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ONION VARIABILITY – PROGRESS IN MAPPING CROP DEVELOPMENT

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Summary of experience 2015-2016
As part of an Onions NZ MPI Sustainable Farming Fund project, several data capture technologies were used to follow and map a developing onion crop. This report covers the devices that capture data to give information about soils and canopy development. Sample images and pros and cons as experienced are noted.

Soil Mapping

An electromagnetic soil map was prepared by AgriOptics using a Dual EM sensor. The survey was completed in early July, prior to the soil reaching field capacity. The soil did not reach field capacity all winter.

The resulting map does appear influenced by irrigation history, with previous onion, sweetcorn and dry bean paddocks evident as different response areas (*Figure 1*). The sweetcorn crop had been fully irrigated leaving soil well recharged at the end of the season. In contrast, the dry beans were allowed to dry down to a significant soil deficit, still evident in the EM survey.

The onions were planted after winter cover crops that followed onions in the previous season. The cover crops were mulched and incorporated six weeks prior to the EM survey. The mustard residues were more completely broken down, but the effect on EM response of the different cover crops is unclear.

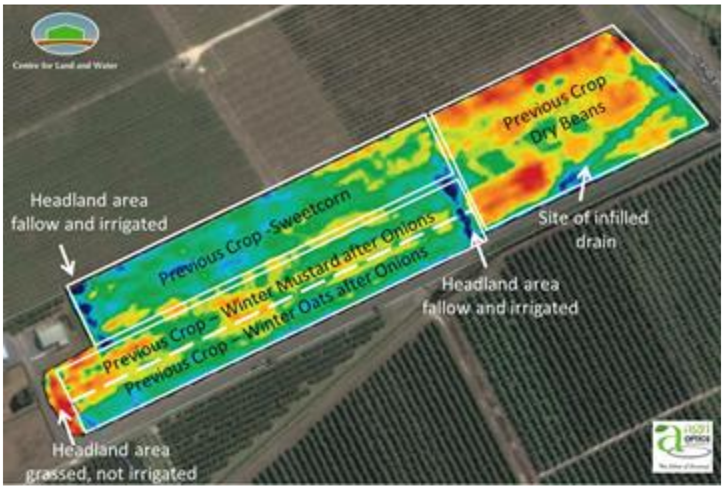

Figure 1 EM Map of Centre for Land and Water paddocks with historic management references

Canopy Mapping

Canopy development measurements sought to identify variation within the crop. Several commonly used reflectance sensors were used to assess canopy size and "greenness". Additionally a novel automated smartphone image analysis application was used to determine canopy ground cover. These field measurements were compared against detailed plot assessments made by Plant and Food Research in a parallel monitoring exercise.

All the sensors used were able to capture data to create spatial difference maps, and through comparison of successive measurement can show temporal variations. The architecture of the onion plant, a fine vertically oriented plant, made early measurement difficult. Maps created at early stages are strongly influenced by base soil reflectance masking some crop variation.

GreenSeeker
A GreenSeeker provided by AgriOptics was mounted on the front then later the back of the tractor. This was coupled with an sub-metre accurate GPS system to provide location information. At regular intervals the tractor was driven over the crop taking NDVI readings at points along each row. Data were logged using Trimble Field Scout software.

The point information was used to create a map (*Figure 2*) using ESRI ArcGIS and/or Quantum GIS geographic information systems software. These maps could be compared to see correlations between themselves over time and also against other capture devices.

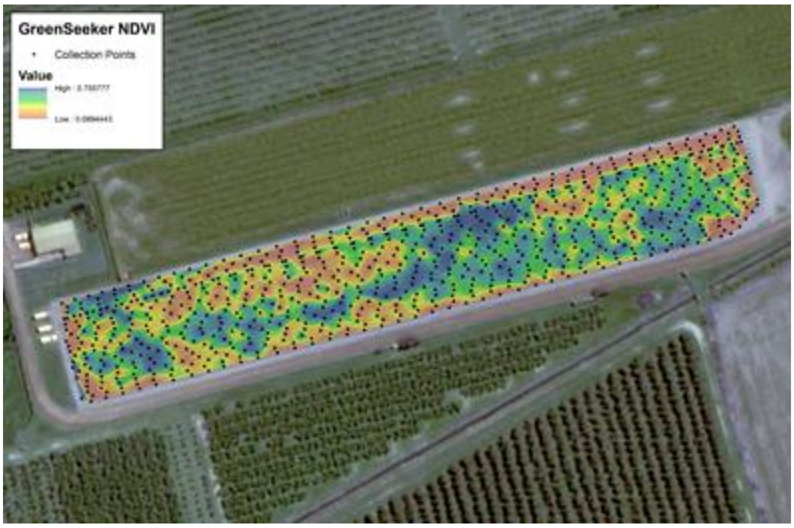

Figure 2 NDVI Map created from GreenSeeker recorded data (black dots) captured on 27 November 2015, interpolated and displayed as colour spread - red low, blue high

