

Final Report

Implementing precision agriculture solutions in Australian avocado production systems

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Delivery partner:

University of New England's Applied Agricultural Remote Sensing Centre

Project code:

AV18002

Project:

Implementing precision agriculture solutions in Australian avocado production systems (AV18002)

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Public summary

The Horticulture Innovation project (AV18002) ‘Implementing precision agricultural solutions in Australian avocado production systems’ focused on provisioning the Australian avocado industry with greater access to new technologies and innovations that offer direct benefits to on farm production as well as industry wide data collation and management. This project directly built on the outcomes of the Rural R&D for Profit Project ‘Multi-scale monitoring tools for managing Australian tree crops’, by delivering on the following objectives:

1. *Establishing an ongoing capacity to maintain and refine the national production area map of commercial avocado orchards.*
2. *Further developing and validating the technologies, to predict yield parameters and tree health, under Queensland growing conditions.*
3. *Develop a minimal viable product (MVP) mobile application that will provide avocado growers with up-to-date information of yield, fruit size and phytophthora severity (Cyber Geigy rating).*
4. *Integrate the national orchard map of crop area with the self- calibration of satellite imagery with on-ground measures of yield parameters, and an understanding of the influence seasonal weather conditions, to develop a more accurate yield forecasting system at the orchard, farm and national level.*

The project delivered a freely available national map of avocado orchards greater than 1 ha, built to Australian mapping standards. The map, hosted on the ESRI ARCGIS online platform, provides the industry with essential baseline data for better understanding industry spread and annual change, supports the quantification of crop area affected by natural disasters as well as improved response to biosecurity incursions. Additionally, the map supports improved production forecasting, forward selling, labour needs and traceability. As a clear demonstration of industry adoption of this output, Avocados Australia Ltd (AAL) host the national map on their website’s homepage (<https://avocado.org.au/>), encouraging growers to directly inform the map, especially for new plantings. The map, as a component of the Australian Tree Crop Dashboard, was awarded the best international dashboard at the Esri user conference in San Diego, 2021 (70,000 delegates).

Accurate yield forecasts enables the wider industry to make more informed decisions around forward selling and market access, whilst at the orchard level, understanding crop load allows growers to better plan harvesting logistics. Project AV18002, successfully developed two methodologies for pre-harvest yield forecasting in avocado: the 18-tree sampling ‘CropCount’ strategy and the ‘time series’ method. The ‘CropCount’ method is designed for predicting within orchard variability, does not require historic data and better accounts for extreme irregular bearing and annual variations in crop performance from severe weather events, pest and disease. The ‘time series’ method requires no field work, uses freely available imagery and provides predictions up to four months prior to harvest. The MVP ‘CropCount’ mobile App was developed and trialed during the project.

The outcomes delivered by project AV18002 has set a national and international standard for the adoption of remote sensing and spatial technologies in Avocado. Growers have seen the benefits of improved yield forecasting through two distinct, but complimentary methods; whilst the industry body has received spatial proficiency and associated architecture to better collate and interrogate national data.

Technical summary

This final project report (AV18002) includes specific yield information and yield variability maps for a number of Australian growers. Additionally, the report includes both the ‘CropCount’ and ‘Time series’ yield forecasting methodologies and as it

is hoped to commercialise these outcomes, it is requested that the full report is not made publicly available.

Keywords

Avocado (*Persea americana*), remote sensing, WorldView, Landsat, Sentinel, yield, forecasting, prediction, tree crop map, CropCount, Minimal Viable Product, Mobile Application, Mapping Applications, biosecurity, natural disaster response

Introduction

The total Australian avocado production in 2019/20 was over 87,546 tonnes with the gross value of production (GVP) estimated at \$493 million. Over the last ten years, the industry has extended its production significantly at an average of 3,448 tonnes, at a value of more than AUS\$26.5 million per annum. However, annual production is seasonally variable, with crops ranging from 60,000 tonnes (in 2016/17) to 82,000 tonnes (in 2018/19) (HIAL, 2019/20). Despite episodic peaks and troughs in production, Avocado consumption in Australia is increasing at a higher rate than the progress of annual domestic production (Barnard & Goucher, 2014). The production forecast trend shows a strong increase with at least 115,000 tonnes per annum expected to be produced by 2025 (HIAL, 2019/20). To ensure the industry can accurately account for this annual growth, both in terms of area of production as well as tonnage produced, it is essential they have access to accurate information.

In terms of understanding area of production, the avocado industry currently achieve this through the tree census data and the Hort. Innovation Stats handbook, with the later somewhat informed by the Aus. Bureau of Statistics (ABS) (<https://www.horticulture.com.au/contentassets/a68c8934a8bf40b4becdc487bacdb60f/hort-innovation-ahsh-20-21-fruit.pdf>). This data is gathered annually within the ABS Rural Environment and Agricultural Commodities Survey (REACS). The final estimates from the REACS are based on a response rate of 78.4% from a sample of 25,642 agricultural businesses selected. Note this data is not provided as a spatial layer. The initial Australian Tree Crop Map (ATCM) developed and published in 2017 by the University of New England's Applied Agricultural Remote Sensing Centre (AARSC) mapped the extent (area and location) of all commercial avocado orchards over 2 ha. This map was established using existing industry data (e.g. member mailing addresses), ACLUMP mapping products, remote sensing analytics, ground based surveys and citizen science through the ATCM: Survey and the Industry Engagement Web App (IEWA). The delivery of the initial map identified 13,136 ha (total) of commercial avocado orchards in Australia. Whilst this output was extremely well received by industry, it did not have a mechanism to capture future plantings and did not include orchards under 2ha in size. Project AV18002 addressed both these issues.

Corresponding with a more accurate measure of orchard area, is the forecasting of actual yield, particularly prior to harvest. At the industry level this information is imperative for ensuring market access, both domestically and internationally, as well as for forward selling decisions. For growers this information supports improved decision making around the logistical planning of field operations (harvest scheduling, number of pickers and bins required, etc.) as well as post-harvest decisions such as the storage, handling, packing and forward selling. The additional the spatial and temporal mapping of yield variability at the block and farm level can support decisions around variable rate application of inputs such as water, fertilizer, pesticides as well as improved response to plant disease such as Phytophthora. (Scholefield et al., 1985; Whiley et al., 1986; Wolstenholme, 1987).

Currently, yield estimation in avocado orchards is undertaken by the systematic visual 'eye ball' count of fruit grown on selective trees, that is then extrapolated to provide an average block yield. However, this method possesses several disadvantages: (1) poor accuracy as the avocado fruit is often occluded by leaves that are the same colour and shape; (2) time consuming and labour intensive, with many man hours required to undertake the counts on selected trees; (3) limited sample size, with the trees selected not accurately representing the high spatial and temporal variability of an entire orchard block (Robson et al., 2014, 2017a, 2017b). The Federal Government and Hort. Innovation funded project (ST15002) 'Multiscale monitoring tools for managing Australian tree crops: Industry meets innovation', identified the potential of remote sensing for measuring variability in tree health as well as for yield forecasting and yield mapping using the 18 tree calibration method. Globally, the use of satellite based remote sensing technologies for the forecasting of avocado fruit yield has been limited. However, the results reported for Australian conditions were extremely encouraging, with predictions of average crop yield far exceeding the accuracies achieved by the currently adopted commercial methods

(Robson et al., 2014, 2017a, 2017b). Additionally, the derivation of fruit yield and fruit size maps from the combination of satellite imagery and the ground-based calibration of selected trees provided the opportunity for harvest segregation and the application of variable rate inputs. Project AV18002 endeavored to further validate the 18 calibration tree method for yield forecasting as well as deliver a minimum viable product (MVP) mobile application that supports grower's accessibility to the emerging technology.

Coinciding with the 18 tree calibration method is the reported potential of 'time series' observations of satellite images at different resolution for monitoring vegetation, identifying crops, detecting land cover change, mapping seasonal patterns and crop yield prediction (Usha & Singh, 2013; Rahman & Robson, 2016; Aghighi et al., 2018; Son et al., 2020; Arab et al., 2021). Time series, as the name suggests, provides a measure of crop response, measured incrementally over an extended period of time, indicating historic crop behavior and the influences of seasonal environmental, climatic or management changes. As such, the time series approach can indicate when key phenological growth stages occur and how these vary across varieties, locations and seasons. This can greatly inform on the optimum timing of when key management activities should be conducted or quickly indicate the onset of severe pest or disease when the seasonal growth curve varies beyond historic extremes. Additionally, matching the historic seasonal growth trend with the subsequent yield produced for that season, and doing this over multiple seasons, can form a strong understanding of seasonal yield potential based on canopy growth. This relationship can be extrapolated over future seasons to support yield forecasting. The time series approach uses freely available imagery e.g. Landsat and Sentinel, and can provide forecasts well before harvesting occurs. Project AV18002 evaluated the accuracies of time series yield forecasting at the orchard farm and block level on orchards in Queensland, South Australia and Western Australia to determine the accuracies this approach on avocados. This was a global first.

Methodology

National map of commercial avocado orchards

Project AV18002 aimed to deliver an accurate updated national map of commercial avocado orchards at a minimum of 1ha, published within the Australian Tree Crop Map. The update was managed within a national program, which progressed by growing regions as categorised in Figure 1.

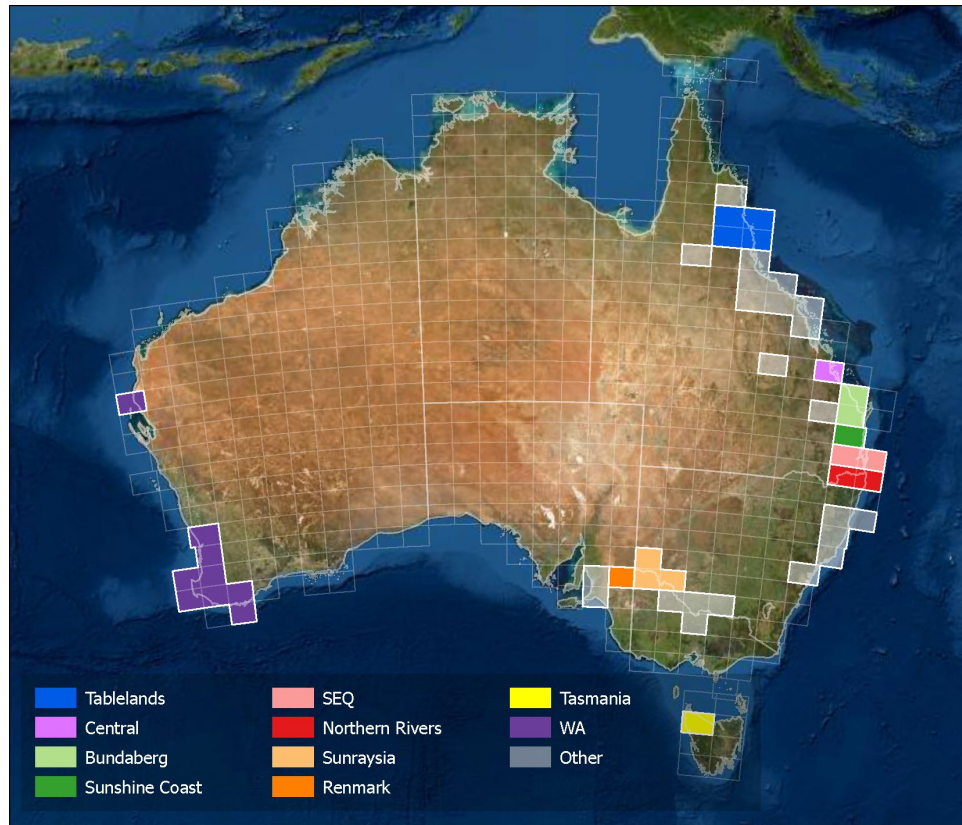


Figure 1: National mapping program, showing major avocado growing regions. (Tiles are 250K standard map grid)

The map was informed from multiple sources including remotely sensed imagery, industry data, existing government land use information, citizen science and field-based data collection (Figure 2). Orchards were mapped as polygons (location and extent) and key attributes recorded at feature level including: source and year of observation (currency)—reflecting the most recent date of observation from either image capture date or when observed in the field. No personal or commercial information is contained within the map (e.g. property boundaries, ownership, variety, yield, etc.), which is built to national standards of the Australian Collaborative Land Use and Management Program (ACLUMP).

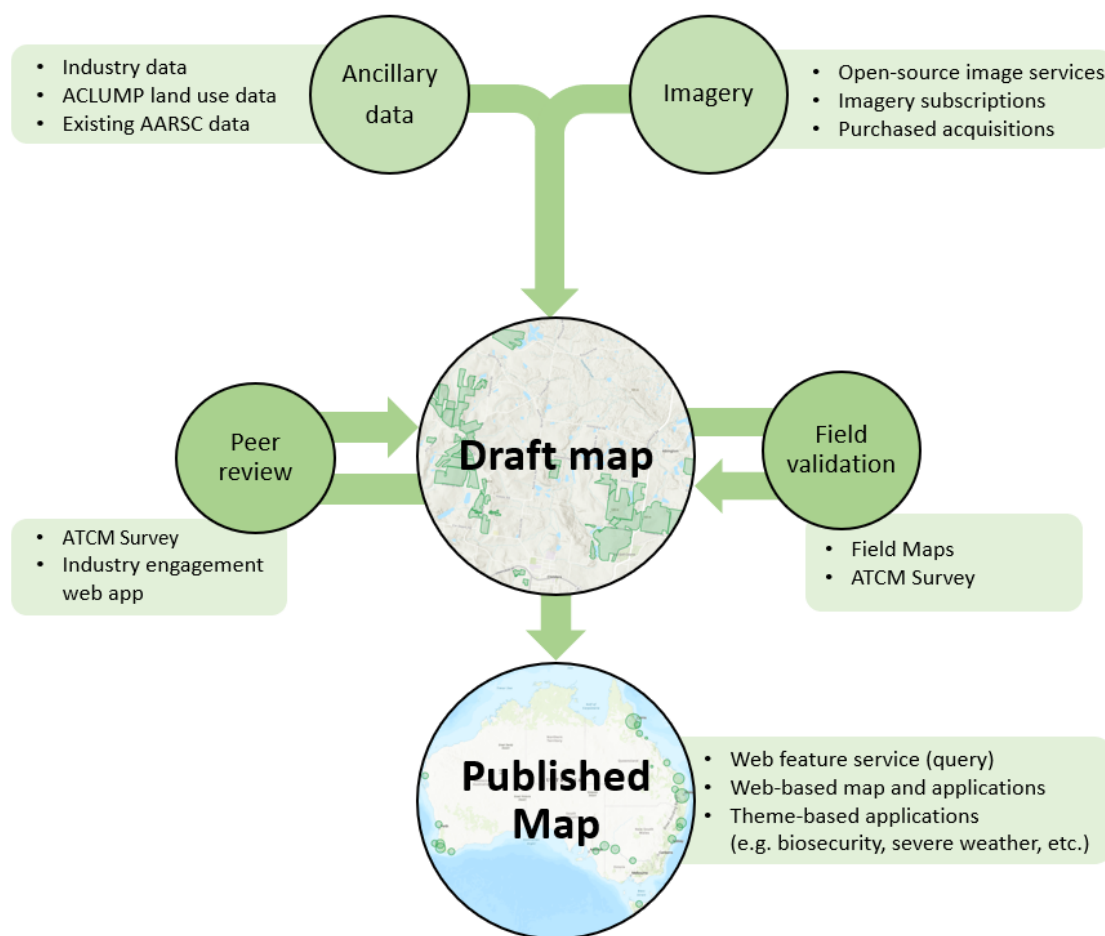


Figure 2: Mapping methodology

Industry data provided by Australian Avocado Ltd (AAL) included 659 individual records, which were geocoded based on the supplied address information. (Figure 3). Typically, these locations related to postal addresses rather than actual orchard location. As an ancillary data layer, industry data informs the mapping program (where to look for tree crops), and aids in image interpretation of crop type. It's especially valuable for classifying new orchards (small trees) which cannot be accurately mapped by imagery alone.

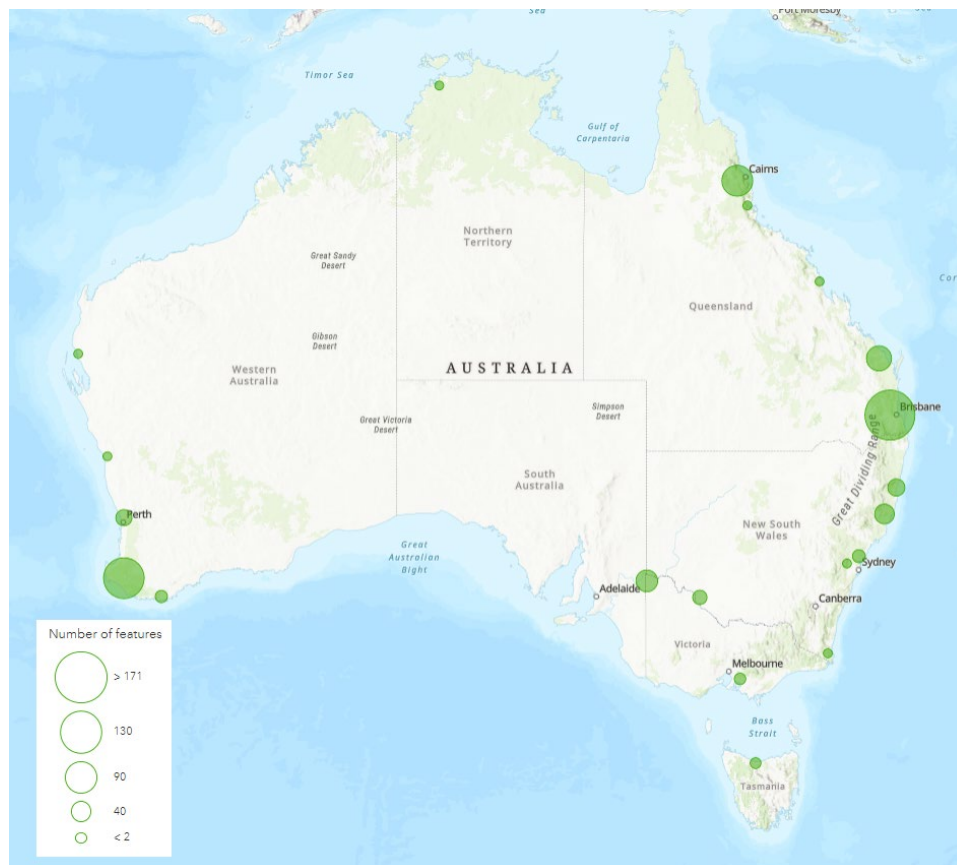


Figure 3: Geocoded Industry data included 659 locations (shown as clustered points)

Publicly accessible imagery provided the primary resource of high-resolution data suitable for interpretation of tree crops (e.g. Google Earth Imagery, Esri Basemap Imagery, Google Street View and other government image services). On occasion the currency of imagery was very timely (<1 year old). However, elsewhere the imagery capture date limits the currency of the map as the newly established plantings are either not visible in the imagery (small trees) or the imagery is not current enough to show the newly planted orchard and/or land use change. To overcome this challenge, we accessed and interpreted coarser resolution (but current) satellite imagery (e.g. PlanetScope) to map the new crops. This was only undertaken where other ancillary data (e.g. industry input or field observations) identified new plantings. This ancillary information was also used to classify the tree crop type, as it was not possible to classify new tree crops with coarse imagery alone. Figure 4 presents four examples of avocado orchards showcasing how variation in tree age, variety and land management practice influence the appearance of the trees. This example clearly demonstrates the need for multiple sources of data to accurately classify avocado orchards, and that methods relying solely on imagery analysis (manual or automated) are not robust.



Figure 4: variation in the appearance of four avocado orchards

Field validation of the map was conducted over each major growing region and within targeted areas of known uncertainty and/or new plantings. Fieldwork improved the accuracy and currency of the map, particularly where new plantings were observed (which are not visible in imagery). As an example, Figure 5 shows the route covered in the Tablelands growing region, presenting 1,363 field observations of tree crops captured as point locations.

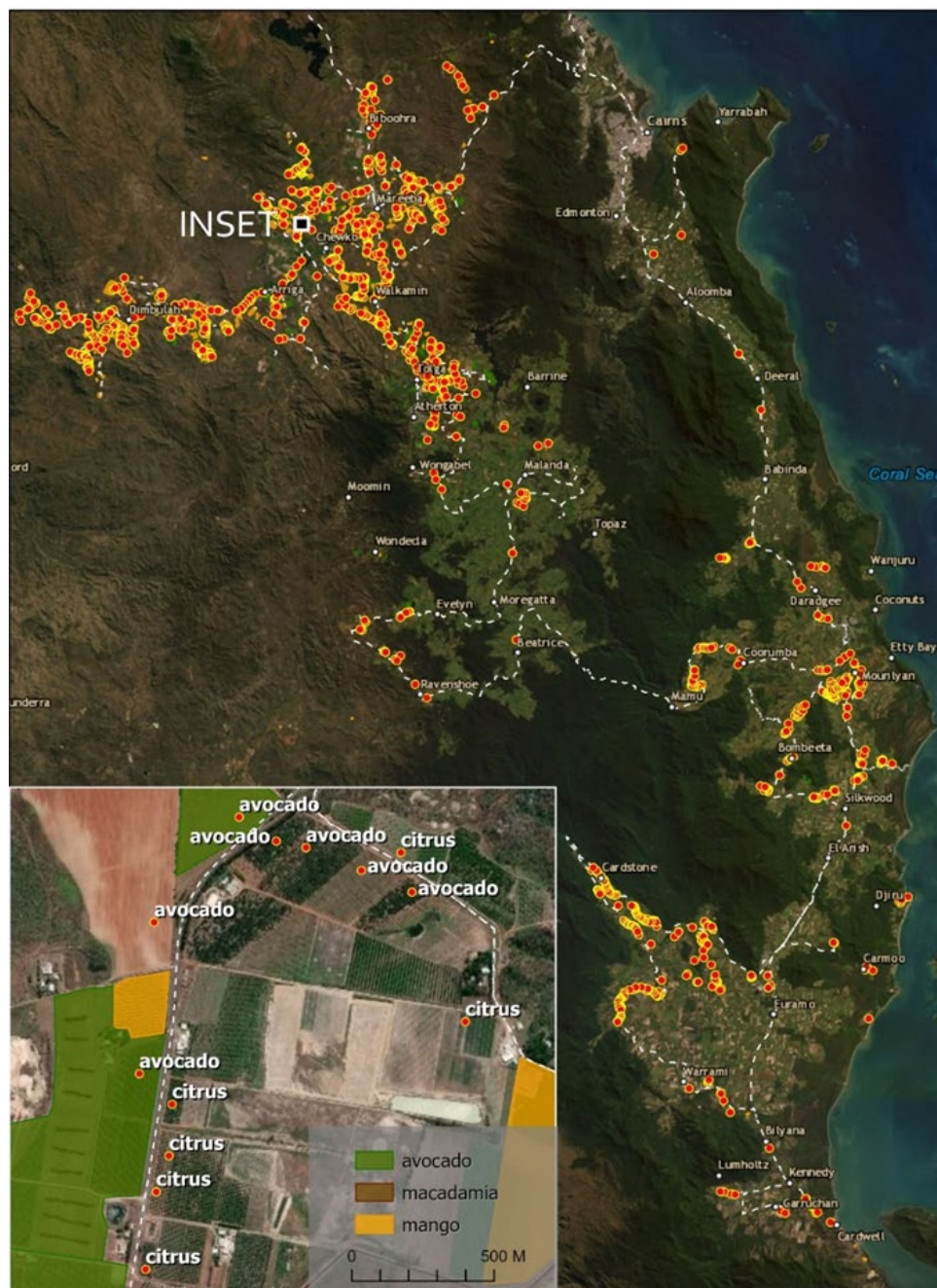


Figure 5: Field validation in the Tablelands growing region, showing observation points collected

Following field work, the mapping was further refined and then published as a draft for peer review in the publicly accessible Industry Engagement Web App. Peer review was anonymously sought from industry experts in each major growing region to review the draft map and provide feedback as comments, which was then interpreted by researchers and actioned.

