SUSTAINABLE VEGETABLE SYSTEMS

Final Report | July 2024

PART 2

Disclaimer

The Sustainable Vegetable Systems (SVS) web application provided on website www.svstool.co.nz (the SVS Tool) has been developed by a partnership comprising the Ministry of Primary Industries (MPI), The New Zealand Institute for Plant and Food Research Limited (PFR), Potatoes New Zealand Incorporated (PNZ), Horticulture New Zealand Incorporated (HortNZ), and the Vegetable Research and Innovation Board (representing Onions New Zealand Incorporated, Vegetables New Zealand Incorporated, Process Vegetables NZ and the New Zealand Buttercup Squash Council) (together the SVS Partners).

The SVS Tool has been designed to provide users with insight about nitrogen flows through a nitrogen budget, and guidance on nitrogen fertiliser application.

Use of the SVS Tool is voluntary and the user should exercise their own discretion before deciding to use it.

Use of the SVS Tool is at the sole risk of the user and none of the SVS Partners provide any warranty or assurance in relation to the accuracy of, or fitness for any particular use or application of, any information or scientific or other result contained in the SVS Tool.

To the maximum extent permitted at law, the SVS Partners shall not be liable for any cost (including legal costs), claim, liability, loss, damage, injury, or the like, which may be suffered or incurred as a direct or indirect result of the reliance by any person on any information contained in the SVS Tool.

Report reference:

Barber A, Stenning H, Searle B, Brown H (2024, July). Sustainable Vegetable Systems Final Report. Prepared by Agrilink NZ and PFR for the Sustainable Vegetable Systems partners.

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4 Workstream Three: Model and tool development

4.1 Model development

The model developed over the course of the SVS programme was based on the **S**imple **C**rop **R**esource **U**ptake **M**odel within the **A**griculture **P**roduction **S**ystems s**IM**ulator (SCRUM-APSIM) model.

Simulations were set-up in SCRUM-APSIM using soil, crop, and management details of each experiment. Weather data for the Lincoln and Hawke's Bay sites were obtained from the Lincoln and Whakatu NIWA stations, respectively. For each crop, the highest measured final yield was used as input in the model with the expectation that the crop would respond to water and N supply limitations imposed by the treatments. Measurements of crop yield, N uptake, soil mineral N, soil water content, and soil solution N concentration were made at different times during the trial period. Measurements of soil water in the top layer (0–30 cm) were made using the Time domain reflectometry (TDR) while a neutron probe (with tubes installed to a depth of 120 cm) was used in other layers.

Determining model fit uses a coefficient of determination (R^2), and describes the change in data as a degree of fit, or the share of total variability explained by the model. The Root Mean Square Error (RMSE) is the square root of the ratio of the square of the deviation between the measured value and the true value of the number of observations. The RMSE has a value equal to or greater than zero, with zero describing a perfect fit for the observed data. The ratio of deviation from observed values or RSR is the ratio of the RMSE and the standard deviation of measured data. The RSR varies from the optimal value of 0 to a large positive value. Classifications of $0 < RSR \leq 0.5$, $0.5 < RSR \leq 0.6$, $0.6 < RSR \leq 0.7$, $RSR > 0.7$ are considered describe very good, good, satisfactory and unsatisfactory model prediction accuracy, respectively. The Nash -Sutcliffe Efficiency or NSE (ranging from minus infinity to 1) is a normalised statistic that determines the relative magnitude of the residual variance compared to the measured variance. A perfect fit is represented by an NSE of 1. A very good, good, satisfactory, and unsatisfactory performance rating are represented by $0.75 < NSE \leq 1$, $0.65 < NSE \leq 0.75$, $0.5 < NSE \leq 0.65$, $NSE \leq 0.5$, respectively.

Graphical representation indicates that the model adequately captured the dynamics of plant growth and N uptake (Figure 56). Yield is an input in SCRUM-APSIM, and the highest measured yield was used for each crop. The accurate estimation of plant biomass and other plant-related variables demonstrates the model captured the effect of water and N supply. Accurate prediction of plant-related variables was supported by model performance indicators, which showed good to very good prediction rating (R^2=0.75–0.91, RSR=0.30–0.53, NSE=0.71–0.91).