The points in *Figure 2* are located in the centre of each onion bed. The interpolation is only between points, so a thin strip of the paddock is missing around the boundary - only half the widths of the first and last rows are presented in the map.

The data at each point is not a single measurement at that point, but an averaged result representing many readings over the distance represented by the point spacing. We were unable to control the Field Scout software to log differently, although using alternative port logging packages we could identify many more data points being exported from the GreenSeeker device.

The interpolation method used compares close points, which in this case puts emphasis on adjacent beds. We are not sure this is valid given identified between bed variation, so are investigating bed by bed interpolations. While this is possible, it greatly increases time cost, so would have implications in a commercial setting.

The key questions are: 1. What is the data being used for? and 2. At what scale of resolution are management interventions possible?

If 20m swath width equipment is used, the management polygon will be 20m wide, so bed to bed variation cannot be managed individually. However if bed by bed or precision variable rate equipment is being used, the swath management polygon width could well be the individual bed. In that case, appropriate in-bed interpolation would be necessary.

GreenSeeker Pros:

- Commercially available equipment and support services
- Farmer can have own equipment and map as wanted
- Provides generally consistent results within varying light conditions due to the built in active light sensor
- Integrates a number of readings into a single averaged result – may mitigate outliers

Cons:

- Higher cost $10,000-20,000
- Requires fitting on to tractor and configuration of hardware to use and extract the data into a format that can be consumed by GIS packages
- May require ongoing technical support
- Level of detail may not be sufficient for accurate research analysis due to the frequency of point data capture – hard to link to specific ground point for truthing

CoverMap

CoverMap software provided by ASL Software was installed on an iPhone 6+ mounted on the same tractor and hooked into the same GPS system. This application recorded GPS position and percentage greenness being shown in each frame captured. The data were converted into a map (*Figure 3*) and interpolated as with the GreenSeeker data.

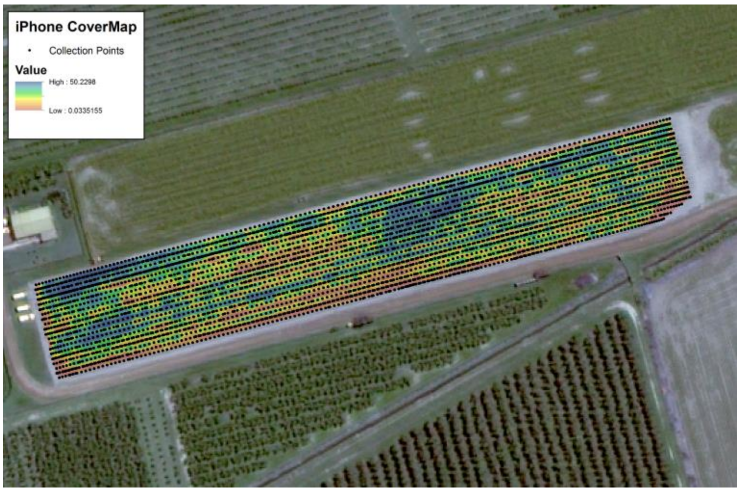

Figure 3 Ground cover map created from CoverMap recorded data (black dots) captured on 27 November 2015, interpolated and displayed as a colour spread - red low, blue high

Changes between the iPhone 5 (for which CoverMap was developed) and iPhone 6+ cameras created problems in varying light conditions. The camera appears to react to changing light by changing white balance and hue. This meant unreliable results if CoverMap settings were not recalibrated, an impossible task in real time while mapping. A solution was found by swathing the sensor and target area in white filter material to give constant diffuse light.

The greater point density of the CoverMap data set results in finer interpolation and bed to bed differences become more apparent (*Figure 4*).