To produce the final mapping product, polygon features representing avocado orchards were derived from the editing layer by aggregating and dissolving features relative to map scale (minimum mapping unit of 1 ha and a width of 25 m). Figure 6 shows an example of the level of detail as presented in the final map. The only information stored at feature level is the source and year of observation, and area in hectares.

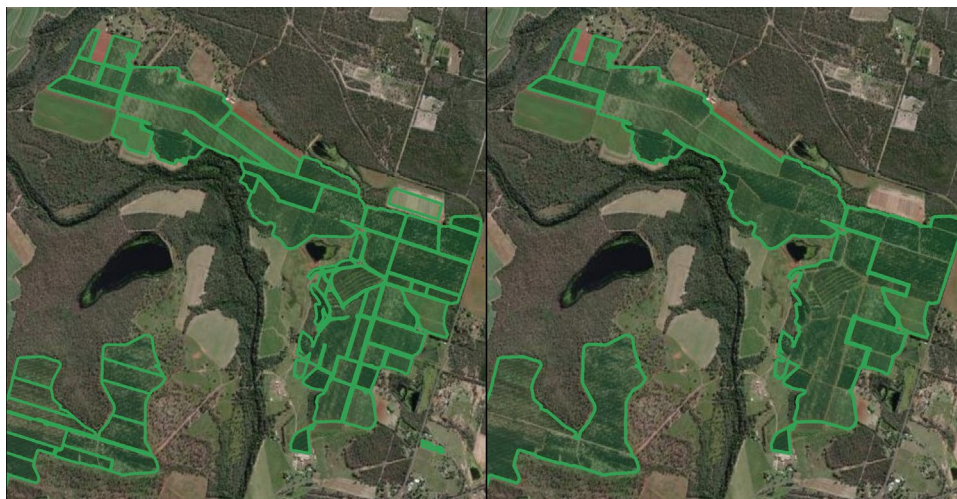


Figure 6: Avocado orchards showing edit layer (left) and derived mapping product (right)

The final national map of avocado orchards was published within the Australian Tree Crop Map as a publicly accessible feature service. The benefit of publishing the map as a service is that when the map is updated, the changes are instantly reflected for all who access it. Note the feature service supports query operations only. The data is not available to copy, export or download.

Yield forecasting

The project focused on the development and validation of two remote sensing-based yield forecasting methodologies the 'CropCount' and the 'time series' approaches. The methodologies for both are explained below in detail:

'CropCount' methodology

The 'CropCount' methodology initially developed by Robson et al. (2014, 2017a, 2017b) and Rahman et al. (2019) (Project ST15016), demonstrated the accuracies of yield forecasting and yield mapping of individual avocado blocks using the relationship between vegetation indices (VIs) derived from high-resolution WorldView3 (WV3) satellite imagery (1.2 m spatial resolution/ 0.31 cm pan sharpened) to targeted samples of fruit number and weight from 18 individual trees representing high, medium and low vigour regions of the orchard.

Project AV18002 further evaluated this methodology over three farms in Queensland (Mareeba: 1 Farm and Bundaberg: 2 Farms). Using the extent of each orchard block, the WV3 imagery was subsetting and classified into 8 Normalized Difference Vegetation index (NDVI) classes, showing variation in tree vigour. From classified normalized difference vegetation index (NDVI) images, 6 replicate trees were selected to represent high, medium and low NDVI regions (n=18). A newly developed clustered sampling technique was also investigated, where clusters of 6 replicate trees at only three locations representing high, medium and low NDVI regions were also selected from each block. The clustered sampling technique was found to be more time efficient, and less labour intensive compared to the previous 18 tree sampling method (Figure 7). In order to locate the selected tree within the orchard, the block, row, and tree number were manually counted from each respective pan-sharpened (30 cm resolution) image. Once located in the orchard, the exact position of each tree center was recorded using a hand-held Trimble DGPS (Trimble, Sunnyvale, CA, USA). The manual harvesting of the selected trees generally coincided with the commercial harvesting of the blocks. All harvested fruits were counted and weighed providing a total number of fruits per tree and total yield per tree (kg/tree).

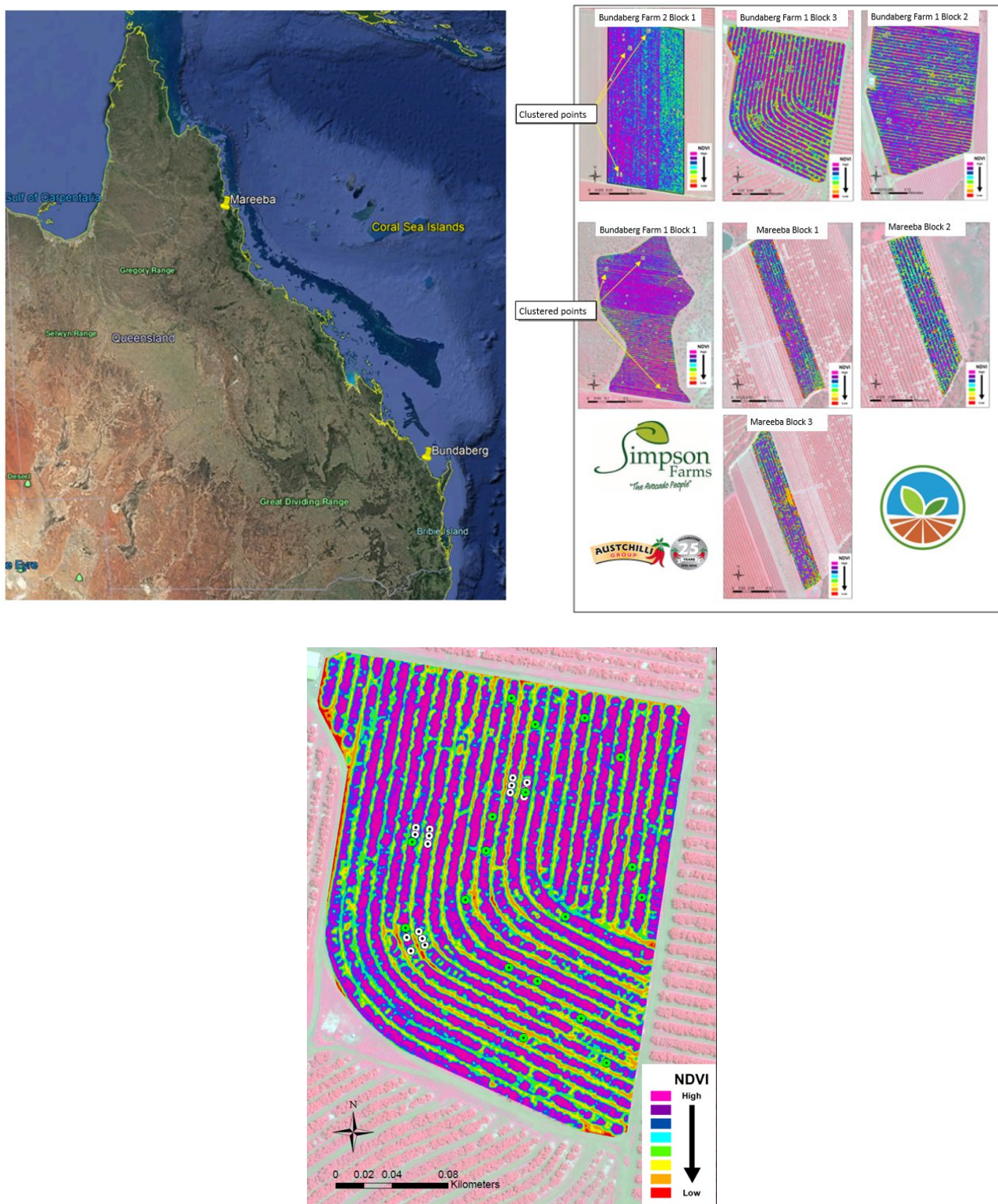


Figure 7: Sampling locations for the 18 calibration tree method (top); Example of normal 18 tree (green markers) and clustered (white markers) sampling techniques (below)

The DGPS locations of each sampled tree were overlaid onto the WV3 images (panchromatic band) using ArcGIS 10.4 (Environmental Systems Research Institute, Redlands, CA, USA). A 1.5 to 2 m radius buffer area was applied around each point depending on the canopy radius of each sampled tree. This ensured that the extracted pixel values were specific to the selected tree canopies only and did not include any pixels influenced by shade or ground cover within the inter rows. Using the open-source software Starspan GUI (Rueda et al., 2005) each AOI was used to subset the 8-band spectral information for each tree canopy from the non-pan sharpened multispectral imagery. From the extracted data, 18 structural and pigment-based vegetation indices (VIs) specific to crop biomass and yield parameters were derived (Table 1) and regressed against total fruit weight (kg/tree). This was undertaken for each block separately.

Table 1: Vegetation indices used in this study

	Name	Formula	References
1	Normalized Difference Red-edge/Red (NDVI red-edge)	$(RE - R)/(RE + R)$	(Gobron et al., 2000)
2	Transformed Chlorophyll Absorption Reflectance Index (TCARI)	$3 \times ((RE - R) - 0.2 \times (RE - G) \times (RE/R))$	(Haboudane et al., 2002)
3	Structure Insensitive Pigment Index (SIPI)	$(NIR1 - B)/(NIR1 + R)$	(Penuelas et al., 1995)
4	Coastal Blue Structure Insensitive Pigment Index (CB SIPI)	$(NIR1 - CB)/(NIR1 + CB)$	(Penuelas et al., 1995)
5	Normalized Difference Red/Red-edge Index (R/RENDVI)	$(NIR1 - R)/(NIR1 + RE)$	(Gitelson et al., 1996b)
6	Normalized Difference Red/NIR2 Index (R/N2NDVI)	$(NIR1 - R)/(NIR1 + NIR2)$	(Robson et al., 2014)
7	Green Normalized Difference Vegetation Index (GNDVI)	$(NIR1 - G)/(NIR1 + G)$	(Gitelson et al., 1996a)
8	Modified Simple Ratio (MSR)	$(NIR1/R - 1)/(\sqrt{(NIR1/R + 1)})$	(Chen, 1996)
9	Ratio Vegetation Index (RVI)	$NIR1/R$	(Jordan, 1969)
10	Normalized Difference Vegetation Index (N1NDVI)	$(NIR1 - R)/(NIR1 + R)$	(Rouse et al., 1974)
11	Normalized Difference Vegetation Index (N2NDVI)	$(NIR2 - R)/(NIR2 + R)$	(Rouse et al., 1974)
12	Normalized difference Red-edge Index 1 (RENDVI1)	$(NIR1 - RE)/(NIR1 + RE)$	(Fitzgerald et al., 2010)
13	Normalized Difference Red-edge Index 2 (RENDVI2)	$(NIR2 - RE)/(NIR2 + RE)$	(Pu & Landry, 2012)
14	RDVI1	$(NIR1 - R)/(\sqrt{(NIR1 + R)})$	(Roujean & Breon, 1995)
15	RDVI2	$(NIR2 - R)/(\sqrt{(NIR2 + R)})$	(Roujean & Breon, 1995)
16	Transformed Difference Vegetation Index (TDVI)	$1.5 \times ((NIR1 - R)/(\sqrt{(NIR1^2 + R + 0.5)}))$	(Bannari et al., 2002)
17	Transformed Difference Vegetation Index 2 (TDVI2)	$1.5 \times ((NIR2 - R)/(\sqrt{(NIR2^2 + R + 0.5)}))$	(Bannari et al., 2002)

18	Non-Linear Index (NLI)	$(NIR^2 - R)/(NIR^2 + R)$	(Goel & Qin, 1994)
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A number of statistical methods were employed to determine the VI most strongly related to the measured yield parameters such as number of fruits and total fruit weight (kg/tree). These included a principal component analysis (PCA) and a non-linear regression, both undertaken using the statistical software R (R Development Core Team, 2017). Although PCA is quite commonly adopted to remove the redundancy in a large number of variables, in this study, it was applied as a variable reduction procedure to select the two optimal VIs out of the 18 most related to the measured yield parameters. The VI that produced the highest coefficient of determination (R^2) and the lowest root mean square error (RMSE) was selected as optimal.

The algorithm developed between the optimal VI and yield parameter for each respective block was then applied to the remaining orchard, producing a variability map of the respective yield parameter (fruit number and fruit weight per tree). Corresponding with the development of the classified yield maps, the average yield of each block. Figure 8 provides a flowchart of the process used for algorithm development, the derivation of block level yield maps and prediction of block level yield parameters. The average and total yield for each block was then compared to the actual harvested yield.

To generate the yield prediction maps WV3 imagery were subsetting according to the extent of each orchard block and the developed algorithm was applied to the extracted band combination or VIs.

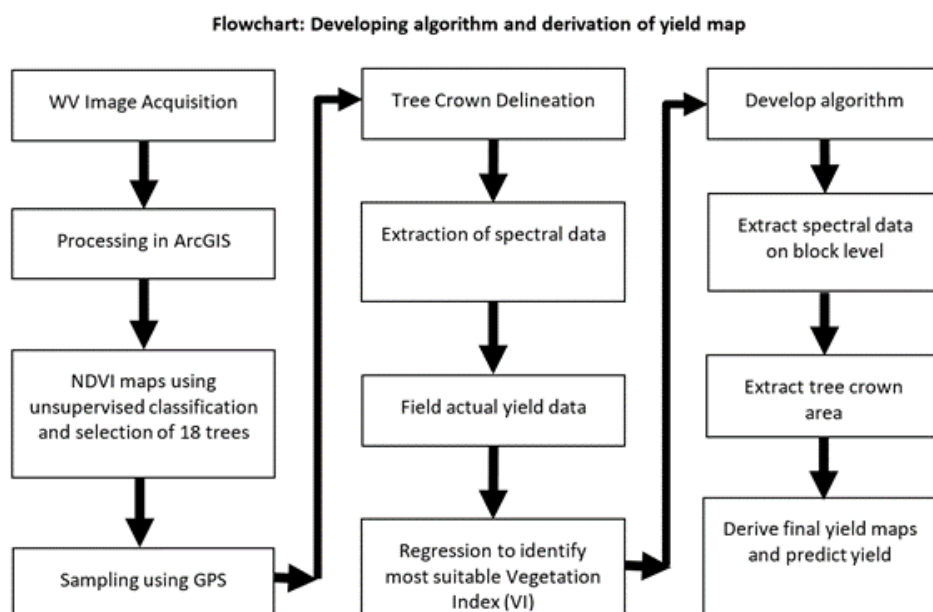


Figure 8: The flowchart of developing algorithms and derivation of block level yield maps.

In 2019/20 season, a comparison between actual block level data and satellite derived predicted yield data for 3 blocks at farm 1 and 1 block at farm 2 in Bundaberg and 3 blocks at Mareeba. For the 2020/21 season the methodology was again evaluated over three orchards at farm 1 in Bundaberg. WV3 satellite imagery was acquired on 14th of May 2021 and field sampling was undertaken at harvest from 7th to 9th of June 2021. The list of blocks where 'CropCount' methodology was applied is shown in Table 2

Table 2: The list of Avocado farms and blocks, WV3 image capture date and sampling date in 2020 and 2021 season

Year	Farm	Block	Image capture date	Sampling date
2020	<i>Farm 1, Bundaberg</i>	Block 1	13 February 2020	11 March 2020
		Block 2	13 February 2020	12 March 2020
		Block 3	13 February 2020	13 March 2020
	<i>Farm 2, Bundaberg</i>	Block 4	13 February 2020	12 March 2020
	<i>Farm 1, Mareeba</i>	Block 1	3 February 2020	17 February 2020
		Block 2	3 February 2020	17 February 2020
		Block 3	3 February 2020	17 February 2020
2021	<i>Farm 1, Bundaberg</i>	Block 1	14 May 2021	7 June 2021
		Block 2	14 May 2021	8 June 2021
		Block 3	14 May 2021	9 June 2021

‘Time Series’ methodology

For the ‘time series’ methodology, historical Sentinel-2 and Landsat imagery was used to plot the annual growth profiles of selected Avocado crops. This alone provides highly useful information for understanding the seasonal influences of management, location and weather conditions on tree vigour (health, size, density) as well as the timing of key phenological growth stages. Historical block level yield data (7 to 10 years) was also sourced from participating avocado farms in Bundaberg, Northern Queensland, South Australia and Western Australia. Corresponding Landsat 7, 8 and Sentinel 2 cloud free imagery were acquired over those farm regions to develop the ‘time series’ models. Canopy reflectance for each orchard block, identified by the green normalized difference vegetation index (GNDVI), plotted over time shows seasonal and cross seasonal growth trends. Figure 9, provides an example of this output for a Bundaberg orchard, with each season showing a peak in vigour in June, with troughs in November. The matching of these growth profiles with corresponding annual yields (T/ ha) enabled past relationships to be identified and then subsequently used to predict future yield potential, using models such as shown in Figure 10.

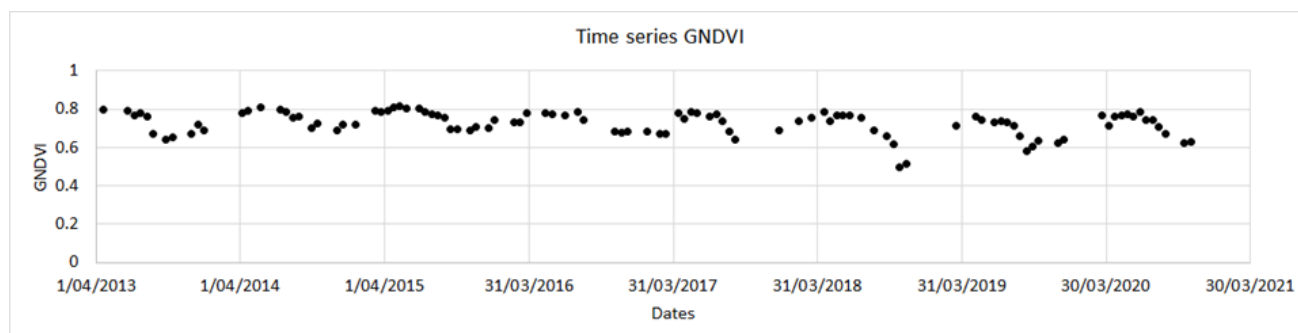


Figure 9: Time series GNDVI data derived from Landsat images for an avocado block

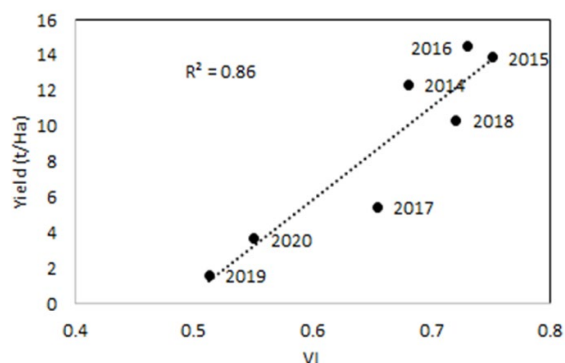
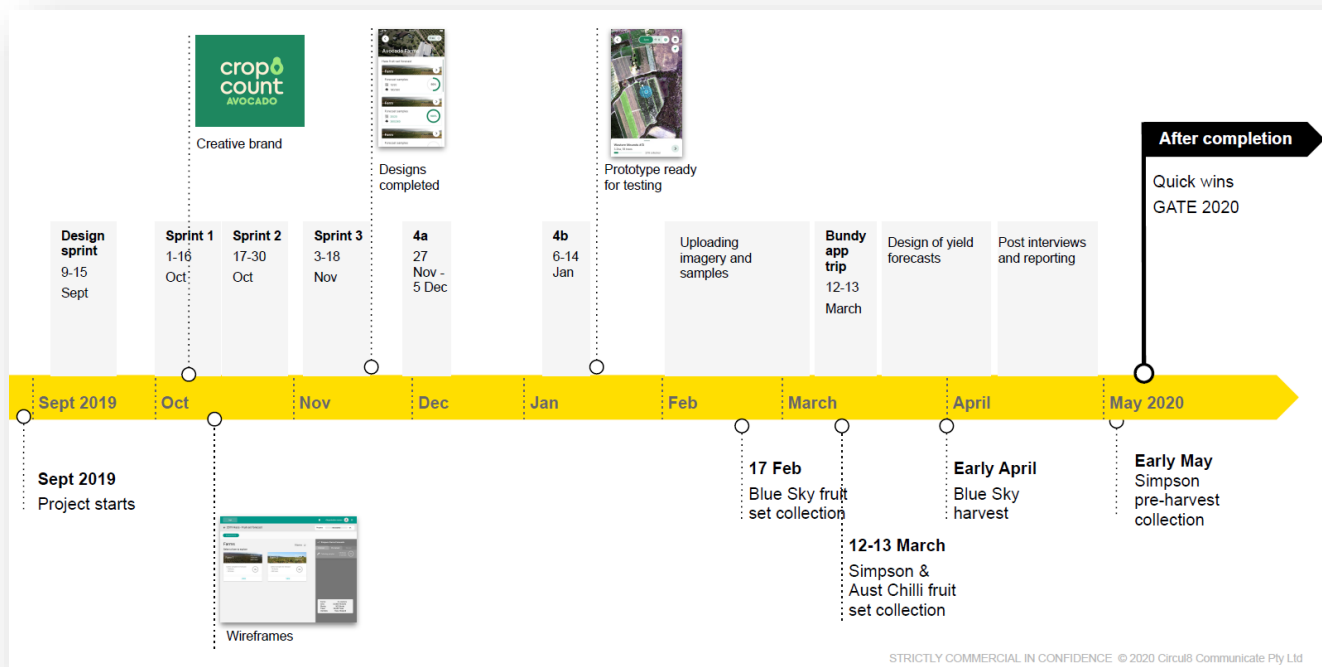


Figure 10: Example of avocado yield prediction model using historical satellite imagery and production data for a block

Through project AV18002, this methodology received great interest from growers and as such was evaluated over 3 Western Australian, 3 Queensland and 1 South Australian farms, totaling 100 individual orchard blocks, in which participating growers provided historic block level yield data. This data was analysed against corresponding historic Landsat and Sentinel imagery to develop the block level models and the subsequent forecasts.

'CropCount' MVP

To support grower access to the 18 tree "CropCount" yield forecasting methodology, the minimum viable product (MVP) 'CropCount' App was developed and evaluated infield by project collaborators Circul8. The following provides a graphical representation of the methodology and processes to develop this App.



UX Research

UX workshop

Prior to this project we had undertaken a 1 day workshop to uncover the core UX artifacts, principles, behaviours and structures that will direct us to create an app or service that delivers a great experience for our identified users.

Outcomes from the workshop included:

- SWOT analysis
- 3 personas created
- User journeys created
- Success metrics defined

 [UX workshop summary](#)



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UX Research

Design sprint

Armed with existing UX work we undertook a 5 day intensive sprint, taking our assumptions to growers so that we could properly understand their perspective. From here we could develop the value proposition and test this with the growers.



3 x grower context interviews:

- Matt Fealy (Blue Sky Produce)
- David DePaoli & Chapman Koga (Aust Chilli)
- Simon Grabbe (Simpson Farms)

Through this process we created journey maps, storyboards and a clickable prototype to test.

