Cartography gets a 21st century update

Forecasting has always been difficult for farmers, especially those growing fruit or nut crops. **Sandra Godwin** reports on Australian company Green Atlas, which has come up with a novel way to measure crops at different development stages, improving operational efficiency.

With so many variables at play during the season, it's traditionally been impossible for fruit growers to know how much fruit they can expect to pick come harvest time.

Gut feel, based on previous experience, is the most common form of forecasting, but it has significant limitations. These include the subjective nature of most observations and the inability of one person to be across everything that's happening to every tree at a particular moment in time.

Enter Cartographer (Fig. 1), an innovative combination of hardware and software which can be mounted on an ATV, developed by a trio of robotics engineers from the University of Sydney.

Green Atlas cofounders James Underwood, Steve Scheding and Peter Morton were researchers at the university's Australian Centre for Field Robotics, the world's second largest research centre of its type.

All three had worked across the defence, mining and logistics industries, before pivoting to agriculture.

James said it wasn't as crazy a change of tack as it might sound, given the commonality in sensing technology and algorithms used in those sectors.

"When I started out in agriculture a decade ago, we used algorithms that were developed in 'Defence' for tracking vehicles and things like that," he said.

"We used them to track cows coming out of a dairy and software that we use for scene understanding, pointing sensors at the environment and understanding what's going on. Similarly, we had developed defence applications we then used to recognise different trees."

James said their focus turned to row crops and tree crops and they built Ladybird, a multi-directional robot for the vegetable industry which later morphed into RIPPA, an autonomous high-speed spot sprayer of weeds.

Figure 1 Cartographer on the back of an ATV

They also built a robot, dubbed Shrimp, to trundle up and down orchard rows and collect information using radar, LiDAR and panospheric, stereovision, hyperspectral and thermal cameras.

Growers guiding research

One factor has been crucial to their success so far: every research project they embarked on was guided by the needs of growers.

"We would sit down around the table with researchers from different universities and industry reps and growers," James said.

"We would have these great conversations and then we'd do farm walks and chat about it further. This was to make sure the research was grounded in both what's feasible in an R&D sense, but also what is practical in terms of whether it was going to solve a grower need."

In 2018, they set up the company Green Atlas and began the process of commercialising Cartographer.

James said they were fortunate to have support from collaborators and were able to sign up their first paying clients "pretty much straightaway".

Early and continuing feedback has been helpful for expanding the machine's capabilities and improving its accuracy to the point where the company operates in almost all tree, nut and vine crops.

Green Atlas now has about 30 Cartographers in operation across Australia and New Zealand, as well as in Europe, the United States and South America.

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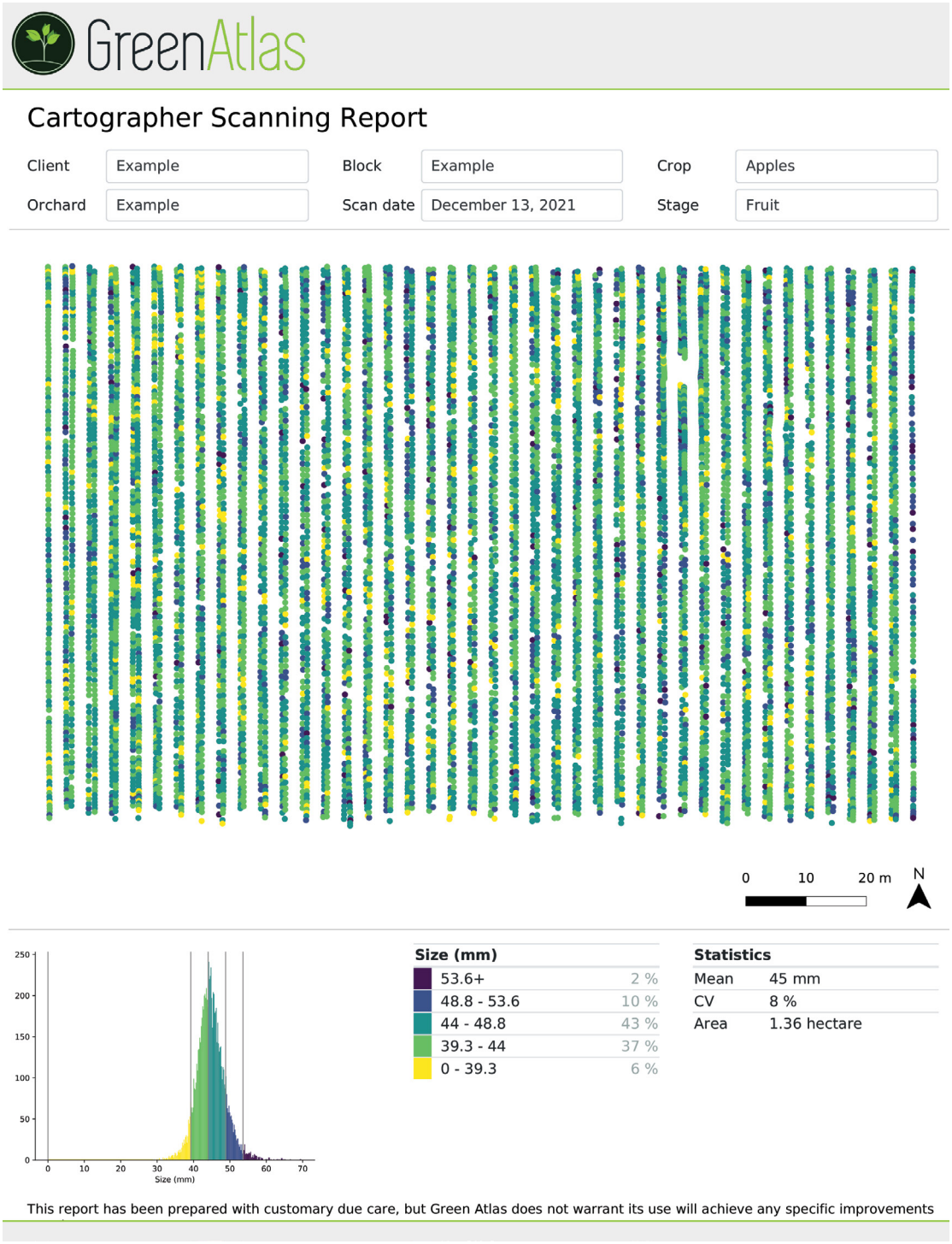

