IRRIGATION BEST PRACTICE

WATER USE OPTIMISATION

PROJECT 1717C

Australian Wine Research Institute

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Final Report

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Project title: Irrigation Best Practice – Water Use Optimisation

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1. PROJECT OVERVIEW

Irrigation is an increasing cost for most Riverland wine grape growers, and in conjunction with poor irrigation practices, can threaten the financial viability and the social license of one of the region's major horticultural industries. The region contributes to the prosperity of the Australian wine sector; Riverland is home to 14.4% of all wine grape vineyards and produces ~23% of all wine grapes in Australia; this represents an annual export value of $900 Million per annum. Wine grape growers continue to make significant productivity improvements, although there is constant pressure to identify further efficiencies. At $400 per ML and an average of 7.5 ML/ha applied in a typical season, irrigation can easily represent a third or more of production costs if purchased on the open market.

Many vineyard irrigation systems perform at a sub-optimal level, with a critical problem being the wide variability in flow rate from individual drippers within an irrigation valve unit. This reduces the efficiency of irrigation systems and results in more water being required to maintain productivity than would be the case if the irrigation system performance were in line with accepted standards. An accepted standard is +/- 5% variation in flow rate across the valve unit.

Hornbuckle et al. (2012) showed that non-uniformity of dripper discharge rates had a significant effect on the total volume of irrigation water applied to vineyards over a season. In Griffith, a dripper discharge variation of 23% was measured across a vineyard, which corresponded to some vines receiving 3.1 ML/ha over the season while other vines received 5 ML/ha. In Tatura, a dripper discharge variation of 60% variation was measured across the vineyard, which resulted in some vines receiving 1 ML/ha while others received 6 ML/ha. Given that yield increases of 1.6 to 3.7 t/ha have been measured with 1 ML/ha of additional irrigation (McCarthy et al. 1992), the potential yield loss from uneven distribution uniformity is considerable.

Despite the importance of even distribution uniformity, a survey on irrigation practices of inland wine regions conducted in Dec 2021 by the AWRI found that 28% of respondents never check the distribution uniformity of their dripper output, 21% have never performed any pump maintenance, 17% have never performed any pressure checks across their irrigation system, 17% have never flushed their driplines and 11% have never cleaned their filters. Addressing variability represents a significant opportunity for growers to improve irrigation practices, providing insulation by decreasing ongoing water requirements; it will also improve overall profitability in the face of high-water prices in the inevitable drought years.

2. PROJECT EXTENSION MATERIALS

This project produced a range of extension materials. The extension activities generated by this project are captured in the tables below:

- Table 1: electronic content
- Table 2: written material
- Table 3: workshops

A summary of the project outcomes has been sent via email to all workshop participants and all Riverland winegrape growers via Riverland wine with a link to the project report, case studies, videos, webinar and podcasts described in the tables below. Further adoption of project outcomes will be facilitated via website content, additional seminars and workshops.

Table 1. Extension video, webinar and podcast content

Presenter/ author	**Format**	**Theme/title**	**Link**	**Views**
Jeremy Giddings	Webinar	New tools and practical techniques for monitoring and maintaining drip irrigation systems	New tools and practical techniques for monitoring and maintaining drip irrigation systems - YouTube	763 views
Jeremy Giddings*	Video	Drip irrigation monitoring	https://youtu.be/CtCUh7W23Lg	478 views
Jeremy Giddings*	Video	Drip irrigation maintenance	https://youtu.be/sOzUo9Cgr9I	612 views
Mark Skewes*	Podcast	Optimising vineyard irrigation – current research	https://www.awri.com.au/industry_support/courses-seminars-workshops/podcast-awri-decanted/	~450 views each
Kim Chalmers*	Podcast	Using less water in a warming climate	https://www.awri.com.au/industry_support/courses-seminars-workshops/podcast-awri-decanted/	

***** Additional content developed above the requirements of the Landscapes SA Vineyard water optimisation project agreement to extend the learnings of the project to Australian winegrape growers.

Table 2. Extension written material

Staff	Format	Title	Link
Robyn Dixon (AWRI)	Case Study	Vineyard Water Optimisation Case Study – Limestone Ridge Vineyard, Riverland SA	See Appendix 4.1 Water management - The Australian Wine Research Institute (awri.com.au)
Robyn Dixon (AWRI)	Case study	Vineyard water optimisation case study – Sherwood Estate, Riverland SA	See Appendix 4.2 Water management - The Australian Wine Research Institute (awri.com.au)
Mark Skewes (SARDI) Paul Petrie (SARDI)	Report	Vineyard Irrigation Best Practices Optimisation Project	See Appendix 4.3

Table 3. Workshops

Date	Location	Format	Title	Agenda	Participants
17 May 2022	Loxton	Face to Face workshop	Irrigation efficiency: getting the most out of every drop	Program_Riverland.pdf (awri.com.au)	50 participants across 2 workshops (the workshops and project were promoted via local media channels (ABC rural news, ABC country hour).
18 May 2022	Renmark	Face to Face workshop	Irrigation efficiency: getting the most out of every drop	Program_Riverland.pdf (awri.com.au)	

3. REFERENCES

Hornbuckle, J., Christen, E.W., Car, N.J., Smith, D., Goodwin, I., McClymont, L., Kerridge, B., 2012. Drip irrigation distribution uniformity in vineyards of Australia: Tools for mapping and estimation of impacts. Acta Horticulturae 931, 119-125.

4. APPENDICES

4.1 CASE STUDY #1

Vineyard water optimisation case study – Sherwood Estate, Riverland SA

Background

Sherwood Estate manages 200 hectares of winegrapes in the Riverland, South Australia, comprising 17 varieties. Chardonnay and Shiraz are the backbone of the business, along with Cabernet Sauvignon, Pinot Noir and the Mediterranean variety, Bianco d'Alessano, which is well suited to the hot and dry climate of the Riverland.

Sherwood Estate is operated and managed by the third and fourth generations of the Proud family, Brett, Andrew and Brayden. The Proud family, who have been farming in the Riverland for almost 100 years, are continually evolving their practices to improve the long-term sustainability of their vineyards and wine brand.

The Proud family know only too well how vital irrigation water is to the sustainability of their vineyards. The average annual rainfall in Loxton is less than 300 mm, meaning that vines growing in the region are totally reliant on irrigation water sourced from the Murray River. When irrigation water is restricted, as it was during the millennium drought, yields can be significantly reduced. When water prices are high, irrigation can easily represent one-third or more of production costs if purchased on the open market.

Irrigation practices within the region

A survey on irrigation practices of inland wine regions conducted by the AWRI in December 2021 found that, like Sherwood Estate, 85% of growers in the Riverland have moved away from flood and furrow irrigation to more efficient drip irrigation systems (AWRI, 2022). Drip irrigation systems require regular monitoring and maintenance to keep them working efficiently. However, survey results show that 28% of respondents never check the uniformity of their dripper output, 17% have never performed any pressure checks across their irrigation system, and 17% have never flushed their driplines. In comparison, Sherwood Estate regularly maintains its irrigation system throughout the season and as a result, has been able to maintain consistent emitter outputs across its vineyard – a key step towards making sure every vine in the vineyard gets the amount of water it needs.

> "Irrigation is crucial to Sherwood Estate's viticulture, therefore investment in irrigation technology and basic maintenance like dripper tube cleaning and flushing is 'normal'."
>
> Brett Proud

This case study explores the practices that Sherwood Estate employs throughout the year to keep its irrigation system performing at its best and ensure winegrape quality and productivity are maintained for the sustainability of the business.

Sherwood Estate's irrigation infrastructure and maintenance

Sherwood Estate, like most winegrape growers in the Riverland, sources its irrigation water from the Murray River via an irrigation trust. Access to river water is critical for sustainable winegrape production in the Riverland but the river water brings with it both suspended clay and organic material. It is therefore essential to have effective filtration infrastructure and a regular maintenance program to avoid emitter blockages.

At Sherwood Estate, the main filters are automatically flushed during operation as well as being thoroughly cleaned manually twice a year. The backup filters and dripper tube are cleaned at least four times a year, twice with hydrogen peroxide and twice with water following the flushing procedure outlined in the AWRI irrigation maintenance video. Hydrogen peroxide helps to remove organic matter from the system while regular flushing with water helps remove clay. In years of high flows from the Darling River, when sediment levels are much higher, additional back-up filter and drip tube flushing is necessary.

It takes approximately 40 labour hours for Sherwood Estates to complete one sub-main and dripper tube flush over 200 ha. This is a significant time commitment, but Brett explains that the performance of the irrigation system would be seriously compromised if the filters and dripper tube were not cleaned and maintained, commenting that "The ability of Sherwood Estates to deliver high quality winegrapes to our customers is put at risk if the irrigation system is compromised".

Conclusions

Sherwood Estate invest in technology which enables the operations team to have excellent control over the vineyard and the quality of the winegrapes produced but they haven't forgotten the basics. "It would be pointless to have invested into precision viticulture technology while at the same time have drip tubes and back-up filters blocked with sediment and organic material", says Brett. Brett explains that maintaining filtration infrastructure and flushing drip tubes is integral to maintaining the productivity of Sherwood Estate's vines and the quality of the winegrapes produced. Ultimately, the sustainability of Sherwood Estate's business depends on good water management with good irrigation maintenance being key.

Find out more

For more information and resources on irrigation monitoring and maintenance, including two 'how to' videos, visit the AWRI's water management webpage.

Acknowledgement

This work was funded by Landscapes SA. The AWRI and SARDI would like to thank Brett Proud for taking part in the benchmarking project and and for generously sharing his knowledge and experience regarding irrigation monitoring and maintenance.

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Vineyard water optimisation case study – Limestone Ridge Vineyard, Riverland SA

Background

Brian Caddy has been farming in the Riverland for almost 60 years. In 1973, Brian established Limestone Ridge Vineyard on his Riverland property, first planting Cabernet Sauvignon and then four years later Chardonnay, one of the first Chardonnay plantings in the region. The Chardonnay has now been grafted over to Fiano – a Mediterranean variety well suited to the Riverland climate.

Growing winegrapes in a region where the average annual rainfall is less than 300 mm, Brian has a deep understanding of the importance of good water management. During his time as a winegrape grower in the Riverland, he has experienced water restrictions as well as significant fluctuations in grape and water prices.

During the 2021/22 season, Brian participated in a SARDI/AWRI irrigation emitter uniformity benchmarking project funded by Landscapes SA, and the results were surprising. This case study explores Brian Caddy's current irrigation system monitoring and maintenance program, his vineyard's emitter uniformity results and changes he is planning to make to his monitoring and maintenance program as a result of these results.

Brian's irrigation water for winegrape production is sourced from the River Murray. The water is generally high quality but brings with it suspended clay and organic material. Brian, like 85% of the winegrape growers in the Riverland, converted from furrow irrigation to drip irrigation. This conversion, undertaken in 2004, significantly improved his water use efficiency but regular maintenance is required to keep the system working efficiently.

Brian Caddy 's irrigation infrastructure and maintenance

Limestone Ridge has an 18-year-old irrigation system with pressure-compensating drippers which is maintained with an extensive annual maintenance program. The quality of the water determines how often Brian needs to flush the system. In high-flow years, the amount of silt and organic matter in the river water increases and additional flushing is required. "If I don't flush enough, then my drippers will become blocked and inefficient" says Brian.

Brian's irrigation maintenance program involves flushing his irrigation sub-mains and laterals with hydrogen peroxide ten times during the season. He follows the flushing procedure outlined in the AWRI irrigation maintenance video, which is a three-stage process involving thoroughly flushing the mains, sub-mains, and laterals with water; injecting hydrogen peroxide into the system and leaving the solution in the lines for 1-2 days; and then flushing the system again with water.

The pre-and post-hydrogen peroxide water flushes take two hours and cost approximately $43.98 (Electricity cost: 8.9 kWh @ 26.576 cents per kWh = $23.65. Water cost: 81 kL @ $25.10 ML = $20.33). Brian reduces his irrigation maintenance costs by flushing his irrigation lines on the weekend when off-peak power is cheaper.

With the increased inflows into the Murray River system due to La Niña weather conditions and full dams upstream, Brian is anticipating a drop in river water quality. To manage this, he is currently installing an automatic injector in the main line, just after his filters, to automatically inject hydrogen peroxide into his irrigation water during each irrigation application.

In addition to grafting to more heat tolerant varieties and installing automatic hydrogen peroxide injectors to improve the water use efficiency of his vineyard, Brian is also refurbishing his pump house, installing a variable speed pump, additional filters, stainless steel piping and new electronics. "All this to try to minimise our power use and have a more flexible and efficient irrigation system", says Brian.

Benchmarking project results

Despite Brian's extensive irrigation maintenance program, results from the SARDI/AWRI irrigation emitter uniformity benchmarking project revealed that the system was performing below standard, with high pressure variation (90%) and high flow variation (23%). In a high-performing system, there will be less than 10% variation in dripper discharge throughout the value unit (±5%). In a system operating with 25% variation, some vines may be receiving 11.5% less water than they need, and others may be receiving 11.5% more irrigation. Under-irrigation can cause yield reductions and over-irrigation can cause nutrient leaching and losses of water through deep drainage.

Pressure-compensating drippers are designed to provide the same discharge over a wide pressure range. They are effective at reducing and controlling dripper flow at high pressures but cannot increase the flow if pressures are too low. After some investigation, it was discovered that the pressures were very low (65 kPa), which increased the flow variation. When the pressures were adjusted to 174 kPa the irrigation system performance improved significantly.

Table 3 Limestone Ridge irrigation emitter uniformity benchmarking project results

	Pressure variation (%)	Flow variation (%)
Limestone Ridge Pre-check	90	23
Limestone Ridge Post-check	34	6

Conclusions

The results of this benchmarking project highlight the need for both good irrigation system maintenance and system monitoring. In response to these results, Brian has implemented an irrigation system monitoring procedure following the guidelines of Giddings (2004) outlined in the AWRI irrigation monitoring video. The monitoring procedure involves checking dripper pressures and flows at several points in each block, at regular intervals throughout the season, and adjusting the pressures as required to maintain consistent flows.

Find out more

For more information and resources on irrigation monitoring and maintenance, including two 'how to' videos, visit the AWRI's water management webpage.

Acknowledgement

This work was funded by Landscapes SA. The AWRI and SARDI would like to thank Brian Caddy for taking part in the project and for generously sharing his knowledge and experience regarding irrigation monitoring and maintenance.

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4.3 REPORT – VINEYARD IRRIGATION BEST PRACTICE OPTIMISATION PROJECT

Vineyard Irrigation Best Practice Optimisation Project

Report to Landscapes SA

Vineyard Irrigation Best Practice – Optimisation Project

Information current as of 30 June 2022

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Introduction

Irrigation is an increasing cost for most Riverland wine grape growers, and if combined with poor irrigation practices, can threaten the financial viability and the social license of one of the region's major horticultural industries. The region contributes to the prosperity of the Australian wine sector; the Riverland is home to 14.4% of all wine grape vineyards and produces ~23% of all wine grapes in Australia; this represents an annual export value of $900 million per annum. Wine grape growers continue to make significant productivity improvements, although there is constant pressure to identify further efficiencies. At $400 per ML and an average of 7.5 ML/ha applied in a typical season, irrigation can easily represent a third or more of production costs if purchased on the lease market.

Many vineyard irrigation systems perform at a sub-optimal level, with a critical problem being the wide variability in flow rate from individual drippers within an irrigation valve unit. This reduces the efficiency of irrigation systems and results in more water being required to maintain productivity than would be the case if the irrigation system performance were in line with accepted standards. An accepted standard is +/- 5% variation in flow rate across the valve unit.