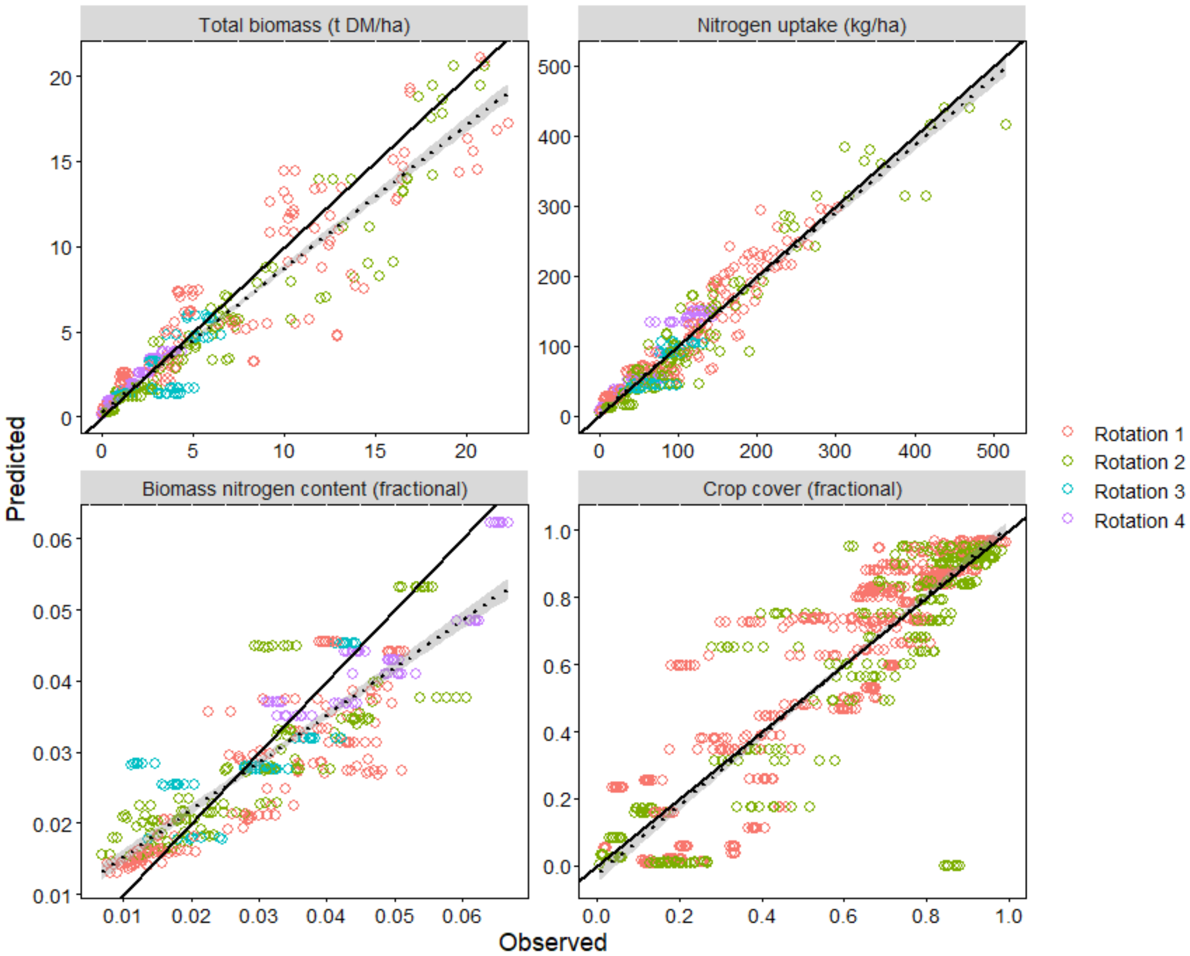


Figure 56. Predicted versus measured values of aboveground biomass and nitrogen uptake four Sustainable Vegetables Systems Project crop rotations evaluated at Lincoln and Hawke's under irrigation and fertiliser nitrogen (N) managements. The solid line is a 1:1 relationship and the dotted line is the linear relationship between observed and predicted with a 95% confidence.

Soil mineral N was accurately predicted except for the deepest evaluated layer (120–150 cm). There was substantial variability in measurements consistent with the association of spatial heterogeneity with soil measurements. There was less noise when soil mineral N data were combined from the surface to specific depths. For the top 60 and 120 cm of the soil profile, the model accurately predicted soil mineral N. This is important because leachate concentration was quantified at 60 and 120 cm depths. While there was noticeably high variability among replicates in measured data, comparison of soil mineral N to 60 and 120 m depth indicated greater under-prediction at the Hawke's Bay sites (Figures 7–10). This can be partly explained by the high water table at these sites.

4.2 Model validation using Workstream 1 and Workstream 2 data

The model that underlies the SVS Tool has been tested against all the field observations collected in the SVS project including:

- Workstream 1 – detailed N balance of 4 separate crop rotations grown on PFR research stations
- Workstream 2 – N balance monitoring of crop rotations on 9 commercial farms across New Zealand.

Testing was facilitated by setting up runs of the SVS model that were configured to be analogous to each of the test crops in the above groupings. Outputs of soil mineral N and crop N uptake were output daily over the duration from the end of the prior crop to the end of the current crop so testing encompassed fallow and crop growth periods.

There was generally good agreement between the model's predictions and the field observations. Each test location is given below (Figure 57–69) with comments about the reasons for lack of agreement in specific cases. The three main phenomena observed where the model did not appear to perform well were:

1) Not accounting for luxury N uptake. The model's coefficients for predicting crop N uptake are set at values to achieve an optimal yield of saleable quality. For some crops N% of product and stover required to achieve this is lower than the N% that will be achieved if surplus N is available in the system. In these situations, the model predicted less crop N uptake and more soil N than was observed. In our testing this occurred in cereal, grass and green manure crops that are planted to control surplus N in the rotation. The model's failure to account for luxury N uptake will not influence the accuracy of its N recommendations as the crops where this phenomenon was observed were unfertilised catch crops. However, it does influence the model's ability to demonstrate the effectiveness of these crops to mitigate higher N in rotations. It is possible to add luxury N uptake mechanisms into future versions of the model to capture this.

2) Under prediction of crop N uptake and soil N. This could be caused by under prediction of mineral N entering the system from predicted mineralisation of soil or plant organic matter. Further testing of these components of the model is warranted to build confidence in predictions of N fertiliser N supply. It may also be caused by and over prediction of losses from the system. The loss model was developed specially for the SVS Tool by fitting a simplified model to loss predictions from the APSIM farm systems model. APSIMs' predictions of losses were validated against losses measured in Workstream 1 and against other experiments in the past. However, a number of assumptions had to be made to simplify measurements based on actual weather events to a model that uses long term average weather to forecast fertiliser requirements. Further testing of the loss model is required to build further confidence in this component of the SVS Tool. It is also possible fertiliser was added to the system, but a record of the event missed, so not all the inputs were included in the model's configuration.

3) Over prediction of soil N occurred in some situations. This could be caused by the opposite of the factors described above, an over prediction of mineralisation or an under prediction of leaching.

From the data collected it is not possible to attribute an exact cause to these over and under predictions.