CoverMap Pros:

- Low cost, cheap to own, available when wanted
- Runs as a simple application on any iPhone (5S and higher)
- Does not require a lot of additional configuration knowledge and training
- Provides more frequent sample points than the GreenSeeker – easier to link result to point on ground.

Cons:

- In current form is susceptible to changing light conditions and produces varying results if light was not consistent and device not recalibrated.
- Recalibration not really possible in real time with current software
- Results varied

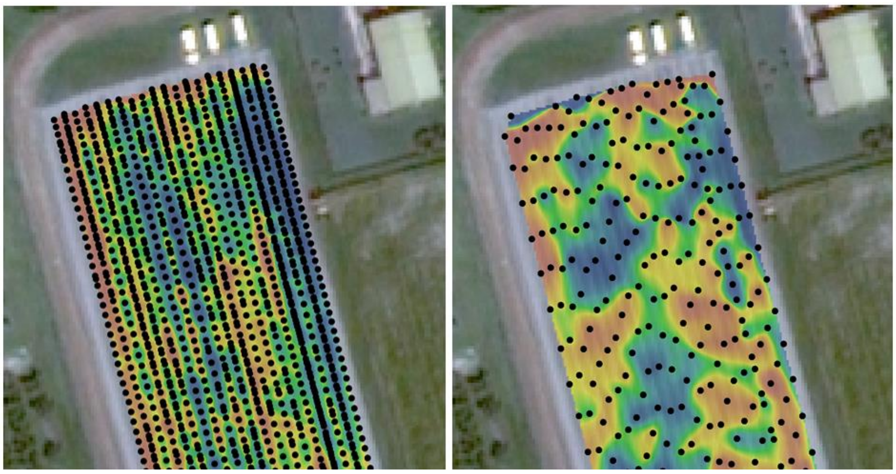

Figure 4 Comparison of logged point density (black dots) and resulting

Satellite

A single satellite image of 100 km^2 of Hawke's Bay was requested from Australian provider GeoImage and tasked for capture on 20 November 2015. The actual image received was captured on 23 November 2015.
The satellite image capture window is 10 days either side of task date, so may not match ideal/critical crop stage in a specific crop. There will be a range of crop stages within 100km^2, so a range of stages was captured overall.

Turnaround and post processing of the data was found to take about 10 days so the captured data is already aged. Depending on purpose for which the image information is to be used, this could mean it does not provide as timely information for decision making as desired.

The image was delivered as a raw four band (Blue, Green, Red and NIR) image at a resolution of 0.50 metre (i.e. 50 x 50 cm pixels). This image was clipped to individual paddocks and converted using ESRI ArcGIS into a standard Normalised Red / Near Infrared index (NDVI) map using the formula:

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

The NDVI value is calculated for each pixel, then the values presented as here using colour bands to represent values with certain ranges.

Figure 5 Area of Heretaunga Plains for which satellite image was captured on 23 November 2015, including NDVI images of certain clipped out paddocks.
MicroFarm in centre above red "Highway 5" sign.

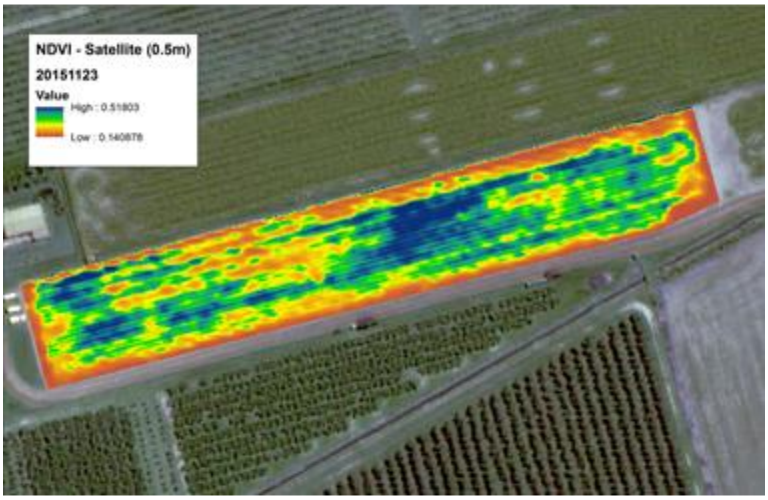

Figure 6 NDVI map created from satellite data captured on 23 November 2015, displayed as a colour spread - red low, blue high