Hornbuckle et al. (2012) showed that non-uniformity of dripper discharge rates had a significant effect on the total volume of irrigation water applied to vineyards over a season. In Griffith, a dripper discharge variation of 23% was measured across a vineyard, which corresponded to some vines receiving 3.1 ML/ha over the season while other vines received 5 ML/ha. In Tatura, a dripper discharge variation of 60% was measured across the vineyard, which resulted in some vines receiving 1 ML/ha while others received 6 ML/ha. The authors also showed a correlation between irrigation volume across the vineyard and NDVI from satellite imagery, which in turn could be expected to influence yield and fruit quality.

Despite the importance of emission uniformity, a survey on irrigation practices of inland wine regions (Dixon, 2021) found that 28% of respondents never check the uniformity of their dripper output, 21% have never performed any pump maintenance, 17% have never performed any pressure checks across their irrigation system, 17% have never flushed their driplines and 11% have never cleaned their filters. Addressing within-valve variability represents a significant opportunity for growers to improve irrigation practices, providing insulation by decreasing ongoing water requirements; it will also improve overall profitability in the face of high-water prices in the inevitable drought years.

Methodology

Twelve vineyards in the Riverland of South Australia were audited to assess variability across the vineyard in emitter pressure and flow rate, and variation from the design flow rate of the system. Comparisons with system age and maintenance information were also undertaken to identify any correlations with system performance. The methodology was very similar to that used in a previous study in Almonds (Skewes, 2020).

Vineyards (and candidate valve units) were identified as part of a parallel Wine Australia funded project that was benchmarking irrigation performance over a full irrigation season in terms of annual water use, drainage, yield and fruit quality. The aim of this broader project was to highlight the management practices of the best performing irrigators in the inland wine growing regions.

Table 4 Site details

Site Code	System Type	Press Compensating	Area of Unit (Ha)	Vine Age (Yrs)	System Age (Yrs)	Dripper Output (L/h)	Application Rate (mm/h)
001A	Drip	Y	6.8	5	5	2.3	1.16
002A	Drip	Y	3.7	19	16	1.0	1.1
003A	Drip	Y	3.1	18	1	2.2	1.1
004A	Drip	Y	3.2	18	18	2.0	1.1
006A	Drip	Y	10.5	5	5	1.6	0.9
007A	Drip	Y	2.5	4	3	2.2	1.1
009A	Drip	Y	4.9	19	3	2.3	1.28
012A	Drip	Y	1.7	20	5	2.3	1.1
040A	Drip	Y	1.2	17	4	2.3	1.13
042A&B	Drip	Y	1.7	12	18	2.3	1.05
058A	Drip	Y	3.3	18	18	1.6	0.87
066A	Drip	Y	1.0	40	15	2.4	1.22

Table 4 Details of the irrigation systems at each site from which system performance measurements were collected. All of the systems tested were pressure compensating drip irrigation systems. There was a wide spread of system age (1 to 18 years) and dripper output rate (1.0 to 2.4 L/h). Application rate, the product of dripper output divided by spacing (across row and within row) ranged from 0.87 to 1.28 mm/h.

Irrigation System Performance

The audit required the collection of flow rate (L/h) and pressure (kPa) from at least nine emitters across each valve unit. A valve unit consists of all pipework and emitters downstream of a single control valve, and which therefore run as a unit when that valve is opened; for this reason, the uniformity of application within a valve unit is critical to applying water evenly across a vineyard.

The pressure and flow rate figures were used to calculate variation in pressure and flow (±% of the highest and lowest readings from the midpoint), and coefficient of uniformity of flow rate (%) across each valve unit evaluated. These indicators have specific standards accepted across the irrigation industry, so each valve unit can be compared to these standards, and its performance rated as within or outside of the relevant standard.

For each valve unit on which an irrigation audit was conducted, additional information was collected about the irrigation system specifications, including dripper model and design flow rate, dripper spacing between and along rows, and design application rate. This allowed comparison of the average flow rate measured with the design/nominal figure for each system. This difference was expressed as percent variation from the nominal figure.

In addition, at some sites the flow rate (L/h) of a complete lateral was measured and compared with the theoretical flow rate of the lateral based on lateral length, dripper spacing and nominal dripper flow rate. The result was also expressed as percent difference from the nominal figure.

Whilst carrying out the system evaluations, data from one site revealed very low system pressures, leading to excessive variability in flow rate due to most of the emitter pressures being outside of the recommended operating range of the pressure compensating emitters used. This situation was remedied by the property owner adjusting the pressure regulator on the valve controlling the unit, prior to and a second evaluation. Both sets of data from this site (042) are presented in the results below (042A is the initial evaluation, 042B is the second evaluation with higher system pressure).

Correlations with Irrigation System Age and Maintenance

Each property manager was asked to provide additional information about the maintenance schedule in place on their property, including sub-main and lateral flushing programs, fertigation practices and chemical (acid, chlorine) dosing programs.

The data on system age and frequency of maintenance activities (flushing and dosing) was plotted against flow rate variation, with the aim of identifying correlations between system age or maintenance and irrigation system performance. Linear correlation trend lines were drawn onto the graphs to illustrate the relationship.

Data presented in the comparison graphs includes only the second evaluation from site 042, as the initial evaluation was greatly influenced by the low system pressure, and inclusion of this data skewed the results relative to other factors such as system age and maintenance.

Spatial Crop Health Data

Multispectral and thermal imagery were collected from each of the twelve vineyards by CERES Imaging on January 19th, 2022, using cameras mounted on a light plane. NDVI and water stress imagery was derived from this base data, providing a spatial presentation of the uniformity of vine size and vine stress levels across each valve unit. High variability between vines may be a result of changes in soil type, vine health or issues with irrigation system emission uniformity.

Emitter pressure and flow rate measurements were superimposed over this imagery to assist in identifying correlations between irrigation system performance and variability in NDVI and/or water stress. In the case of site 042, the initial test results are displayed, as they represent the situation at the time of the capture of the imagery.

Each image and the overlaid system performance data were visually assessed to identify any obvious correlations between system performance and crop health/vigour as displayed in the imagery.

Results and Discussion

Irrigation System Performance

The results of the uniformity tests conducted on each of the valve units are presented below in a series of graphs. In each case the sites have been sorted from poorest performance on the left to best performance on the right.

The data has been collected under a guarantee of anonymity, so the sites are not identified by location or owner/manager. Instead, site codes are used to identify each site as an aid in comparisons between different graphs, and to allow the site managers to identify their own data.

Variation in emitter pressure at each site (blue bars) is presented in *Figure 1*, along with the performance standard for maximum variation of ±10% (orange line). The variation in emitter pressure represents the percentage variation of the highest and lowest readings relative to the midpoint reading. The standard of <±10% indicates that the highest reading is no more than 10% higher than the midpoint reading, and the lowest no more than 10% below this reading.

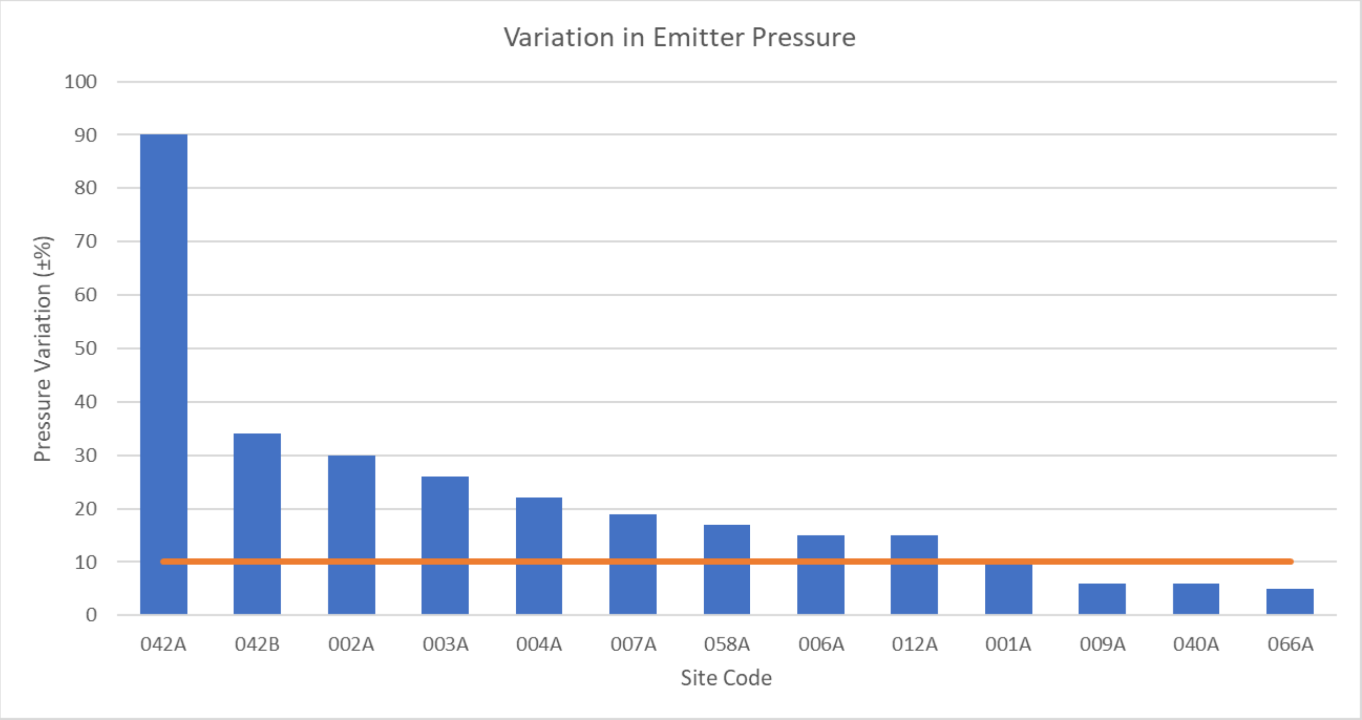

Figure 1 Variation in emitter pressure within a valve unit, performance standard (orange line) is less than ±10%

Only 4 of the 12 sites had pressure variation equal to or less than the standard, with all other sites exhibiting greater variability than is desirable.

However, all the dripline installed at these sites is pressure compensating. This means that pressure can vary quite widely, within specified bounds, and the flow rate of the emitters will remain very similar. In this sense the pressure variation shown here is of no consequence to the variability of dripper outputs. What is important is that the pressures are within the specified operating range for the dripline.

There are two readings for site 042, labelled A & B, both in this figure and the following figures. Readings labelled 042A represent the initial measurements for this site. On this occasion it was identified that the pressures measured within the valve unit were very low, many of them being below the specified operating range for the dripline installed at this site. The grower adjusted his valve settings to increase the pressure in the valve unit, and a second set of readings were collected (042B). This increase in pressure also resulted in more even pressures across the valve unit.

Figure 2 displays variation in emitter flow rate, which directly impacts the uniformity with which irrigation water is delivered to individual vines within the vineyard. As above, this represents the variation of the highest and lowest readings from the midpoint, and the standard is shown as an orange line, in this case at ±5%.

Despite the use of pressure compensating dripline, which should result in even output from all emitters across a wide range of emitter pressures, only 2 sites achieved the standard of <±5%. This is only two less than the number that were out of specification for pressure variation (see *Figure 1*). Another eight sites showed variation of up to ±10%, with three sites above this level. Note that at Site 042 the variation declined from 23% (042A) to 6% (042B) following the increase in system pressure into the correct operating range for the emitters.

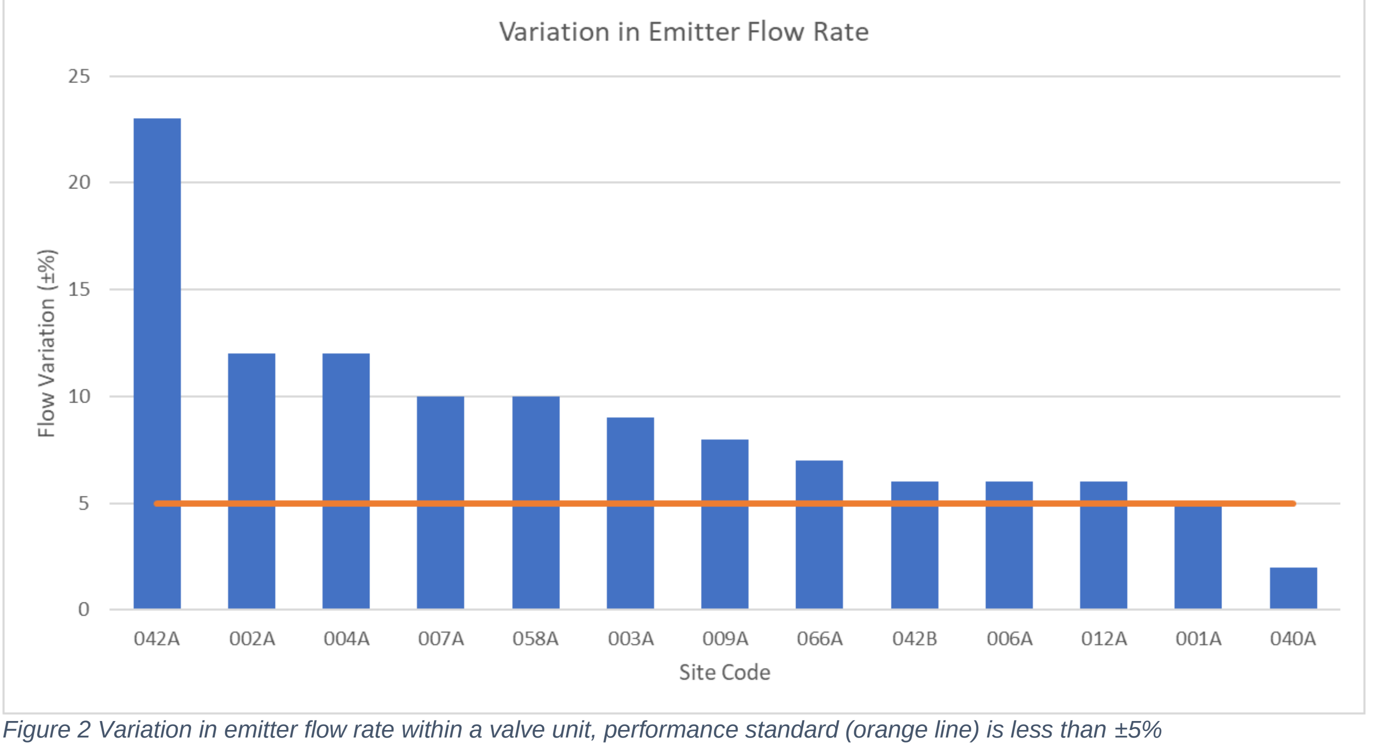

Figure 2 Variation in emitter flow rate within a valve unit, performance standard (orange line) is less than ±5%

The most likely explanation for the high variation in flow rate at so many sites is partial and/or complete blockage of emitter flow paths, resulting in high or low flow rate of individual emitters relative to their design flow rate.

Reduced flow rates can clearly result from partial blockage of flow paths, as restricted flow paths increase resistance to water flow. However, partial blockage of emitters can also lead to increased flow rates in pressure compensating emitters, by interfering with the operation of the pressure compensating diaphragm. This diaphragm works by pressing down on the flow path and restricting flow as the pressure in the dripline increases. Therefore, material trapped under the diaphragm can prevent it from pressing down on the flow path, leaving the flow path unrestricted and allowing flow rate to vary with variation in pressure.

The observation of individual emitters dribbling or squirting instead of dripping is an obvious sign of this occurring. This was observed at some of the sites evaluated here.

Coefficient of uniformity (*Figure 3*) measures the overall uniformity across all measurements of flow rate, with 100% indicating absolute uniformity (all flow rates equal), and lower numbers indicating greater variation in flow rate amongst emitters. One recognised standard for coefficient of uniformity is greater than 90%.