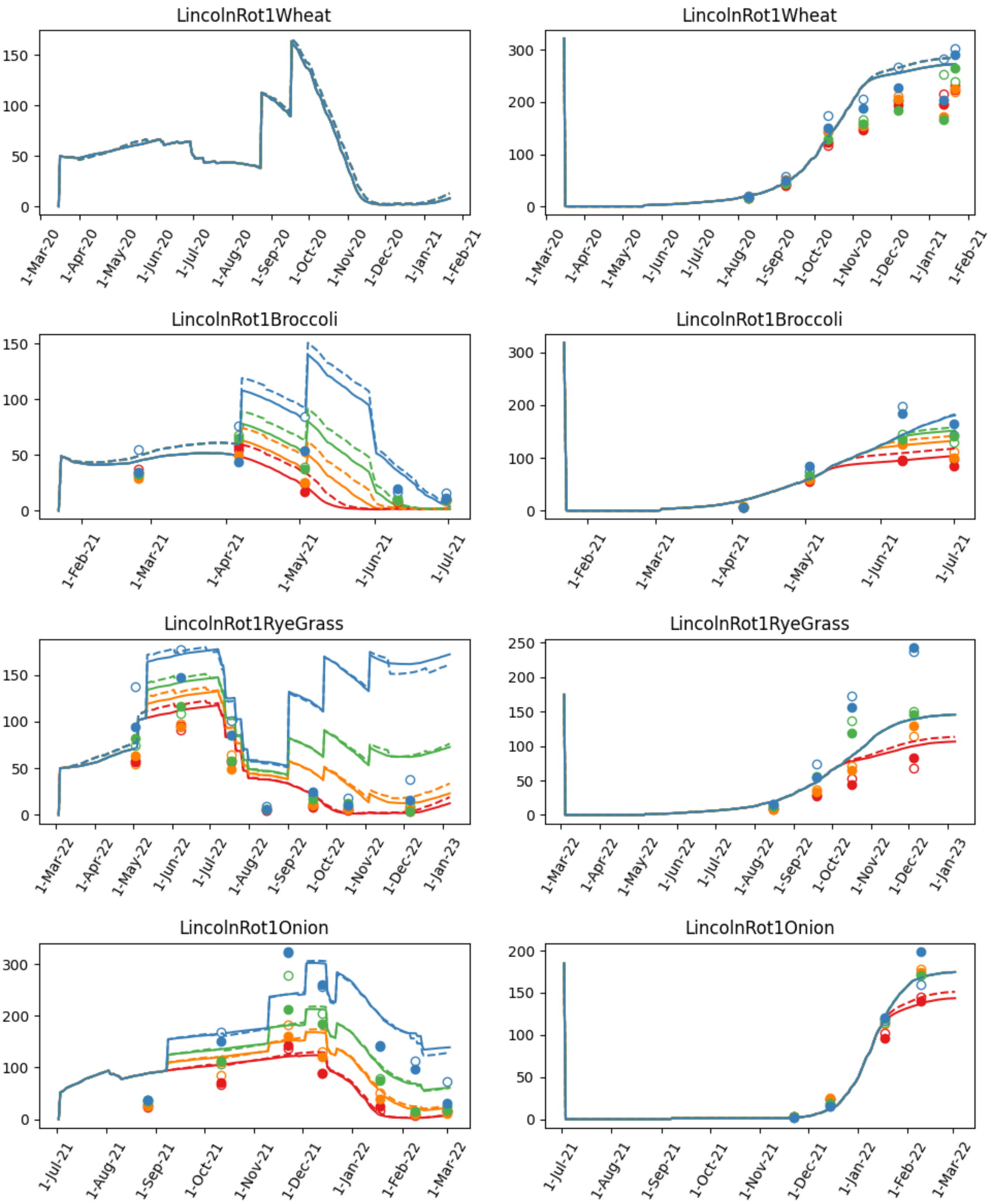


Figure 57. Lincoln Rotation 1. The model under predicted nitrogen (N) uptake by up to 100kg/ha in the higher N treatments in the ryegrass seed crop which resulted in an equivalent over prediction of soil N in these treatments. This is related to the model not predicting luxury N uptake in crops; when crops receive more N than in required for maximum biomass yield but continue to take up nitrogen and achieve a higher N% in product and stover. The model's coefficients have been derived to ensure adequate N for a saleable product so it would have recommended enough N to achieve that in this case. Plots on the left are soil mineral N levels, plots on the right are crop N uptake. Lines indicate predicted values and dots indicate measured values. Colours red, orange, green and blue represent N treatments N0, N1, N2, and N3 respectively. Units are in kg N/ha.

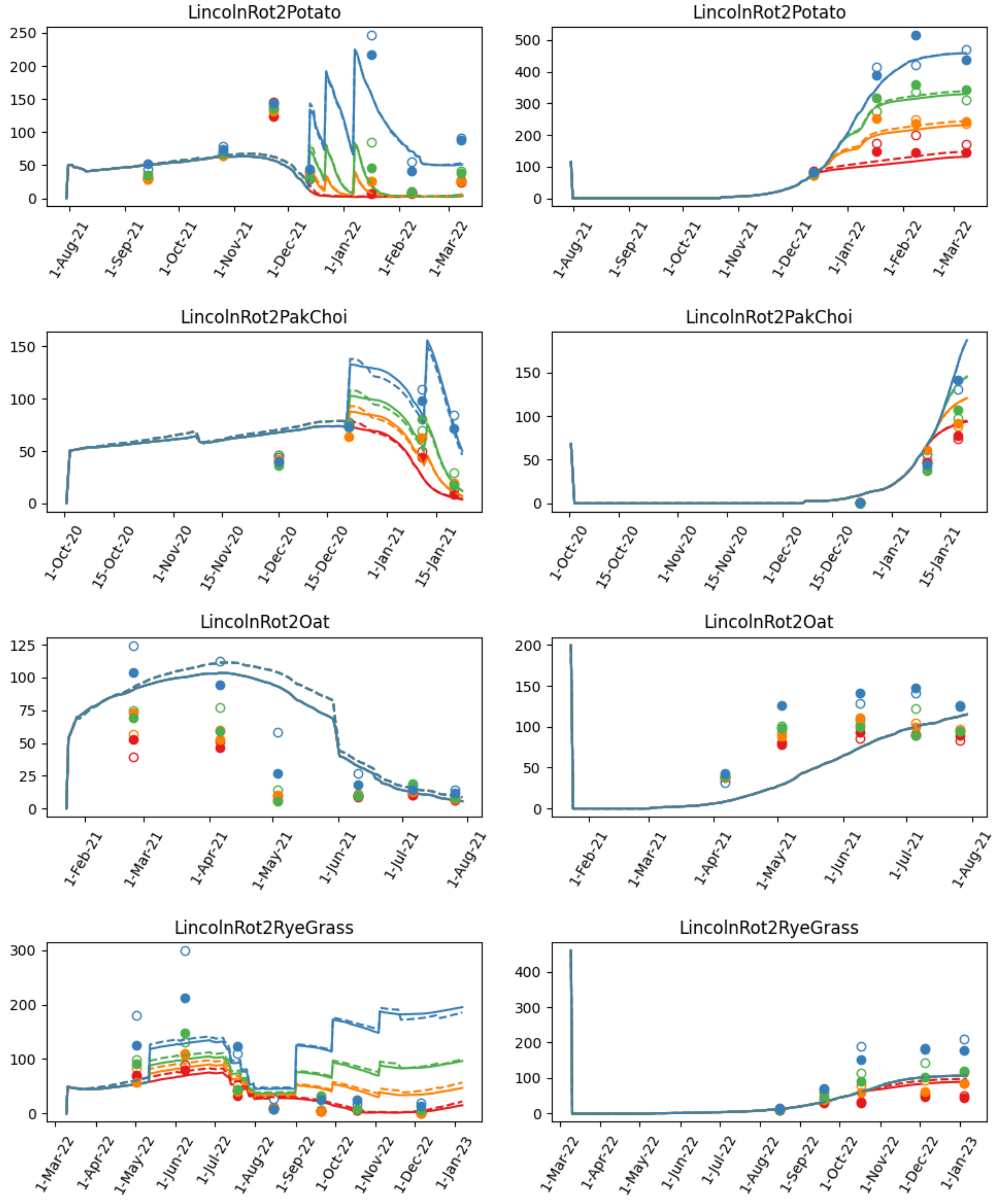


Figure 58. Lincoln Rotation 2. There was good agreement for the potato and pak choi crops but an under prediction in the early uptake for the oat crop and for the higher N treatments for the ryegrass seed crop. This is related to the luxury N uptake issue outlined above. Plots on the left are soil mineral N levels, plots on the right are crop N uptake. Lines indicate predicted values and dots indicate measured values. Colours red, orange, green and blue represent N treatments N0, N1, N2, and N3 respectively. Units are in kg N/ha.

