DECEMBER 2022

HEALTHY SOILS, HEALTHY PROFIT

Precision ag trial case study at Koo Wee Rup, Victoria

KEY MESSAGES

- ✔ **A precision agriculture trial was undertaken at Koo Wee Rup, Victoria from 2018-2022 in celery, leek and baby leaf crops which had many benefits for farm productivity, profitability and sustainability.**
- ✔ **Celery yield assessment showed higher average celery heart weights and more uniformity across the trial block from 2018-2020. Average leek yield increased in the trial area compared to the control from 2020-2022, with a significant increase in minimum yield.**
- ✔ **Soil health has improved in the trial area when looking at soil fertility indicators, nutrient status, plant nutrient availability and free-living nematodes.**
- ✔ **There has been a reduction in soil-borne disease risk and severity over time at the site, which has been more pronounced in the trial area compared to the control.**
- ✔ **Improved yield and crop uniformity contributed to increased gross profitability of $53,000, or $5,000 per hectare, largely driven by reduced costs from post-harvest labour efficiencies in cleaning, grading and packing produce.**

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HEALTHY SOILS, HEALTHY PROFIT AT KOO WEE RUP **December 2022**

Soil Wealth NURTURING CROPS
Integrated Crop Protection PROTECTING CROPS

SOLVING PROBLEMS THROUGH INNOVATION

In 2018, Schreurs & Sons, Stuart Grigg Ag-Hort Consulting and the Soil Wealth ICP team partnered to explore the application of precision agriculture in celery, leek and baby leaf production systems. A trial was developed at the Soil Wealth ICP demonstration site which is located at Adam Schreurs' Cora Lynn farm, about 80km south-east of Melbourne, Victoria.

Like many intensive Australian vegetable production systems, Adam has challenges with soil management, crop health and variability, and weeds while continuing to supply customers with high quality produce year-round. This can be compounded by poor drainage and waterlogged soils, nutrition constraints and insect pest damage depending on the seasonal conditions. Adam sees on-farm research and innovation as key to addressing these challenges and continually improving management practices.

"The demo sites provided the opportunity for us to look right into it, see what we could do, and measure some of the differences," he said.

Over the past five years Adam and the team have aimed to improve nutrition, irrigation and drainage management, and insect pest and beneficial monitoring as a basis for soil and crop health. To achieve this, we've used technology like EM38 mapping, gridded soil sampling, variable rate fertiliser spreading, remote weather stations with soil moisture probes, automatic insect pest traps with cameras, microwave weeding prototypes, as well as drones.

This case study explores some of the key practice changes made by Adam and Stuart and the benefits for farm productivity, profitability and sustainability.

SITE AND TRIAL OVERVIEW

The precision agriculture trial ran from 2018 to 2022 on a 10.1 hectare (25 acre) area of the farm (Bays 1 to 12). A separate control block (Bays 30-42) on the same farm was used to compare the results of the trial to conventional management practices.

The crop rotations over the past five years included:

- 2018-2020: leeks (winter) – rye grass cover crop – celery (summer) – leeks
- 2020-2022: leeks (winter) – rye grass cover crop – leeks (summer).

The specific activities and timeline for the demonstration site are summarised in Figure 1 below.

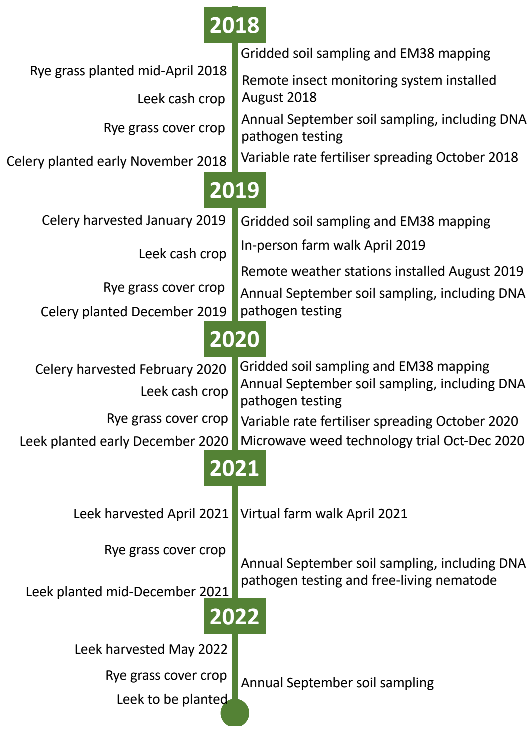

Figure 1: Timeline of activities at the Koo Wee Rup demonstration site.