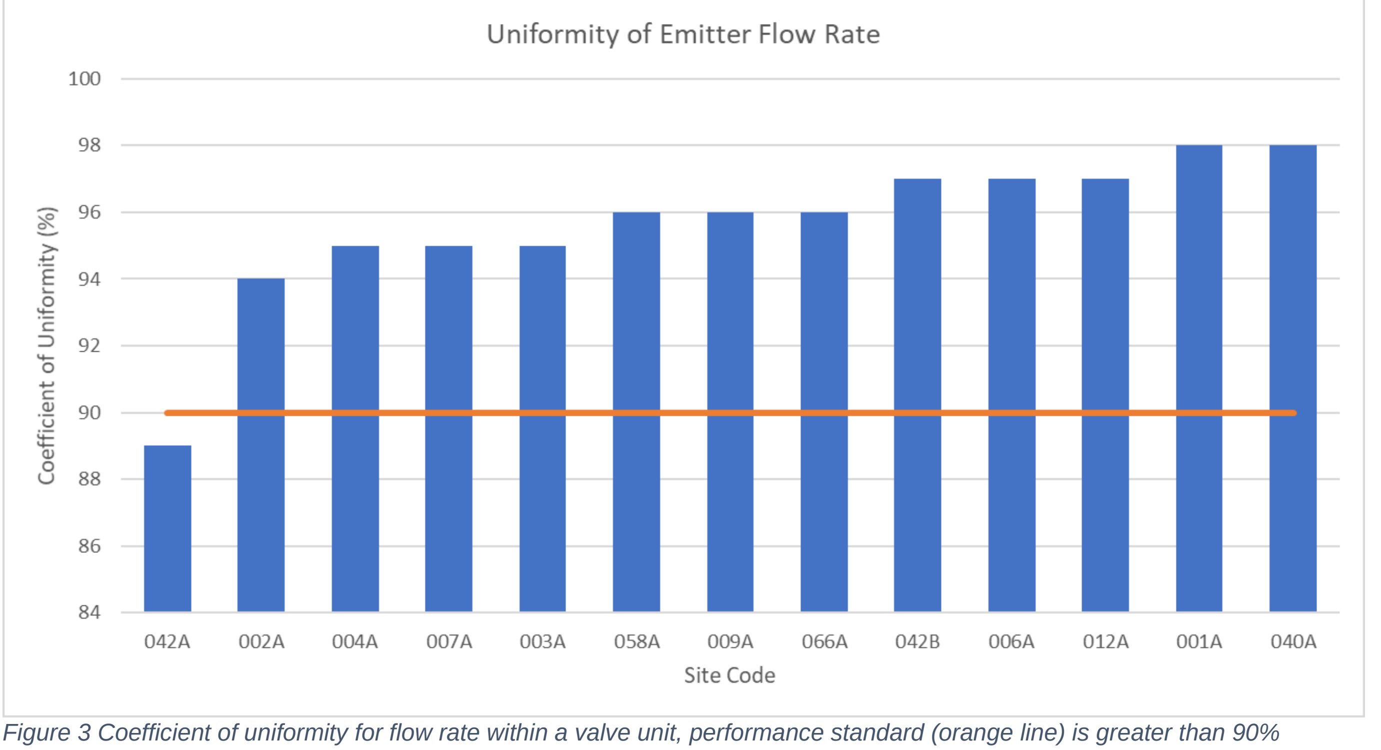

Figure 3 Coefficient of uniformity for flow rate within a valve unit, performance standard (orange line) is greater than 90%

All but one of the sites measured in this study achieved this standard (*Figure 3*), and the poor performing site was initially assessed to have very low pressures (042A). After this issue was addressed the performance of this site was within the standard (042B).

This figure suggests that all these sites performed well, in direct contrast to the conclusions reached from the data for flow variation (*Figure 2*), where almost all sites did not meet the performance standard. This difference reflects the difference in the calculation of these two indicators. Percent variation in flow highlights only the highest and lowest readings, and therefore accentuates any variability within the valve unit. Coefficient of uniformity measures the average variability across all readings taken, and as a result the maximum and minimum values have much less influence on the result.

As an indicator of problems with the irrigation system, percent variation (*Figure 2*) is much more sensitive to issues at individual emitters, whereas coefficient of uniformity (*Figure 3*) is more indicative of overall performance across all emitters. The good apparent performance of most sites in this study against coefficient of uniformity (*Figure 3*) should not distract from their poor performance against percent variation (*Figure 2*). The difference between the two indicators simply highlights that the issues for most of these sites are a few high and/or low flow rates within the valve unit, suggesting that emitter blockages are the most likely cause.

Variation of average flow from the nominal flow rate (*Figure 4*) indicates how the measured flow rates compare to the specified flow rate of the emitters used. In a pressure compensating system (as used at all sites) the flow rate of each emitter should be very close to the nominal flow rate as long as the pressure at those emitters is within their specified operating range.

Eight of the 13 assessments returned average flow within 5% of the nominal value (*Figure 4*). The use of ±5% in this data set does not reflect an established standard, rather it is used as an informal comparison based on the ±5% standard for flow variation referred to above.

Of those sites exceeding ±5% variation from nominal flow rate, three show average flow rate just over 10% higher than the nominal value (009A, 066A and 002A). This may reflect a high number of partial blockages leading to higher flow from emitters, consistent with the higher flow rate variability at these sites (*Figure 2*).

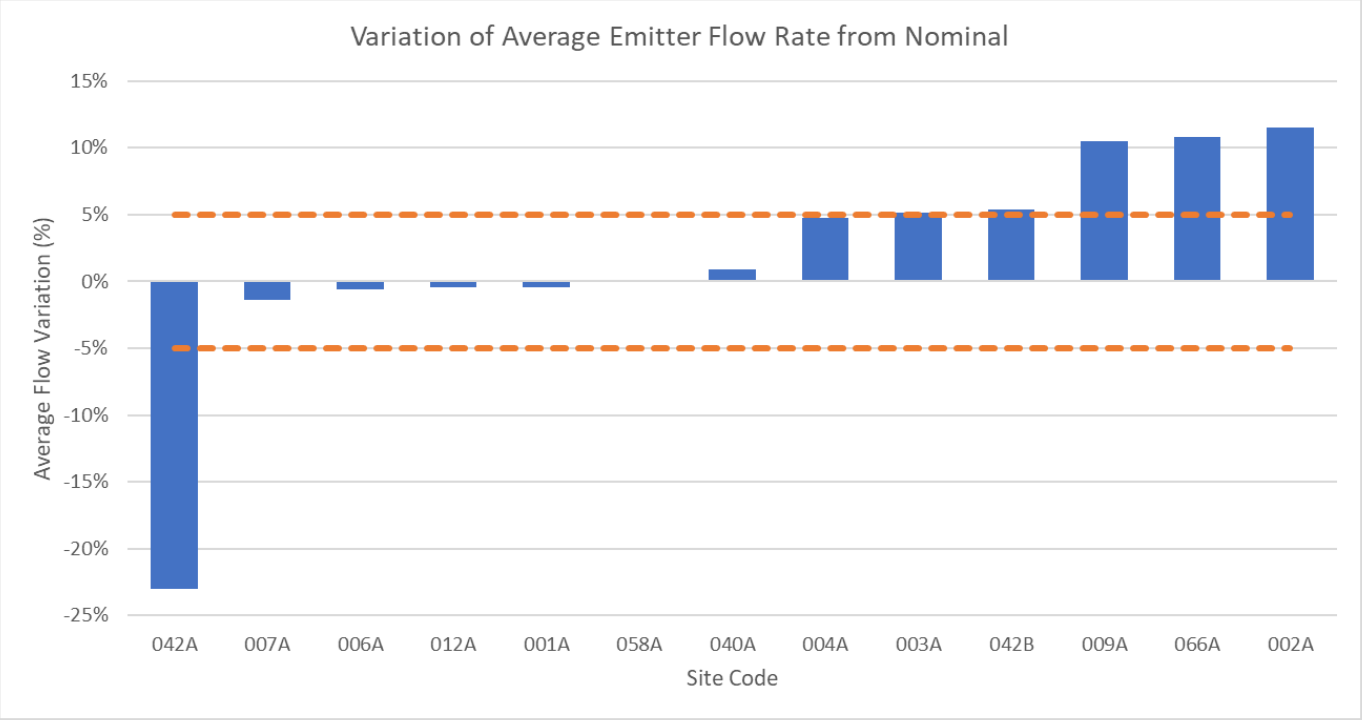

Figure 4 Variation in average measured emitter flow rate from nominal flow rate, 5% lines as a guide

The site showing an average flow rate that was well below nominal (042A) is the site that had very low system pressure at the initial assessment. This directly explains the low flow rate, as most of the pressures measured were well below the specified operating range for the emitters. It is interesting to note that in the subsequent assessment, after the pressures were increased (042B), the average flow rate was slightly more than 5% higher than nominal, demonstrating the impact of the initial low pressures even more clearly.

Variation of lateral flow rate from nominal (*Figure 5*) is a very similar measure to variation of average flow from nominal (*Figure 4*). The difference is that rather than comparing flow rates from individual emitters across the valve unit, the flow rate of a whole lateral is measured and compared to the calculated nominal flow rate of that lateral, based on the nominal output of the emitters multiplied by the number of emitters in the lateral (estimated by emitter spacing and lateral length).

The general pattern of data in *Figure 5* is very similar to that in *Figure 4*, noting that site 042A (very low pressure, average flow rate well below nominal) is not represented in *Figure 5*. Most of the sites are within ±5% of the nominal figure, with three sites outside of that range.

The performance of specific sites did vary between the two measures. For example, of the three sites whose average measured emitter flow rate is >5% above the nominal figure (*Figure 4*), only one (002A) shows measured lateral flow rate >5% above nominal. The other four sites show quite different performance between the two different methods of comparing measured performance against nominal.

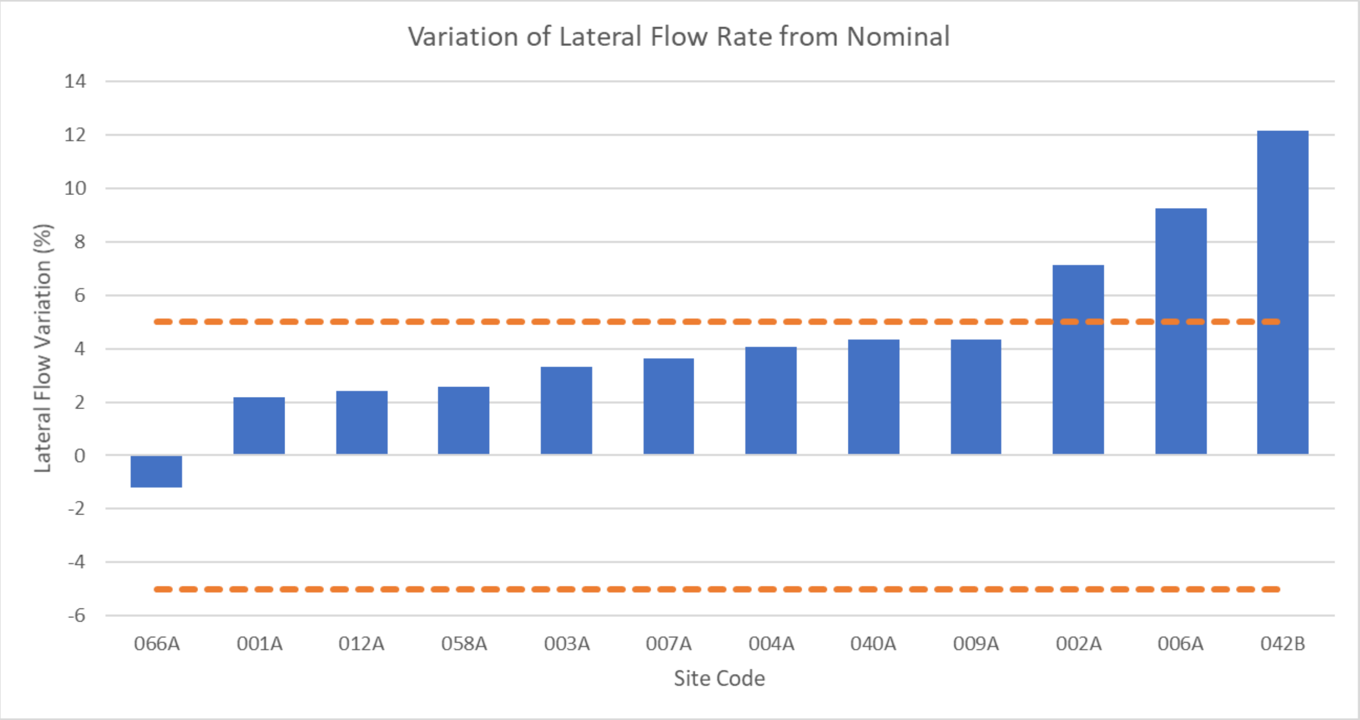

Figure 5 Variation in measured lateral flow rate from nominal lateral flow rate, 5% lines as a guide

This highlights that there is no one test which is completely comprehensive in defining the performance of an irrigation, apart from testing every single emitter, clearly not an option in a drip irrigation system. Regular testing using a number of different methods (randomly selected individual emitters as well as whole lateral tests for example) will give the best opportunity to identify issues at the earliest opportunity.

Correlations with Irrigation System Age and Maintenance

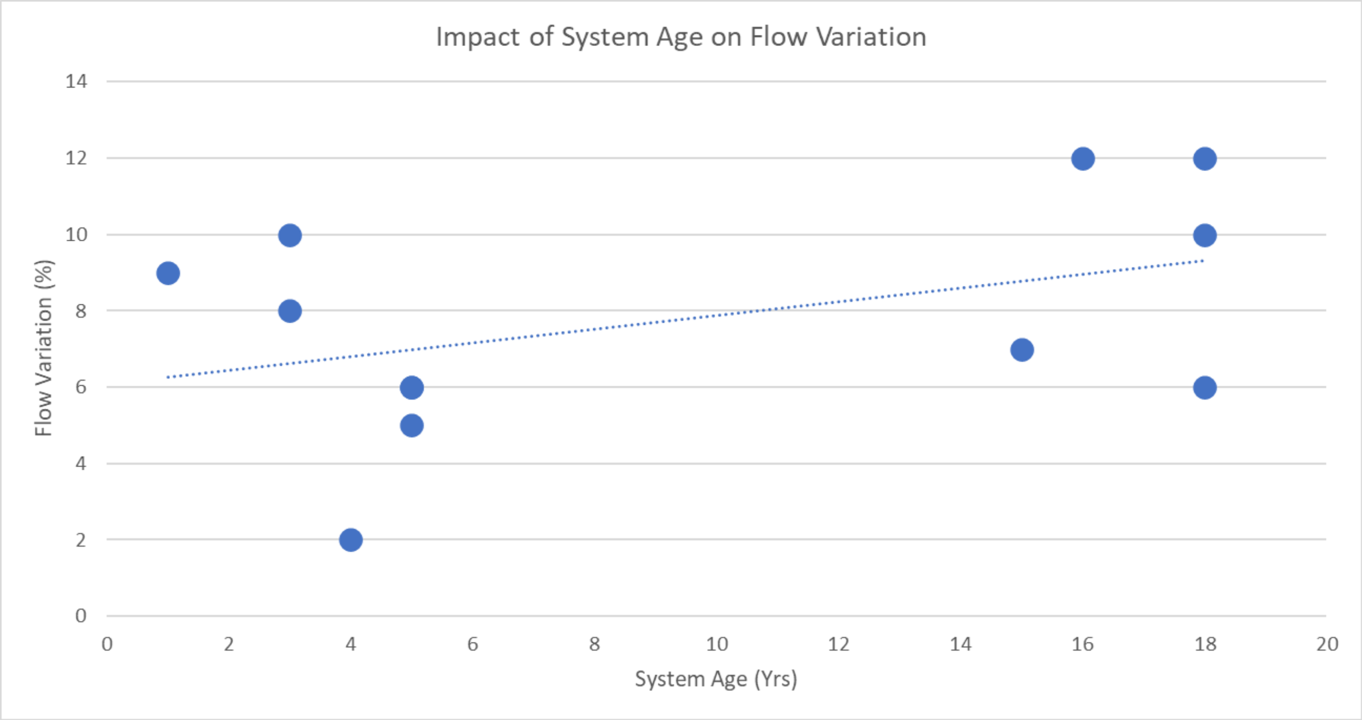

Figure 6 Correlation between irrigation system age and flow rate variation

Percent variation in emitter flow rate was plotted against a range of measures of irrigation system age and maintenance, to identify any relationships which might assist irrigators to manage their irrigation systems to avoid or minimise variability. Note that the results for the initial assessment at site 042 (042A) have been excluded from these comparisons, as the primary cause of the poor performance at this site was low operating pressure (as opposed to age or the maintenance program). Site 042B is included, showing the performance of this same site at correct operating pressure.