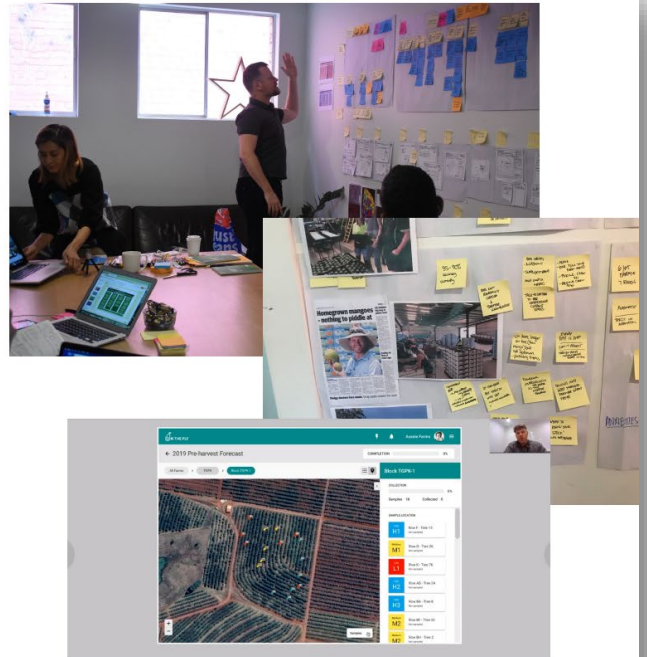


3 x prototype testing interviews

- Matt Fealy (Blue Sky Produce)
- David DePaoli & Chapman Koga (Aust Chilli)
- Simon Grabbe (Simpson Farms)



[Design sprint summary](#)



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Creative branding

Introducing Crop Count

Design

We've used flat colour and rounded stylings to create a contemporary brand mark. The design nods to the location and tracking functions of the app by replacing the avocado icon's 'seed' with a 'map pin', the graphic placement also brings balance to the mark's composition.

Name

CropCount is colloquial, to-the-point and tells you exactly what it's about. We use alliteration mixed with a hard C, to create a punchy name that won't be misheard or misunderstood. Its flexible name can be adapted easily for other produce markets.

Domains currently available

cropcount.com.au (purchased 2 years)
cropcount.farm (purchased 1 year)
cropcount.net (purchased 1 year)



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Design & Development sprints

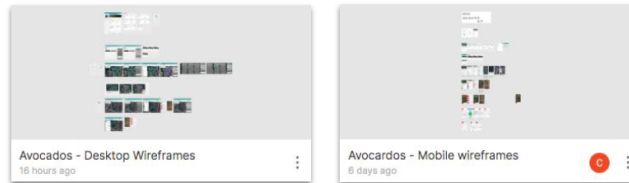
The process

Wireframes

Desktop and mobile wireframes were created to define the overall user interface and user flow

 [View desktop wireframes](#)

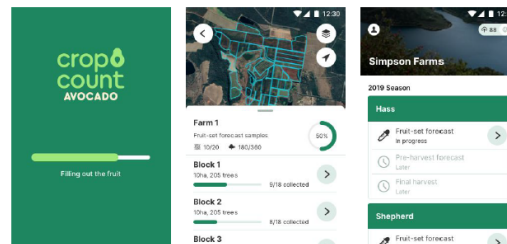
 [View mobile wireframes](#)



Mobile designs

Detailed mobile designs were created using the new branding

 [View mobile designs](#)



Interview with Chad Simpson to test mobile app designs

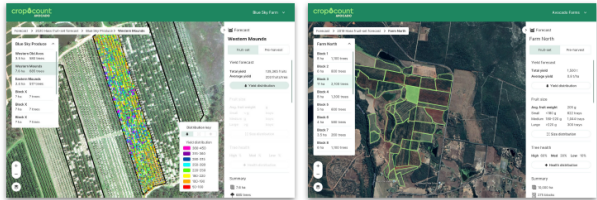
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Design & Development sprints

The process

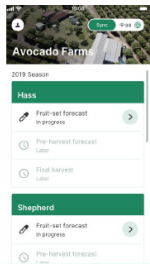
Desktop forecast designs
Detailed desktop designs were created using the new branding

 [View mobile designs](#)



Interview with Matt Fealy
Interview with Simon Grabbe

Mobile design updates
Mobile designs were updated to accommodate adjusted scope for what would be tested in the prototype. This included the ability to sync data.



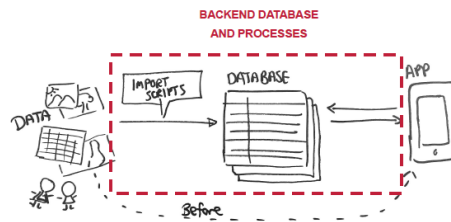
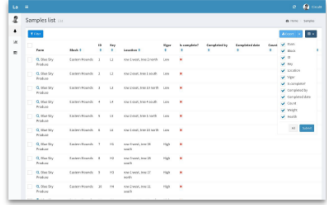
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Design & Development sprints

The process

Creation of backend admin
Database created with admin interface to allow collection of data.

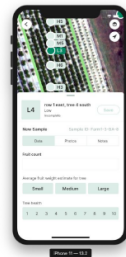
 [Crop Count admin](#)

Area	Area ID	Area Name	Area Type	Area Status	Area Location	Area Date	Area Time	Area User	Area Action
Area 1	1	Area 1	Area 1	Area 1	Area 1	Area 1	Area 1	Area 1	Area 1
Area 2	2	Area 2	Area 2	Area 2	Area 2	Area 2	Area 2	Area 2	Area 2
Area 3	3	Area 3	Area 3	Area 3	Area 3	Area 3	Area 3	Area 3	Area 3
Area 4	4	Area 4	Area 4	Area 4	Area 4	Area 4	Area 4	Area 4	Area 4
Area 5	5	Area 5	Area 5	Area 5	Area 5	Area 5	Area 5	Area 5	Area 5
Area 6	6	Area 6	Area 6	Area 6	Area 6	Area 6	Area 6	Area 6	Area 6
Area 7	7	Area 7	Area 7	Area 7	Area 7	Area 7	Area 7	Area 7	Area 7
Area 8	8	Area 8	Area 8	Area 8	Area 8	Area 8	Area 8	Area 8	Area 8
Area 9	9	Area 9	Area 9	Area 9	Area 9	Area 9	Area 9	Area 9	Area 9
Area 10	10	Area 10	Area 10	Area 10	Area 10	Area 10	Area 10	Area 10	Area 10

Data uploads

Processing and uploading of all maps and sample data in preparation for testing in the field



CropCount

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App testing

On the road - testing in field

The Crop Count mobile app was tested in the field across all 3 farms. We were looking to understand:

- How much effort & time was required to complete the counts?
- Did using the app assist with finding sample tree locations?
- Where there any technology issues?
- Were there any pain points?
- General feedback on app usage



- Follow up interview with Matt Fealy (Blue Sky Produce)
- Field testing in Bundaberg: observation and informal conversations with Paige (Simpson Farms) and Kaushal (Aust Chilli)



Design & Development sprints

Crop Count iOS mobile prototype app

The mobile app prototype includes the following features and functionality:

- iOS mobile prototype app
- Ability to log in with password to show specific farm info
- Ability to select username
- Ability to select maps or list to navigate
- Ability to zoom into a block to see samples
- Indicators to show collection progress
- Can work on or offline with synching capability
- GPS (blue dot) functionality
- Ability to view NDVI maps and turn on and off
- Ability to collect count, weight and tree health data
- Ability to handle counts at different stages of the crop cycle (pre-harvest, fruit-set)



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Yield forecast designs

Yield forecasts

Count data was put into the desktop yield designs and tested. We were looking to understand:

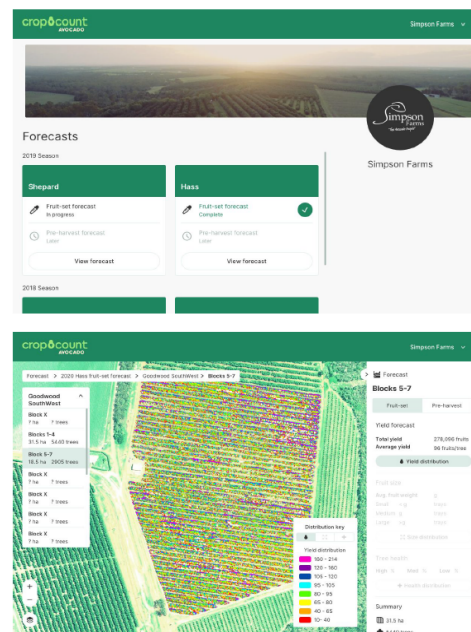
- Was the information clear and easy to understand?
- How would they use this information?
- How are the NDVI maps used?



Follow up interviews with

- Matt Fealy (Blue Sky Produce)
- Simon Grabbe (Simpson Farms)

Note: No follow up obtained from Aust Chilli due to changing staff



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Measured canopy temperature and relative humidity of individual trees

One objective of project AV18002 was to determine the influences of seasonal climate conditions on yield potential, and therefore potentially use this input as a predictor of future yield. To investigate this at the tree level, the microclimate of individual trees (temperature and relative humidity) representing high vigour (large healthy canopies), to medium and then low (small, low leaf density canopies), were measured using Sensohive sensors placed within a number of trees selected for yield sampling on two of the Bundaberg farm 1 orchard blocks (Figure 11). Wi-Fi connectivity was established on Bundaberg farm 1 via the installation of a base station, with data made accessible through the Thinxtra network. The sensors were placed in Stevenson screens that were attached to the trunk of the southern side of the tree at a height of 1.5 m. The data was logged over the full duration of the project.



Figure 11. Locations of canopy sensors placed on one of the Bundaberg farm 1 blocks; the steveson screen attached to the trees and Sensohive RH and Temperature sensor.

Results and discussion

National Mapping

The following results section presents the mapping applications developed through project AV18002 that support the development and extension of the national map of avocado orchards to industry. Also presented are the production metrics (ha of production at the national, state and local government area) derived from the 2022 mapping layer, as well as the change in production area between the baseline map (2017) and the updated map (2022). Note statistics were extracted 29th April 2022 and are available within the ATCM: Dashboard (as pop-ups), by State/Territory and Local Government Area (LGA). Additional analysis by Natural Resource Management Regions, Federal and State Electoral boundaries, and the ABS Census SA2 areas have also been provided direct to industry in the form of Excel spreadsheets.

Finally, a number of value-added mapping applications developed through this project are also presented.

Applications Summary

The national map of commercial avocado orchards was developed and is presented by a range of location-based web applications, all available for access from the AARSC Industry Applications and Maps Gallery (www.une.edu.au/webapps) (Figure 12). These applications support both the sharing of the national map and industry engagement tools to inform on-going updates.

- [Australian Tree Crop Dashboard](#)
- [Avocados Australia Map](#)
- [Australian Tree Crop Survey App](#)
- [Avocados Australia Survey](#)
- [Industry Engagement Web App](#)
- [ATCM: Severe Weather App](#)
- [Bushfire Rapid Response Map](#)

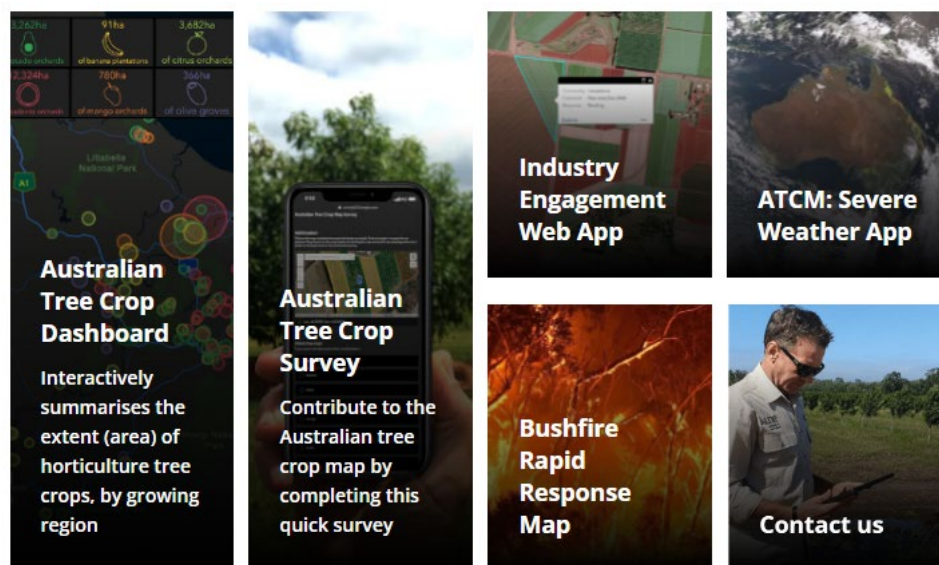


Figure 12: AARSC Industry Applications and Maps Gallery

Australian Tree Crop Map (ATCM) Dashboard

This dashboard-style web application features the latest map from the ATCM and presents metrics for avocado, mango, macadamia, citrus, olive, banana and truffle orchards (area of production in hectares) based on the zoom/view extent of the user. The dashboard includes the functionality to return metric by state and territory and local government area in a pop-up window as well as by zooming in. To navigate the map with the bookmark tool, the user can type an address or place name into the search box and/or simply pan and zoom will update the statistics for each tree crop (at bottom) on-the-fly, based on the map view extent. (Figure 13).

The ATCM: dashboard has been viewed (opened) 15,492 times. Significantly the dashboard was awarded first place as ‘Best dashboard’ application in the map gallery at the 2021 Esri International User Conference. This conference was attended by 70,000 delegates and as such the award is considered highly prestigious within the international mapping community.

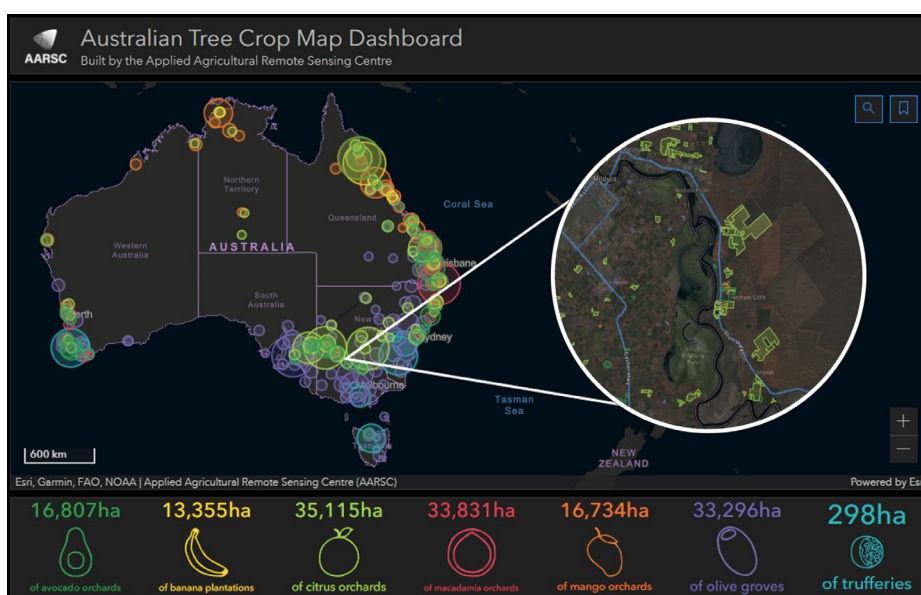


Figure 13: Australian Tree Crop Map Dashboard

For project AV18002, the AARSC built an ‘avocado only’ map application, which presents the same information as shown in the ATCM: Dashboard, but only features avocado orchards. Figure 14 presents the application which can be accessed here. (<https://experience.arcgis.com/experience/6ef58a0afdbc480baf2283bdf1f420>)

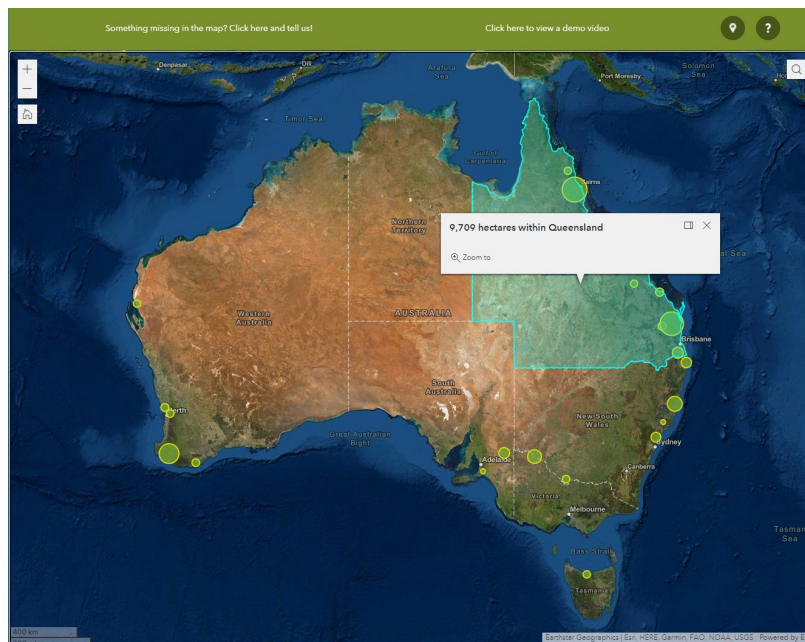


Figure 14: Avocado industry map (presents avocado only)

Industry Engagement Tools:

The location-based tools (e.g., ATCM survey and Industry Engagement Web App) described below, successfully supported peer review and ad-hoc updates of the map.

Australian Tree Crop Map (ATCM) Survey

The survey (built using Esri Survey123 for ArcGIS) has been configured to run in any browser on any device – mobile, tablet or desktop. Users do not need to download or install any third-party software to use it. The survey provides an extremely reliable and efficient means of engaging with industry and stakeholders to contribute to the mapping. Point observations submitted via the survey include location information, crop type and optionally a photo. This information is interpreted at the desktop, it is extremely valuable in correctly classifying tree crops from one-another and essential for mapping new crops. Figure 15 shows one example of new orchard (and photo) submitted from the Tablelands.

In response to feedback from Avocados Australian Ltd (AAL), the AARSC built a custom application developed specifically for avocado orchards. This tool provides the same capabilities as the Australian Tree crop Survey (ATCM: Survey (<https://survey123.arcgis.com/share/55e952a30f534ad3ab3c7da95f5e1f1e>)) but only displays avocado features. The application is hosted on the AAL homepage (<https://avocado.org.au/>: live from 7th October 2021) and continues to inform on-going updates of the map.

During the 2021 avocado tree census campaign, AAL actively promoted the survey as an engagement tool and sought the contribution of their growers by challenging them to check ‘is your orchard on the map?’ (www.avocados.org.au) (Figure 16). If the orchard was missing or incorrectly mapped, growers were asked to complete the survey in six simple steps.

Analysis of the surveys received during the tree census campaign showed 136 new submissions were received. Each was interpreted and actioned in the updated map, which in summary amounted to 484 ha of new avocado orchards being added, 54 ha removed (misclassified) and a further 865 ha confirmed as avocado. This application not only demonstrates the adoption of this output by industry, but serves as a vital link to support the ongoing updating of the map, post project.



Figure 15: Survey observations for avocado orchards

The screenshot shows the Avocados Australia homepage with a green header. The main content area is titled 'Is your orchard on the map?' and explains the purpose of the ATCM. It lists six steps for adding a location: 1. Locate the orchard by selecting the crosshair button or using the search bar. 2. Enlarge the map and click 'Large Map' to exit full screen. 3. Zoom/pan around the map and click to place a marker. 4. Enter any comments in the 'Add comment' field. 5. Add a photo, such as a map of your property (optional). 6. Click submit to complete the survey. The form on the right includes a map of Australia with a search bar, a 'Find address or place' input, and a 'Submit' button. Below the map are sections for 'Add comment' (with a text area), 'Attach image' (with a file selection button), and 'Attach file' (with a file selection button).

Figure 16: ATCM hosted on the Avocados Australia homepage

Industry Engagement Web App (IEWA)

The app features draft mapping and enables comments to be added directly (anonymously). The app includes simple web-GIS capabilities that allow anyone to add (draw) a feature (as a point or polygon) on the draft map (Figure 15). AARSC interpret the information submitted and action updates to the ATCM. This application is critical to inform the mapping of new and future crops.

The Industry Engagement Web App has now been viewed a total of 4,881 times. Comments provided by participating growers include both point (location) and polygon (extent) observations, which specifically for avocado total 25 and 195 respectively (Figure 16). The total number of comments received (for all tree crop observations) through this tool is 909.

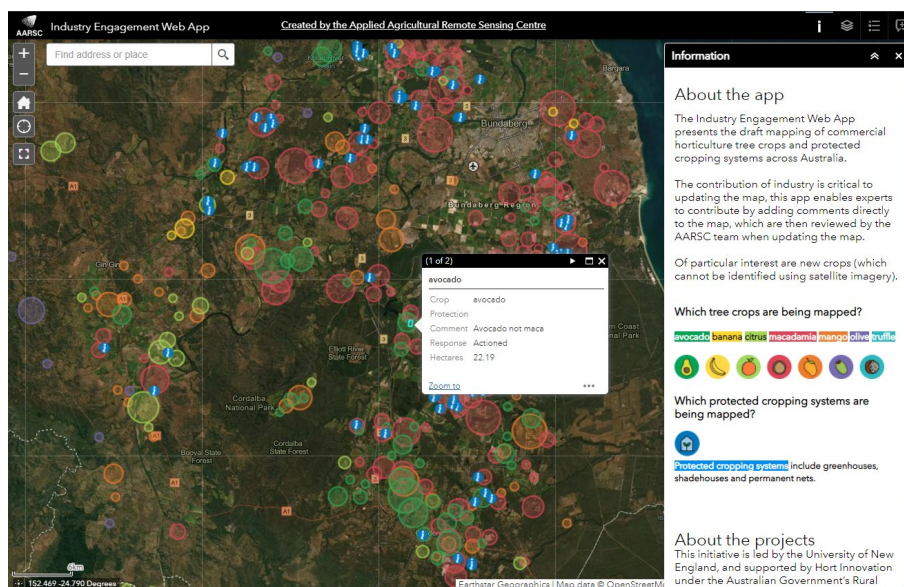


Figure 17: Industry Engagement Web Application, showing comment for a misclassified feature in Bundaberg

Other value-adding Applications

Biosecurity

The availability of the national map of avocado orchards offers significant benefit to biosecurity preparedness and response. Knowing where all orchards are located greatly facilitates the establishment of exclusion zones or the deployment of surveillance personnel in the event of a high risk incursion. Being a spatial layer, the national map can be overlaid with transport routes, water courses, topography, surrounding land cover types and incidences of severe weather events that can all be vectors of pest and disease. Additionally, using the individual orchard polygons (boundaries), highly temporal remotely sensed imagery (e.g. Sentinel every 5 days), can be rapidly sub-setted and classified into benchmarked crop health or vigour maps, where any drastic change at the within block, orchard, or even national level can be quickly identified. This functionality can greatly assist the ‘when’ and ‘where’ to conduct on ground surveillance for possible threats. Fortunately during the timeframe of project AV18002, there was not an incursion where the mapping could be utilised, but that does not diminish the potential benefit this layer will provide in the future.

ATCM: Severe Weather App

This app features ‘live’ (near-real-time) authoritative weather information across Australia sourced from the Bureau of Meteorology (BoM). Layers include rainfall (radar), thunderstorm (wind / hail), tropical cyclone (severity, track, impact zones and forecast), severe thunderstorm warning (hail, wind), and severe weather warning zones (wind). (Figure 18). Presented with the national map of Australian tree crops, and updated as the weather events progress, users can visually interpret potential impacts.

In response to feedback from AAL, the AARSC have upgraded the app which now includes historic data for past severe weather events. When severe thunderstorm cells are detected they are recorded and updated daily. Cells can be viewed by toggling on/off using the filter for events that occurred: yesterday, last week or this year. Clicking within a cell will show the date and time the event occurred and present the area of potential impact to tree crops, in a pop-up. (Figure 19).