Satellite Pros:

- Allows for the capture of large areas in a single tasking
- Resolution down to 30 cm pixels
- Relatively low cost for large areas
- Increasing options available including finer resolution, more spectral bands and lower cost

Cons:

- Is weather and satellite availability dependent – generally provide a window ten days either side of capture date.
- NZ more susceptible to cloudy conditions due to geographic location and formation
- Slow turnaround and post processing of the data delays availability
- Cost $6,000 US plus processing time
- 100 km^2 minimum order size is costly for small areas

UAV – Altus UAS and MicaSense

The paddock was flown on a semi-regular basis by a UAV provided by ALTUS UAS. This platform carried a MicaSense camera which recorded five bands of light – Blue, Green, Red, Red Edge and Near Infra-Red in rather narrow bands. This allowed it to produce detailed NDVI (and other spectral) maps that were created by stitching multi-images together.

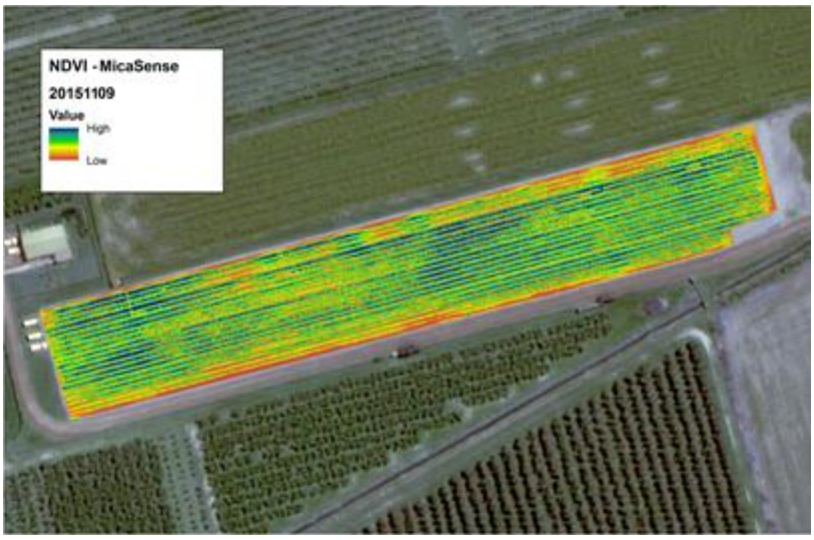

Figure 7 NDVI map created from MicaSense Red and Near Infrared bands captured on 9 November 2015, displayed as a colour spread - red low, blue high

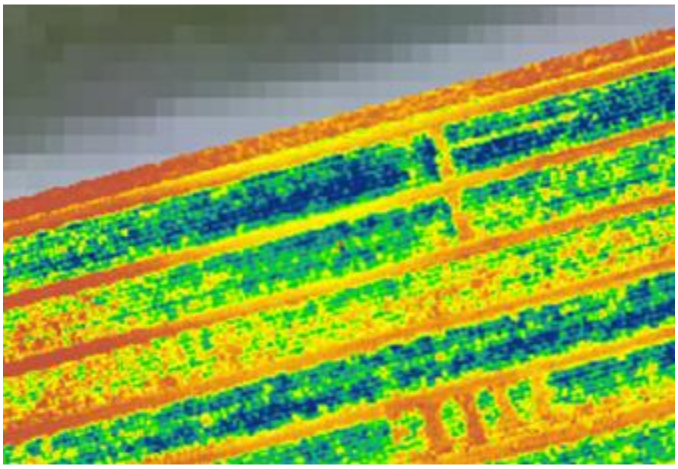

Figure 8 Close up of MicaSense NDVI map showing detail possible. The grey squares at top left are 0.5 m x 0.5 m pixels from background satellite image.

By selecting different combinations of light bands and applying different formulae, a number of different crop indices can be generated. The map presented in *Figure 7* is the standard Normalised Red / Near Infrared index.

Similar maps can be created using a range of other bands and formulae including variants such as substituting the Red Edge band for the NIR band in the equation above, substituting the blue band for the red band, showing only the green band and so on.

Many maps can be produced that show variation within the paddock (*Figure 9*). Some maps have similar patterns, others different. But at this stage we do not know what the maps are really telling us and what factors are causing the variations apparent in the maps created.