Figure 2 Apple fruit size report

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How does it work?

Cartographer is a device, usually mounted on an ATV or side-by-side vehicle, which photographs trees and vines from both sides at high speed – up to 50km/hr in almond orchards.

The camera has its own light source to ensure the photos are reliable in all conditions, whether it's night, day or the sun is high or low in the sky. More technical details of the camera, which has a patent pending, are not yet publicly available.

Cartographer combines the camera's high resolution RGB photos with information from a LiDAR sensor and GPS data to generate maps showing a range of features of interest: from tree and vine height, canopy area and density, to flower, fruitlet and fruit size and density, as well as weeds and symptoms of pests and diseases.

The maps can be used as a guide to the performance of different blocks, identify variability and help growers better understand the differences between the upper and lower canopies.

"We try to be relevant all the way through the growing season in different stages," James said.

As an example, flower maps can be used to drive the spray program for apple growers using chemicals to thin potential crop loads.

A flower map will show areas that need heavier thinning, which can be sprayed manually, or it can be plugged as a prescription map into smart variable rate spraying equipment that will automatically apply more or less spray volume where it's needed.

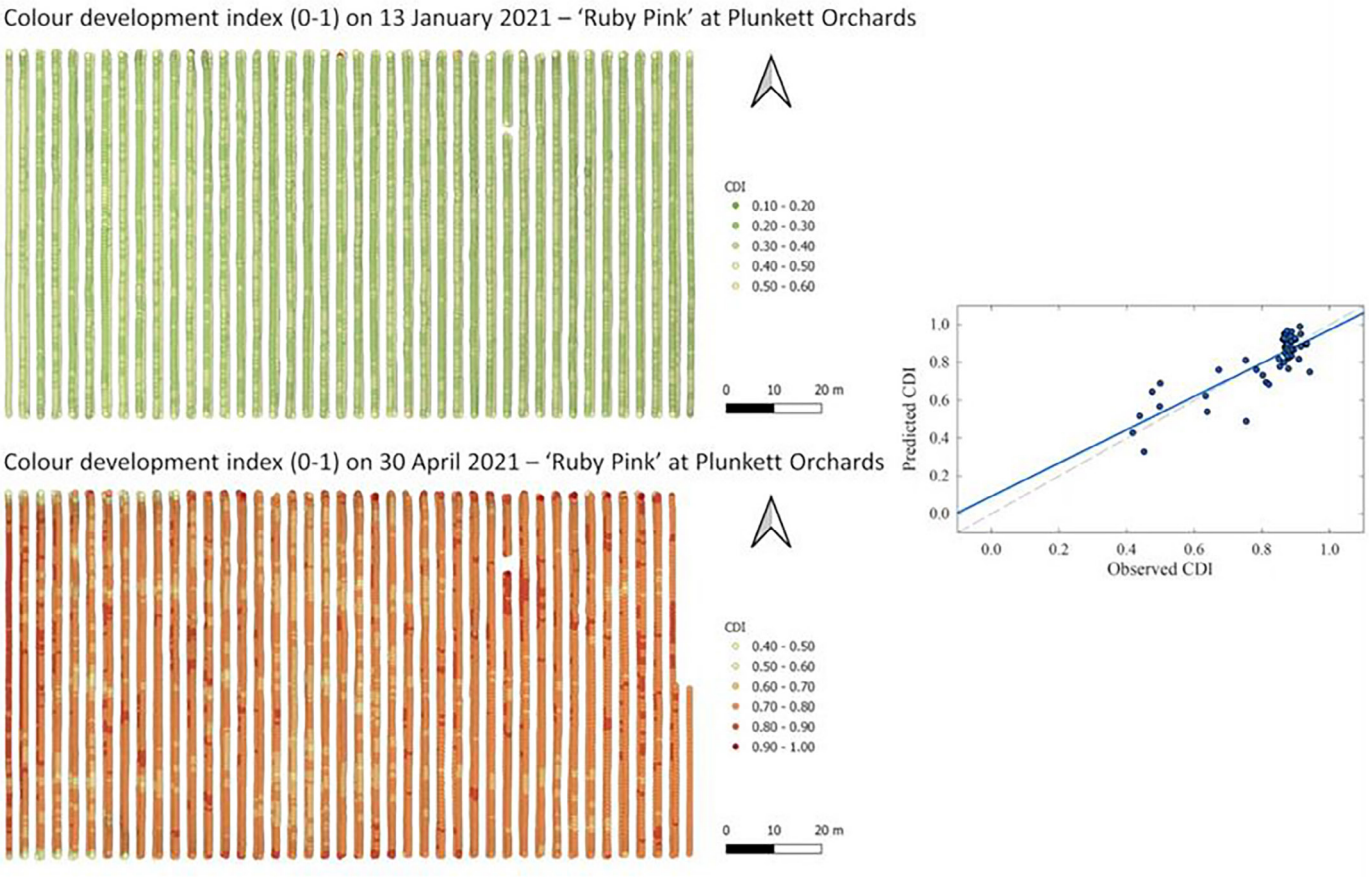

Figure 3 Colour development index Agriculture Victoria

Later in the season, yield estimates – using individual fruit diameter (Fig. 2) and colour (Fig. 3) as a proxy for how close to harvest fruit is – can provide guidance for planning labour needs during the picking, packing and marketing phases.

"In all those cases, the detection software is built using tens of thousands of previously photographed examples that are 'baked in' to it and runs each time a new scan is processed," James said.