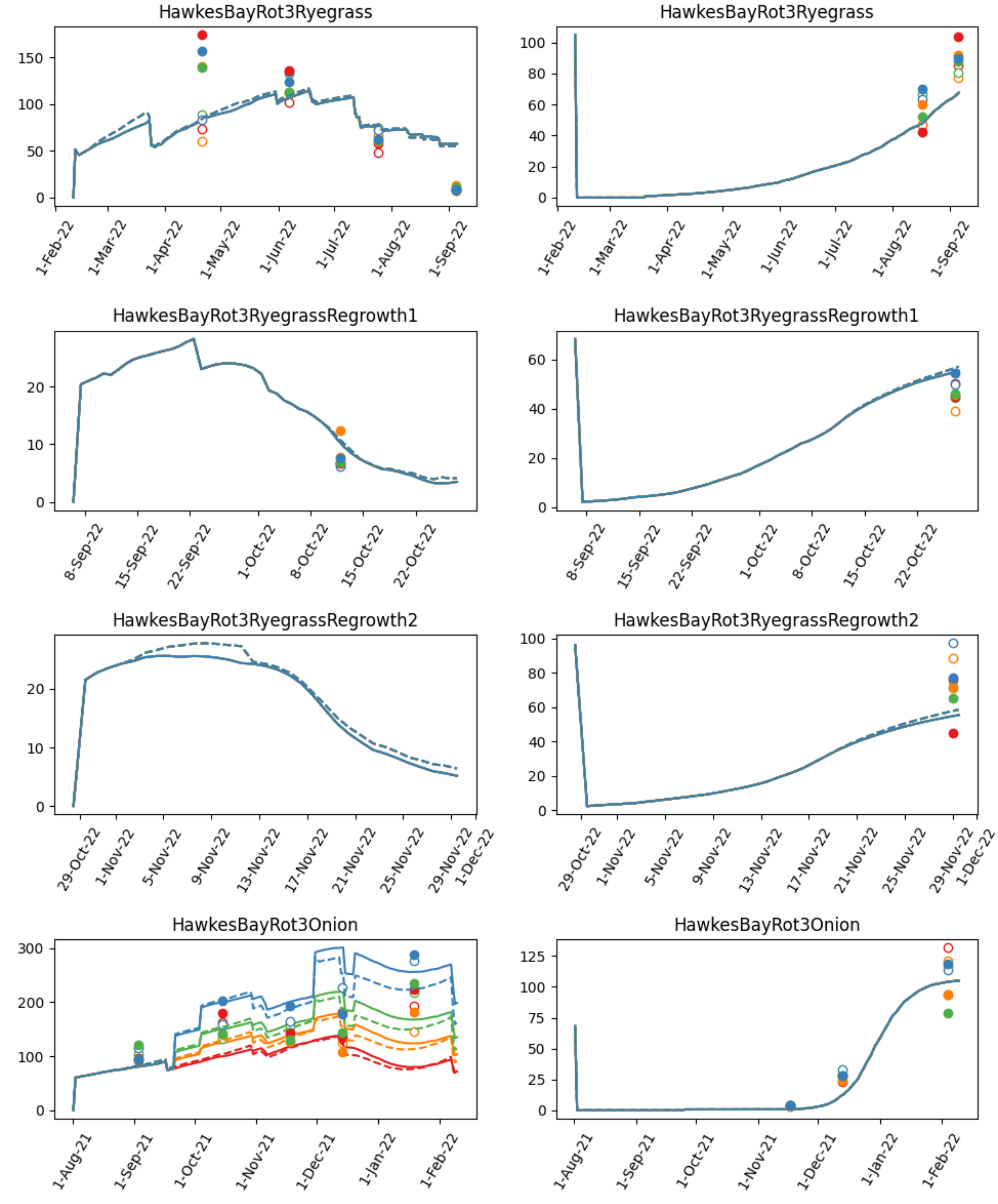


Figure 59. Hawke's Bay Rotation 3. There is good agreement between observations and predictions. Plots on the left are soil mineral N levels, plots on the right are crop N uptake. Lines indicate predicted values and dots indicate measured values. Colours red, orange, green and blue represent N treatments N0, N1, N2, and N3 respectively. Units are in kg N/ha.