Plotting variation against system age (*Figure 6*) indicates a positive relationship between system age and variability, that is as systems get older, the variability in emitter flow rate increases. There is still quite a lot of variation in performance within systems of similar age, highlighting the fact that age is not the only factor influencing system performance. However, drip irrigation system performance declines with age.

This is consistent with the findings in Skewes (2020). Even though drip systems do not have many moving parts, dripper construction materials deteriorate over time, the flow of water and entrained materials cause wear on dripper structures, and foreign material accumulates in the flow-paths of drippers, all leading to more variable performance.

The comparison of maintenance measures with flow variability produces more complex results. The trend line for frequency of submain flushing (*Figure 7*) indicates a positive relationship with flow variation, indicating that flow variation increases as submain flushing frequency increases. This is opposite to what could be expected; that flushing foreign material out of the system will reduce the potential for clogging and therefore maintain consistent dripper flow rates.

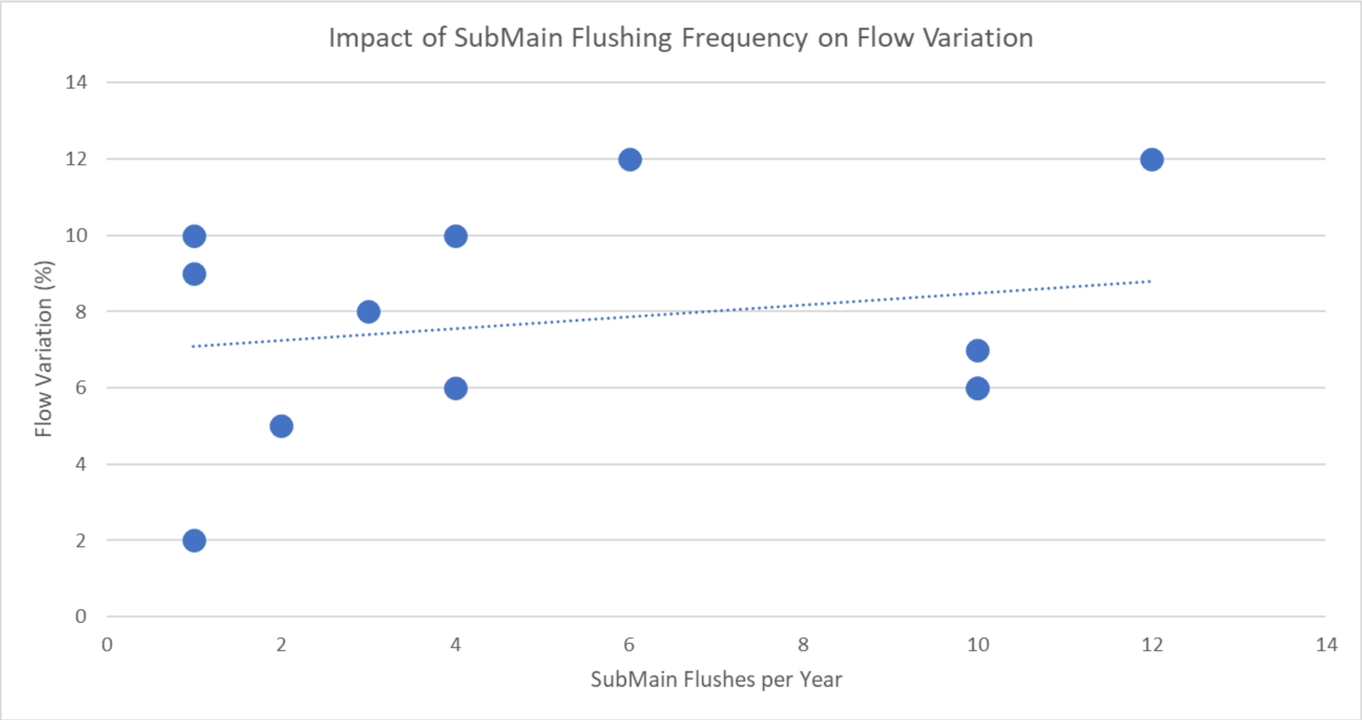

Figure 7 Correlation between frequency of submain flushing and flow rate variation

It should be noted that the two systems with the highest variability are 16 and 18 years old, so their poor performance is more likely related to their age than to their high flushing frequency. Also, water quality contributes to the need for flushing, so ideal flushing frequency may vary between sites depending on where their water is accessed and what treatment it receives before it is delivered to the valve unit. Even different positioning of pump intakes within the river can impact the amount of foreign material in the water, and therefore its impact on the irrigation system.

The relationship between lateral flushing frequency and flow variability is almost flat (*Figure 8*), suggesting no relationship between frequency of flushing of laterals and system performance. Again, this conclusion is counter-intuitive, and suggests that other factors are at play in this relatively small sample.

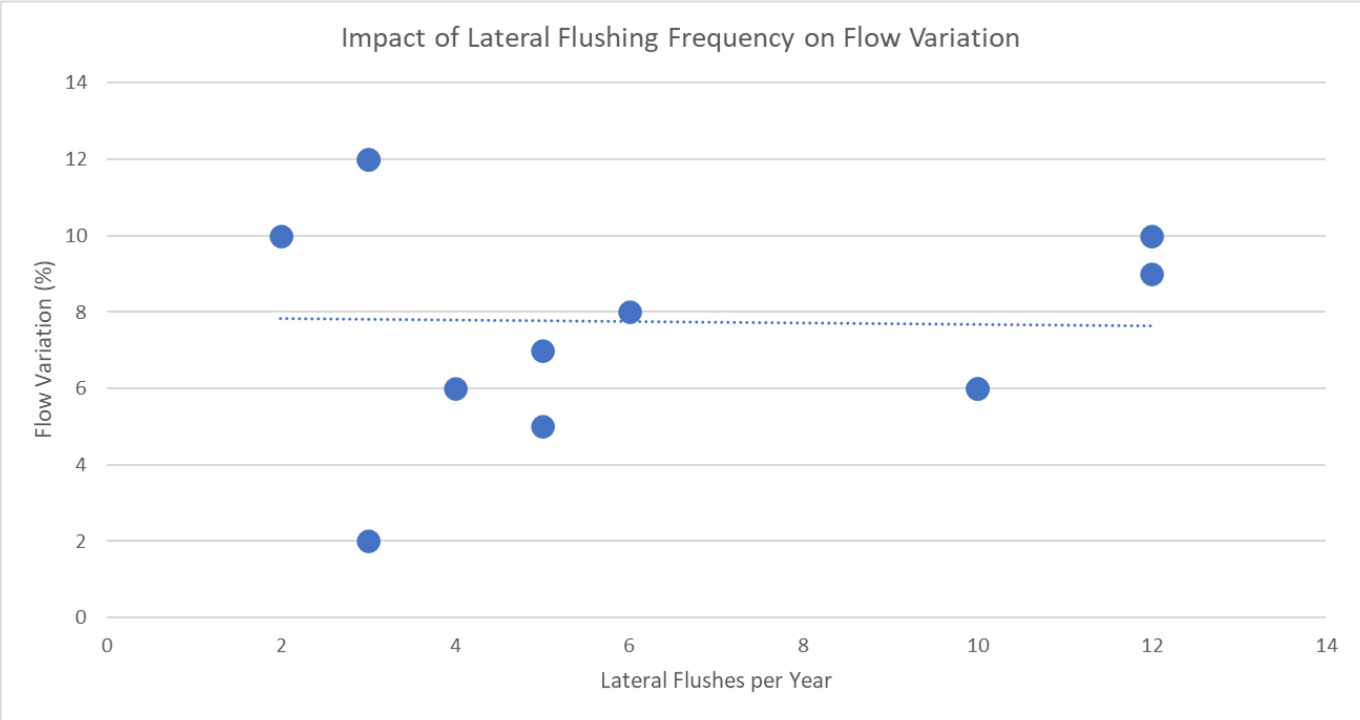

Figure 8 Correlation between frequency of lateral flushing and flow rate variation

The relationship of chemical treatment with flow rate variability (*Figure 9*) is negative, implying that more chemical treatment leads to decreased flow rate variation. This reflects expectations, but the presence of one site with very low variation (2%) that was subject to only one chemical treatment per year suggests that this is not the only factor impacting system performance, as discussed above for other maintenance activities.

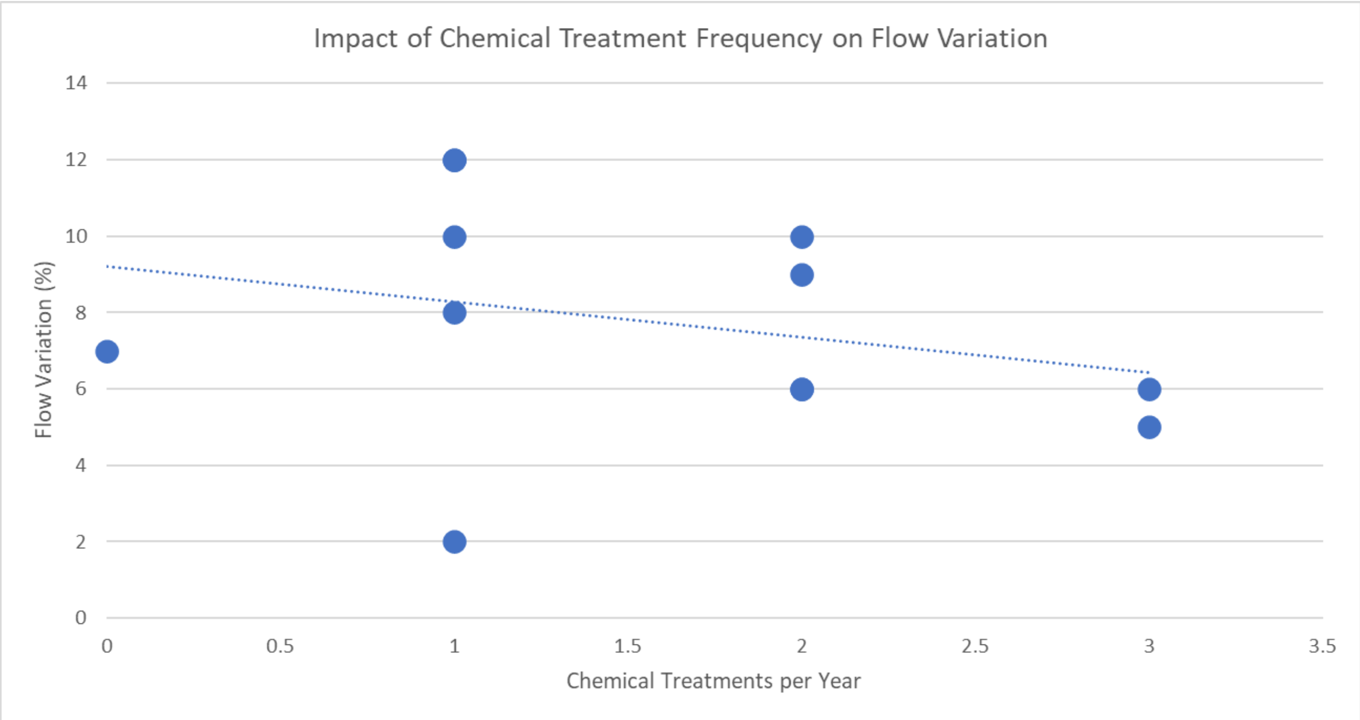

Figure 9 Correlation between frequency of chemical treatment and flow rate variation

In summary, a range of factors influence irrigation system performance, and specifically in this case flow rate variability within a valve unit. The effects of wear and accumulation of foreign materials are cumulative over time, and while good flushing and chemical treatment practices are critical to maintaining good irrigation system performance, eventually dripline wears out and must be replaced.

Spatial Crop Health Data

The emitter pressure and flow measurements collected at the sites were overlaid onto spatial imagery of NDVI and Water Stress indicators derived from multispectral imagery collected by CERES Imaging (**Appendix 1 – Spatial Imagery**, page 35). This provided the opportunity to directly compare emitter pressure and flow at specific locations with these indicators of canopy size and performance, to identify any direct impacts of system performance.

Note that for site 042 the initial set of pressure and flow readings (042A) have been used with the imagery, as they represent the situation at the time of the imagery.

The imagery reveals a relatively high degree of variation in NDVI and/or Water Stress across each of the valve units assessed. It could be expected that this variability would bear some relationship to the pattern of emitter flow rates measured in those valve units. However, there is little evidence of correlation between emitter flow rates and NDVI or Water Stress as revealed in the imagery.

It appears that the main causes of variation in NDVI and Water Stress at these sites are factors apart from the performance of the irrigation system. The most likely factor is soil variability across the valve units. This is despite all of the property owners indicating that the irrigation systems were designed and installed to match the soils on the property. However, no matter how carefully valve units are matched to soil changes, they will always contain areas of deeper and shallower water holding capacity, which can lead to variability in crop response.

Other potential factors leading to crop health variability could be pest and disease issues, and the influence of adjacent vegetation, both horticultural and native.

There were two sites with responses apparent in the imagery which appeared too regular to be random environmental influences, and these were investigated more closely.

At site 007A (page 40) there was evidence of an issue in the Water Stress imagery, evident as an area of red response (Highest Stress) in the central eastern area of the patch, right next to an area of blue response (Unstressed). Subsequent investigations revealed that the ground is littered with charcoal, and the grower confirmed that this was the location of the burn pile for existing vegetation during the development of the current vineyard, only 4 years prior to testing. The grower reported difficulty in establishing young vines in this specific area, vines were small with many misses, leading to the low NDVI and high Water Stress readings.

Site 042 (page 44) had an area of 4 rows at the northern edge which showed up as consistently lower vigour in the NDVI image. This area is a separate valve unit of a different variety, which is irrigated with the valve unit below but was not included in the test due to being on a different valve.

Irrigation system effects would generally only be expected to show up in crop health imagery if there was a systematic effect, for example due to poor design resulting in excessive pressure loss along laterals and consequent low water application at one end of the unit.

Conclusion

Assessment of irrigation system performance against established standards found differences in performance.

Pressure variation was not important in the pressure compensating dripper systems assessed here. However, it is critical that operating pressures at all emitters are within the specified range for the emitters. One site had very low pressures, with almost all pressures measured well below the specification. The property owner increased the pressure to the valve unit and the test evaluation was repeated.