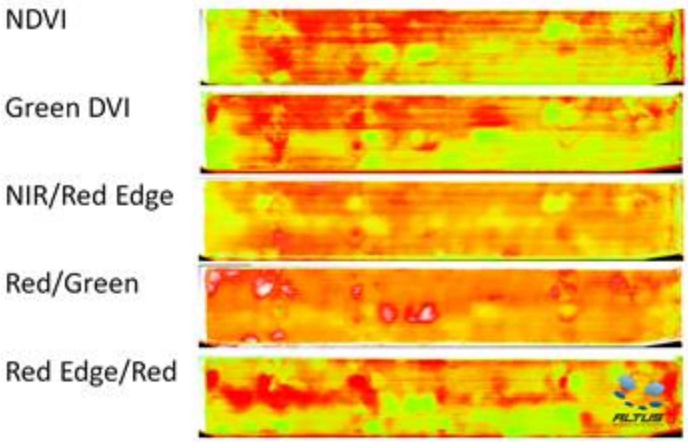

Figure 9 Sample of band crop indices created from five bands of image stitched spectral data collected by MicaSense camera showing some of the different presentations of field variation.

MicaSense Pros:

- Provided highly detailed map (centimetre pixel size)
- Not restricted by cloud cover
- Can choose resolution by camera choice and flight height
- A number of indices can be calculated and mapped

Cons:

- Relatively expensive equipment ~ $US 30,000 + $US 6,000
- Unreliable demonstrator availability gave sporadic and limited data sets to compare
- Requires image stitching and post-processing
- Must obey CAA regulations which may restrict permitted flight areas

Phantom 3 and RGB

A DJI Phantom 3 was used to capture standard full colour images (*Figure 10* and *Figure 11*) of the whole field. Images were photo-stitched to create single image high resolution maps that can be included as layers in GIS databases.

Farmer owned consumer UAVs provide new ability to track a crop over time gaining insight into stages of development.

One possible use of this information relates to crop quality and storage potential and segment crops for short and long term storage. We could track top down in the crop (*Figure 12*), identifying early and late top down zones. Plant and Food Research has taken samples from early and late top down zones to assess storability. This season top down was driven largely by very strong winds as plants matured.

The opportunity for advanced image analysis using similar technology to CoverMap is being explored. This would automate zoning from image data.

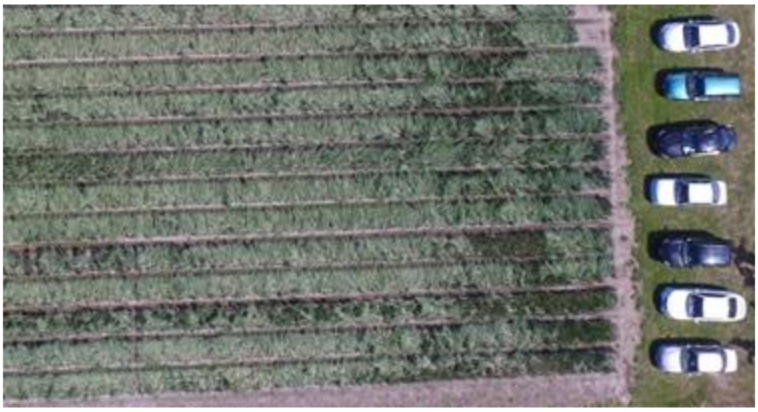

Figure 10 Close up of image captured by standard RGB camera on DJI Phantom 3 Advanced showing top down progress erect plants dark, prostrate plants pale

Figure 11 Sample of colour images photo-stitched to create single whole field image of 1ha MicroFarm paddock

Figure 12 Sequential images captured by standard RGB camera on DJI Phantom 3 Advanced showing top down progress erect plants dark, prostrate plants pale

Phantom 3 Pros:

- Relatively cheap ~$2,000
- Readily available consumer grade user friendly device
- Easy to control, not overly intrusive

- Can choose resolution by camera choice and flight height
- Other sensor variations becoming available
- May be supported by smart image processing algorithms?