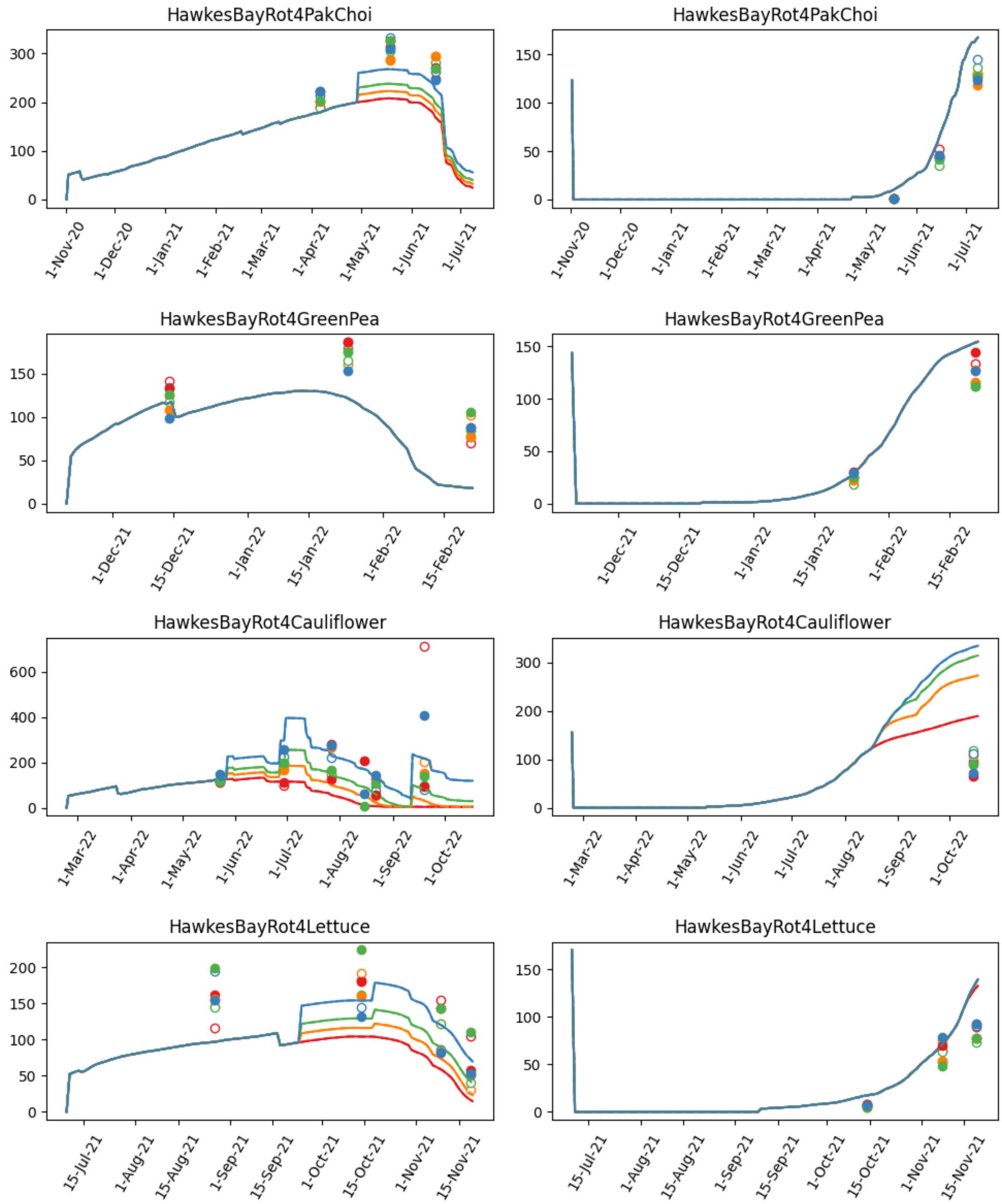


Figure 60. Hawke's Bay Rotation 4. There is good agreement for all crops except the cauliflower crop which took up considerably less nitrogen (N) than was predicted and had a higher soil N at the end of the crop as a result. This is because the cauliflower crop did not perform as anticipated and gave a poor yield. Plots on the left are soil mineral N levels, plots on the right are crop N uptake. Lines indicate predicted values and dots indicate measured values. Colours red, orange, green and blue represent N treatments N0, N1, N2, and N3 respectively. Units are in kg N/ha.

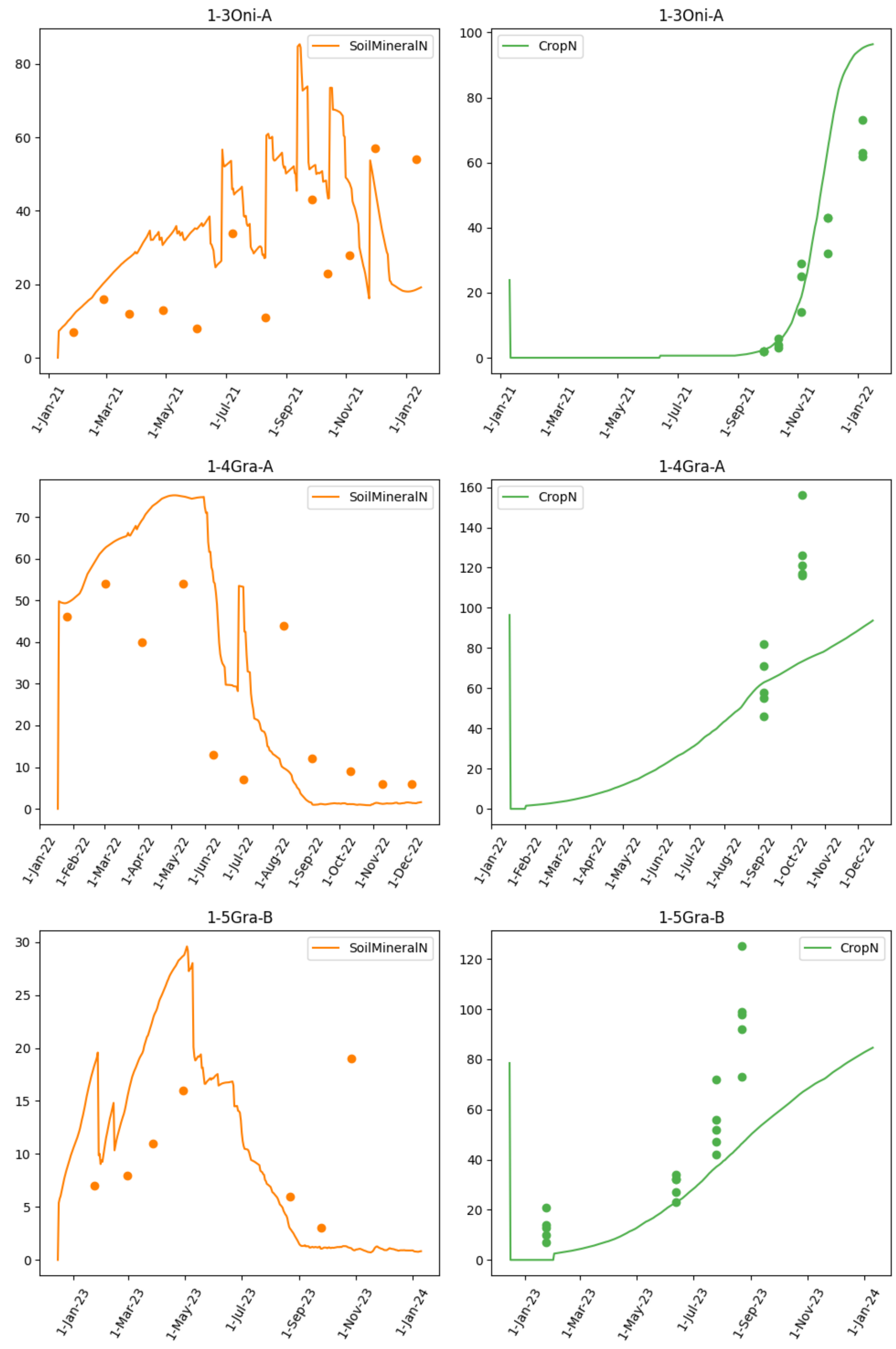


Figure 61. Site 1. The model over predicted in the nitrogen (N) uptake in the onion crop by about 20 kg/ha but then appeared to under predict the N uptake in the two following grass crops. The grass crops were not fertilised, and the model predicted low soil N contents toward the end of each crop which could be due to an over prediction of N loss or and under prediction of N from soil mineralisation. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