Variability in emitter output within a valve unit is a potential source of variability in crop performance. This variability can be measured in different ways. Percent variation measures the difference of the highest and lowest measurements from the midpoint, with a standard of less than ±5% variation. Of the systems tested in this exercise only two sites were within the standard. In one case this was due to very low system pressure which meant that the pressure compensating feature of the emitters was not working. Increasing the pressure improved the variability, but still did not bring it within the standard.

Partial blockage of emitters due to accumulation of debris carried in the water is the most likely explanation for the failure of these systems to meet the standard.

When flow variability was measured by Coefficient of Uniformity all sites met the standard of greater than 90%, except the system with very low pressures. This highlights the difference between Coefficient of Uniformity and Flow Variability as measures of system performance. Flow Variability is preferred as it highlights problems more effectively, as illustrated by the performance of these sites against both indicators.

Comparison of Flow Variability with system age and maintenance practices gave variable results; but highlighted the impact of age on system performance. Good maintenance is critical to the short to medium term performance of irrigation systems, but it is difficult to be prescriptive about the frequency of flushing and chemical dosing required as water quality is very variable (both spatially and temporally). In the long-term system components wear out and must be replaced, and this includes dripline.

Overlaying irrigation system evaluation data onto spatial imagery of crop vigour (NDVI) and water stress did not reveal any examples of a clear link between system performance and crop performance. Most of the variation in crop performance appeared to be due to other factors, most likely environmental factors including soil variability.

The results of this study indicate that many irrigation systems across the Riverland winegrape industry may not be performing within the commonly accepted standards. The variability in emitter output may result in some vines receiving less water than others, and their reduced irrigation could impact their growth, yield and fruit quality.

The performance measured in this study suggests that most irrigation systems in the Riverland are well designed, as no systematic issues were revealed. The pattern of issues observed suggests deterioration of system performance can occur due to less than adequate maintenance in some cases; and aging of systems in others.

It is recommended that maintenance practices such as flushing and chemical treatment are promoted as an important factor in maintaining system performance, and irrigation system evaluations are also highlighted as a necessary practice for monitoring system performance.

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Dixon, R., 2021. AWRI Irrigation Efficiency and Practice Change Survey March 2021. The Australian Wine Research Institute, Glen Osmond, South Australia.

Hornbuckle, J., Christen, E.W., Car, N.J., Smith, D., Goodwin, I., McClymont, L., Kerridge, B., 2012. Drip irrigation distribution uniformity in vineyards of Australia: Tools for mapping and estimation of impacts. Acta Horticulturae 931, 119-125.

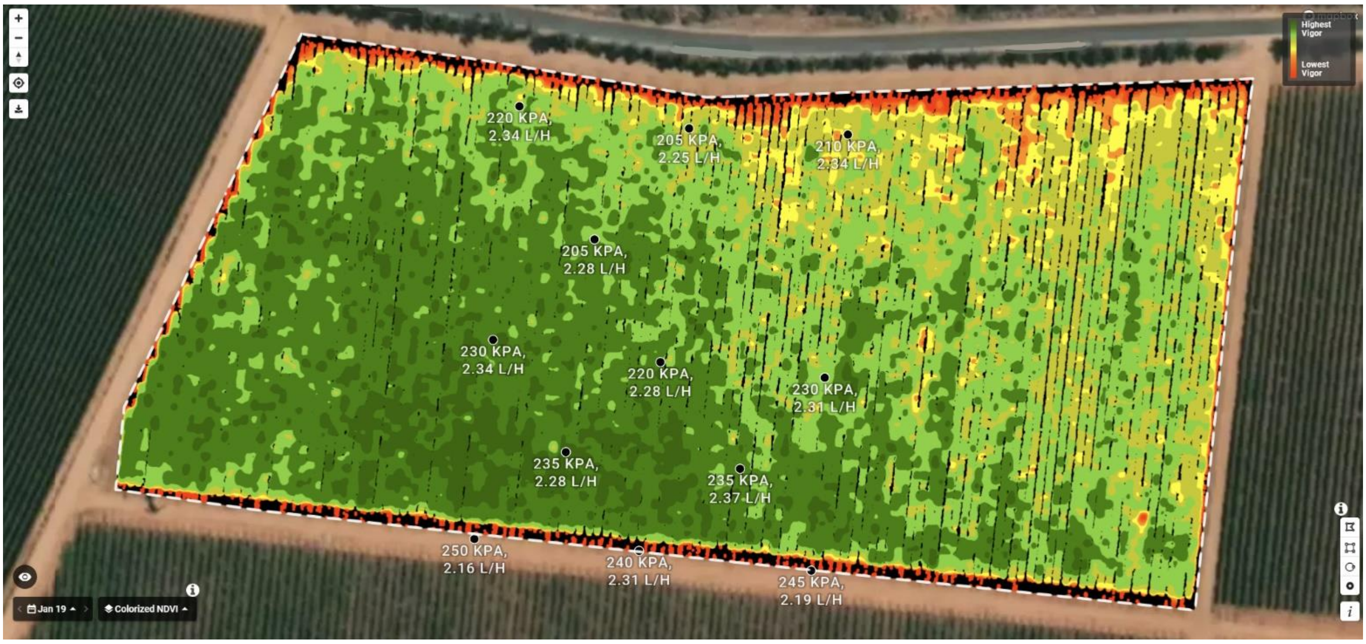
Skewes, M.A., 2020. Almond Irrigation Best Practice Website. Australian Nutgrower 34, 32-33.

Appendix 1 – Spatial Imagery

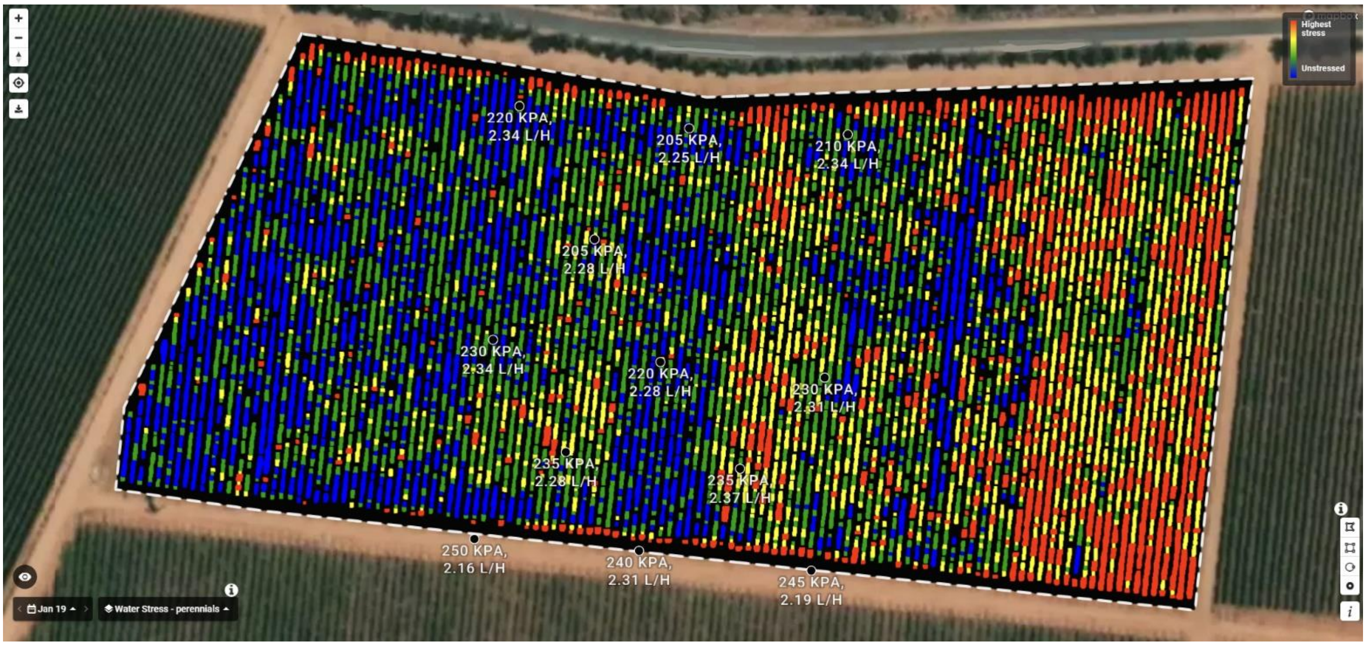
The imagery displayed in this appendix is discussed in the section **Spatial Crop Health Data** on page 31.