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INCREASED YIELD AND UNIFORMITY

Marketable yield is what drives farm profitability and returns to Adam's business. There has been an increase in yield and crop uniformity in both celery and leek over the past five years due to the trial.

Looking back at previous summer celery crops, Adam noted, "Last year's crop (2019) was the best quality we'd had but there was still so much variation in crop growth and head weight from row to row and across the farm."

The results showed a more consistent yield from the trial area from 2019 to 2020 (Figure 2). Celery yield assessment data showed a significant improvement in consistency of the 2020 crop, ranging in variability from 4-12%, compared to the 2019 crop, ranging from 45-53% across multiple samples within the trial block.

"The harvest from the demo site (in 2020) was so uniform. It was really noticeable when it was coming off the block. It was a fantastic result – it beat the best crop off the farm," Adam said. This meant easier grading and packing of celery by staff and ability to supply customers with a product that better met their specifications.

The comparison between the control and trial areas showed an increase in average leek yield in 2021 from 66.4 tonnes per hectare (t/ha) to 67.0 t/ha. Importantly, there was also greater uniformity in the trial area with less of a difference between the minimum and maximum yield in each bay. This range was 15 t/ha in the trial area (57.9-72.9 t/ha) but much larger at 21.5 t/ha in the control (53.1-74.6 t/ha) (Figure 3).

Leek harvest data also showed an increase in yield in 2022, ranging from 68.8-74.3 t/ha, compared to the 2021 summer crop, ranging from 57.9-72.9 t/ha across multiple samples within the trial block (Figure 4). What was most impressive was the increase in minimum yield from 57.9 t/ha to 68.8 t/ha – a difference of almost 11 tonnes, or 19%. This improved Adam's ability to target important markets with larger sized leeks that met customer needs.

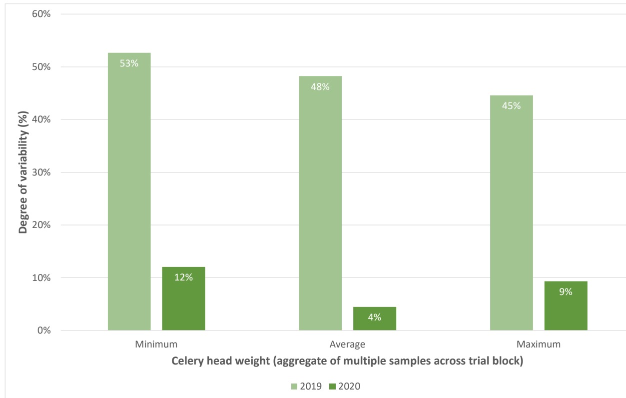

Figure 2: Degree of variability in celery head weight between 2019 and 2020 harvest in the trial area.

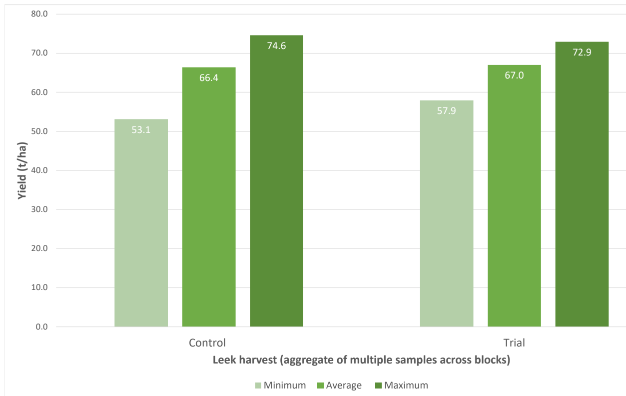

Figure 3: Comparison of leek yield between the control and trial areas in 2021.