Cons:

- Processing costs can be relatively high for low volume users
- Only RGB at this stage though options to configure with other sensor types available
- Colour / hue change according to light conditions
- Requires image stitching and processing which can be expensive for small users
- Must obey CAA regulations which may restrict permitted flight areas

Comparison of CoverMap, Satellite, GreenSeeker and MicaSense Maps

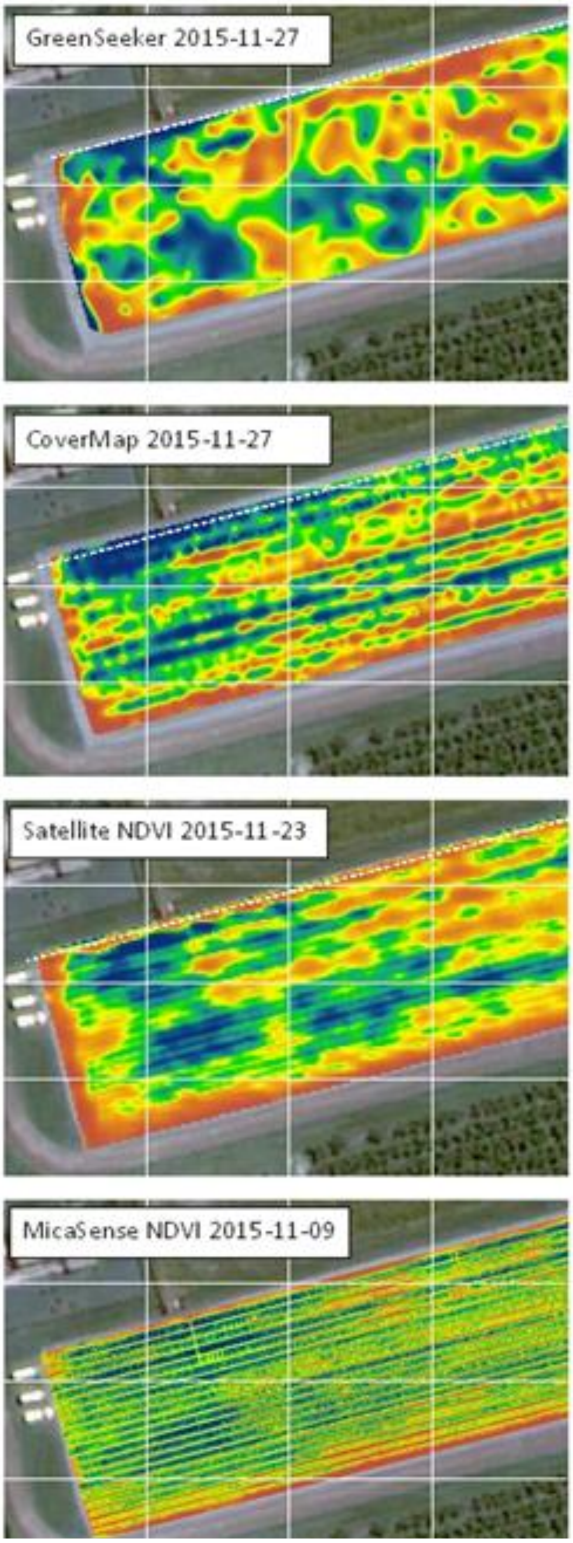

Figure 13 Comparison of GreenSeeker, CoverMap, Satellite NDVI and MicaSense NDVI maps created from data captured mid-November

Figure 13 shows one section of the onion field mapped from data captured by the four main sensors. A grid imposed on the images helps align the eye to compare positions like with like.

The GreenSeeker and CoverMap sensors are ground carried on a tractor. The maps are generated from data points logged with GPS by interpolating (calculating probable point values between) these known points.
The interpolation process used means maps are influenced by the relative position of these points, which have quite different distributions in the two sets of data (see *Figure 4*)

The Field Scout software logged fewer points, so the map is smoothed and generalised. The logged points are further apart along the bed than the actual distance between beds, so the map features are more "blended across" the beds.

The CoverMap software logs more frequent data points so a more details map is created. Because the points are closer in the bed, the interpolation has a stronger in-bed effect.

The satellite map (captured four days earlier) is created from complete cover images with each pixel about 0.5 x 0.5 m in ground size. There are at least two full pixels across the bed at any location, plus some pixels that are part bed and part wheel track. There is no interpolation needed as the data already forms a full image.

The MicaSense map (captured two weeks earlier) still shows similar patterns. It is also created from complete cover images with each pixel about 20 mm x 20 mm in ground size (Figure 8). The high resolution means individual plants and even individual leaves may be identified. One possible use would be early disease identification.

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