Site 001

NDVI

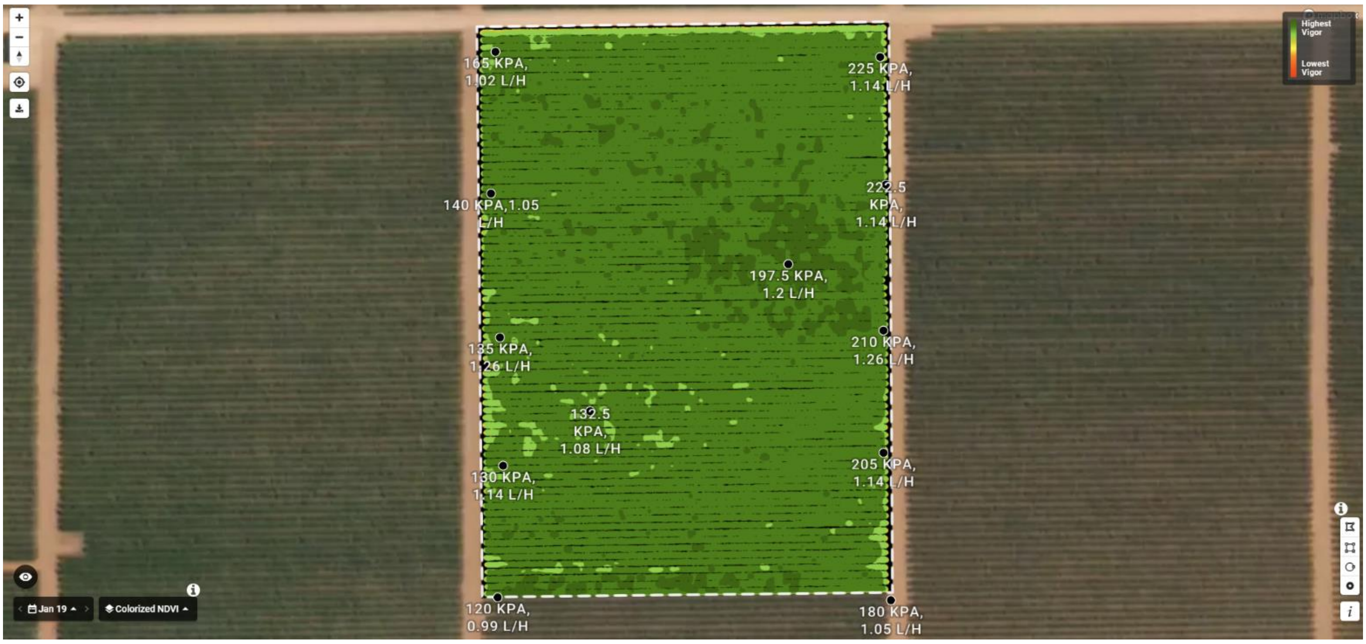


Water Stress

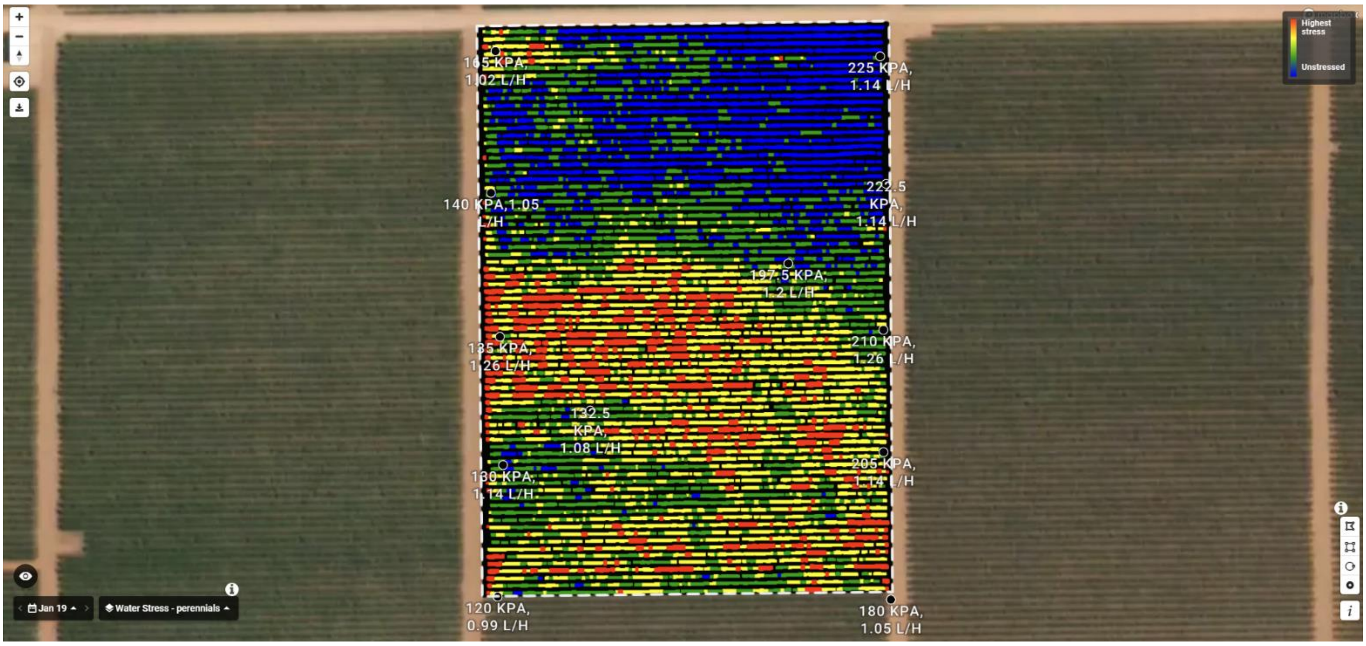


Site 002

NDVI

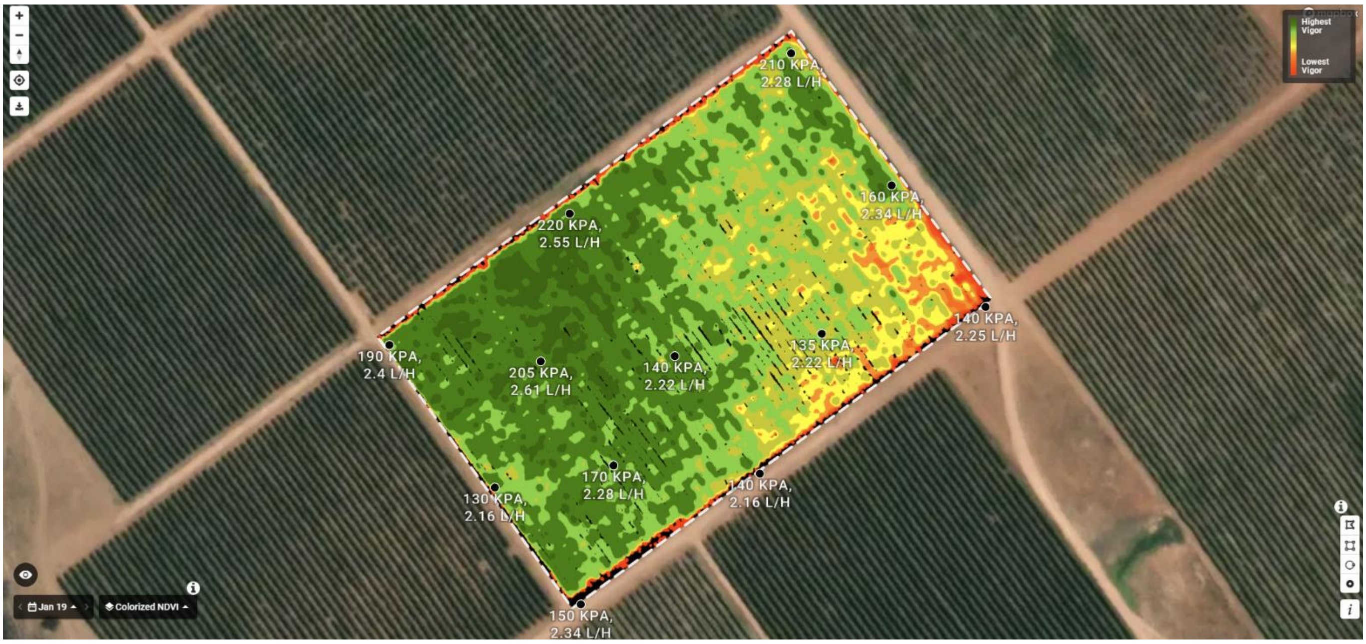


Water Stress

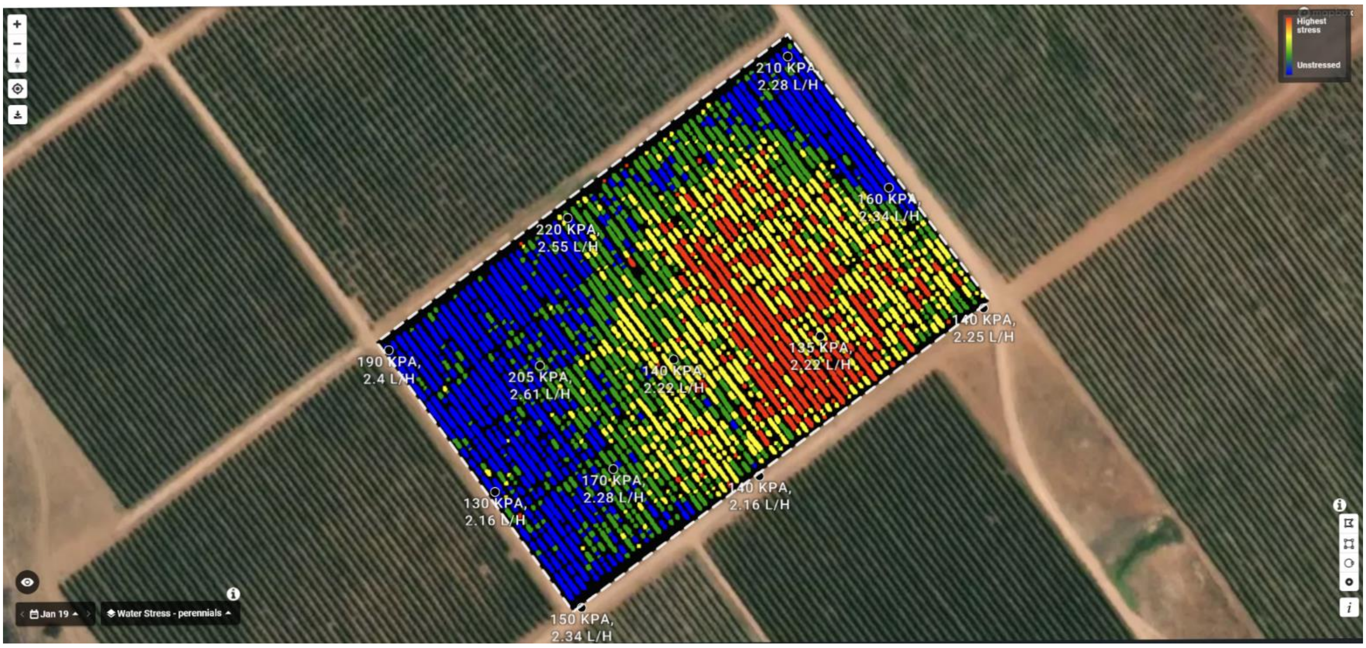


Site 003

NDVI

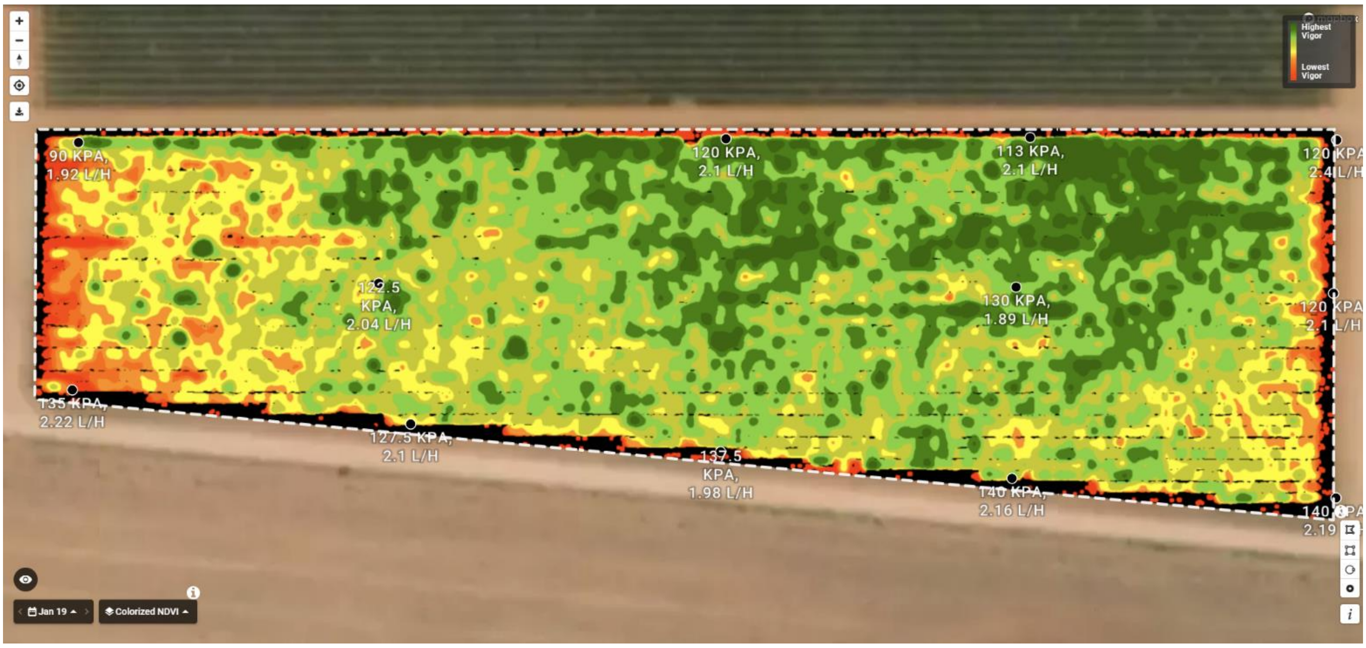


Water Stress

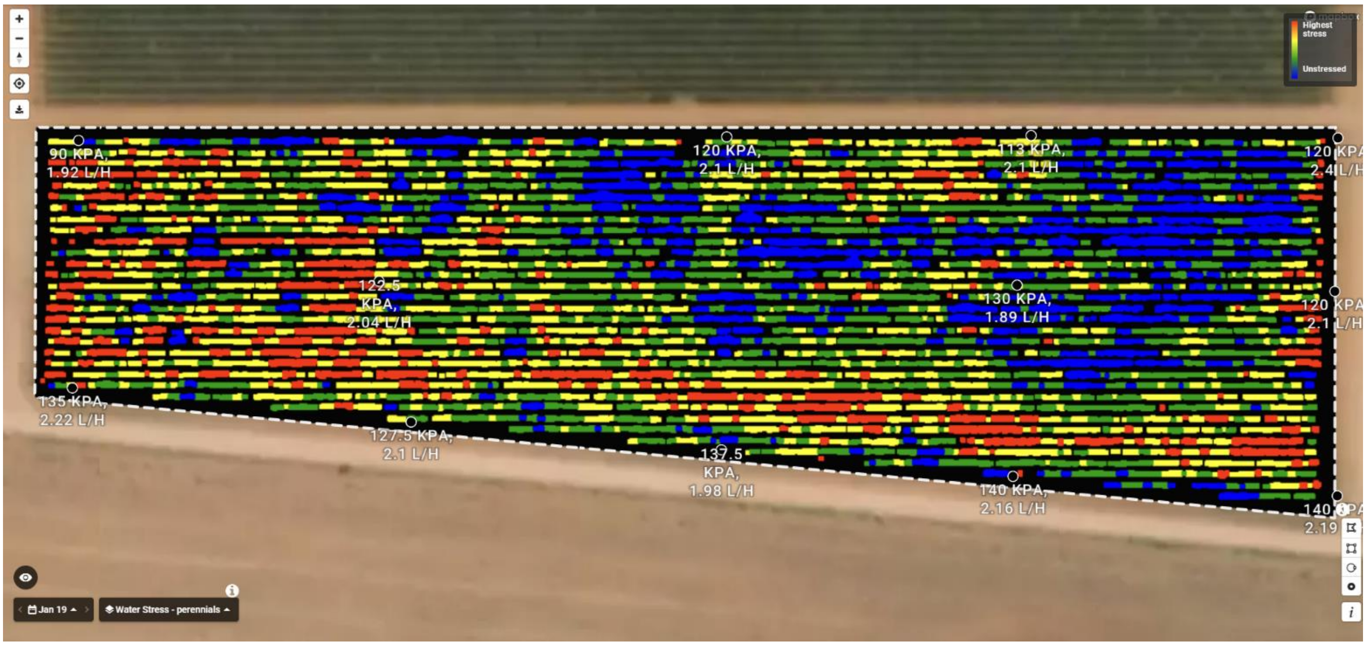


Site 004

NDVI

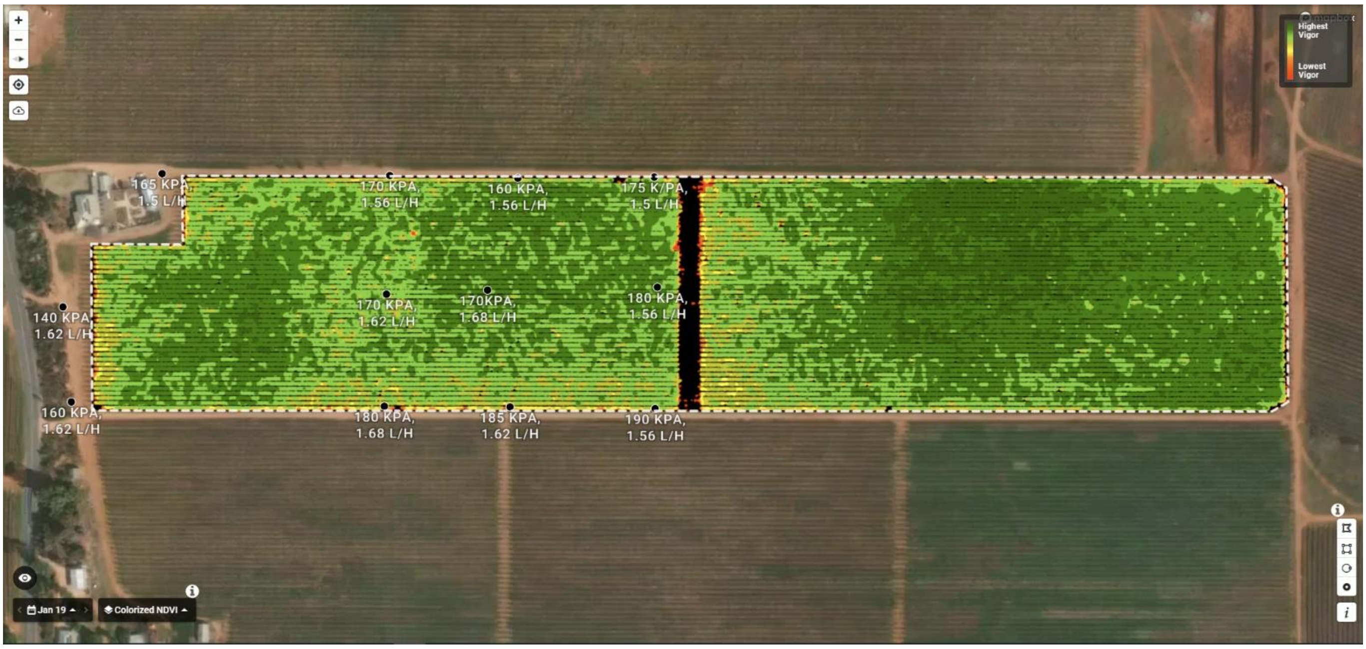