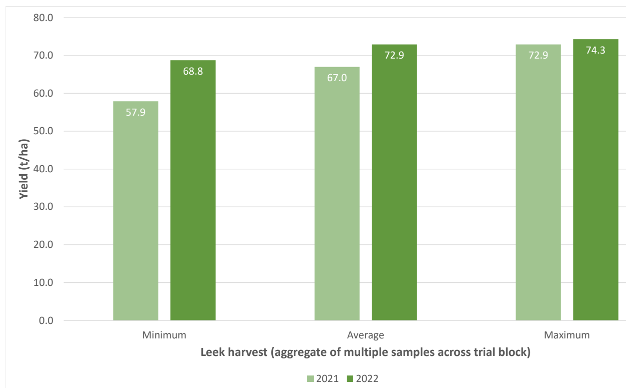

Figure 4: Comparison of leek yield between 2021 and 2022 in the trial area.

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IMPROVED SOIL HEALTH

Soil health can be assessed many different ways, looking at changes in chemistry, biology and structure. While visual structural assessments were undertaken over the duration of the trial, this section focuses on soil chemistry and changes in soil fertility indicators and nutrient status that influence plant nutrient uptake.

Soil fertility indicators

Soil testing showed that nitrate, the major component of the available nitrogen, decreased in both the control and the trial bays' soils. However, the decrease observed in the control bays was more than 10 times larger than the decrease observed in the trial bays (Table 1). Historic constraints of the site, which was reclaimed by draining the Koo Wee Rup swamp, include poor drainage and waterlogging; some nitrate loss likely occurred through surface runoff and leaching.

Peat soil over heavy clay characterises the Koo Wee Rup site. It was therefore unsurprising that, although the organic matter content decreased slightly between 2018 and 2021, organic matter was above the desired range every year regardless of whether the management involved precision agriculture or not.

Figure 5: Soil testing showing the difference in structure between the control (left) and trial areas (middle and right) in September 2020.

Higher soil electrical conductivity (EC) indicates that soil nutrients are more available to plants, but if EC is too high, cations like sodium (Na+) and magnesium (Mg+) can be detrimental to soil health. Given the high clay and organic matter content of the Koo Wee Rup soils, relatively high EC levels are expected. The high EC levels may also be due to the presence of sulphate salts from historic fertiliser application in addition to somewhat elevated levels of sodium and chloride.

		TRIAL			CONTROL		
Analyte	**Ideal**	**2018**	**2021**	**Change**	**2018**	**2021**	**Change**
Nitrate (kg/ha)		21	11.6	↓ -9.4	72.2	30.8	↓ -41.4
Ammonium (kg/ha)		1	1.1	+0.1 ↑	1	0.8	↓ -0.2
Total Available Nitrogen (kg/ha)		22	12.7	↓ -9.3	73.2	31.6	↓ -41.6
pH (H_2O)	6 to 7	6.58	6.435	↓ -0.145	6.01	6.23	+0.22 ↑
EC (dS/m)	0 to 0.15	0.239	0.212	↓ -0.027	0.415	0.357	↓ -0.058
CECe (meq/100g)		29.2	28.55	↓ -0.65	36.2	33.3	↓ -2.9
C:N		11.3	13.493	+2.363 ↑	10.15	11.21	+0.96 ↑
Organic Matter (%)	3.25 to 5.2	6.8	6.4	↓ -0.4	8.5	8.2	↓ -0.3

Key: Very low | Low | Satisfactory | High | Very high

Table 1: Soil fertility indicator levels in the trial and control blocks in 2018 and 2021.

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Nutrient status

The net decrease in the available nitrogen in the control bay was an order of magnitude greater than the loss observed in the trial bays (Table 2).

The very high phosphorus levels in the trial bays, and the high phosphorus levels in the control bays, were consistent over time.

Potassium (K) remained consistently satisfactory in the trial bays, but it increased from satisfactory to high levels in the soil of the control bays. This difference may be attributed to unnecessarily high application of K in the control bays, where fertiliser was conventionally spread. Alternatively, this may have been caused by the high vigour of the celery cash crops harvested from the trial bays in January 2018, January 2019 and February 2020 relative to the same celery crops harvested from the control bays.

Magnesium decreased from high to satisfactory levels in the trial bays, whereas it remained consistently high and saw a net increase in the control bays.