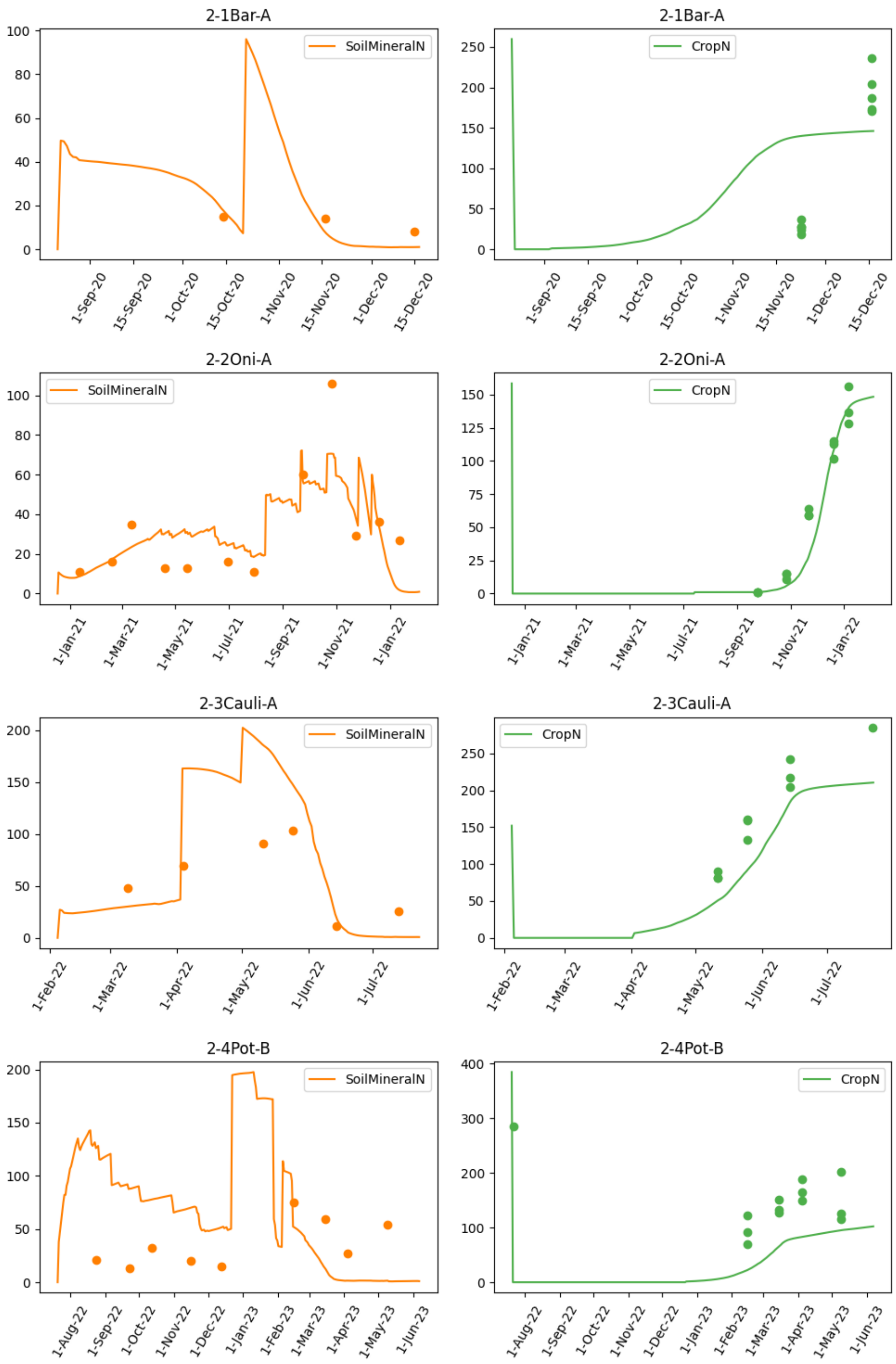


Figure 62. Site 2. There was good agreement at this site except for the cauliflower and potato crop nitrogen (N) uptake was under predicted by about 50 kg N/ha. In both cases we see a flattening off of the N uptake curve which means uptake was constrained by lack of N supply in the soil. This could be due to an under prediction of N entering the system from mineralisation or an over prediction of N losses leaving the system. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

