250/mth

Pix4Dmapper: US\$350/mth

Appendix

DJI P4M spec sheet: <https://www.ferntech.co.nz/DJI-Phantom-4-Multispectral>

DJI Terra: <https://www.dji.com/nz/dji-terra/info>

DJI GS Pro: <https://www.dji.com/nz/ground-station-pro>

DJI P4Pro: <https://www.dji.com/nz/phantom-4-pro/info#specs>

Sentera sensors: <https://sentera.com/sensors/>

Sentera FieldAgent: <https://sentera.com/fieldagent-platform/>

Pix4Dfields: <https://www.pix4d.com/product/pix4dfields>

Pix4Dmapper: <https://www.pix4d.com/product/pix4dmapper-photogrammetry-software>

MyJohnDeere: <https://discoveroperationscenter.com/en>