Boron is an especially critical nutrient for celery, and soil levels increased from very low to low, both in the trial and in the control. Boron should be prioritised in future fertiliser application at Koo Wee Rup.

Sodium in the conventionally fertilised soils in the control area remained very high over time, whereas the trial area decreased sharply from very high to satisfactory levels. Both copper and chloride levels stayed consistently within the satisfactory range. Copper is especially important for celery.

		TRIAL			CONTROL		
Element	**Ideal**	**2018**	**2021**	**Change**	**2018**	**2021**	**Change**
Nitrogen NO_3 and NH_4 (kg/ha)		22	19	↓ -3	73.2	31.6	↓ -41.6
Phosphorus (kg/ha)	19.2	38.5	38.2	↓ -0.3	25.5	24.4	↓ -1.1
Potassium (kg/ha)	95.5	80.5	83.1	+2.6 ↑	96.4	115.2	+18.8 ↑
Sulphur (kg/ha)	8.4	22	27.71	+5.71 ↑	40.15	37.8	↓ -2.35
Calcium (kg/ha)	799.5	1065.8	1098.4	+32.6 ↑	1063.1	1038.4	↓ -24.7
Magnesium (kg/ha)	97.7	122.2	107.6	↓ -14.6	121.1	133.5	+12.4 ↑
Boron (kg/ha)	1.2	0.1	0.5	+0.4 ↑	0	0.5	+0.5 ↑
Iron (kg/ha)	42.9	73.64	84.59	+10.95 ↑	65.37	83.91	+18.54 ↑
Manganese (kg/ha)	13.0	4.4	3.3	↓ -1.1	5.1	3.2	↓ -1.9
Copper (kg/ha)	1.9	1.7	1.3	↓ -0.4	0.8	1.1	+0.3 ↑
Zinc (kg/ha)	2.0	1.8	3.7	+1.9 ↑	4.6	4.7	+0.1 ↑
Sodium (ppm)	32 to 115	193.1	110.6	↓ -82.5	206.4	197.1	↓ -9.3
Chloride (ppm)	0 to 200	62	29.985	↓ -32.015	78	54.27	↓ -23.73

Key: Very low | Low | Satisfactory | High | Very high

Table 2: Nutrient status at the trial and control blocks in 2018 and 2021.

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Plant nutrient availability

Variable rate allows fertiliser to be applied at different rates depending on the changes in soil chemistry across the block. The aim is to achieve a more consistent and high-quality cash crop through more precise application of nutrients – where the soil and crop needs it.

Large areas of the trial site have improved uniformity of nutrient availability due to the gridded soil sampling and variable rate fertiliser spreading over the past five years. The gridded soil sampling results show that large areas of the trial site have:

- **Improved pH** from lower (5.2-5.7 [$CaCl_2$]) to higher (5.9-6.5 [$CaCl_2$])
- **More consistent potassium** (154-342mg/kg, average 214mg/kg)
- **More consistent phosphorus** (250-440mg/kg, average 330mg/kg)
- **More consistent magnesium** (281-436mg/kg, average 336mg/kg)
- **Lower average sodium** (50-99mg/kg) down from 100-199mg/kg.

The output of the gridded sampling for two key parameters, pH and potassium, and the changes from 2018 to 2020 are shown in Figure 8 and Figure 9 respectively on page 7. This information helped Adam revise and adapt the nutrition program for the site.

Figure 6: Results from the trial being communicated to growers and industry members during an in-person farm walk in April 2019.

Figure 7: Demonstration site showing celery crop in late maturity in January 2020.