Similarly, tropical cyclone events are also logged including fix position, track, threat area and wind area—updated in this app every three hours. Events can be viewed individually by selecting the event name from the drop-down list. Clicking within the wind area polygons will present the area of potential impact to tree crops, in a pop-up, by type of wind:

damaging, destructive or very destructive. (Figure 20).

The ATCM: Severe Weather App has been viewed 1,062 times.

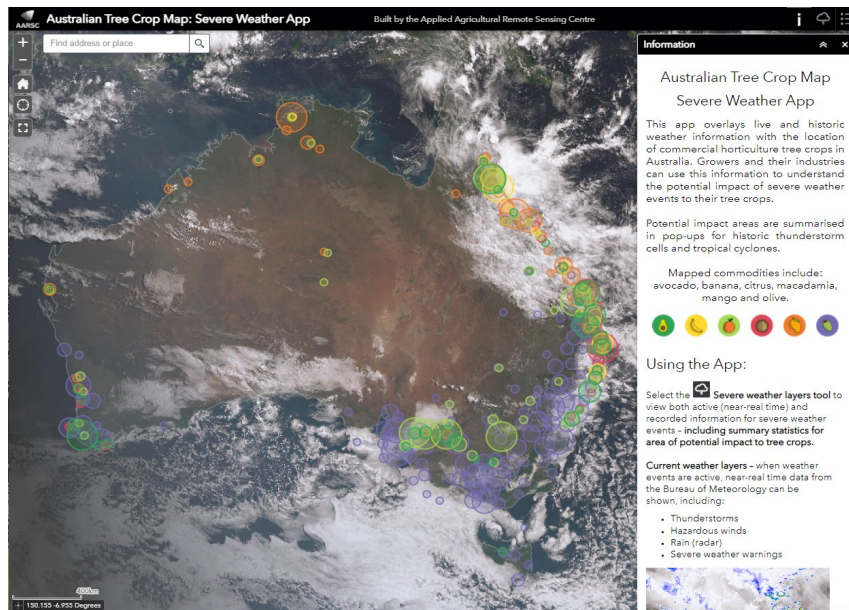


Figure 18: Australian Tree Crop Map: Severe Weather App

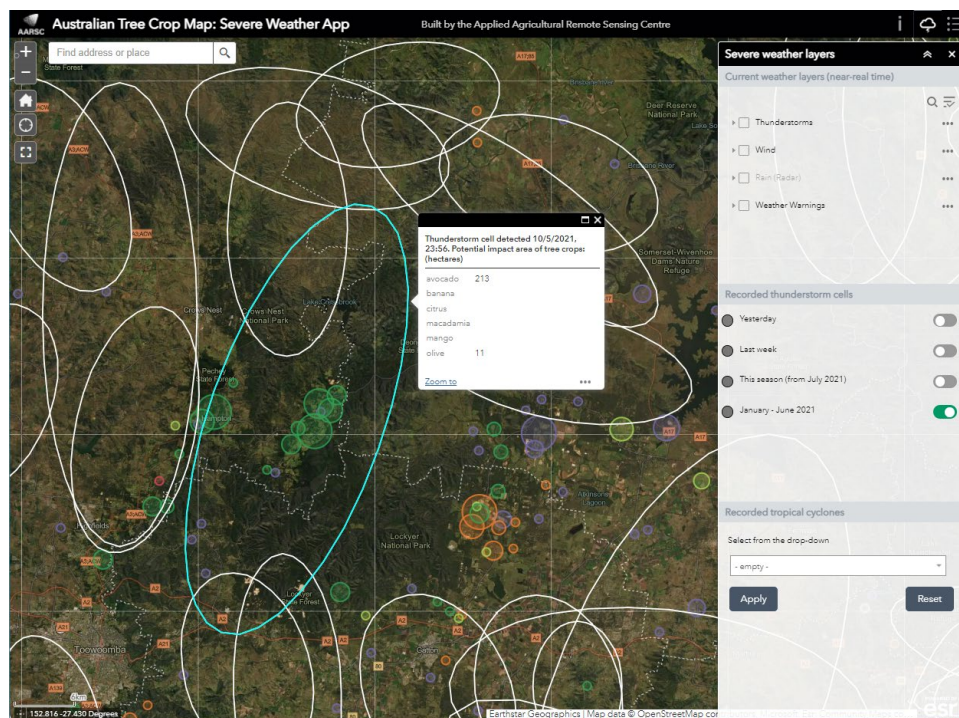


Figure 19: Severe thunderstorm cell, detected 11.56pm 10th May 2021. Potential impacts to 213ha of avocado orchards.

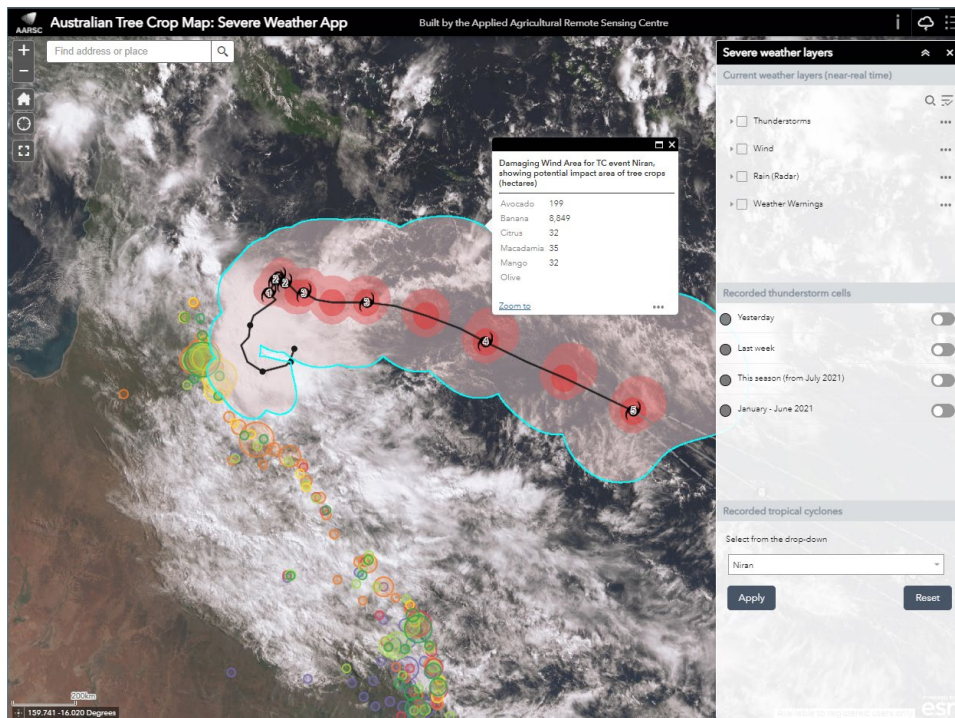


Figure 20: TC Niran, observed 2nd March 2021. Showing potential impact to 199ha of avocado orchards within the damaging wind area.

Australian Bushfires Rapid Response Map

In response to the recent Australian bushfire crisis over the summer (2019–2020), the AARSC launched the Australia Bushfires Rapid Response Map (Figure 21) which presents the location of selected tree crops across Australia, overlaid with a map of burnt areas. The bushfire extent layer was compiled by the Emergency Management Spatial Information Network Australia (EMSINA) group members and Geoscience Australia, as a consolidated National Bushfire Boundary Webservice. The feature service was processed at Geoscience Australia, to extract a 'time stamped' copy of the bushfire boundaries which was then processed (updated) in the web map every ten minutes.

The map serves as an excellent example of the application of commodity level land use mapping when combined with other spatial information (in this instance bushfire burnt area extent) to aid response and recovery to natural disasters. The Australia Bushfires Rapid Response Map has been viewed 7,970 times.

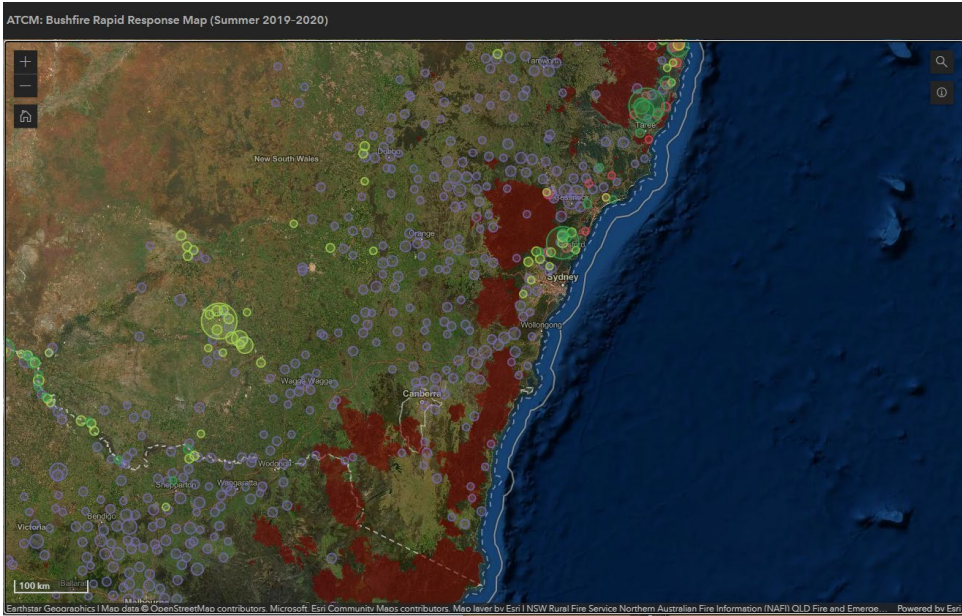


Figure 21: Australian Bushfires Rapid Response Map

Case Study: Water Security (Paradise Dam, Bundaberg)

During project AV18002, the Australian avocado, macadamia and mango industries requested the provisioning of tree crop areas measured from 2017 to 20122 in response to ongoing water security in the Bundaberg growing region i.e. related to the repair of Paradise Dam. Analysis included summary statistics for avocado orchards (Table 3) for each section of the Burnett Water Supply Scheme (BWSS) (Figure 22).

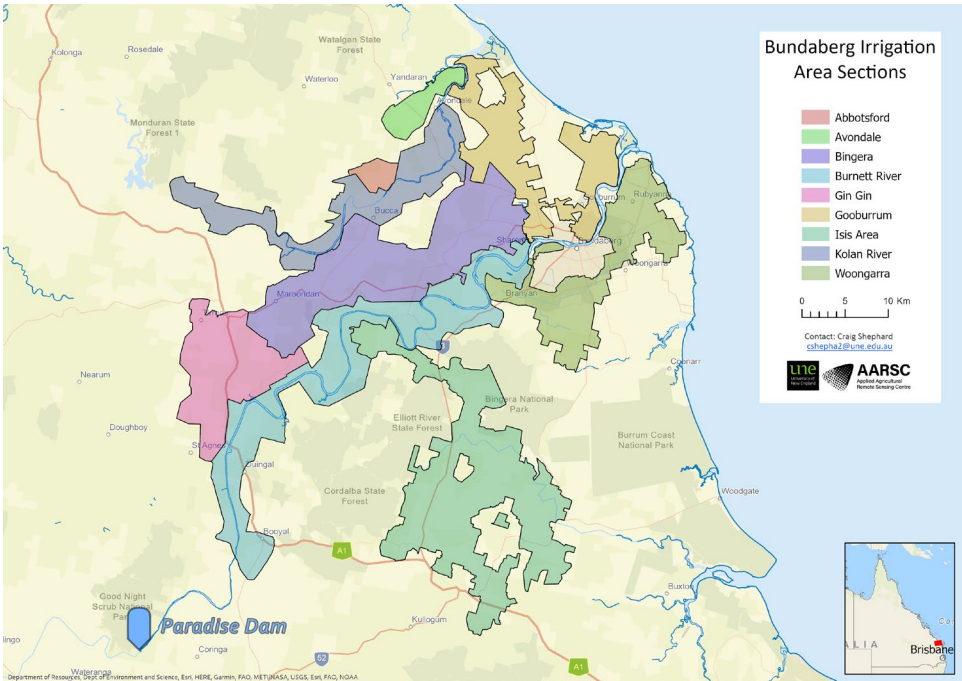


Figure 22: Bundaberg Irrigation Area Sections (Paradise Dam)

Table 3: Summary statistics for avocado orchards by Bundaberg Irrigation Area Section

Avocado orchards by BWSS Section (hectares)	Bingera	Burnett River	Gin Gin	Gooburrum	Isis Area	Kolan River	Woongarra	Total
ATCM (6th Sep 2021)	5	27	35	8	2,025	124	96	2,322
New crops (since 2017)	1	8	35	0	527	48	78	697

This application again demonstrates the great benefit that the data, now freely available in the ATCM, offers the participating tree crop industries, including avocado.

Change analysis

Analysis of the 2022 map was undertaken to derive a change mapping product showing the expansion of the industry since the Phase 1 baseline map was first published in 2017. Table 4 provides a comparison of total avocado area mapped between 2017 (Phase 1 tree project) to April 2022 (Project AV18002) for each State/Territory. As shown, there has been a substantial increase in area planted nationally ~38%, with all avocado producing states contributing to the expansion. This information is highly beneficial for the industry to measure annual growth and as such make more informed decisions about supply and market access both domestically and overseas. It also assists in identifying where key resources such as labour need to be directed throughout the harvesting season to cope with the expanding area of production.

Table 4: provides a comparison of total avocado area between 2017 (Phase 1 tree project) to April 2022 (Project AV18002) by State/Territory

Production Area	Phase 1 (2017)	AV18002 (2022)	Increase (%)
Australian Capital Territory	0	0	0
New South Wales	1,642	2,295	40
Northern Territory	0	0	0
Queensland	9,044	9,766	8
South Australia	177	406	129
Tasmania	4	18	362
Victoria	555	981	77
Western Australia	1,714	4,669	172
Grand Total	13,136	18,136	38

To accompany statistics of area change, the AARSC mapping team also produced a mapping output that represented the change. Figure 23 presents the new crops mapped (3,076 ha) within the Bundaberg growing region.

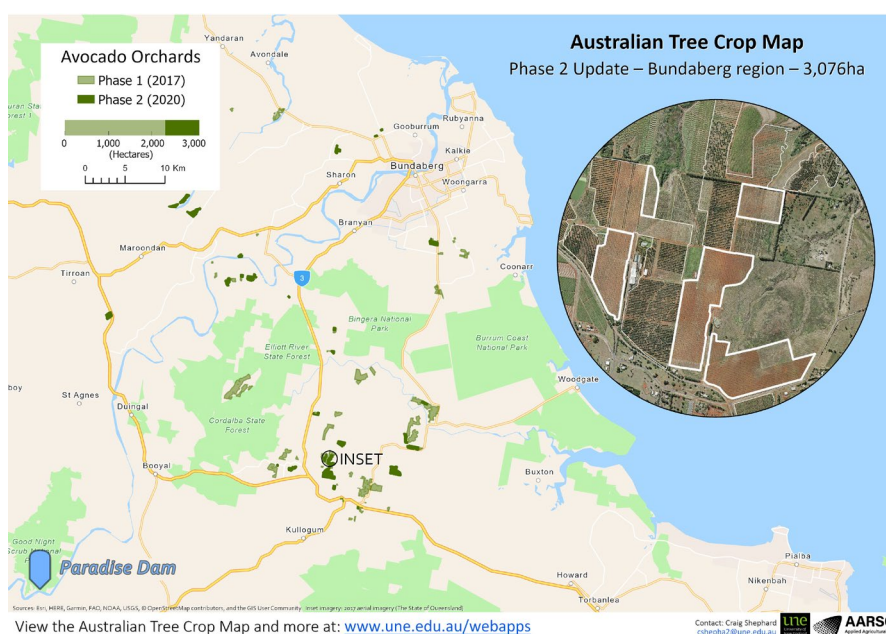


Figure 23: Avocado orchards within Bundaberg, showing new crops since Phase 1 (2017)

Yield forecasting of Avocado using both the '18 calibration tree' and 'time series' methodologies:

As mentioned in the methodology section, the '18 calibration tree' and 'time series' yield forecasting methodologies were applied over a number of orchards during project AV18002.

For the 18 tree method, a comparison between actual block level data and satellite derived predicted yield data for two blocks at farm 1 in Bundaberg and three blocks at Mareeba farm in 2019/20 season produced encouraging accuracies (Figure 24). For Bundaberg farm 1, block 1 and 2, the accuracies were 99.5 % and 94% respectively. For the Mareeba farm,

the accuracy for block 1, block 2 and block 3 were 83%, 92% and 83% respectively. The accuracy achieved for the Bundaberg farm 2, block 1 was 67%, with the higher inaccuracy attributed to very young trees with small canopies (around 4 m²) that were difficult to see with WV3 1.2 m pixel imagery. Additionally, 5 out of the 18 trees sampled produced no fruit, making the derivation of the algorithm difficult. As a result of the young age of the trees, block was not included in the following season of the project.

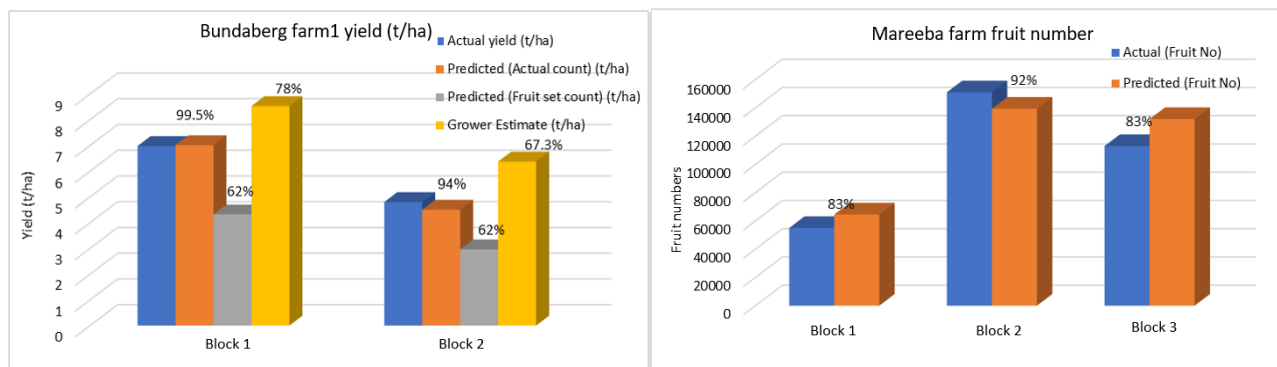


Figure 24: Comparison of actual and predicted yield (t/ha) (Bundaberg farm 1) and fruit number of (Mareeba farm)

For the 2020/21 season the methodology was again evaluated over three orchards at Bundaberg farm1. WV3 satellite imagery was acquired on 14th of May 2021 and field sampling was undertaken at harvest from 7th to 9th of June 2021. The accuracies of the block level forecasts using this method are shown in Figure 25, alongside the grower estimates. Note because of severe weather, a visual count of fruit on each tree for the third block was used as opposed to actual destructive sampling (picking of all fruit). This resulted in a large under prediction as fruit in large dense canopies as they are difficult to see and count. In short, if the calibration of the 18 trees is not done with the highest level of accuracy, then the prediction for the entire block will also suffer.

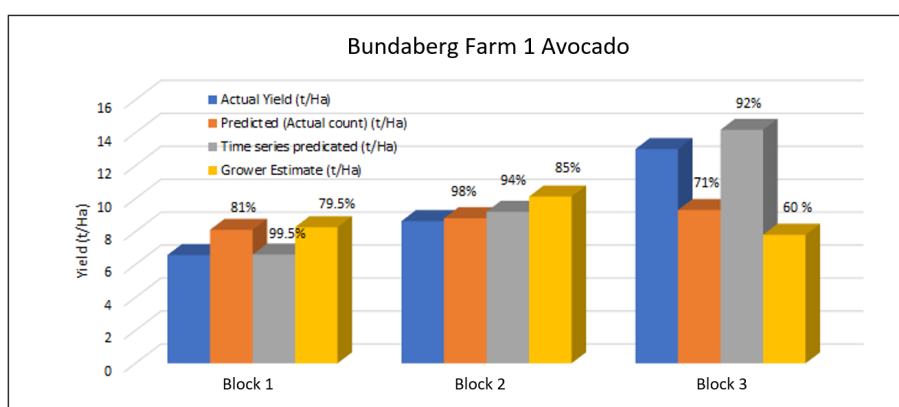


Figure 25: Comparison of actual yield data with grower's estimation, 18 tree sampling method and 'time series' model prediction in three orchard blocks of Bundaberg farm 1

Figure 25, also compares the prediction accuracies achieved for these three blocks using the 'time series' method, which again are highly encouraging with accuracy ranging from 92% to 99.5% .

The evaluation of 'time series' approach ended up including 100 individual orchard blocks from orchards in WA (3), Qld (3) and SA (1). The accuracy of the models compared to the actual harvest data are shown in Figure 26.

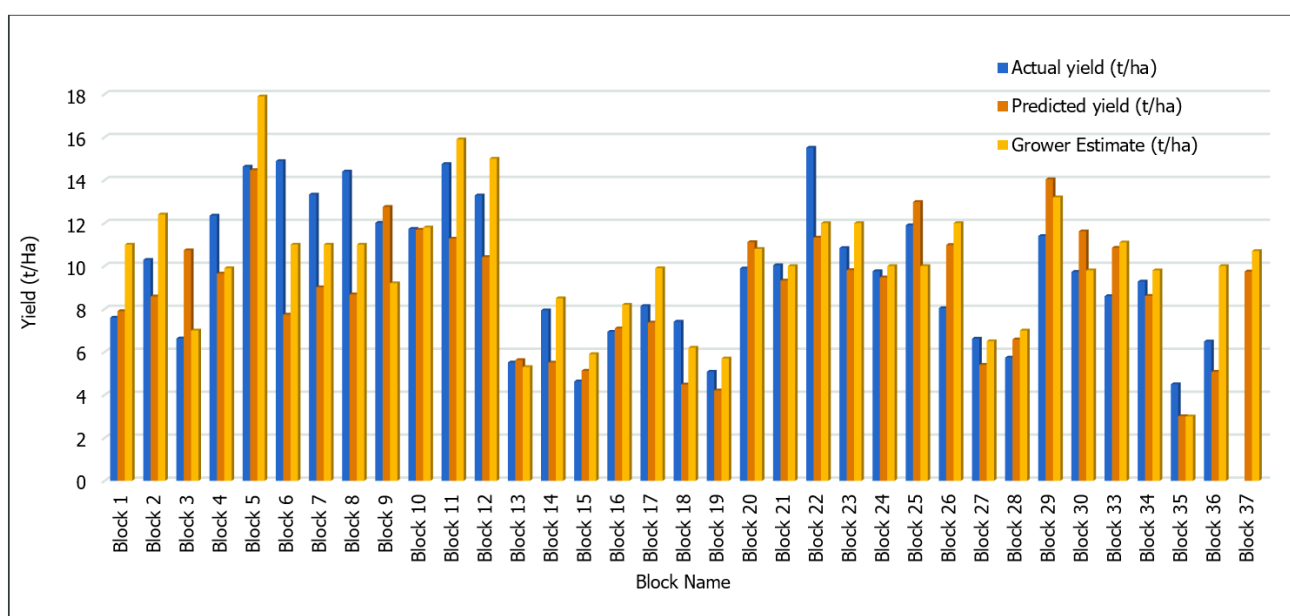
For Bundaberg farm 1, the average accuracy achieved for 37 blocks was 81.52%, ranging from 69.9% to 99.1%. This was

better than accuracy achieved by the grower estimation (76.6%). Bundaberg Farm 2, achieved accuracy ranging from 89% to 98.5%, whereas the accuracy of grower estimation was from 45% to 98%. South Australia farm also showed higher prediction accuracy ranging from 79.3% to 97.8%.