"At the same time, although we are detecting individual fruit et cetera, no technology can literally see all the fruit, because a percentage of it is hidden behind foliage. So this type of system can't just count what it sees and declare that to be the yield, or it would undercount by too much."

James said the most accurate yield estimates were obtained by manually counting fruit at three locations in a block and comparing that to the data collected by Cartographer from those areas.

"This tells us about the extent to which fruit is hidden, allowing the whole block total estimate to be corrected for that," he said.

"So now the calibrated maps and estimates are indicating specifically 107 fruit here, and 247 there, etc. Conventionally without Cartographer, people might field-count a few dozen trees in three areas, then take the average count, and multiply it by the total number of trees they have, to estimate the total yield.

"Even with perfect field counting, this could be out by more than 50 per cent, because the average of those dozens of counted of trees is not equal to the average of all trees in the block.

"With our system, for yield estimation you still need to count those trees, but because we have scanned every single tree throughout the whole block, including those field-counted trees, we know exactly how these trees relate to all of the rest. Combined, this leads to an accurate yield estimate."

Fruit counting accuracy at the commercial block level is typically +/- 5 per cent, for apples, pears and stone fruit. As for return on investment, James said that was always of interest, but not something that could be quantified "in real dollar terms".

"ROI arises not from just receiving our data, but from actioning it," he said.

"When people adopt the tech and make the changes to their operations to reap the benefits, they can't compare to 'what if' they did it the old way, because they've stopped doing it the old way.

"Theoretically they can compare the old way in previous years to the new way in the current year, but seasonal changes also affect profitability each year so it's never a like-for-like comparison."

James said they'd love to see hard data on ROI which would allow them to give potential customers an even more compelling reason, but in its place they look at levels of repeat custom and churn.