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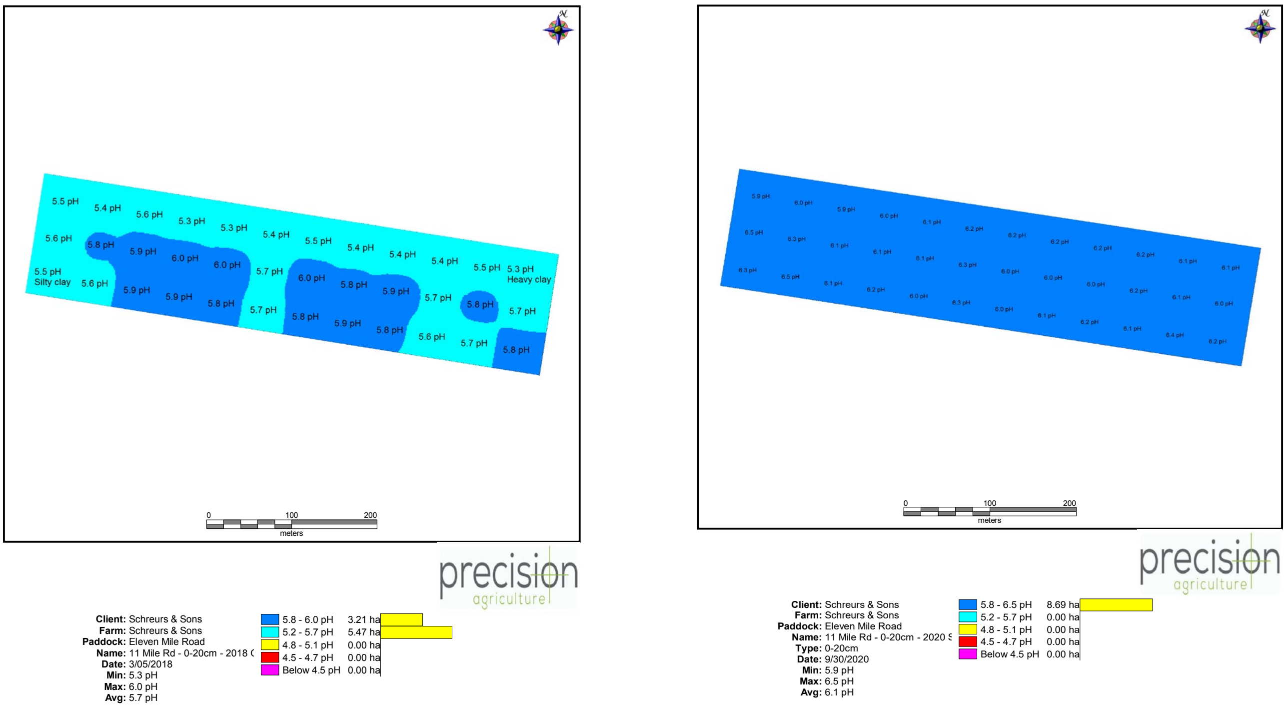

Figure 8: Changes in variability of pH at 0-20cm from 2018 (left) to 2020 (right).