Water Stress

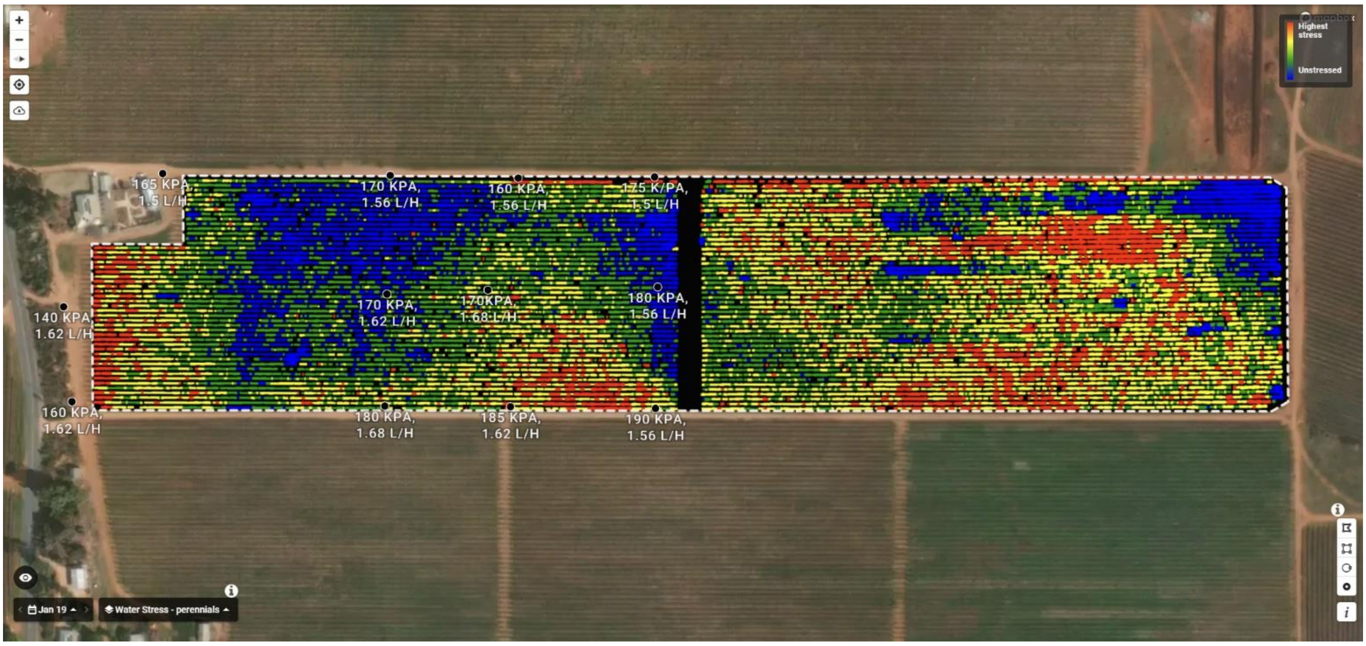


Site 006

NDVI



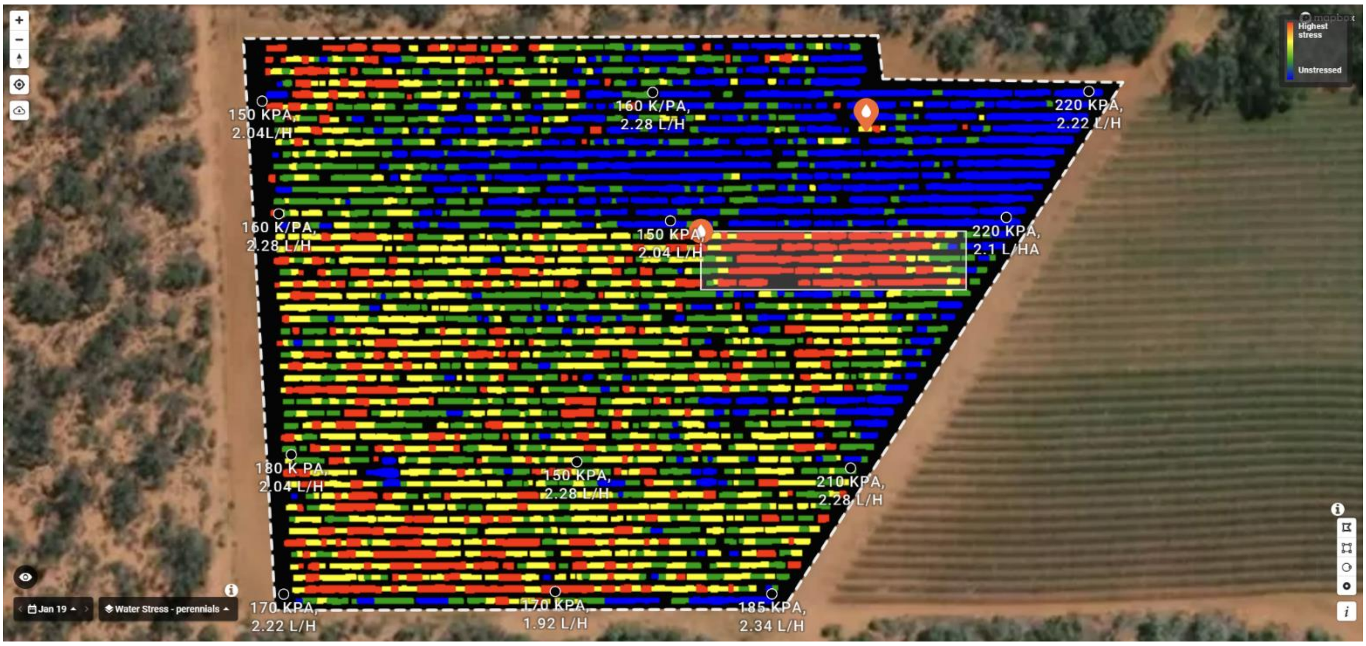
Water Stress



Site 007

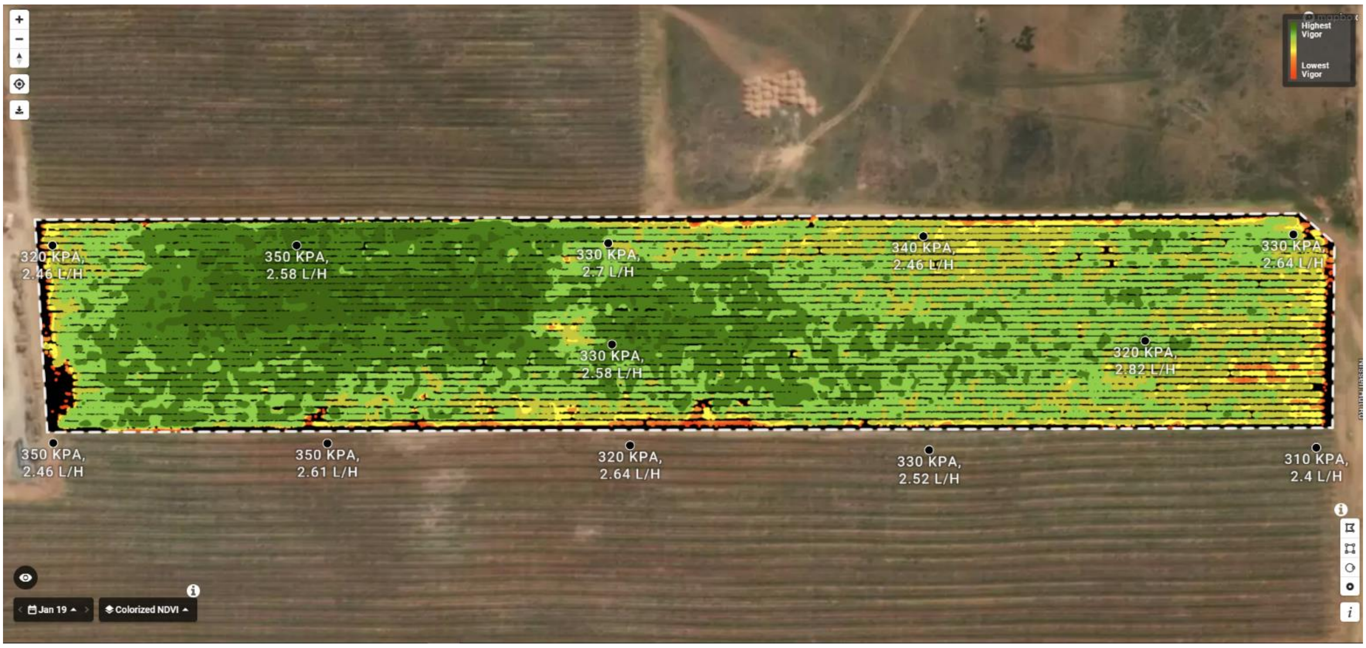
NDVI

Water Stress

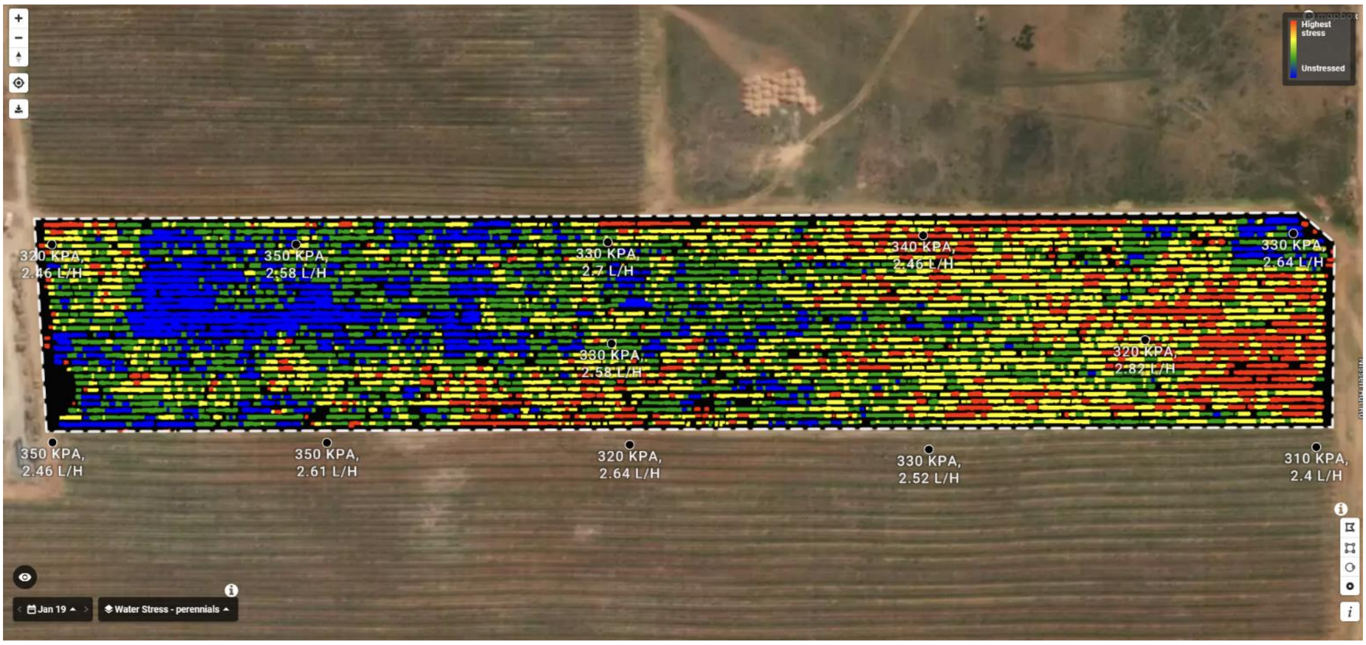


Site 009

NDVI

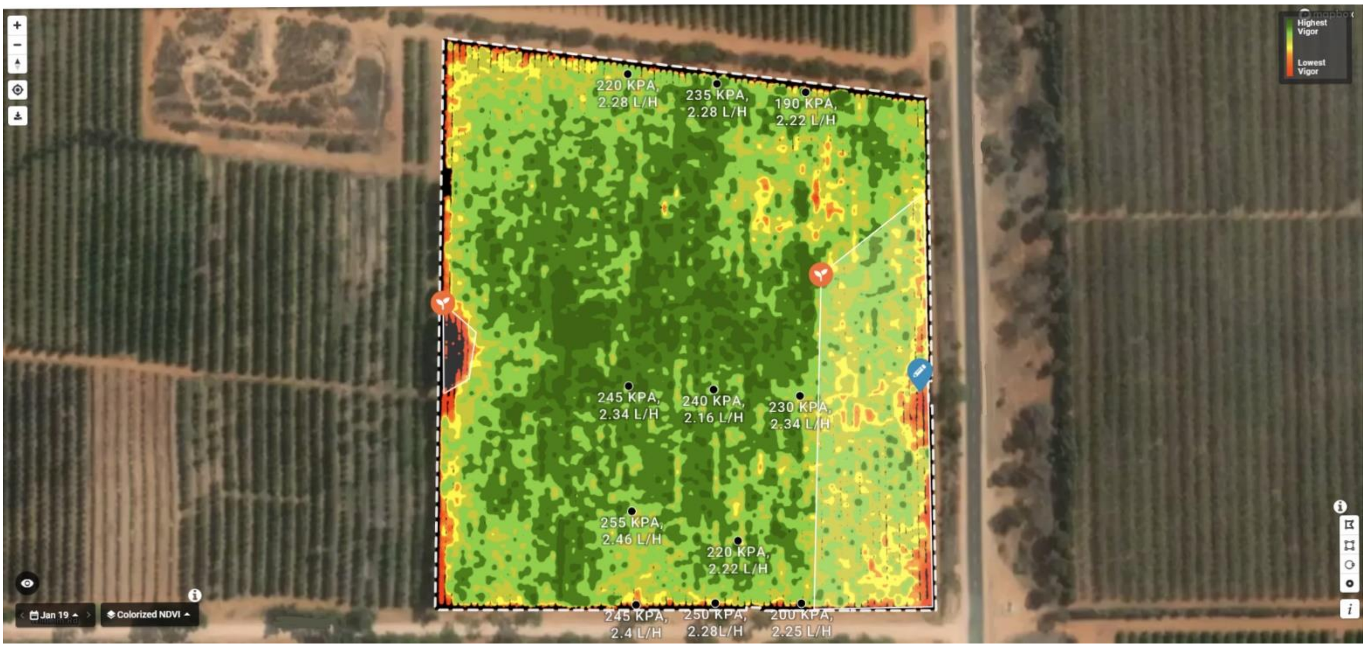


Water Stress

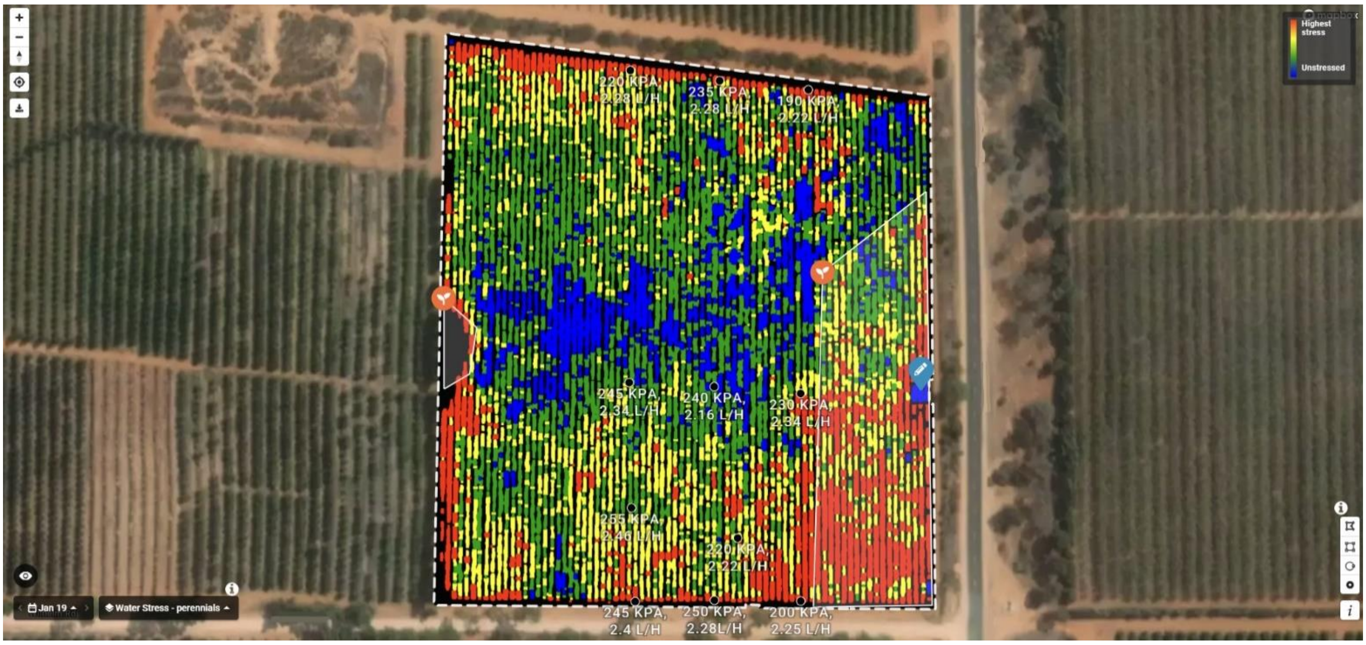


Site 012

NDVI