"The vast majority of our systems are fully commercially used," he said.

"And the vast majority of end users (farms) who are paying for and using the system in their operations continue to do so year on year, meaning even though it's hard to measure the ROI directly, they are seeing the value in it, and putting their money where their mouth is."

One of their most successful products has been mapping mummy nuts in almonds, the nuts left on the tree after shaking which can be a host for disease and food source for pests.

"We provide them with maps of the mummified nuts, which allows them

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Scanner provides a big picture view

Figure 4 Plunkett Orchards manager Jason Shields inspects Ruby Matildas

As one of the first Australian fruit growers to embrace Cartographer, Plunkett Orchards manager Jason Shields (Fig. 4) was looking for a way to gather more information to identify potential problems or confirm they were making the right decisions.

Plunkett Orchards is one of the Goulburn Valley's biggest fruit growers, with about 200ha of orchards in production at Ardmona, west of Shepparton.

They produce mostly apples: Pink Lady, Granny Smith, Royal Gala, Sundowner, Rocket and Kanzi varieties.

The orchard has been transformed over a period of 15 years to a multileader tree system to promote more uniform fruit quality and make mechanisation easier.

Workers now use elevated semi-automated work platforms for pruning trees, and thinning and picking fruit.

Jason is constantly on the lookout for new ways to improve efficiency and hosts numerous research trials, including a three-year project from 2020-2023 by Agriculture Victoria examining the accuracy of Cartographer in measuring new metrics, including fruit colour.

The work was part of PIPS3 Program's Advancing sustainable and technology driven apple orchard production systems (AP19003) project. The project was funded by Hort Innovation using grower research and development levies, contributions from the Australian Government and investment by Agriculture Victoria which bought a Cartographer unit.

In 2021-22, Jason used Cartographer across the Granny Smith and Pink Lady apples for its first full season.

The block was scanned in December before thinning and in April before harvest, with accuracy of 93 per cent and 94 per cent, despite relatively high variability in fruit numbers.

The first thing it identified from flower mapping was two "part rows" that had been missed during pruning.

Later in the season it provided estimates of yield and fruit size profiles.

"This was good because it helped us make decisions based on which blocks we had the best size in and where we needed to pick first, how many pickers we'd need and how many bins we'd need," he said.

As a large scale grower, with a wide harvest window for the two varieties, Jason said the maps were also useful for suggesting where they could best target application of growth regulators, such as Harvista, to delay ripening, reduce fruit drop, and allow smaller fruit to keep growing for another three or four weeks.

The major benefit of fruit mapping was having the "big picture", something that was impossible to get from driving up and down a few rows at a time.

"I had been driving around my Granny Smiths before we sent the scanner through," he said. "I'd drive through one day and go 'Everything's small' then a week later 'It's all good' and then I'd drive it a week later and go 'No, it's small again'. It all depended on which row you drove down. I'm thinking I might have 15 rows of light trees and 15 rows of heavy trees in the same block; maybe I should be just picking half a block at a time. But the map didn't come back like that. It told a different story to what my eyes were telling me."

Scanning for fruit colour also picked up the difference between a row in an Agriculture Victoria crop load experiment and the rest of the Pink Lady block where a mechanical defoliator had been used to remove leaves to help the fruit develop its trademark pink blush.

"The picture showed there was just one row that had bad colour," Jason said. "We'd ribboned it off and told everyone they can't drive down that row, so we didn't defoliate it. The difference was amazing."

Summer storms seriously affected fruit production so Cartographer was not used by Plunkett Orchards this year. However, given the positive results from the Agriculture Victoria trial, Jason remains keen to further explore the benefits and costs of the Cartographer technology in future.

"I think there's so much potential in this, it's really exciting," Jason said.

"But to effectively use new technology, robots et cetera, we need to have a consistent canopy, a consistent yield throughout the block, and this technology is helping us to do that."

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to streamline their labour for orchard sanitation and removal," James said.

In macadamias, Cartographer can detect fruit on the tree and on the ground, as well as the invasive parasitic weed mistletoe, which is an emerging pest in macadamia orchards in NSW and Queensland.

It also has been used to map the presence of leafroll virus and snails in vineyards and identify blocked irrigation sprinkler emitters.

The Green Atlas team is currently working on ways to detect fire blight in overseas pome fruit orchards – the disease is not yet present in Australia but is well established in New Zealand, Asia, Africa, North and South America, and Europe – and damage from leaf curling midge in apples, as well as mapping and quantifying hail damage for insurance assessments.

Green Atlas won Best in Horticulture at the 2023 Australian Agritech Awards in June.

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