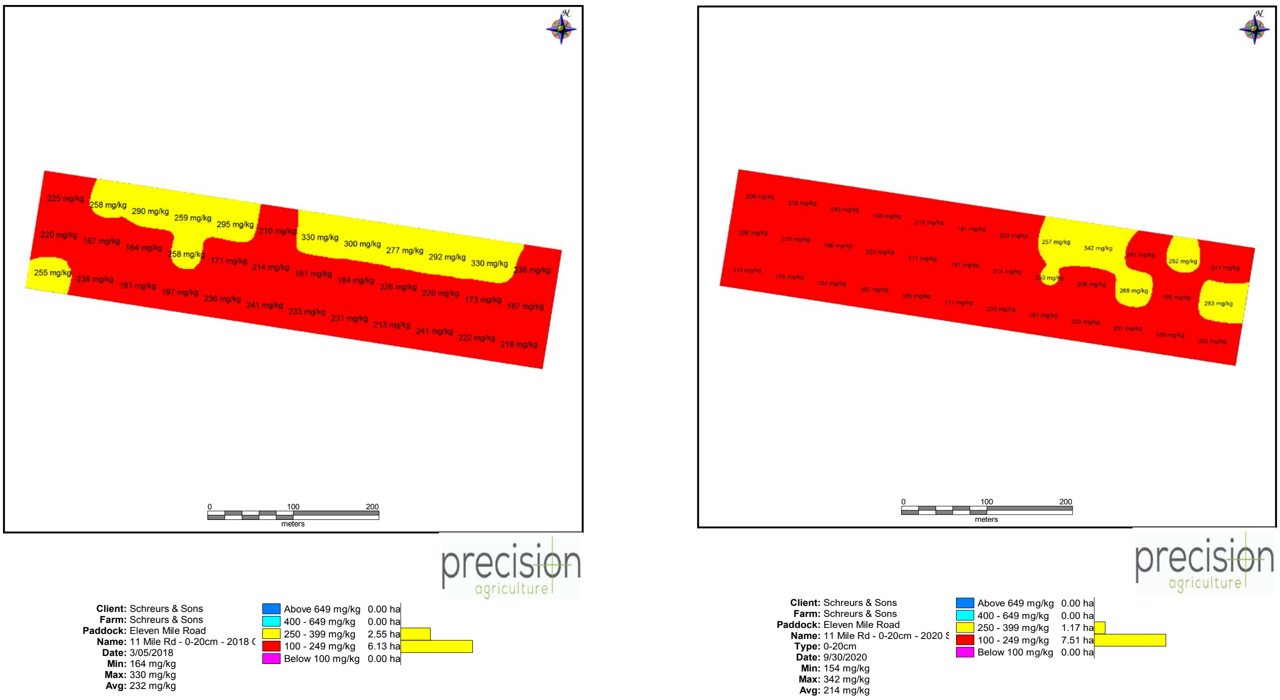

Figure 9: Changes in variability of potassium at 0-20cm from 2018 (left) to 2020 (right).

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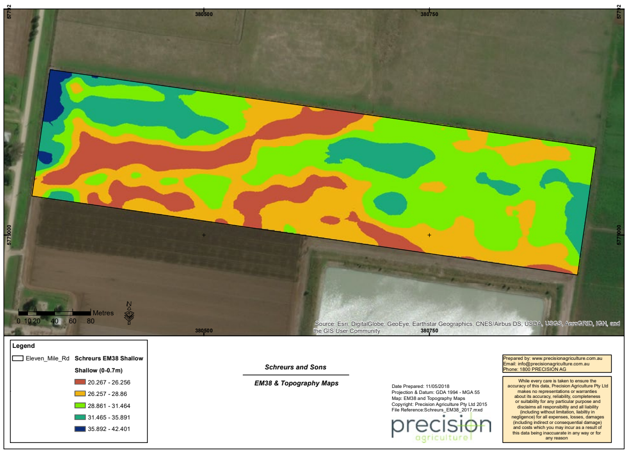
In addition, there have also been further improvements in soil constraints such as soil texture, salinity and/or water held in the soil profile (indication of drainage) as measured by the EM38 mapping (blue and green areas). Figure 10 shows a reduction in the red and orange problem areas in the north and south of the trial site from 0-75cm that have historically caused reduced yields due to waterlogging or other soil structure problems (e.g. compaction).



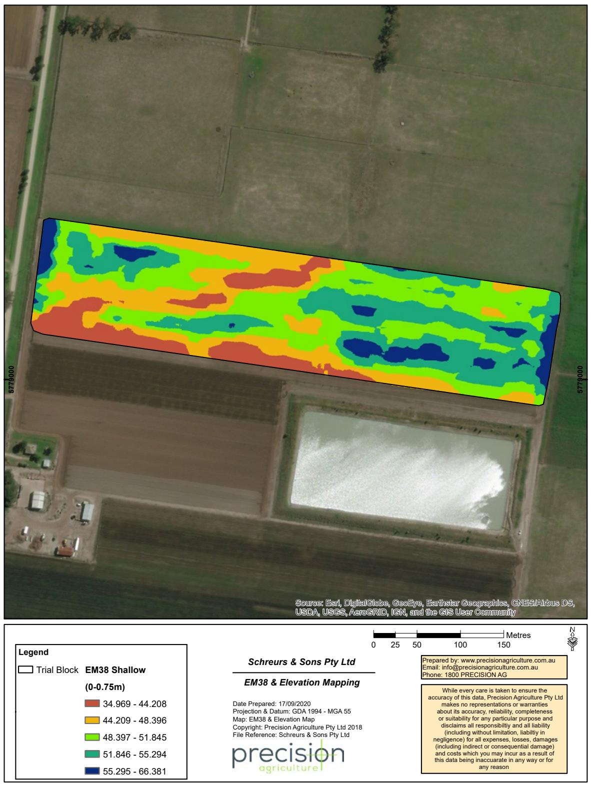


Figure 10: Changes in EM38 from 0-75cm from 2018 (left) to 2020 (right)

Free-living nematodes

Free-living nematodes (FLN) are usually the most abundant type of nematodes in soil. They are typically beneficial in vegetable growing systems because they break down and release nutrients in organisms' tissues, making them available for plant use, while also improving soil structure and water holding capacity. FLN are often considered indicators of soil health because they cannot survive in anaerobic (e.g. waterlogged) nor extreme soil conditions.