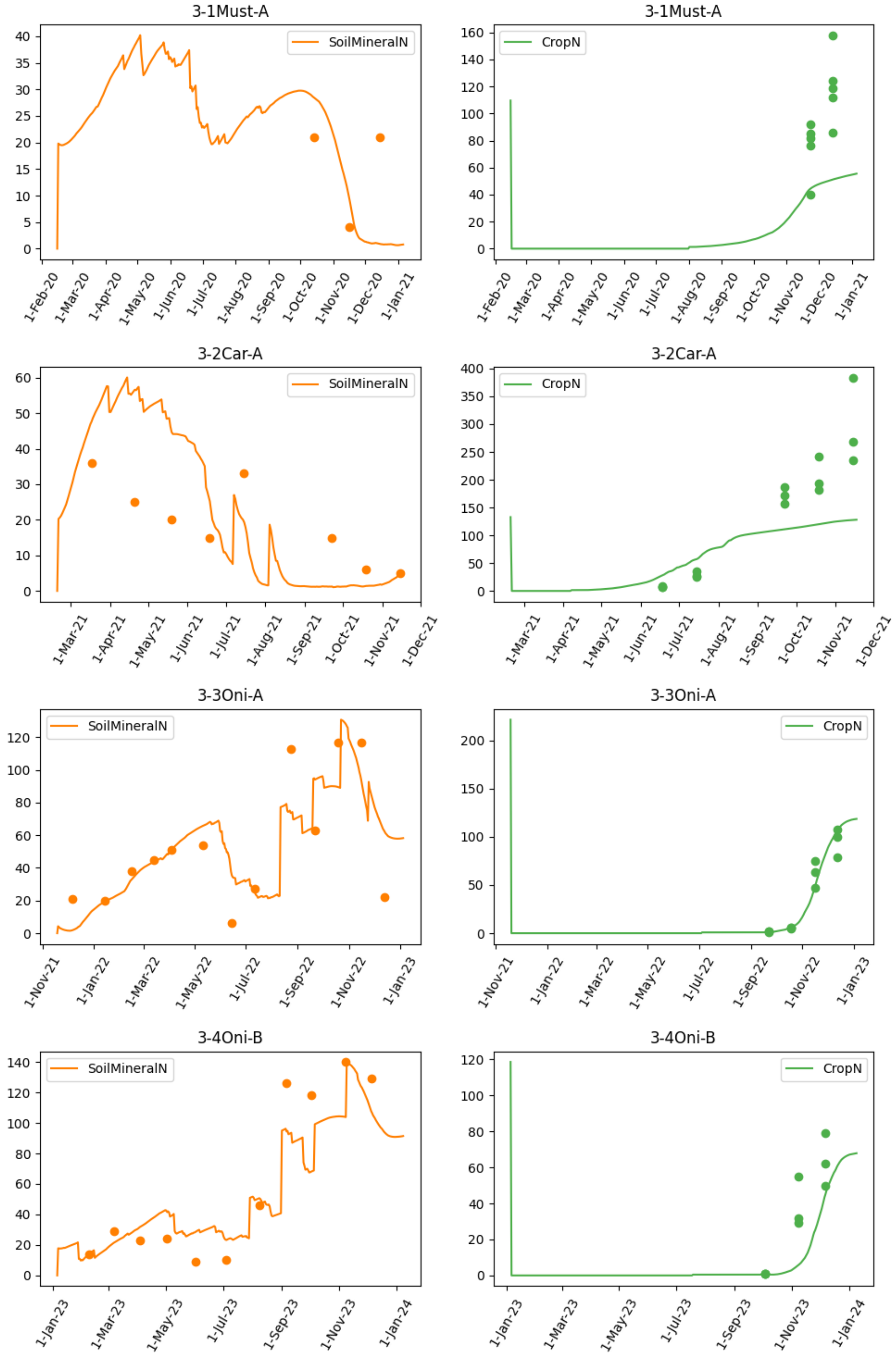


Figure 63. Site 3. The model performed well for the two onion crops measured at this location but under predicted nitrogen (N) uptake for the mustard and carrot crops due to lack of N in the soil. This could be due to an under prediction of inputs from mineralisation or an over prediction of losses. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

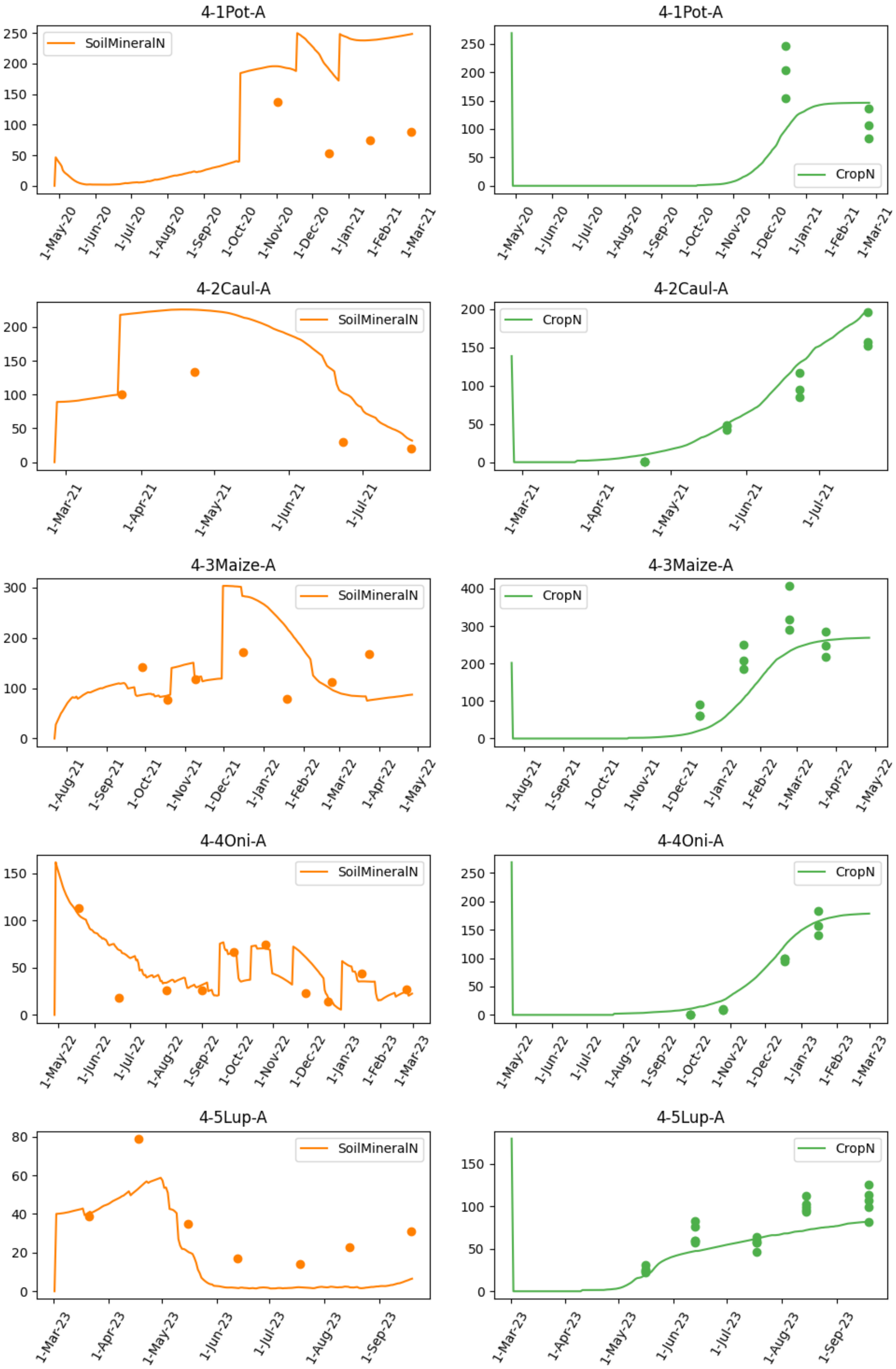


Figure 64. Site 4. The model performed well at this location. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