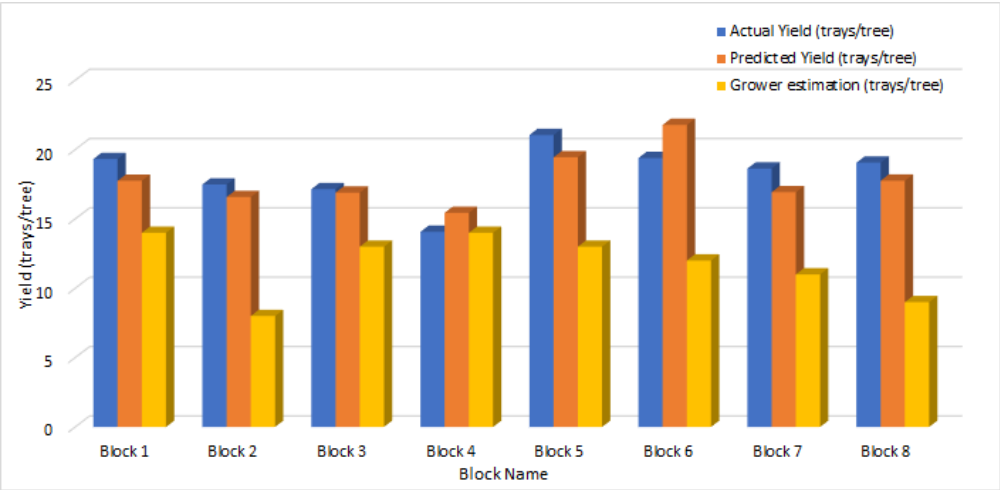
For Northern Queensland farm, the accuracy achieved was comparatively low, because of mixed varieties within the orchard blocks and only 4 years of historical yield data being available to develop the time series model, which ideally needs 5 to 7 years of data. Additionally, the previous 4 years of yield data did not experience yields as high as those achieved in the test year and as such the model has no precedent to work from. This results reinforces the need for as many years as possible in the development of the model, particular historic years that have produced yield variability.

For Western Australia farm, although the accuracy achieved with grower estimation was average 96.6% for nine blocks, the actual harvest data showed high yield (t/ha), around 40% more than both time series and grower estimation. It occurred due to double harvesting in that farm, one in May – June, 2021 and another in January – February, 2022. For four out of nine blocks the actual harvest data was not yet received for that farm. Moreover, the time series prediction for that farm was done around 10 months before the final harvest, which could affect the yield estimation.

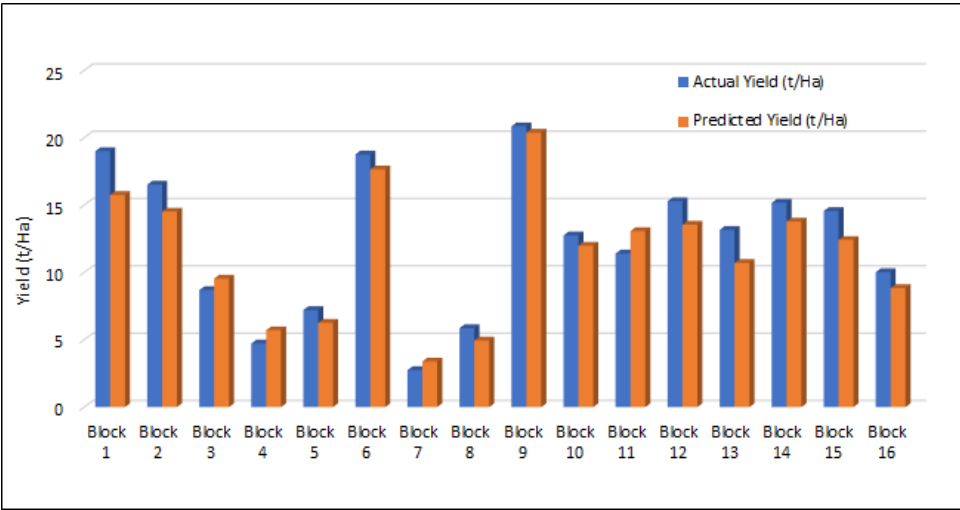
Bundaberg Farm 1:



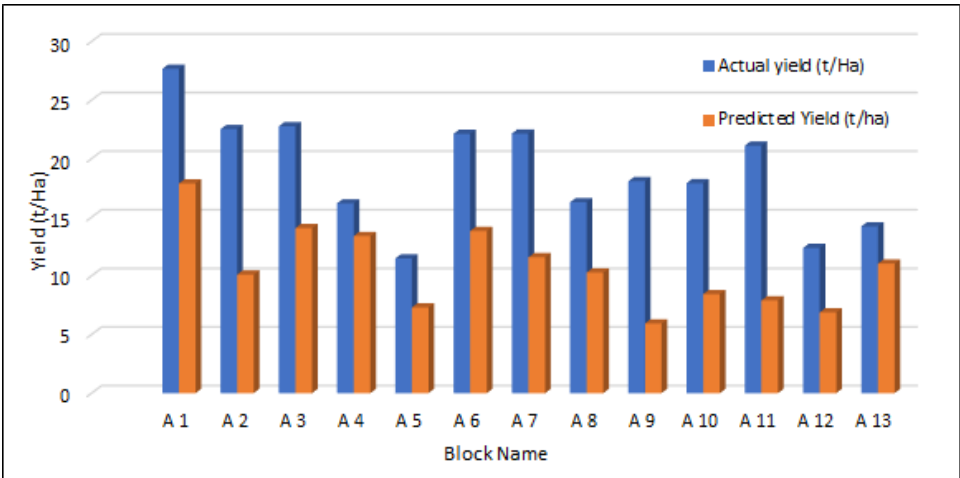
Bundaberg Farm 2:



South Australian Farm:



Nth Queensland farm:



Western Australia farm: Not yet received actual yield data from four blocks.

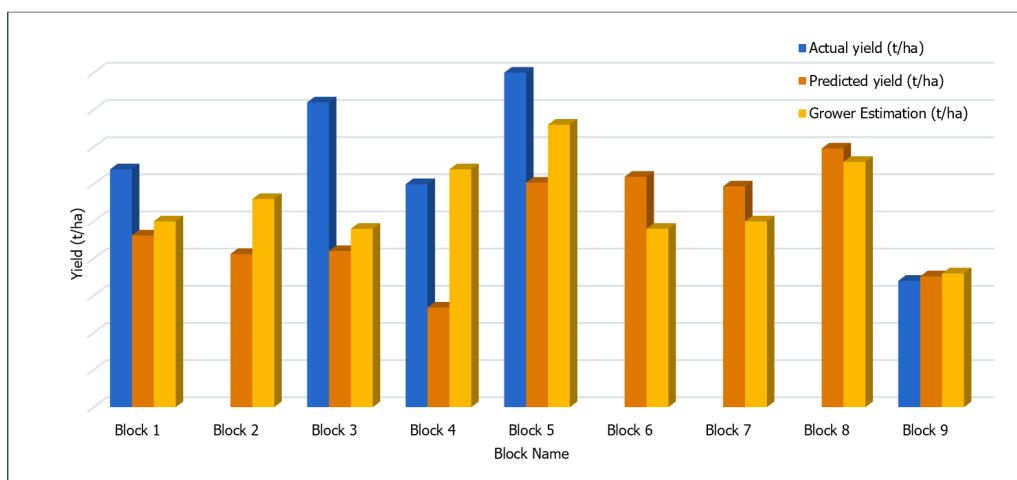


Figure 26: Comparison of actual yield per block (trays / tree) (top) and tonnes per hectare versus grower's estimation and predicted yield from the 'time series model' for orchards in Bundaberg, north Queensland, South Australia and Western Australia.

The results achieved from both the '18 calibration tree' and 'time series' methods were encouraging, producing accuracies that in most cases exceeded current commercial methods. The following discusses the pros and cons of each method:

'18 Calibration Tree':

- Pros:
 - More responsive to extreme events, including incidences of irregular bearing, pest, disease and natural disasters;
 - Can be used when no historic data is available e.g. young orchards or those recently purchased;
 - Incorporates current commercial 'eye ball' estimation method, but greatly reduces the number of trees required;
 - Able to map yield variability at the within orchard level;
 - Can be applied to satellite, airborne or UAV imagery.
- Cons:
 - Requires high resolution imagery, that does come at cost to growers;
 - Requires in field counting of fruit that can be time and labour intensive;
 - Predictions can only be made once fruit is of a size that can be seen and accurately counted;
 - Provides a measure of yield as fruit number per tree, unless fruit weight is also measured, or a default fruit weight is applied.

'Time Series':

- Pros:
 - Uses freely available imagery;
 - Requires no infield fruit counting;
 - Provides forecasts many months before harvest;
 - Model can be developed and applied in a relatively short time;
 - Provides forecasts at the block, farm and possibly regional level.

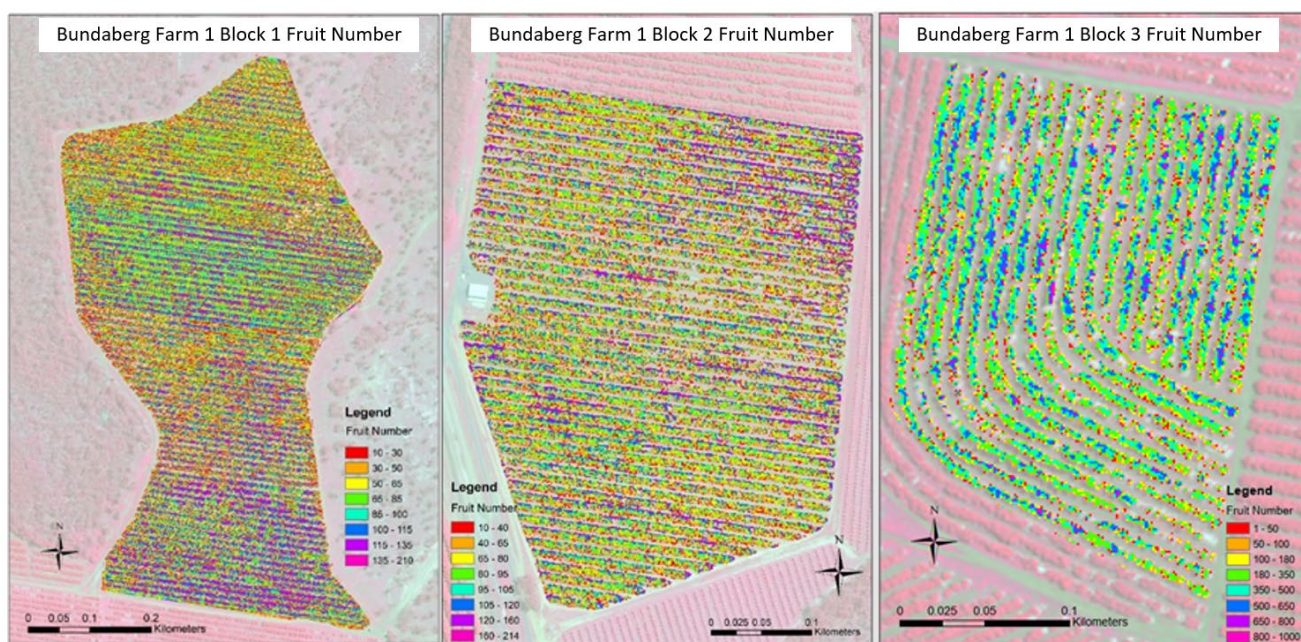
- Cons:
 - Requires historic yield data (at least 4 years);
 - Less responsive to extreme events, including incidences of irregular bearing, pest, disease and natural disasters. Especially extremes that have not occurred historically;
 - Not designed to predict within orchard yield variability.

Considering the pros and cons, both yield forecasting methods are complimentary. Using the 'time series' method, a grower can obtain a forecast earlier in the growing season without cost for imagery or the need to enter the orchard. This forecast can be used to guide harvesting logistics and forward selling decisions well before harvest. After final fruit set, a grower can adopt the '18 calibration tree' method to better quantify yield variability (fruit number per tree) across an orchard, as well as fruit size and the incidence of disease such as phytophthora.

Yield prediction maps

Fruit number/ yield/ tree vigour maps provided as pdf

The classified 'Fruit number' maps (pdf files) generated by extrapolating ground truthed fruit numbers collected from '18 calibration tree' method to all trees in the orchard, for Bundaberg Farm 1 and 2, and Mareeba Farm are presented in Figure 27. The provision of these maps to growers allows them to better understand the spatial variability in production. This information can assist with the refinement of harvesting logistics (where to deploy labour, bins etc), also through targeted agronomy help identify where and what constraints may be limiting production in certain regions. The later supporting the future adoption of variable rate technologies.



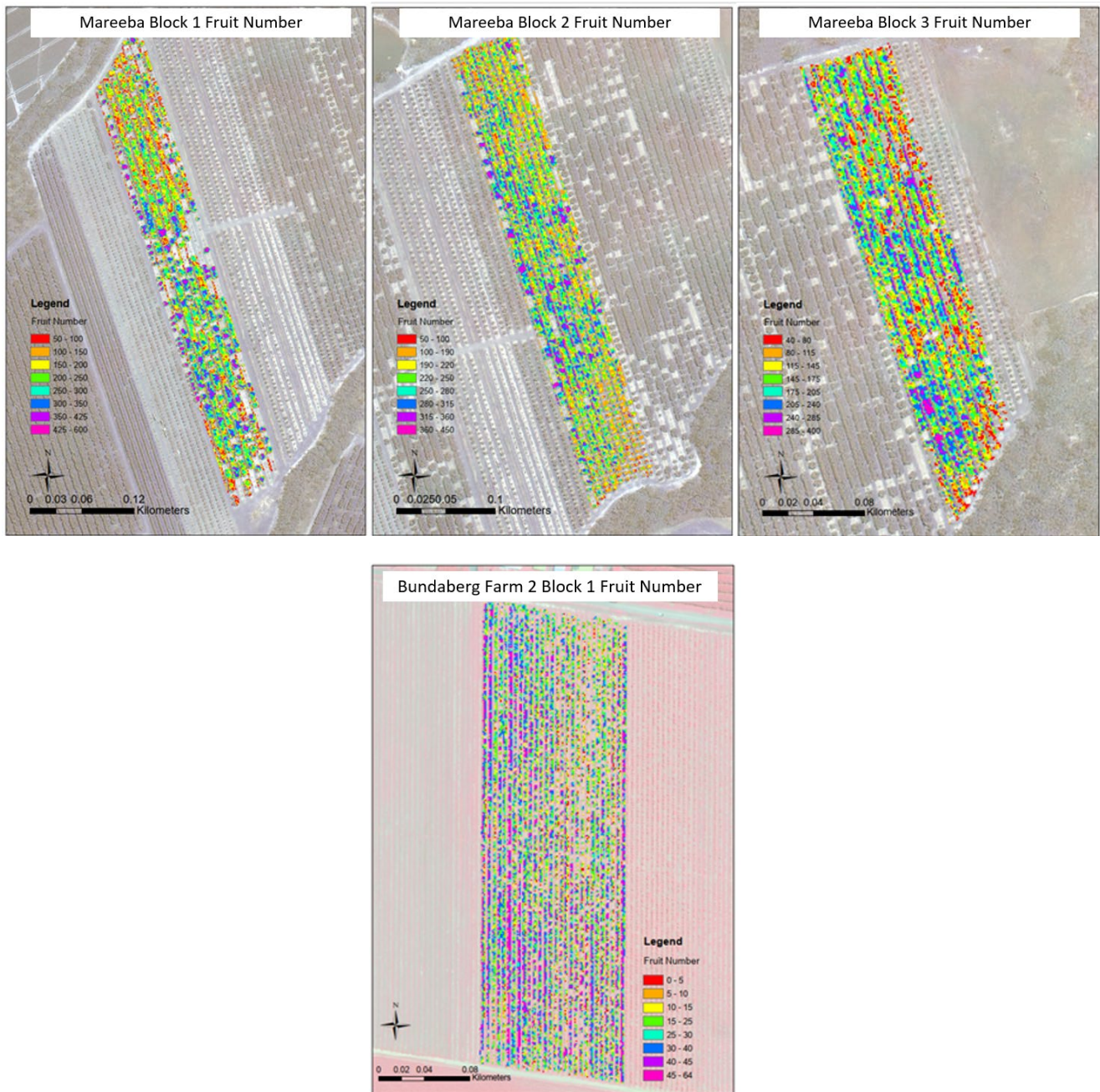


Figure 27: Classified 'fruit number' maps derived from the 18 calibration tree method.

Fruit number/ yield/ tree vigour maps provided as WebApps

Coinciding with the delivery of the derived fruit number and yield (tonnes/ha) prediction maps as pdfs, was the first use of the freely available WebApps using ArcGIS online (Figure 28). The benefits of this mode of delivery is the ability for growers to actively engage with the map by zooming in and out of particular orchard areas of interest, or viewing classified layers to compare temporal change or within block variability (variation of tree health within an individual block) to farm level (block performance compared to all other blocks on the farm) (Figure 28)



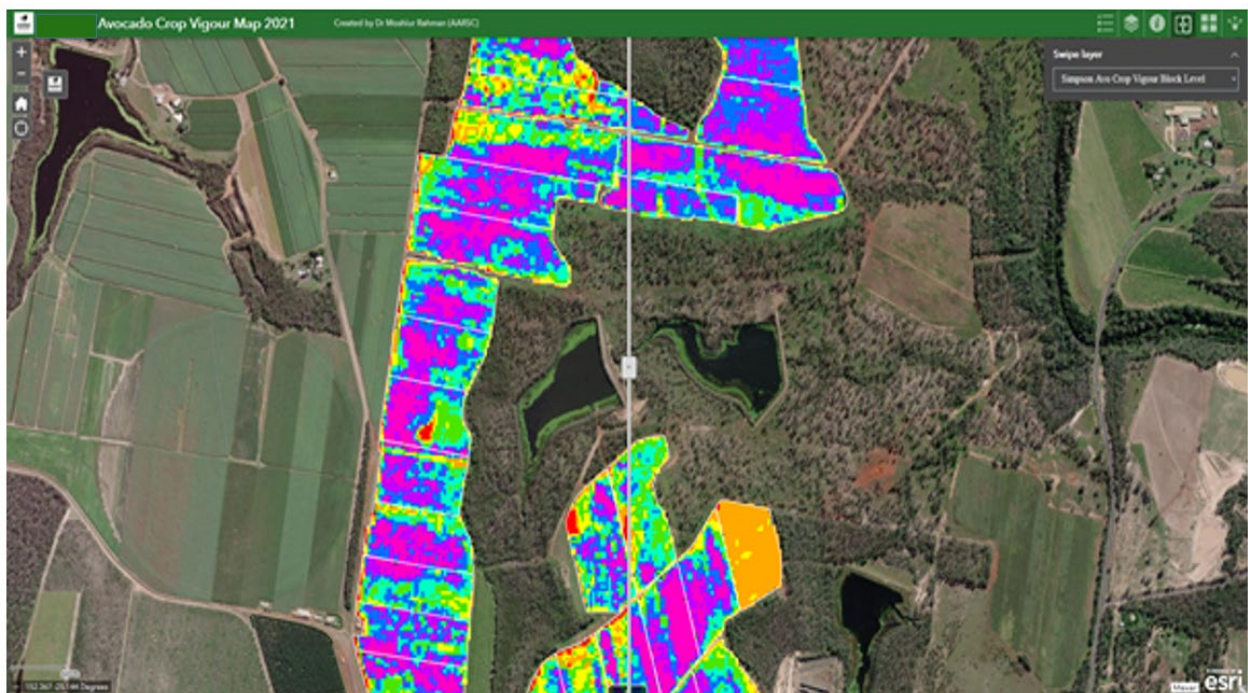
An example of WebApp generated using classified NDVI or crop vigour map



The information about the map can be found on the [AARSC] logo at the upper left corner.



Legend and Layer list can be found in the first two icon in the upper right corner.



The swipe tool shows the performance of Avocado crop on block and whole farm level. The block level information can be found by clicking on the boundary layer of any block

Figure 28: An example of WebApp generated using classified NDVI or crop vigour map

Crop Count MVP (Minimal Viable Product) Mobile Application

To further develop and evaluate avocado yield forecasting and mapping, the 'Crop Count' prototype App, developed by Circul8 for iOS devices, was tested on four orchard blocks in the Bundaberg region (3 blocks in farm 1 and 1 block in farm 2) and 3 blocks in Mareeba. The app successfully provided the growers with access to high resolution WV3 satellite imagery, identified the key locations of the 18 trees per block that required sampling and allowed them to record fruit number and fruit size per tree in the orchard. The fruit counts per tree were undertaken after final fruit set and at harvest.

Both sampling events produced strong relationships between VIs (derived from measures of canopy reflectance) and fruit number per tree, with the harvest measure identifying strong correlations to average fruit weight per tree (refer to earlier results). The subsequent prediction of total and average crop yield for all orchards from both measures were compared to actual harvested yield. The block level predictions made from the fruit set counts were well under actual yield for Bundaberg farm 1, the result of not being able to visually see all small fruit in the canopies of the larger trees. This is a limitation of early prediction whether using the App or following the standard commercial practice of 'eyeball' estimation. In order to address this, the sampling regime of the 18 trees was amended where the 6 replicates of high, medium and low vigour trees were clustered at only 3 locations across the orchard. This significantly reduced the time required to do the counts per orchard (45 minutes per block) providing the grower more opportunity to obtain more accurate fruit counts per tree. The yield forecasts made from the harvest fruit counts (actually picked fruit from the 18 trees) were highly accurate when compared to commercial harvested numbers of the entire block.

As well as yield forecasts, derived yield maps were provided to each of the growers showing them the spatial variability in yield. These results again confirmed the accuracies of the methodology and the benefit of the App once fully developed and commercialised.

The following insights were obtained from the evaluation process of the MVP:

Insights

It all comes down to accuracy and confidence

The most significant learning has been the importance and difficulty of getting an accurate count from each tree and also that the confidence in the count is also crucial. Blue Sky felt they needed 3 counts for each tree to feel confident in the data and Simpson and Aust Chilli both required 2 counts. This suggests that it is essential to allow multiple counts to be input into the app.

Interestingly, this could possibly be more about confidence than actual accuracy of the count. More analysis could be carried out to establish if using a single count could still be accurate enough, however the underconfidence in people submitting the count is still significant. We could include a 'confidence' score that is input which could be included in the modelling.

Physical counters were used for Bundaberg farms and whilst not used for Blue Sky, Matt expressed that this was an oversight. There is the potential to include features that assist the count itself into Crop Count. eg: digital counter, 'painting' tree as parts are counted.

How might we...

- Assist people to collect more accurate counts
- Provide more confidence in their counts
- Allow multiple counts for each sample



Insights

Finding the trees takes time

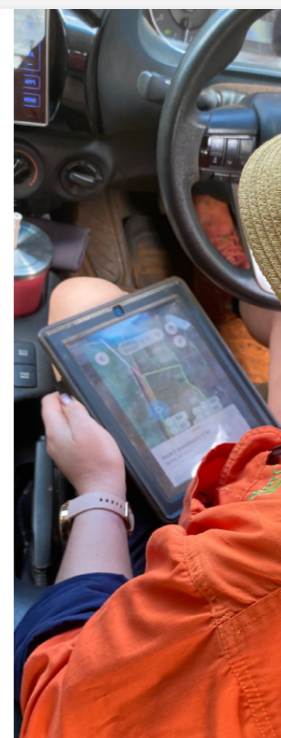
“What does the app say?” was a common phrase used during collection which indicated that Crop Count was successful in assisting people to find the correct location of the sample trees. The GPS was showed good accuracy on both Simpson and Aust Chilli farms however was not accurate enough to pinpoint exact tree location. Crop Count was effective to direct to the general location and then numbering or sighting of tagged trees was used from this point.