The trials bays generally contained more beneficial FLNs than the control bays. Proportionally, however, the nematode community structure was similar to that found in the control bays.

The total abundance of FLNs in the trial bays decreased by about 75% between 2020 and 2021 to 1,053 kDNA copies per gram sample, whereas the total nematode abundance in the control bays remained relatively static between years at 1,031 kDNA copies per gram sample.

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REDUCED SOIL-BORNE DISEASES

High soil moisture and unbalanced soil microbiology are conducive to the pathogens that cause soil-borne diseases in vegetable crops. The most important pathogens of celery are *Sclerotinia* spp. (cause of leaf and petiole wilting and plant death), *Pythium* spp. (cause of damping off) and *Rhizoctonia* spp. (cause of root rots). The priority diseases for leek are caused by the pathogens *Pythium* spp., *Rhizoctonia solani* and *Fusarium* spp. (cause of root rots), which often appear together as a disease complex.

There has been a reduction in soil-borne disease risk and severity over time at the site, which has been more pronounced in the trial area compared to the control. This may be due to the precision agriculture activities at the trial site as well as other factors such as soil moisture, temperature and variation in planting times.

The soil pathogen DNA results show the trial bays, where precision agriculture practices were implemented, only experienced decreases of detected pathogens over time. In contrast, the conventionally managed control bays experienced a decrease of three key pathogen types and an increase of two key pathogen types (Table 3).

"We started out looking at different types of cover crops, from grasses to broadleaf, and found rye grass – rye corn in particular – to be very good with the leek crops we grow and alternating between these. From a disease point of view these have been very good as well," Adam explained.

		TRIAL			CONTROL		
Pathogen	**Unit (per gram sample)**	**2018**	**2021**	**Change**	**2018**	**2021**	**Change**
Pythium Clade F (multiple species)	pgDNA	599	301	↓ -298	1246	706	↓ -540
Pythium Clade I (multiple species)	pgDNA	298	52	↓ -246	344	141	↓ -203
Pythium sulcatum	kDNA copies	4	4	0	3	4	+1 ↑
Rhizoctonia solani (AG2.1)	pgDNA	101	10	↓ -91	2	58	+56 ↑
Sclerotinia sclerotiorum	kDNA copies	3	0	↓ -3	20	1	↓ -19

Key: **Low** | **Low-moderate** | **Moderate** | **Moderate-high** | **High**

Table 3: DNA concentrations of soil pathogens in the trial and control blocks in 2018 and 2021.

INCREASED PROFITABILITY

So, what does all this mean for the bottom line? There was an increase in gross profit of approximately $53,000, or $5,000 per hectare, based on the leek harvest in 2021. The partial budget analysis showed that increased yield, crop uniformity and price received contributed to additional revenue of $8,000. In addition, the reduced costs from post-harvest labour efficiencies in cleaning, grading and packing produce as well as reduced fertiliser use were significant at $52,000 (Table 4). Even through there were some additional costs, such as gridded soil sampling and depreciation on equipment, these were minimal and did not offset the positive profit result. A great outcome for Adam and the business.

Item	Calculation	Value ($/ha)
Additional revenue	A	$7,825
Reduced revenue	B	$0
Additional costs	C	$6,861
Reduced costs	D	$52,326
Net change in gross profit	**A-B-C+D**	**$53,291**
Net change in gross profit (/ha)	**÷ 10.1 ha trial block**	**$5,276**

Table 4: Partial budget analysis based on leek harvest in 2021.