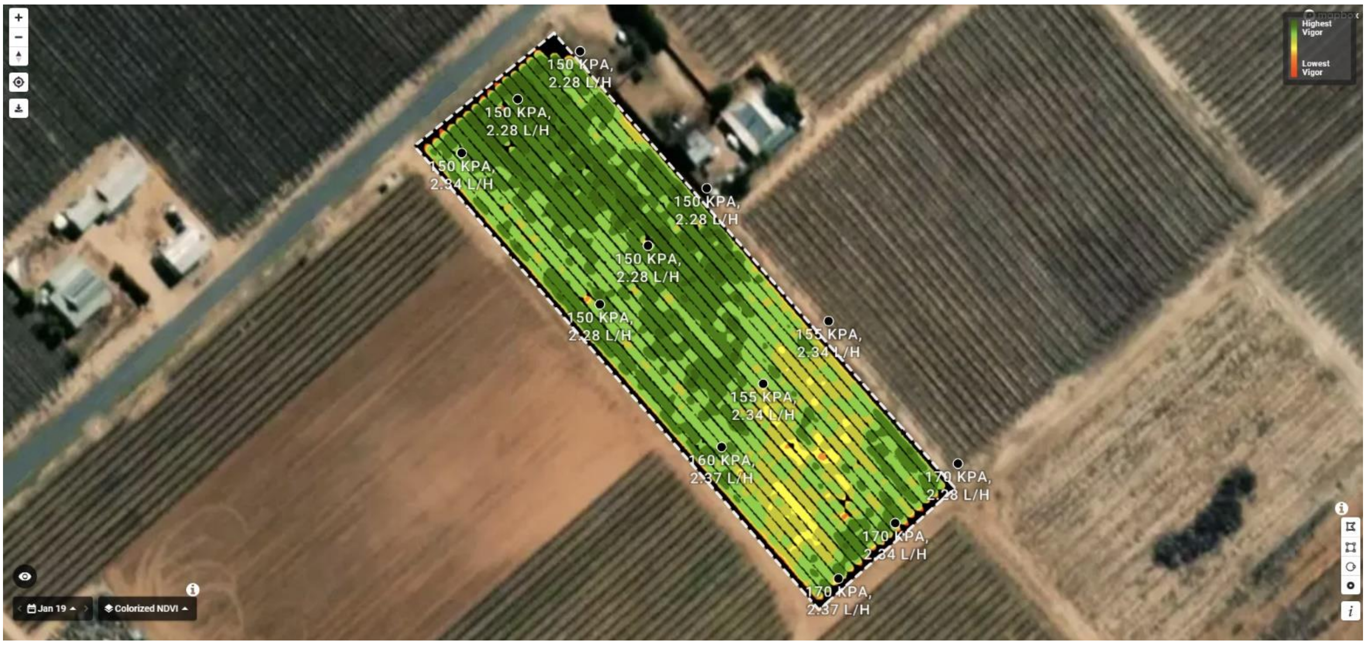


Water Stress

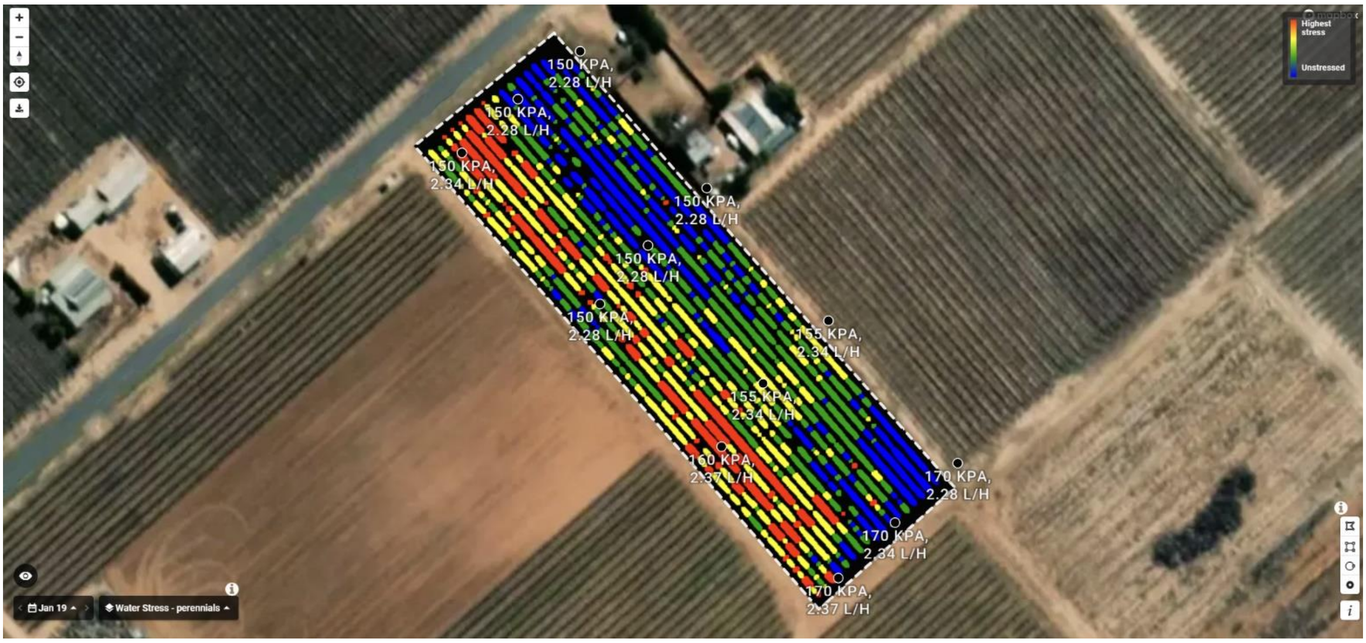


Site 040

NDVI

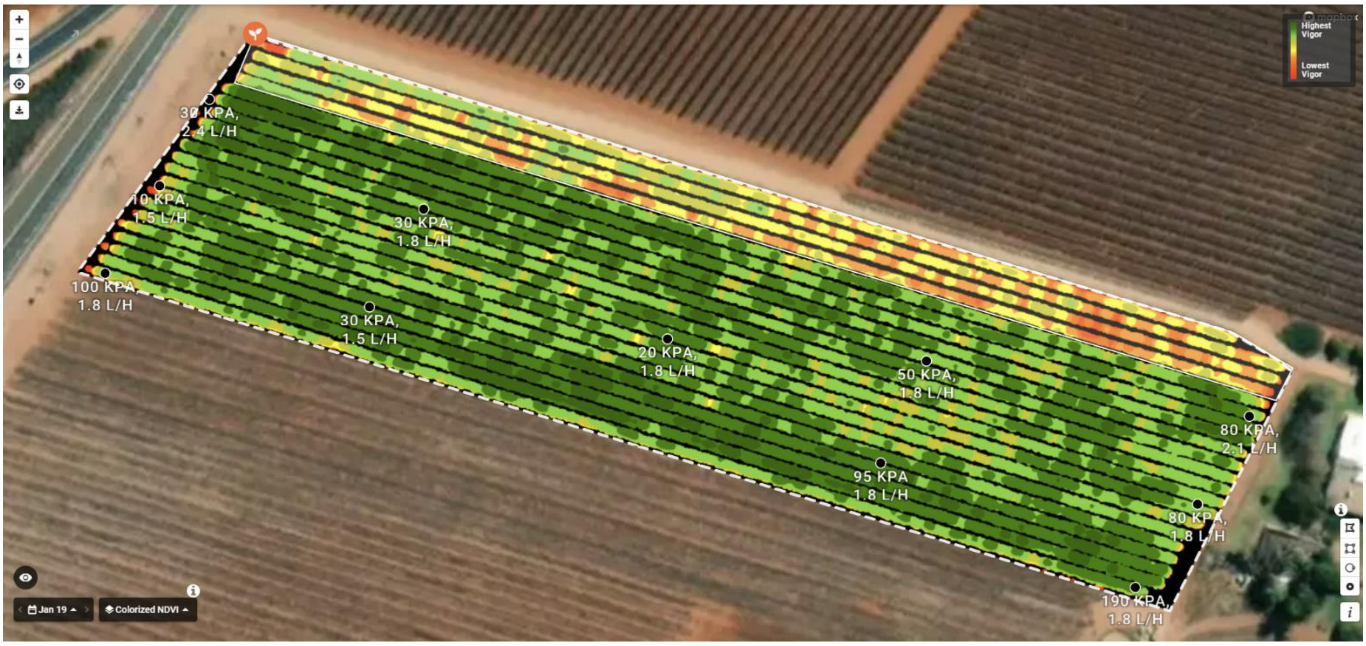


Water Stress

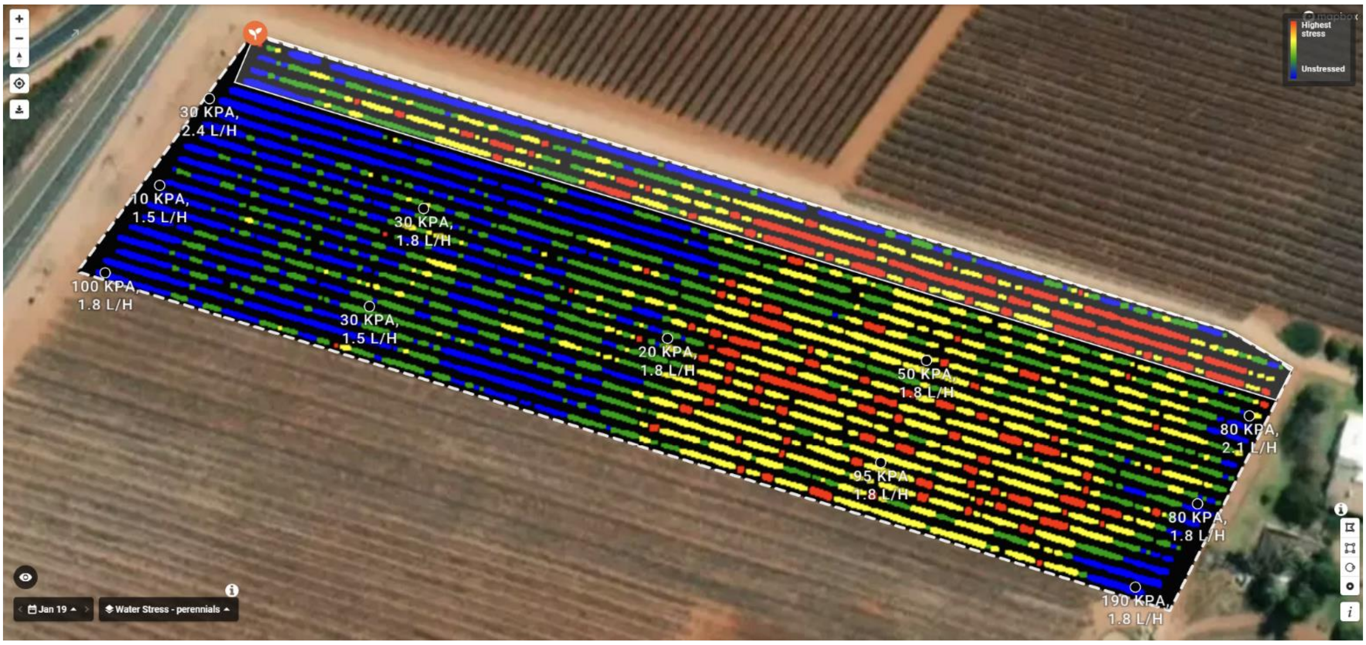


Site 042

NDVI

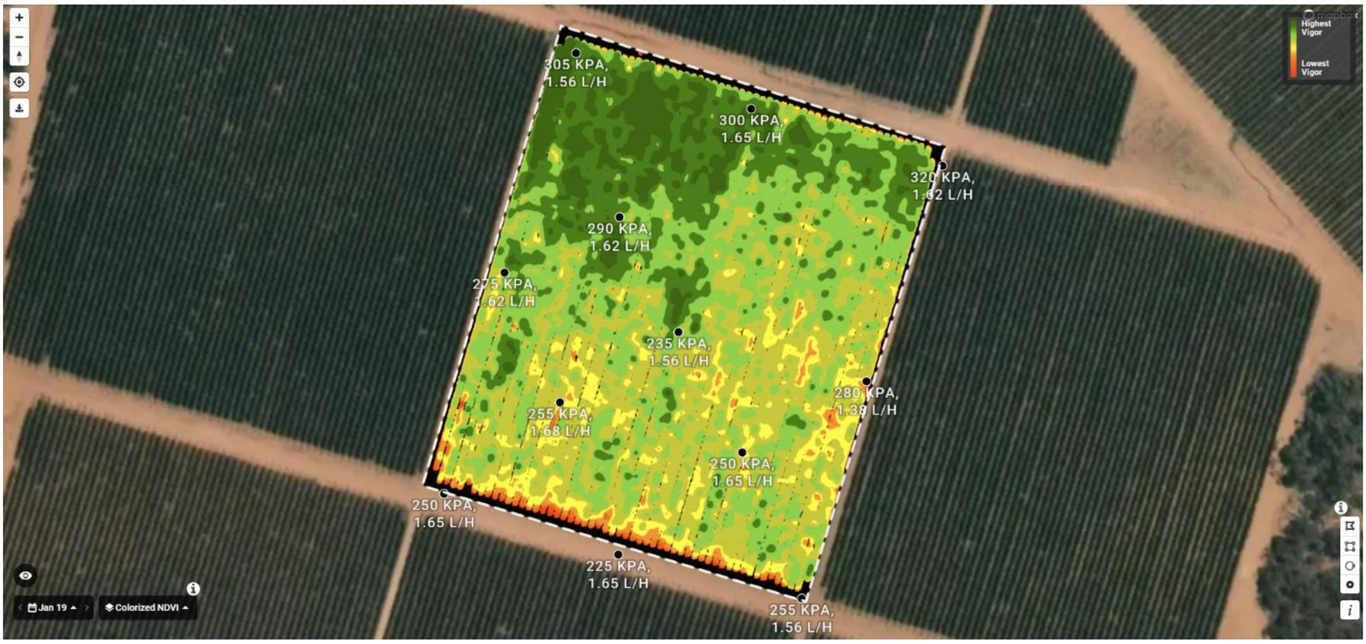


Water Stress

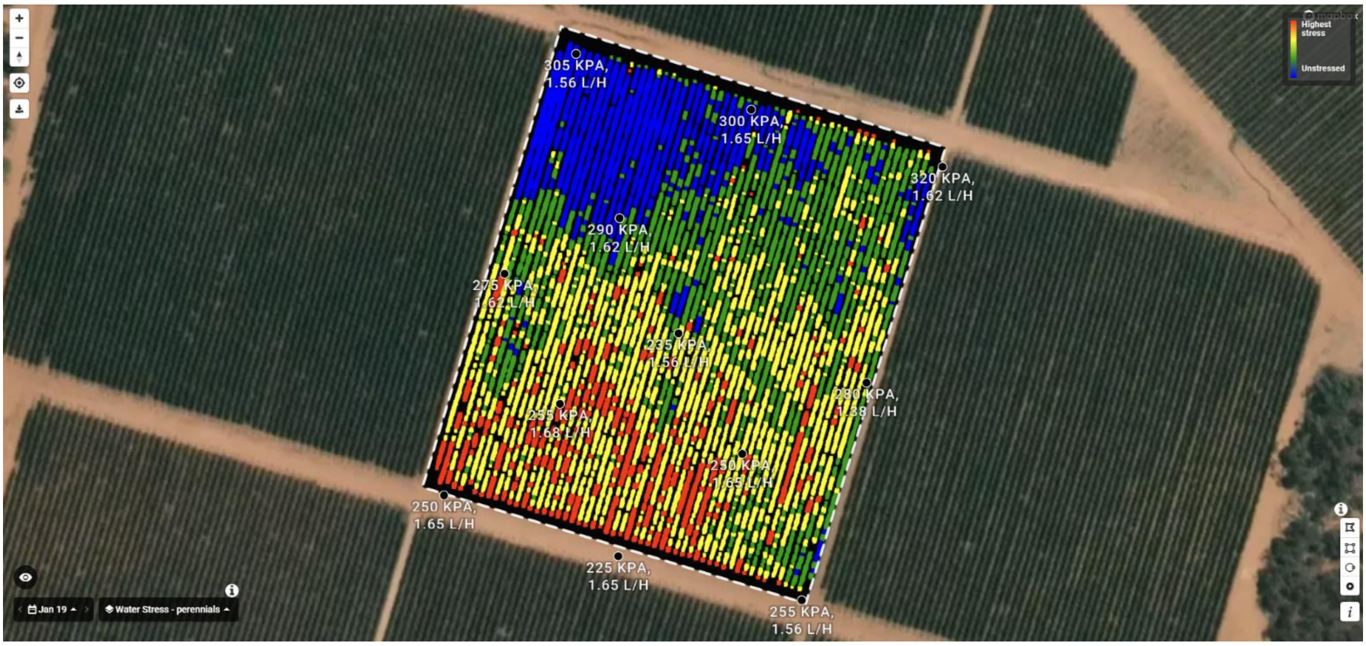


Site 058

NDVI



Water Stress



Site 066

NDVI

Water Stress