As the labelling of rows and trees did not match farm labelling systems this required some extra interpretation and pre-work.

It took Blue Sky 9.5 hours to complete the count of 18 trees. This was partly because of interruptions when Matt's phone kept ringing. To cut down the time a **new clustering method** was trialed for Simpson farms which reduced the time to approx 3 hours. On Aust Chilli which was a denser farm it only took 40 mins. This new method of clustering trees was very effective at cutting down time for finding the trees. However, more data will be required to determine if the clusters will provide significantly different accuracy from the original samples.

How might we...

- Allow the app to work with clusters better (increased zoom, re-organise data collection)



Insights

The best device is the one on you... unless it keeps ringing

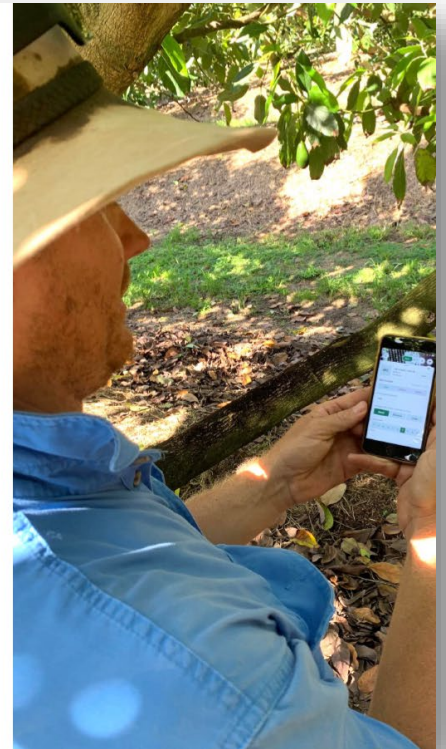
Matt (BlueSky) suffered a lot of interruptions on his personal mobile during the count. For him the ability to load onto the work ipad would be useful.

Paige (Simpson) would prefer to use her own mobile as this is on her all the time. Simon (Simpson) only had an Android device and the Simpson iPads needed to have cellular data to access the GPS.

The Crop Count app needs to be accessible on as many devices as possible to allow for easy use.

How might we...

- Best rollout Android, ipad and tablet access
- Consider battery life when GPS is being used
- Consider best design for light conditions when used outdoors
- Provide farm management of accounts and access so new users can be easily added



Insights

Yield forecasts are understood but can be improved to allow better comparison

The fruit-set forecast designs were received favourably by BlueSky and Simpson Farms (follow up not obtained for Aust Chilli).

The NDVI maps were used to validate or investigate existing knowledge of the farm and management practices in process. "It's interesting in that NDVI image because you can see the impact of the work we did there. It's good to see it coming through." Simon (Simpson Farms)

Simpson Farms had combined blocks to reduce the number of samples required. However when using this forecast Simon wanted to have the information split back into single blocks.

Both growers requested the ability to see a whole farm view and ideally select and join blocks together.

Both growers recognised that for the fruit set count the number of fruits made more sense than tonnes/hectare. However, for Simpson, because the standard was to talk in tonnes/hectare it would be good to allow the use of a nominal weight to calculate this.



Insights

The differing scale of the yield maps caused some confusion.

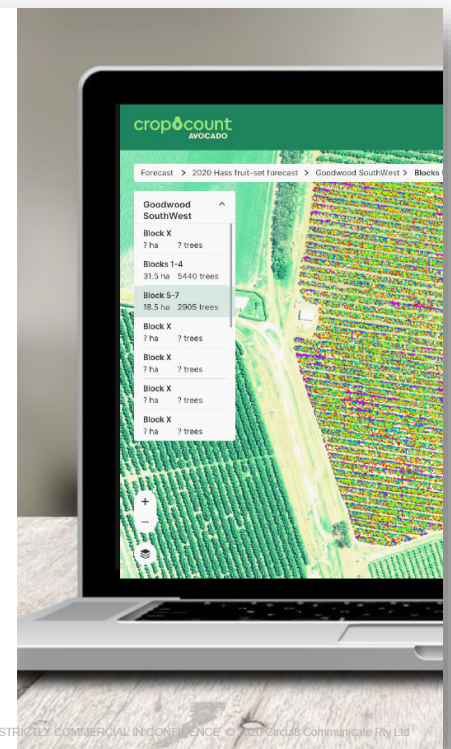
"This is something I always struggle with, because it's a different scale for every block" - Simon (Simpson).

A way to export the data so that it can be used easily was desirable.

For Matt (Blue Sky) the value of this platform would come with history and trends over time.

How might we...

- Improve the overall farm data displays so that blocks can be better compared with each other and rollup data can be obtained easily
- Provide yield forecast in tonnes/hectare so that it can more easily transfer to industry standards and other farm practices (fertilising)
- Make the data easy to export in a format that is useable
- Provide trend analysis over time



Insights

More than just yield

Throughout all interviews it was clear that just knowing the forecast numbers was not where the real value of Crop Count lies. Farms are connected systems - yield is affected by tree health which is affected by farm management practices. The value of Crop Count is not just to provide a yield number at a single point in time. Instead it is a tool that is used alongside existing knowledge to improve the entire farm management.

Matt (Blue Sky) particularly talked about how using the tool to take photos of the trees and write notes would greatly increase the value. There is an opportunity to make use of the time investment to allow growers to keep better track of their farms.

This was also apparent when growers looked at the yield forecast designs. They were looking to validate and improve existing farm management practices.

How might we...

- Allow more data to be collected on the sample trees (photos and notes)
- Allow general data to be collected on the blocks
- Allow export of data for integration with other systems



Insights

User experience and design gets a tick

Feedback about the design and useability of Crop Count (both the app and desktop designs) has extremely positive throughout all user testing.

"That's looking really really good. I wasn't quite sure what I was going to see... it's quite exciting to see it at this stage actually" - Chad Simpson

"I really did like the approach you've taken and just the simplicity and the hierarchy of it was quite intuitive." - Matt (Blue Sky Produce)

"For a couple of backpackers who have never looked at it, they could pick it up straight away - that's a good sign." - Matt (Blue Sky Produce)

"Really, I think it'll be good to see them happen. They look good." - Simon Grabbe (Simpson Farms)



STRICTLY COMMERCIAL IN CONFIDENCE © 2020 Circu8 Communicate Pty Ltd

The project team participated in the GATE program (run by NSW DPI and supported by Horticulture Innovation) to identify pathways that support the final development and commercialisation of the App. The experience provided the opportunity to develop a 'Road map to market release' provided in the Appendix section of this report. Additionally, the following promotional 'pitch' of the CropCountApp' was developed:



This pitch was well received, attracting interest from companies in South America, South Africa, New Zealand and Australia.

Measured canopy temperature and relative humidity data

To better understand the relationships between climate variable such as relative humidity and temperature with yield, RH and temperature sensors were placed within individual trees representing high, medium and low vigour trees (defined from satellite imagery), with data recorded throughout the duration of project AV18002 (Figure 29). Whilst, data recorded from 6th of February, 2020 to 28th of October, 2021 indicated the low vigour trees reached up to 2°C warmer than the high vigour trees (daily mean temperature), a consistent variation over the full time period was less obvious (Table 6).

Whilst project AV18002 collected tree level temperature and relative humidity data to compare with individual tree yields, it was unable to run intensive analysis to determine its variation seasonally across an orchard and its possible relationship to yield potential. This was due to project being unable to find a suitable PhD student to have the time to undertake the analysis and the success and ultimate demand of the 'time series' approach, which by association includes the influence of seasonal climatic factors.

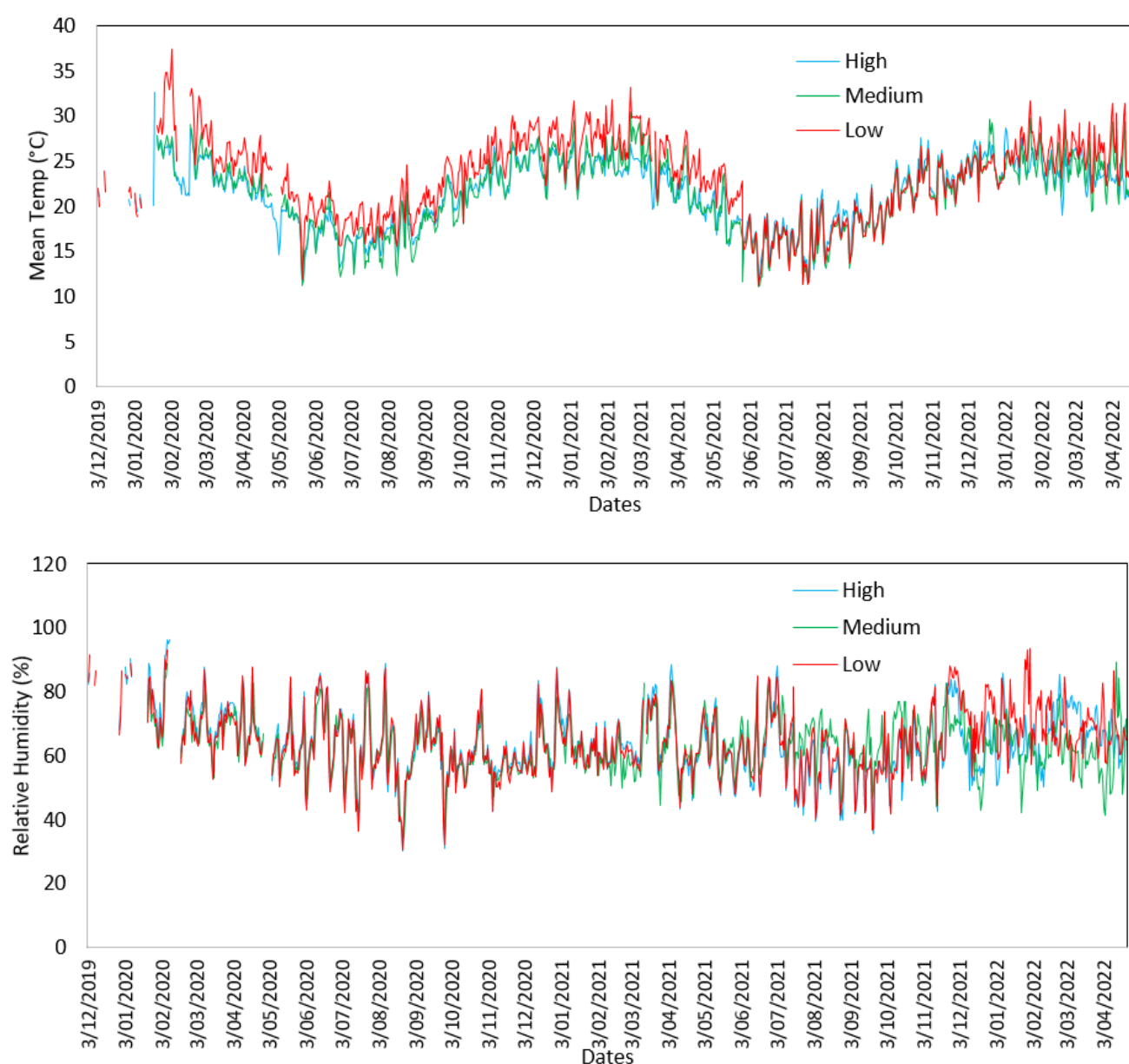


Figure 29: Mean temperature (top) and Relative Humidity (%) (bottom) variation between high, medium and low vigour trees from 3rd of December, 2019 to 28th of May, 2021

Table 6: Averaged measures of temperature and humidity from high, medium and low vigour canopies.

Class	min_temp	mean_temp	max_temp	min_hum	mean_hum	max_hum
Low	15.8	20.8	27.2	43.7	62.6	77.8
Medium	15.6	20.4	26.8	45.0	63.6	78.3
High	16.3	21.1	27.0	44.8	63.0	77.5

Outputs

The following Table has been included to detail the outputs achieved by project AV18002

Table 7: Output summary

Output	Description	Detail
Seven Web Map Applications	These applications support both the sharing of the national map and industry engagement tools to inform on-going updates.	The mapping applications developed are presented across a range of location-based web applications, all available and freely accessible via the AARSC (Applied Agricultural Remote Sensing Centre) Industry Applications and Maps Gallery. Additionally, AAL has hosted the avocado survey app on their home page to encourage engagement and participation from growers. This has resulted in 168 avocado survey submissions since launch on 7 th Oct 2021.
'time series' yield forecasting algorithms developed for 100 orchard blocks	Historic yield data and corresponding satellite imagery sourced from orchards in WA (3), Qld (3) and SA (1)	Individual yield forecasting algorithms developed for 100 avocado blocks.
Prediction maps of individual avocado blocks	Classified fruit number and fruit yield (tonnes/ha) maps were generated by extrapolating ground truthed fruit numbers collected from 18 sampled trees for several farms in Queensland.	The derived block level fruit number and fruit yield (tonnes/ha) maps were provided as pdf file to the relevant growers.
Development and evaluation of the MVP (Minimal Viable Product) to then establish the commercial viability of developing a complete version of app. See appendix.	The MVP 'CropCount' mobile application has been developed and tested for iOS with Bundaberg Farm 1 - 3 blocks and Bundaberg Farm 2 - 1 block. AARSC and Circul8 participated in the 2020 GATE program to establish the commercial viability of a complete application.	The YouTube pitch deck (see appendix) has been viewed 377 times. We received enquiries about investment and collaboration (both domestic and international) after the pitch went live. The opportunity to take this MVP to market still exists, next steps required include additional investment into the back-end development of the app, additional validation of the CropCount methodology on farms at the construction of a comprehensive commercialisation plan that details a clear pathway to market.

Outcomes

Table 8: Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Establishing an ongoing capacity to maintain and refine the national GIS database of	All Australian commercial avocado orchards > 1ha mapped	Location-based tools enable industry engagement to update the map (particularly for new crops). As a clear	During the 2021 avocado tree census, conducted by AAL growers were encouraged to view the

commercial avocado orchards ('Australian Tree Crop Rapid Response Map' and the 'Australian Tree Crop Rapid Response App' both available online)	Location-based tools developed enable this: • ATCM: Survey • Avocado Survey • Industry Engagement Web App	demonstration of industry adoption and use of this output, Avocados Australia Ltd (AAL) now host the national map of avocado orchards on their website, accompanied with a request to growers to contribute to the accuracies of the map, especially with new plantings.	map and "Check your orchard is in it!", and if needed provide feedback using the survey tool. As a measure of success some 136 surveys were received during the tree census campaign, which resulted in a further 484ha of avocado orchards added to the map.
Further validating the relationship of canopy reflectance, measured by remote sensing technologies, to yield parameters and tree health, under Queensland growing conditions.	Produce yield forecasting accuracies that exceed current commercial practice (~90%) The WV3 satellite imagery derived optimal vegetation indices (VIs) provided a positive relationship to total fruit number and fruit weight (kg/tree) to develop yield prediction models in both 2020 and 2021 season. Time series model using historical Landsat 7, 8 and Sentinel 2 imagery have been developed for several avocado farms in Bundaberg, Northern Queensland, South Australia, and Western Australia.	The participating growers: Bundaberg 2 farms and Mareeba 1 farm have gained some understanding of the yield forecasting process through their testing of 'Crop Count' methodology. With the outcome of time series model, which does not need any field calibration, the project team has received direct requests from many of Australia's growers to be involved in the yield forecasting component of the project, providing sensitive historic yield data sets and tree management information.	The continued effort to better extend the project objectives to the wider Avocado industry has been well received with a significant increase in grower engagement in the project period. Historic production data and associated farm maps have been provided by six major Australian growers in WA, SA, QLD. The promotion of the avocado 'CropCount' App has resulted in extensive interest globally, for avocado as well as many other horticulture industries.
Develop a minimal viable product (MVP) mobile application that will provide avocado growers with up-to-date high resolution satellite imagery as well as the ability to calibrate the imagery for yield, fruit size and phytophthora severity (Cyber Geigy rating). This MVP will be evaluated throughout the initial stages of this project to determine industry acceptance of	Evaluation of industry acceptance of the technology; knowledge of the product and its capabilities amongst industry and growers.	Additional validation and engagement (by way of testing and interviews) with industry and growers is required to further measure the acceptance of the CropCount application.	Proposed methods were number of MVP downloads and active users in a calendar year, interviews, website marketing analytics (growers and industry) however due to a Stop/Go decision not being made this evidence was not able to be collected.

the technology			
Integrate the national orchard map of crop area with the self-calibration of satellite imagery with on-ground measures of yield parameters, and an understanding of the influence seasonal weather conditions, to develop a more accurate yield forecasting system at the orchard, farm, and national level.	Produce a yield forecasting model that exceeds current methods. Understand how seasonal weather parameters influence accuracies of the prediction model. Source historical block level yield information from growers.	The time series method provides a measure of historic orchard performance, which includes the influences of weather variables.	Accuracy achieved from the 'time series' models when evaluated against actual yields. This included different growing regions, varieties and seasons.

Monitoring and evaluation

Table 9: Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project directly built on the outcomes of the Rural R&D for Profit Project – Managing Tree Crops?	National map updated at larger scale (1ha) and timeliness (currency) accounts for many new orchards	New RFP for ongoing annual update of the national map
To what extent has the project established an ongoing capacity to maintain and refine the national GIS database of commercial avocado orchards?	Location-based tools enable it, the survey and map now hosted on AAL homepage, encouraging growers to check the map and complete a survey if required.	Additional development of this spatial dataset. Greater involvement of industry representatives/experts by directly contributing to the map using bespoke tools.
To what extent has the project further validated the relationship of canopy reflectance, measured by remote sensing technologies, to yield parameters and tree health, under Queensland growing conditions?	'CropCount' methodology has been validated on 4 blocks of Bundaberg farm 1 and 2, and 3 blocks of Mareeba farm in 2019/20 season and only 3 blocks of Bundaberg farm 1 in 2020/21 season. 'Time Series' approach has been developed for 3 Western Australia, 3 Qld and 1 South Australia farms, totaling 100 individual orchard blocks.	The continued effort to better extend the project objectives to the wider Avocado industry has been well received with a significant increase in grower engagement in the project period. Historic production data and associated farm maps have been provided by six major Australian growers in WA, SA, QLD
To what extent has the project developed a minimal viable project MVP mobile application?	An MVP mobile application has been developed.	Additional validation and testing across different farms and locations, as well as the development of the back

		end of the MVP.
To what extent has the acceptance of this technology (mobile app) been evaluated?	Mid term review by industry and RMCG positively identifying industry interest in the App, including its adoption	Greater industry engagement, including grower interviews and marketing of the MVP.
To what extent has the national orchard map of crop area been integrated with the self-calibration of satellite imagery?	The polygons used to delineate the individual orchards (> 1 ha) have been used to subset historic imagery required for the development of the time series algorithms	Opportunity to automate this process for its application over all delineated orchards in the national map (pending availability of historic yield information).
To what extent has the project improved yield prediction accuracies for the avocado industry?	Both the 'CropCount' and 'Time Series' methodologies have produced accuracies above 90%, in the majority of cases exceeding accuracies achieved by current commercial practices.	The continued development of these methodologies over more orchards (varieties, locations, seasons, management) will assist in the development of regional, state and national level forecasting.
To what extent has the national map of orchards supported decision making within the avocado industry?	Industry metrics supported at multiple-scales (national, regional and local). Successfully applied in severe weather events (bushfire crisis, floods, severe thunderstorm), and the Paradise Dam class action.	The further delivery of these applications following future events. Also the application of the national map and associated imagery products for biosecurity preparedness and response. Also further development to support traceability.
Have Australian Avocado growers and industry stakeholders been engaged in the development of the project outputs?	Yes, through media and engagement opportunities (44 separate examples) included in appendix.	Having the opportunity to undertake live demonstrations at conferences and field days would help with further engagement.
Were growers and industry informed about project updates and achievements in an accessible and engaging way?	Yes, via project reference group meetings, industry newsletters, publications, and various forms of media (see appendix).	Attending more industry field days, workshops, webinars, and conferences.
What forms of communications have been used in this project to engage with Australian Avocado Industry?	Both traditional and digital media. Fieldwork trips, online meetings, conferences, and webinars.	Continue to build on the successful engagement experienced throughout the project. More face-to-face meeting opportunities.
What efforts did the project make to improve efficiencies throughout the project to ensure appropriate use and allocation of time, money, effort and other resources?	Fieldwork was scheduled and collated by growing region, across multiple projects. Inclusion of more sites for the evaluation of the 'time series' methodology as doesn't require field visits and utilizes free imagery. Adapt field work program in response to COVID e.g. having growers conduct the sampling and	Combine field validation of the map with another industries, to optimize travel budgets and time.

	evaluation of the App themselves. Discontinued 1 of the sites as the trees were too young to offer a fair assessment of the 'Cropcount' App methodology	
How well did the project engage with other complimentary projects and initiatives to evaluate what was being achieved?	As above, national mapping program set by growing region.	Continued development of the national map with other commodities. This outcome will help promote the benefits of this application to state and federal governments and other non participating industries.
What feedback has been received from industry and external entities to demonstrate interest in the project and future adoption of project outputs?	Currency of the map with respect to maintaining it for new plantings. The industry engagement tools support this. Increased request by growers to participate in the 'time series' approach domestically and overseas. Commercial contracting by COSTA to deliver 'time series' models for all their avocado orchards	Annual update to maintain currency, and on-going support for the theme-based applications for viewing and analysing the map.

Independent midterm review of project AV18002:

In early 2021, project AV18002 received two forms of independent review:

1. **Industry review:** AV18002 progress update and feedback workshop 10th Feb 2021 (list of attendees provided in the Appendices of this report)
2. **Independent midterm review:** RMCg were contracted by Hort. Innovation (Project code AV20005), to undertake an independent review of project AV18002. The full report is accessible from Hort. Innovation.

From the industry workshop the main outcomes were as follows:

Value of project

- Attendees saw value in the project as it is important to know expected yield reasonably early in the production process to effectively adjust inputs and manage the crop for harvest. Visual estimation is limited and it is difficult to estimate an average count for the block due to variations in the orchard. Fruit drop is also an issue.
- The ability to gain a bird's eye view of canopy health within the block can help growers understand where the issues are and decrease variability. If growers can understand the broader picture and the reason for variability in yield and size of fruit, they will be more motivated to make changes.
- There is value in the national map with benefits to individual growers and industry.
- Mapping has had success in the macadamia industry and there may be an opportunity for collaboration.

Current progress and areas for consideration

- The national map is not yet 100% accurate of orchard locations when compared with industry data and there is a need to validate this.
- It is important to protect the privacy of individual farmer data.
- The process to select 18 trees for calibration within orchard mapping should be automated.

Industry engagement and adoption

- Gaining historic data from more orchards for forecasting purposes will be challenging.
- Testing of the app and engagement with growers was difficult due to COVID restrictions but there is potential for this to improve in 2021.
- Project outputs are not widely known in the industry, but this could be a fallout from COVID restrictions.
- The online extension events were difficult to understand and primarily focused on the map. It will be necessary to engage growers in the field for this project.
- The adoption of technologies developed from this project may need to be an additional piece of work.
- The app needs to be user-friendly, particularly for farm hands, and easy to implement to increase adoption.
- Growers will need to build confidence in the value it provides.