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LESSONS LEARNT

The team has learnt a number of lessons in implementing precision agriculture practices and technology at the site over the past five years. These include:

- **Gridded and pre-plant soil testing** allowed more detailed understanding of where nutrients are available to the plant.
- Development of a **nutrition program and variable rate spreading** enabled precise nutrition application across smaller areas.
- **Drainage and crop health monitoring using drones** meant problem areas could be identified and managed early before they impacted yield and the bottom line.
- **Plant tissue testing** provided a useful cross-check to see what nutrients the plant had taken up and whether this varied across a paddock.
- **Installation and use of remote monitoring insect traps** provided another 'safety net' cross-check for manual scouting. "We're now hardly spraying insecticides on our winter crops and summer crops would be lucky to get two or three soft, targeted insecticide sprays just for certain insects," Adam said.
- **Remote weather stations and soil moisture probes** have improved irrigation scheduling and managing problematic waterlogged areas.
- Celery yield assessment showed **higher average celery heart weights and more uniformity** across the trial block from 2018-2020. **Average leek yield increased** in the trial area compared to the control from 2020-2022, with a significant increase in minimum yield.
- **Soil health has improved** in the trial area when looking at soil fertility indicators, nutrient status, plant nutrient availability and free-living nematodes.
- Improved yield and crop uniformity contributed to **increased gross profitability of $53,000, or $5,000 per hectare**, largely driven by reduced costs from post-harvest labour efficiencies in cleaning, grading and packing produce.

Adam highlights the importance of starting small and then scaling up when seeing productivity benefits from on-farm trials in a commercial setting.

"Through gridded soil sampling and variable rate lime and fertiliser (application) we've been able to even everything up correctly. After doing this for a couple of years the crop was much more uniform and yields were increasing. I did a little bit more on the property, and then a little bit more. We're now using the system from the trial plots right across the board (at other farms) with very good results," he said.

There are still challenges through, with Adam mentioning: "We can put up with a little bit of (crop) damage ... but with (crop residue) trash around it's probably one of the hardest things for us to manage and remains one of our biggest challenges."

Figure 11: A virtual farm walk during COVID-19 in April 2021.

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NEXT STEPS

Adam will continue to refine and expand the use of the precision agriculture technology across other farms to continually improve yield and crop uniformity.

"It's a really good demo of what technology can be used in the field and what we can get out of it. All of those things I'll be using in the future, more and more," Adam explained.

Stuart reflected on the trial and hopes other growers will benefit from the lessons and insights from the demonstration site.

"It's been a pretty exciting journey taking this precision agriculture technology from the broadacre grains industry into vegetables. It's a no-brainer for anyone breaking up new country, but a real revelation for how it can work on older country and the benefits it can give to growers more broadly," he said.

"It's good to bring a lot of these different technologies together in the one site and really look at which ones we can use and what benefits we can get as well."

Acknowledgements

The Soil Wealth ICP team acknowledge the significant contribution, time and expertise of Adam Schreurs and Stuart Grigg to the Koo Wee Rup demonstration site from 2018-2022. Thanks also to our demonstration site partners Precision Agriculture, Metos – Australia & NZ, OneHarvest and Brown's Fertilisers.

FURTHER INFORMATION

You can access further information about the Koo Wee Rup demonstration site and precision agriculture in vegetable production in the following resources.

Case studies
- Precision ag pays off in bumper celery crop: Koo Wee Rup demonstration site (2020)
- Exploring the application of precision agriculture: Koo Wee Rup demonstration site (2019)
- Koo Wee Rup demonstration site: Practice change case study (2017)

Fact sheets
- Precision agriculture in vegetable production (2019)

Podcasts
- Precision ag pays off in bumper celery crop: Koo Wee Rup demonstration site (15 mins) (2020)

Videos
- Soil Wealth ICP grower panel discussion – 2022 Annual Vegetable Industry Seminar (2022)
- Precision ag in celery and leeks virtual farm walk: Koo Wee Rup VIC demonstration site (2021)
- Informing irrigation decisions with remote weather stations at Koo Wee Rup (2021)
- The benefits of cover crops and reduced tillage: Koo Wee Rup (2021)
- Taking soil samples? We show you how it's done at Koo Wee Rup (2021)
- A breezy video update from Koo Wee Rup (2021)
- Soil health a big winner from precision ag trial (2020)

Articles
- Ag-tech trial turns up the heat on weeds (2021)

Posters
- Variable rate application: Is it right for your farm? (2020)