Increased investment for app

- The project was contracted to develop a prototype of the app and further investment is needed to automate the backend of the app and data inputs. Prior to contracting and following advice from the SIAP, the original budget for the project was scaled back.
- IP is currently 50% UNE and 50% Hort Innovation. There is an opportunity for foreign investment (New Zealand and South America) which could be used to further develop the app and put it in the hands of growers, however it would be necessary to see the benefits to the Australian industry in this case.
- The app has great potential to benefit growers through quick and accurate crop forecasting, particularly from a regional perspective. Growers and industry will have greater confidence in crop estimates and be able to better manage the supply chain. There is interest in its development.
- The app may be of greater value to medium and larger enterprises rather than smaller growers.
- It is difficult to commit to an additional investment of the app without further clarification on what the funding will be used for and the final outcome. An open tender may be necessary to ensure competitiveness.
- A commercialisation plan will be necessary to justify increased investment. Commercial partners may be considered to drive the development of the app.
- The app hasn't been seen by many growers as it can only be accessed through the project team. To justify increased investment, it may need to be tested by a panel of growers to understand how it works.
- There is a need to understand how much it would cost to further test the app in the field in specific locations and farms versus the cost component to further develop the app so that it is more automated.

From the RMCG review the following excerpts are supplied from the executive summary:

1.3 FINDINGS

Effectiveness:

Activities and outputs from AV18002 to date have made good progress and are on track to achieving the stated intermediate and end-of-project outcomes. These outcomes align with the priorities stated within the Avocado strategic investment plan (SIP) 2017–2021, by seeking to refine and commercialise technologies and innovations that improve on farm production and efficiency. Activities and outputs have included:

- Development of block yield maps for producers based on their historic production data. Progression of this element of the project has initially been slow due to difficulty in accessing historic yield data from producers (only

Bundaberg Farm 1 provided this data prior to March 2021). Since the workshop held with industry in early March four more producers have provided their data (1 x QLD, 1 x SA, 2 x WA).

- Recording of ‘micro-climate’ data within trees and a literature review of use of remote-sensing technology completed by the PhD student.
- Annual updates to the national tree crop maps and apps which were initially developed in the Rural R&D for Profit Tree Map project. The precision of the original maps developed for avocado have included the resolution of the map to a 1 hectare level (previously 2 hectares) and the inclusion of this data in the web map apps to assist industry in responding to bushfire and extreme weather events.
- Development of a minimum viable product (MVP) App ‘Crop Count’ which assists producers in locating appropriate trees for pre-harvest ‘fruit’ counts and the recording of this information into the App. The App has also facilitated the ability to record a ‘rating’ of tree health which can then be mapped and provide an indication of phytophthora risk. The project team participated in the GATE2020 program and developed a video promoting the MVP. The video has resulted in interest from several international companies regarding further development of the App.

Evaluation of the App at three avocado properties in Queensland has been insufficient to determine the usefulness of the App and its potential value to industry. The original scope of works proposed included wider evaluation of the App in other production regions (WA and SA) and this would be of benefit given variation in production between the three regions and the need for greater exposure and promotion of the App to industry. One of the properties used to evaluate the App was unsuitable due to the age of the trees (young and not properly fruit bearing) which means that meaningful data was only collected from two properties. Feedback from the properties involved indicate that the App is useful and the ability to reduce the time and labour required to count early fruit is of great benefit. The difficulty in detecting small fruit at fruit set is still an issue and does impact on the accuracy of the predicted yield at harvest. However, the time saved by selectively targeting which trees are used for counting should enable producers to spend more time at each tree and thus improve overall accuracy.

Efficiency:

The project team managed the restrictions associated with COVID-19 well and improved the efficiency of project outputs (such as the counting strategy) and sharing data between UNE and Avocadoes Australia when opportunities were identified. There was also substantial (220 hours) of time provided in-kind by the subcontractor Circul8 to participate in the GATE 2020 program, as well as leveraging additional funding from the Rural R&D for Profit Project – Managing Tree Crops.

Relevance:

The project outputs are highly relevant to addressing several key challenges for the avocado industry which include:

- Accurate prediction of fruit yield at harvest to enable forward planning
- Improving the accuracy and availability of national data regarding production within growing regions for forward planning and industry response to biosecurity incident management and extreme events such as bushfire and adverse weather.

Appropriateness:

The approach used to engage with industry during the project to date have been appropriate given restrictions associated with COVID-19 and the nature of the App as an MVP. Moving forward increased engagement and communication with industry regarding the App is warranted and will provide useful feedback on its effectiveness at predicting fruit yield.

As a monitoring and evaluation exercise, both these reviews provided useful feedback to ensure the progress of the project was ‘as contracted’ and that the outcomes and outputs delivered were both relevant and beneficial to industry as well as adoptable. The findings overall were positive and as such confirmed industries support of the project.

Recommendations

Both the independent review by RMCG and participation through the GATE program enabled a number of recommendations to be derived through the mid and final stages of project AV18002. These have been provided in the final report as many are still relevant to future development and adoption of the outcomes and outputs from project AV18002.

Recommendations from the independent RMCG report:

#	RECOMMENDATION	TIMING	PRIORITY
1	Continue to refine and validate outputs to secure achievement of end-of-project outcomes		
1.1	CropCount App: Expand testing and validation of the App from Queensland to other major avocado producing regions in Western Australia and South Australia, as well as ensuring optimum tree age of 7–8 years amongst participating orchards.	3–6 months	High
1.2	CropCount App: Develop a structured process for testing and capturing feedback on the performance and functionality of the App, including handling, and incorporating of historic yield data.	3–6 months	High
1.3	CropCount App: Explore opportunities to further leverage levy investment through other projects and interest from potential international partners.	6–9 months	Medium
1.4	CropCount App: Use data from expanded testing, structured feedback process and potential investor interest to inform decision-making on whether to proceed with a commercially available App.	6–9 months	Medium
1.5	Web Map Apps: Continue updates to the six Web Map Apps to improve their accuracy and usefulness to the avocado industry and build on good progress to date.	6–9 months	Medium
1.6	Yield forecasting model: Continue to investigate the relationship between climate and yield to inform the remote sensing climate based yield prediction model through the current PhD candidate.	6–12 months	Medium

1.7	Refine the end-of-project outcomes in the program logic to be less-output focussed (e.g. delivering an MVP), and better link the intermediate outcomes and longer-term SIP Outcome 4 (e.g. improved decision-making and orchard management by producers using the CropCount App as a means of improving productivity, rather than focussing on the delivery of the App itself)	3–6 months	High
2 Increase the focus on industry engagement and extension			
2.1	Develop a stakeholder engagement and communication plan to more deliberately target key producers (e.g. industry champions that can advocate for the project and provide useful historic data and input) and industry stakeholders (e.g. PIBs, regionally important advisors) in the refinement and validation of the project outputs and to increase uptake of the outputs. This should include the use of existing industry (Avocado extension program) and government communication channels to amplify the reach of the project outputs.	1–2 months	High
2.2	Use the avocado extension program and other government channels to promote and engage industry in the outputs of AV18002. Holding workshops where producers can test and provide feedback on the App would be useful in determining future viability.	1–2 months	High
2.2	Shift focus from isolated applied research in Queensland to broader promotion and uptake of project outputs in all major avocado producing regions to maximise impact of the project investment.	6–12 months	Medium
3 Improve the robustness of project management arrangements to deliver value to industry			
3.1	Ensure the continuity and involvement of the Hort Innovation project manager with the UNE project team to better manage scope, strategic direction, and expectation of the project, including at the industry and producer level.	6–12 months	High
3.2	Extend timeline of project to allow team to capture data over one more season since the delay in procuring a mid-term review and decisions regarding the stop/go for the App has resulted in the 2021 season being 'missed'. This will also align with the timeline of the PhD candidate.	6–12 months	Medium
3.3	Improve the partnerships and collaboration of the Project Reference Group and Avocadoes Australia to refine and validate the project outputs and increase the two-way interaction with industry (e.g. sharing of historic data, awareness raising, increasing uptake).	6–12 months	Medium

Recommendations relevant to CropCount App provided from the GATE program:

Recommendations

Where to from here

Crop Count has been created with regular input from growers to continually validate it's value. Our next recommended steps for the platform are:

1. Collate and combine with accuracy reporting after pre-harvest and final harvest numbers are returned
2. Prioritise insights to determine future development. Suggested minimum priority features are:

APP

- Allow multiple counts per sample
- Improve display to allow for increased zoom if cluster method continues
- Add value to app including photo and notes functionality

DESKTOP FORECAST

- Development of desktop yield forecasts based on designs and feedback
3. Rollout improved platform (app and desktop) to a larger beta group of growers and wider stakeholder group (agronomists and industry bodies).



Commercialisation - work to do

Area	Strategy for making further progress <i>(be specific in WHY we need to undertake what strategy)</i>	Who is responsible?	What activities need to occur?	What resources are needed?	How long will it take?
Ecosystem Map	More research required to properly map and validate who they key players are (this was advised by GATE team and our coach David Ireland)		Interviews and research on agronomists, pack houses and additional growers, plus further exploration of potential competitors	2 people	Time investment of ~60 hours to organise and facilitate 12 interviews and transcribe insights into map and value proposition
Customer & Value Proposition	Review and further refine to validate assumptions for agronomists, packhouses and growers		Acquire more contacts for agronomists, packhouses, growers to conduct more interviews AA - possible opportunity for collaboration through member meeting?	2-3 people. Access to relevant growers to lead to agronomists and packhouse contacts	Combined with ecosystem map for research interviews + ~8 hours to refine VP.
Competitive Advantage	Build relationships to increase CA. Better understand competition.		Desktop research to understand competitors. Negotiate a deal with an image provider (consider all options).	1 person. Access to competitor systems (possibly need to pay to join up)	Time investment 16 hours to research competitors and analyse. Time to talk to image providers and possible partners
Business Model Canvas	Develop cost structure and revenue stream		Work out cost for next phase and ongoing costs. Interview growers to ask what value this adds/what they would be willing to pay? Identify what our assets/liabilities would be - what would our capitalization table look like (shareholders stake etc).	Commercialisation expert to drive this phase	Time investment of 3 months/1 day per week.
MVP	Investment funds to further develop MVP		Backend integration Front end yield displays Further infield testing - expand regions and target early adopter growers	Investment required for C8 to continue front-end development. Backend developers.	6-12 months development in response to interviews and research refining the VP.
Market Size	More research required		Research into market size of other crops domestically and internationally	1 person.	Time investment 16 hours to research other markets
Team	Discuss with Hort		Owners of product, Hort/UNE required to lead the commercialisation or invest \$ to pay someone to perform the role.	Dedicated person to drive investment negotiations and help build desired business model	

Area	Strategy for making further progress <i>(be specific in WHY we need to undertake what strategy)</i>	Who is responsible?	What activities need to occur?	What resources are needed?	How long will it take?
Financial Projections/Metrics	Need to demonstrate possible options with the information we have		Estimates on market uptake (domestic and international?) and resources required to deliver this. Gather more data through new trials.		
Pitch	Further refine/strengthen MVP (using data/insights from above actions) Additionally this could be simply about additional promotion and communication of the pitch/opportunity		Activities above to be completed - second phase to this could come in multiple forms, an edit of the video, creating of additional assets, explore a digital media campaign?		Existing pitch video is sufficient for now. As the project progresses marketing and communication plans will be required
Investor/Partner Relationship	Acquire a number of different interested parties/contacts to work with on potential investment/partnership		Look for ~6 more possible investors and build relationships		

National Mapping:

The establishment of the AAL hosted orchard map and the provision of the associated grower engagement tools have enabled the industry to maintain temporal currency of the map post project. However, to ensure complete accuracy into the future it is recommended that there is ongoing inclusion of remote sensing analytics, ground validation of newly established growing regions, maintenance of the web products and QAing of the map accuracy itself. AARSC are currently working with National Committee for Land Use and Management Information (NCLUMI) to establish a national plan to map all crops every 6 months, if successful this would provide one avenue where the currency of the Avocado tree map could be annually updated.

Block builder application

The 'Block-builder' application is another tool developed by AARSC that can also support on-going updating of the national map. The block-builder is currently being used by Citrus Australia under a new 'Traceability Project' (funded by AgVic) (Figure 30). Through this project Citrus Australia edit an 'industry only' map (in-house) which value-adds the essential information to support traceability at block level (e.g. ID, ownership, variety, planting year, etc). Importantly all feature services and apps are managed and secured under sign-in for access by industry only. The app delivers the capability for industry to spatially enable their tree census information and serves as an additional mechanism to inform on-going updates to the national map. Features at 'block-level' in the industry map can be aggregated, dissolved (relative to the scale of the national map), stripped of all attributes and then updated in the national map. It is recommended that the Avocado industry develop and adopt a similar application for improved traceability and biosecurity capabilities.

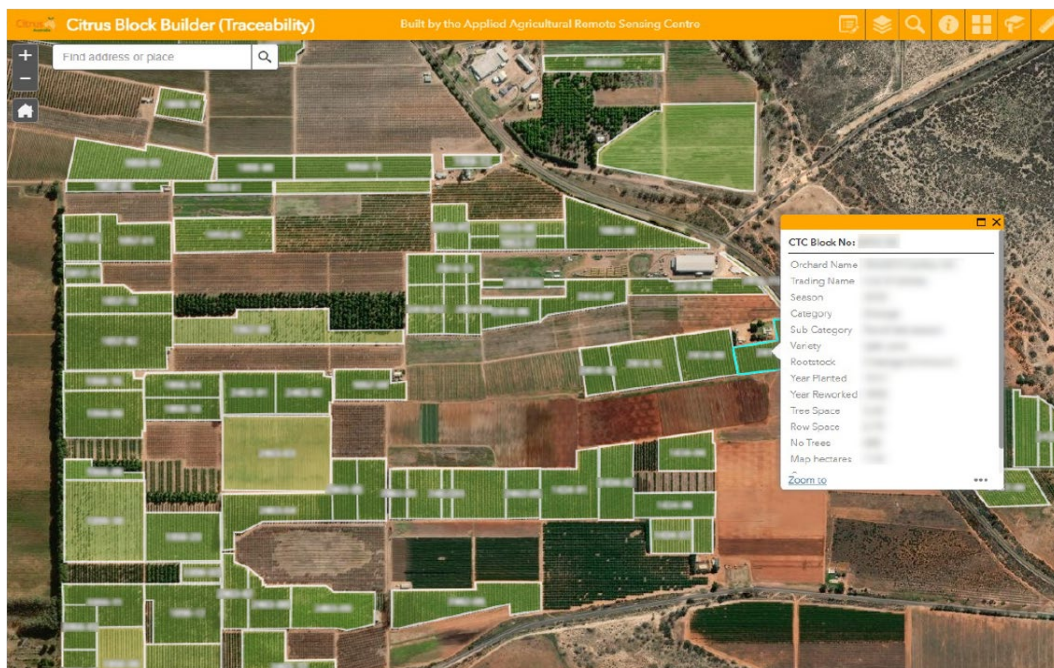


Figure 30: Block builder application as developed for Citrus Australia, showing attributes at block level

Yield forecasting

The accuracies of both the 'CropCount' and 'time series' methods have been very encouraging and well received by the avocado industry. As an example the COSTA group have contracted AARSC commercially to develop 'time series' models and associated forecasts for all their avocado crops nationally. Apart from this outcome strongly supporting the success of project AV18002, it does provide a highly beneficial pathway for establishing models across many Australian growing regions, varieties and managements. These models, in conjunction with those developed for other growers, will provide an unprecedented collation of industry data that will ultimately support the development of yield forecasting models at the regional, state and national level. This analysis and outcome is recommended for the further development of this research.

Whilst project AV18002 collected tree level temperature and relative humidity data to compare with individual tree yields, it was unable to run intensive analysis to determine its variation seasonally across an orchard and the possible relationship it has to yield potential. This was due to project being unable to find a PhD student and the success and ultimate demand of the 'time series' approach. The inclusion of climate information both at the regional level (e.g. BOM data) as well as the tree level and its potential relationship to yield potential (and fruit quality and disease susceptibility) is still of interest to the AARSC as it may assist in the refinement of yield forecasting models. Again this analysis and outcome is recommended for the further development of this research.

Refereed scientific publications

Project AV18002 intentionally did not publish outcomes achieved due to a commercialisation focus for the ‘CropCount App’ and subsequently the ‘time series’ approach. The public release of methodologies would render any potential IP invalid and would likely inspire many alternative versions of the Apps to be developed.

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Intellectual property

Part 1 -Pre-Existing/Background IP (BGIP) and Third Party IP (TPIP) to be used in the Project

Previous projects of the Parties:

BACKGROUND INTELLECTUAL PROPERTY (BGIP) AND THIRD PARTY INTELLECTUAL PROPERTY (TPIP) REGISTER								
No	Date (ie date on which details were initially listed and/or modified)	Owner(s) of BGIP or TPIP (If TPIP - list the name of the organisation which provided it)	IP Category (eg plant variety, gene, formulation, software, thesis, report, data etc)	Specific Description of IP	Nature of IP (eg copyright, patent, trade mark, design, PBR) Form in which the IP subsists (eg device, process, formulation, document)	Registration/ application details (if registered) (eg registration number, date of registration and expiry)	Intended purpose and value of the IP that is provided	Used or may be used for Commercialisation of Project IP (yes/no) and, if yes , how it is used
1	BASED ON PROJECT START DATE AND SCHEDULE	TPIP - MAXAR	SOFTWARE AND DATA	CLOUD PLATFORM USED FOR RUNNING ANALYTICS ON SATELLITE DATA	COPYRIGHT			YES – LICENCES ARE AVAILABLE. THIS MAY BE USED FOR RUNNING SCRIPTS ON WV3 SATELLITE IMAGERY TO PRODUCE RESULTS AT A CHEAPER COST COMPARED WITH THE

								PURCHASE OF IMAGERY AND THEN RUNNING SCRIPTS ON THE PURCHASED IMAGERY.
Details of restrictions on use (eg licence conditions, security conditions, encumbrances, confidentiality requirements, including any restrictions on publication of the BGIP/TPIP as part of publication of Project results and use of BGIP/TPIP which is part of Project IP): The IP can be used for commercial purposes with an appropriate licence issued by Digital Globe.								
2	BASED ON PROJECT START DATE AND SCHEDULE	TPIP – PLANET LAB	SATELLITE DATA API SOFTWARE AND DATA	API FOR ACCESSING SATELLITE DATA CAPTURED BY PLANET LAB	COPYRIGHT			YES – LICENCES ARE AVAILABLE. USED TO SEARCH AND DOWNLOAD APPROPRIATE SATELLITE DATA FOR ANALYSIS.
Details of restrictions on use: Use is determined by the type of account subscribed to.								
3	BASED ON PROJECT START DATE AND SCHEDULE	TPIP – EUROPEAN SPACE AGENCY	SATELLITE DATA API SOFTWARE AND DATA	API FOR ACCESSING SATELLITE DATA CAPTURED BY THE ESA	COPYRIGHT			YES – LICENCES ARE AVAILABLE. USED TO SEARCH AND DOWNLOAD APPROPRIATE SATELLITE DATA FOR ANALYSIS.
Details of restrictions on use:								
4	BASED ON PROJECT START DATE AND SCHEDULE	BPIP – UNE, AUSTRALIAN FEDERAL GOVERNMENT AND HORT INNOVATION AUSTRALIA	FORMULATIONS, PUBLICATIONS	NATIONAL , REGIONAL AND SUB REGIONAL ALGORITHM DEVELOPMENT OF YIELD FORECASTING MODELS FROM REMOTE SENSING AND SITE SPECIFIC WEATHER DATA. : METHODOLOGY FOR THE 'ON- THE-FLY' CALCULATIONS OF YIELD	COPYRIGHT			YES – LICENCES ARE AVAILABLE

				AT THE INDIVIDUAL CROP LEVEL AS WELL AS THE DERIVATION OF YIELD AND FRUIT SIZE MAPS.				
Details of restrictions on use:								

Part 2 - Intellectual Property to be developed (Project IP)

PROJECT INTELLECTUAL PROPERTY REGISTER							
No	Date (ie date on which details were initially listed and/or modified)	IP Category (eg plant variety, gene, formulation, software, thesis, report, data etc)	Specific Description of IP	Nature of IP (eg copyright, patent, trade mark, design) and the form in which the IP subsists (eg device, process, formulation, document)	Registration/ application details (if registered) (eg registration number, date of registration and expiry)	Intended purpose and value of the IP that is provided	Contains BGIP and/or TPIP (yes/no) and, if yes , description of the BGIP and TPIP
1.	SOFTWARE TO BE DEVELOPED BASED ON PROJECT START DATE AND SCHEDULE	SOFTWARE - APP	SOURCE CODE AND BESPOKE FRAMEWORKS DEVELOPED FOR THE AVOCADO MOBILE APP. SOURCE CODE CONTAIN CODES FOR BOTH IOS AND ANDROID PLATFORMS	COPYRIGHT - SOURCE CODE	UPON CODE CREATION, COMMITS AND DEPLOYMENTS.	THE SOURCE CODE OF THE AVOCADO APPLICATION	No
Details of restrictions on use of Commercialisation of Project IP (ie restrictions on BGIP and TPIP subsisting in Project IP):							
2.	SOFTWARE TO BE DEVELOPED BASED ON PROJECT START DATE AND SCHEDULE	SOFTWARE - WEBSITE	SOURCE CODE AND BESPOKE FRAMEWORKS DEVELOPED FOR THE AVOCADO WEBSITE	COPYRIGHT - SOURCE CODE	UPON CODE CREATION, COMMITS AND DEPLOYMENTS.	THE SOURCE CODE OF THE AVOCADO APPLICATION	No
Details of restrictions on use of Commercialisation of Project IP:							
3.	DESIGN TO BE DEVELOPED BASED ON PROJECT START DATE	DESIGN - UX AND CREATIVE	DESIGN, USER EXPERIENCE AND CREATIVE DIRECTION OF THE PLATFORM	COPYRIGHT	UPON DESIGN AND CREATIVE CREATION, COMMITS AND DEPLOYMENTS.	THE DESIGN, UX AND CREATIVE DIRECTION OF THE AVOCADO PLATFORM, WEBSITE AND APP.	No

	AND SCHEDULE						
Details of restrictions on use of Commercialisation of Project IP:							
4.	DEVELOPED BASED ON PROJECT START DATE AND SCHEDULE	PUBLICATIONS	METHODOLOGY AND ALGORITHMS SPECIFIC TO YIELD FORECASTING AND MAPPING IN AVOCADO	COPYRIGHT - DOCUMENT	UPON DEVELOPMENT OF IDEA, METHODOLOGY AND ALGORITHMS	METHODOLOGY AND ALGORITHMS FOR AVOCADO	NO

Acknowledgements

The project team acknowledge the extensive industry support and engagement in this project from Avocados Australia Ltd and many associated growers. The project team also acknowledge and greatly appreciate the undertaking and benefits of both the RMCG and industry midterm reviews. The project team acknowledge the participants of the project, especially Circul8, whom delivered well and truly above what was required in the project, and kept a positive and constructive engagement even through challenging times. Finally, the project acknowledge Hort Innovation for funding the project as well as the opportunity to participate in the GATE program.

Appendices

Project Media Captured

42 communications pieces that communicated the project and progress were captured from June 2021 till the conclusion of the project, April 29, 2022.

DATE	PROJECT COVERAGE	PRESS TYPE	PUBLICATION	ARTICLE	PUBLICAITON LINK
7/04/2022	AVOCADO	SOCIAL MEDIA	LinkedIn	Validation of fieldwork underway in WA	https://www.linkedin.com/feed/update/urn:li:activity:6917707874915823616
1/02/2022	AVOCADO	INDUSTRY MAGAZINE	Talking Avocadoes	Orchard Census Update	Summar 2022 edition page 17
22/09/2021	ALL PROJECTS	SOCIAL MEDIA	Twitter	A 3 year trail using sat imagery to predict mango yields in the NT nears completion	(@Hort_Au)
22/09/2021	ALL PROJECTS	SOCIAL MEDIA	LinkedIn	AARSC wins Maxar's Best Organization in Imagery Application Award.	https://www.linkedin.com/feed/update/urn:li:activity:6846296703239385088
22/09/2021	ALL PROJECTS	ONLINE ARTICLE	Geolmage	AARSC wins Maxar's Best Organization in Imagery Application Award.	https://www.geoimage.com.au/geoimage-congratulates-the-aarsc/
22/09/2021	ALL PROJECTS	E-NEWS	Geolmage	AARSC wins Maxar's Best Organization in Imagery Application Award.	sent out to Geo Image's email database
21/09/2021	ALL PROJECTS	SOCIAL MEDIA	Twitter	AARSC wins Maxar's Best Organization in Imagery Application Award.	(@geoimageAU)
1/09/2021	ALL PROJECTS	SOCIAL MEDIA	LinkedIn	Stem_Q Connecting research, industry and investment for people, place and purpose	https://www.linkedin.com/feed/update/urn:li:activity:6838706412739284992
27/08/2021	ALL PROJECTS	SOCIAL MEDIA	LINKEDIN	UNE'S vision for the Stem Q Quarter - Connecting research, industry and investment	https://www.linkedin.com/posts/uninewengland_what-is-unes-vision-for-stemq-activity-6836540717129621504-VOnC
11/08/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	Australian Tree Crop Map Dashboard wins first place	(@une_aarsc) Fresh Plaza
10/08/2021	TREE PHASE 2 and AVOCADO	ONLINE ARTICLE	Fresh Plaza	Australian Tree Crop Map Dashboard wins first place	https://www.freshplaza.com/article/9342771/australian-tree-crop-map-dashboard-wins-first-place/#.YRMHKXY4DHU.twitter
4/08/2021	TREE PHASE 2 and AVOCADO	ONLINE ARTICLE	Citrus Australia Industry News	Australian Tree Crop Map Dashboard wins gold on world stage	https://citrusaustralia.com.au/news/latest-news/australian-tree-crop-map-dashboard-wins-gold-on-world-stage
29/07/2021	TREE PHASE 2 and AVOCADO	Online News	North Queensland	Record oil volume from bumper Australian olive harvest	https://www.northqueenslandregister.com.au/story/7358711/ripper-olive-harvest-set-to-break-record/

			Register		
29/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	Ripper olive harvest set to break record	(@une_aarsc)
29/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AARSC Tree Crop Dashboard published in ArcGIS Living Atlas of the World	(@une_aarsc)
28/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	LINKEDIN	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.linkedin.com/posts/australian-mango-industry-association_innovation-research-achievement-activity-6825659692317057024-tBqA
27/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	LINKEDIN	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.facebook.com/australianmangoes
26/07/2021	TREE PHASE 2 and AVOCADO	E-NEWS	THE SLICE	Congratulations Craig and Joel	https://mailchi.mp/mangoes/the-slice-july?e=b5b6df3ad7
23/07/2021	TREE PHASE 2 and AVOCADO	ONLINE PUBLICATION	ArcGIS Living Atlas of the World	AARSC Tree Crop Dashboard published in ArcGIS Living Atlas of the World	https://www.arcgis.com/home/item.html?id=f6dd44763f0b476e8a1c2f0504fc8779
23/07/2021	TREE PHASE 2 and AVOCADO	e-news	Guacamole	Tree crop mapping efforts win global award	https://avocado.org.au/newsletter/guac-23072021/?utm_source=newsletter&utm_medium=email&utm_term=https%3A%2F%2Favocado.org.au%2Fnewsletter%2Fguac-23072021%2F&utm_content=Guac+23%2F07%2F202
22/07/2021	TREE PHASE 2 and AVOCADO	e-news	ESRI AUSTRALIA	Key highlights from the Esri UC	https://info.esriaustralia.com.au/acton/rif/19230/s-0db5-2107/-/l-124e7:68/l-124e7/showPreparedMessage?utm_term=Click%20here&utm_campaign=EsriUC2021_nature%20campaign_strike_1&utm_content=email&utm_source=Act-On+Software&utm_medium=email&cm_mmc=Act-On%20Software--email--Key%20highlights%20from%20the%20Esri%20UC--Click%20here&sid=TV2:zdm4rFlis
22/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	FACEBOOK	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.facebook.com/UniNewEngland/
22/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	FACEBOOK	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.facebook.com/RegionalUniversitiesNetwork/
22/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	FACEBOOK	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.facebook.com/uneagriculture/
17/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AWARD FOR TREE CROP MAP PUTS AUSSIE RESEARCH ON THE GLOBAL STAGE	(@une_aarsc)
16/07/2021	TREE PHASE 2 and AVOCADO	Online News	Australian Macadamia	AWARD FOR TREE CROP MAP PUTS AUSSIE RESEARCH ON THE	https://australianmacadamias.org/industry/news/award-for-tree-crop-map-puts-aussie-research-on-the

			Society News	GLOBAL STAGE	global-stage
15/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AARSC put *on the map* with *FIRST PLACE* in global conference	(@AvocadosAu)
15/07/2021	TREE PHASE 2 and AVOCADO	e-news	UNE NEWS STAFF LETTER 'PULSE'	International recognition for Remote Sensing Centre	
14/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AARSC put *on the map* with *FIRST PLACE* in global conference	(@esriaustralia)
14/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AARSC put *on the map* with *FIRST PLACE* in global conference	(@estrimalaysia)
13/07/2021	TREE PHASE 2 and AVOCADO	BLOG	UNE Connect	AARSC put on the map with first place in global conference	https://www.une.edu.au/connect/news/2021/07/aar-sc-put-on-the-map-with-first-place-in-global-conference
13/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	LINKEDIN	AARSC put *on the map* with *FIRST PLACE* in global conference	https://www.linkedin.com/feed/update/urn:li:activity:6820604552300105728
13/07/2021	TREE PHASE 2 and AVOCADO	SOCIAL MEDIA	TWITTER	AARSC put *on the map* with *FIRST PLACE* in global conference	(@une_aarsc)
23/06/2021	ALL PROJECTS	Discussion session Q&A with Angelica Suarez	How the pandemic has changed the IT- trends in the Agricultural sector	Discussion session, kind of Q&A to talk about how the pandemic has changed the IT- trends in the Agricultural sector, how can we improve the technological development and practices in Colombia.	https://www.youtube.com/watch?v=cUmwCGzXZ4
9/06/2021	AVOCADO	SOCIAL MEDIA	TWITTER	Avocado project fieldwork June 2023	https://twitter.com/jamesbrinkhoff
8/06/2021	AVOCADO	SOCIAL MEDIA	TWITTER	Avocado project fieldwork June 2022	https://twitter.com/jamesbrinkhoff
7/06/2021	AVOCADO	SOCIAL MEDIA	TWITTER	Avocado project fieldwork June 2021	https://twitter.com/jamesbrinkhoff
4/06/2021	AVOCADO	SOCIAL MEDIA	LINKEDIN	World-first yield forecasting technology offers avocado growers 93% accuracy	https://www.linkedin.com/feed/update/urn:li:activity:6806448196102041600
3/06/2021	AVOCADO	ONLINE ARTICLE	TREDE FARM MACHINERY.COM.AU		https://www.tradefarmmachinery.com.au/product-news/2105/yield-accuracy-boost-in-avocado-app
3/06/2021	AVOCADO	e-news	UNE NEWS STAFF LETTER 'PULSE'	Revolutionising avocado yield estimates	

3/06/2021	AVOCADO	SOCIAL MEDIA	LINKEDIN	World-first yield forecasting technology offers avocado growers 93% accuracy	https://www.linkedin.com/posts/andrew-robson-9666a658_world-first-yield-forecasting-technology-activity-6804681407122812928-IPxs
Jun-21	AVOCADO	ONLINE ARTICLE	GrowAG	World-first yield forecasting technology offers avocado growers 93% accuracy	https://www.growag.com/highlights/article/world-first-yield-forecasting-technology-offers-avocado-growers-93-accuracy?mkt_tok=NjQzLU5PRy0zMDAAAF9TtErVYsu_6xNvHedIsKa8Zl2sZ9SAMT34MRGGKSLYMmCXAllqKfleOF6GCinvKr4Dlyq03lv8SQdENxt9SY8HnZOjufGb9wNcuAq

See attached agenda: Project Update to SIAP as well as mid-term interviews with industry

AV18002 ‘Implementing precision agriculture solutions in Australian avocado production systems’

PROJECT UPDATE AND REVIEW

Zoom online meeting

11am – 1pm (AEDT) Monday 10 February 2021

<https://zoom.us/j/6138610874?pwd=QUZ5WmtYOWRRSnAvUm14TDdQVnpWUT09>

ATTENDEES

Georgia Sheil (Hort Innovation- Industry Strategic Partner), Bianca Cairns (Hort Innovation- R&D Manager), Byron de Kock (Hort Innovation- Head of R&D), Kristen Stirling (RMCG), Dimi Kyriakou (RMCG), Andrew Robson (UNE), Simon Grabbe (AV18002 participating producer- Simpson Farms), Matt Fealy (AV18002 participating producer- Blue Sky Produce), David De Paoli (AV18002 participating producer- AustChilli), Chris Searle (MacAvo Consulting), Chad Simpson (E.E. Muirs), Clayton Lynch (R&D SIAP), Dudley Mitchell (R&D SIAP), Kylie Colins (R&D SIAP), Simon Newett (R&D SIAP), Stewart Ipsen (R&D SIAP), John Tyas (Avocados Australia CEO and R&D SIAP), Jim Kochi (Avocados Australia QLD Director and R&D SIAP), Daryl Boardman (Avocados Australia Director QLD), Ian Tolson (Avocados Australia Director Central NSW), Brad Rodgers (Avocados Australia Director WA), Eric Carney (Avocados Australia Director Central QLD), John Walsh (Avocados Australia Director Central QLD), Kym Thiel (Avocados Australia Director Tristate), Robert Price (Avocados Australia Director Sunshine Coast), Tom Silver (Avocados Australia Director Tamborine and Northern Rivers)

APOLOGIES

Corrine Jasper (Hort Innovation- Head of Industry Strategic Partnerships)

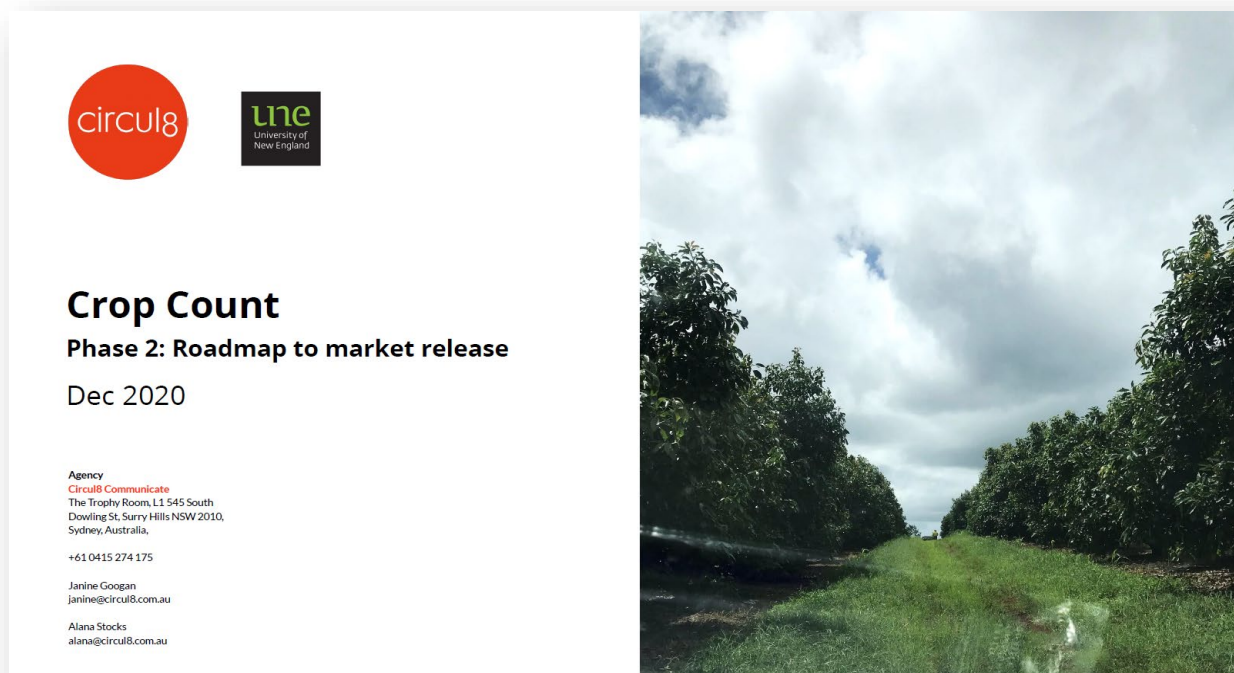
PURPOSE

- Update industry stakeholders of progress and achievements of AV18002
- Inform industry stakeholders of planned (future) activity for remaining duration of project
- Flag opportunities/challenges
- Seek industry feedback on project progress and outputs
- Discuss industry focussed communication and promotion of project outputs
- Identify priorities for future investment.

AGENDA

TIME	SUBJECT	WHO
11:00am	- Introductions - Background – drivers, objectives and timelines of project - Purpose – <i>why are we meeting today?</i>	Georgia Sheil (All) Bianca Cairns (HI)
11:15am	Project presentation: - Approach – <i>how was it done?</i> - So what? - <i>outputs, outcomes and industry impact</i> - Next steps - <i>what's planned for remainder of project.</i>	Andrew Robson (UNE)
11:35am	Q&A on presentation	Georgia Sheil (HI)
11:55am	Outline of mid-term review process	Kristen Stirling (RMCG)
12:05pm	Review of project to date: - To what extent has the project provided more accurate pre-harvest yield forecasting? - To what extent has the project provided information that will support improved decision making around forward selling as well as labour, transport and storage requirements? - How has the national map of commercial orchards supported the industry with improved biosecurity response and post disaster monitoring? - To what extent do the project outputs meet the needs of avocado producers and industry in general? - How has the avocado industry been informed of, and involved with, the project?	Kristen Stirling (RMCG)
12:35pm	Next Steps: - What value does industry place on the project outputs? - What should be the next steps? - Is additional investment to further develop the App of industry value? - Does industry see merit in conducting further testing of current version of App (in other locations etc)? - Is IP of importance to industry? Should international investment be sought to help fund further development of the App?	Kristen Stirling (RMCG)
12:55pm	Close	Georgia Shiel (HI)

CropCount Roadmap developed through the GATE program



Project overview

OVERALL OBJECTIVE	Provide the Australian industry with better methods to forecast and get a better understanding of crop yields			
PROJECT AIM	To develop and test the Crop Count prototype to be ready for distribution to market			
USERS	Large scale corporate avocado growers (+ 50 hectares)	Smaller scale mum & dad avocado growers (<50 hectares)	Agronomists	Industry data analysts
OUTPUTS	Automated and sustainable backend process	Tested value proposition	Additional features for Crop Count app based on insights	Distribution and business model

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Project aim

From prototype to market

Phase 1 has produced:

- CropCount iOS and Android mobile prototype app:
 - Farm login
 - Ability to see NDVI maps
 - Ability to see sample locations and use GPS to help locate them
 - Ability to collect count, weight and tree health data
 - Ability to collect multiple counts per sample location
 - Can work on or offline with syncing capability
- Initial brand: name, logo, font and colours
- Forecast: desktop wireframes and designs
- In field testing across 3 QLD farms which has produced insights to guide the next phase.

Phase 2 will take this prototype through the necessary development, research and testing to ensure it is ready to be distributed with a viable business model.



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Phase 1 insights

Summary of recommendations

The below points show insights/recommendations derived from Phase 1 research and testing. These points have been prioritised in the proposed roadmap for Phase 2.

- The importance of getting an accurate count from each tree is crucial to ensure accuracy. This is the most vital factor to get right and is also the most difficult.
- Confidence in the count is low
- Clustering is effective but needs further development to show in app
- Easy distribution across multiple devices would aid workflow
- Mismatching with existing farm labelling systems created extra work
- Allowing general data to be collected would be beneficial
- Forecast displays should be flexible and easy to export data



Commercialisation

Pathway to commercialisation

During **phase 1** we completed:

- Design sprint: 3 grower context interviews & prototype testing
- 2 x grower design testing interviews
- 1 x agronomist design testing interview
- 2 x grower follow up interviews after field testing

As part of **GATE 2020** we completed:

- 1 x agronomist interview
- 1 x interview with John Tyas (Avocados Australia)
- 1 x interview with Avo Aust data team
- Version 1 of ecosystem map
- Version 1 of value proposition canvas
- Version 1 of business model canvas
- Pitch deck
- Pitch video

Documentation:

<https://drive.google.com/file/d/1SPA3dju0lFu3YETzHFXoYLtoRoANlaca/view?usp=sharing>

Phase 2 involves further research, networking and business development. Further detail of commercialisation work required is in Appendix A.



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Progress

Past

5 years of trials

We've tested for 5 years across several farms to ensure that the scientific model can provide up to 93% accuracy

Done

Phase 1: App prototype

We have created a prototype which has been tested across 3 farms to put the science in the hands of the farmers

**Hort
Innovation**

Next

Phase 2: More farms / build backend

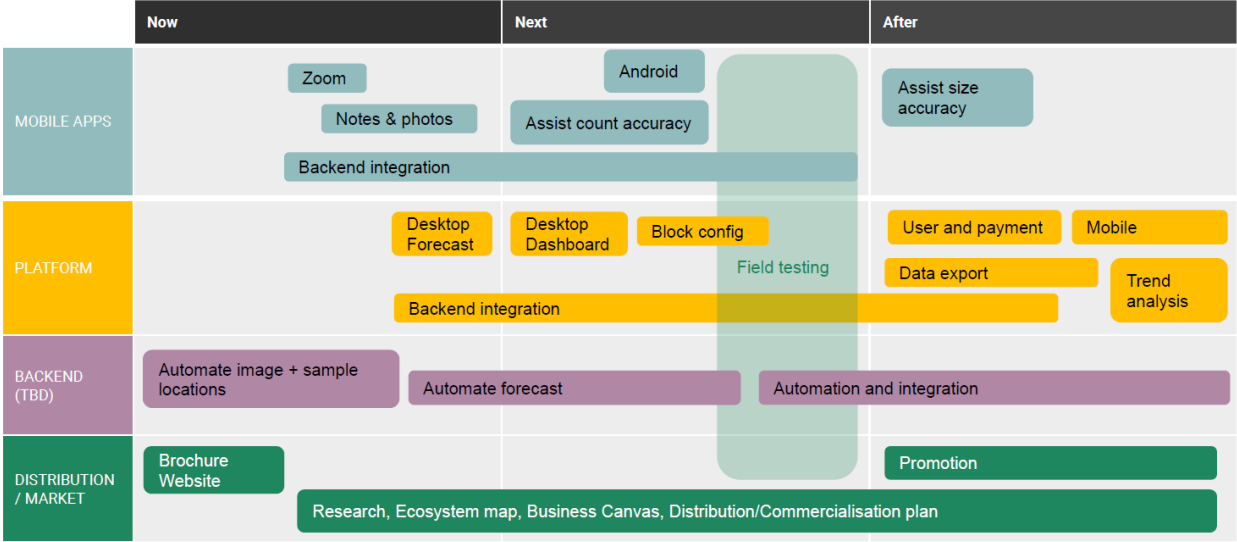
Development of components to automate backend and ensure scalability

Further field testing across 3 more farms, more regions and farm types.

See roadmap for more detail

Phase 2 Roadmap

This is a guide to show prioritised features. Each sprint will begin with sprint planning that allows refinement and adaptation as the project progresses. We estimate this work to be carried out over a period of 9 months to align with the commercialisation milestone requirement.



Phase 2 - Progression

Within a 9 month timeframe we will anticipate the following deliverables:

Now	Next	After
• Brochure website • iOS app improvements: ◦ zoom ◦ notes and photos • Desktop forecast per block • Integration to pull images and data for collection from backend BACKEND • Image processing • Sample locations • Integration to input directly to app	• App improvements: ◦ Assist count accuracy ◦ Android parity • Desktop forecast dashboard • Ability to configure to match farm labelling system • Integration to backend BACKEND (Automation) - Identify area of imagery required - Download preprocess subset imagery - Overlay data points - Extract canopy information - Develop algorithm from ground sampling points - Deliver forecast and derived yield fruit size map	• App improvements: ◦ Assist size accuracy • Mobile/Tablet display for forecasts • User registration and payment • Trend and history in dashboard • Engagement material for launch BACKEND - Testing application across multiple growing locations and farm - Commercialisation (licensing, partnership, startup, sell IP).

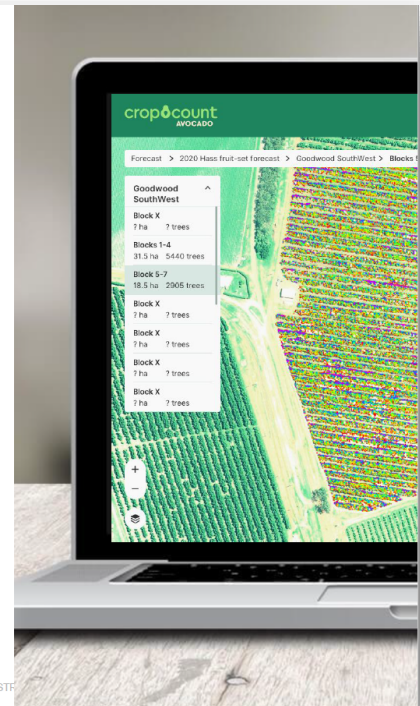
Distribution/Marketing

Website and engagement material

Marketing is about aligning the right distribution model with a promotion and engagement plan to target your primary users. The details of the distribution/business model are still to be determined, however we know that any model requires engagement material to reach the right audience.

We anticipate that a promotional website will be necessary for a market launch of Crop Count. Engagement material possibilities include:

- Promo video
- Webinar series
- Printable info sheets
- Case study content



Distribution/Commercialisation

A dedicated business development manager

Dedicated person to drive investment negotiations and help build desired business model.

Expected outcomes:

- Successful launch of Crop Count with distribution to Australian avocado industry
- Sustainable financial model/forecast for 2 harvests
- Interest in 1-2 other industries

Expected outputs:

- Ecosystem map
- Value proposition canvas
- Business model canvas
- Financial modelling showing projected revenue



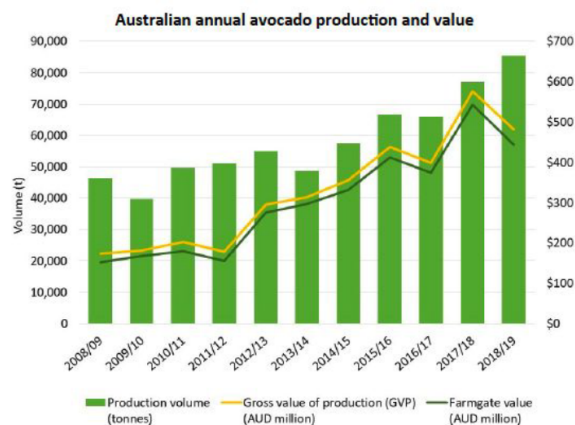
Distribution/Commercialisation

Australia first

Australia produced just over 85,546 tonnes of avocados in 2018/19, which was 11% more than the previous year. The gross value of production (GVP) for Australian avocados was estimated at \$483 million. **The primary goal for Crop Count is to give the Australian industry access and advantage.**

In 2018, a record 3.2 million tonnes of avocados are being harvested worldwide. Mexico remains the largest producer, with almost 1.9 million tonnes (60%) of the total. Other major producers of Hass avocados are Peru (13%), Chile (7%), California (5%), South Africa (4%), Colombia (3%), Israel (3%), Australia (2%) and Spain (1%).

From a commercialisation perspective a global outlook may be important.



Australia produced just over 85,546 tonnes of avocados in 2018/19, which was 11% more than the previous year. The gross value of production (GVP) for Australian avocados was estimated at \$483 million.

Source: Avocados Australia: Facts at a Glance 2018/19