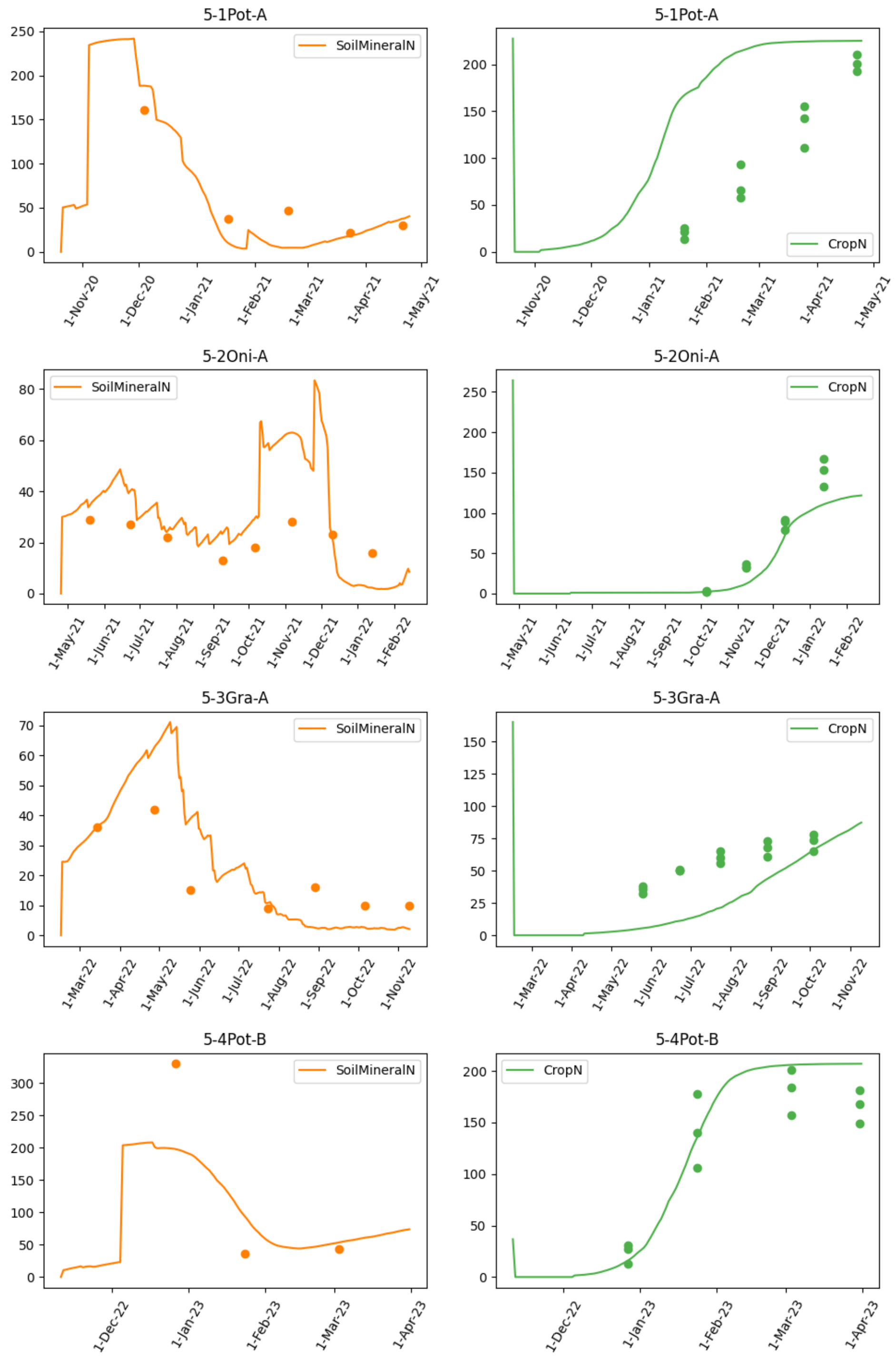


Figure 65. Site 5. The model performed well at this location except for an over prediction of early nitrogen (N) uptake by the first potato crop and an under prediction of early N uptake by the grass crop. We are unclear what caused the under prediction in the potato crop but the observed pattern of uptake is not consistent with other potato crops measured so there may have been a problem with the sampling protocol. The grass crop was continuously grazed and it was not possible to configure the model to represent this in a realistic way. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

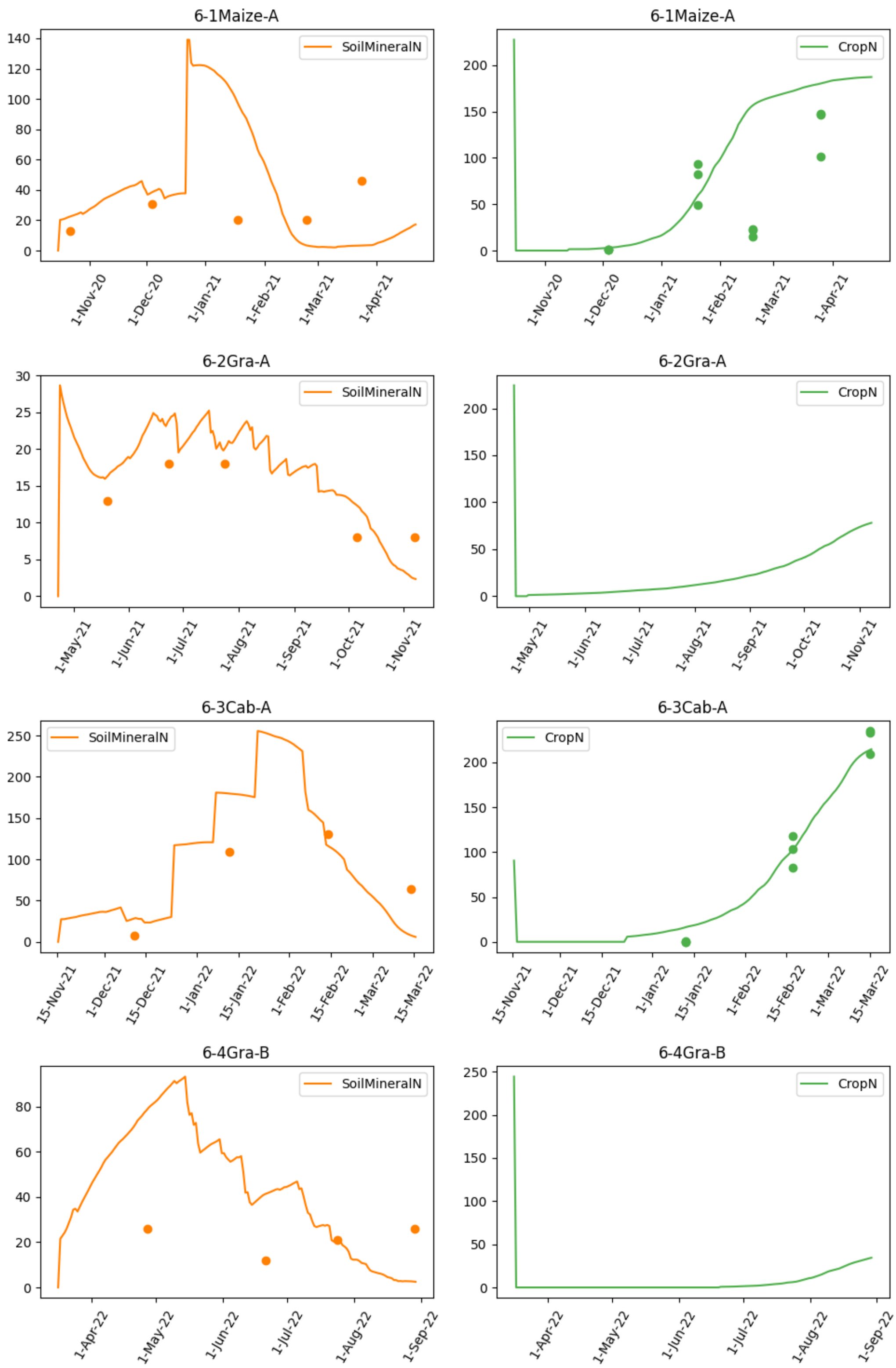


Figure 66. Site 6. There was good agreement for the cabbage and grass crops although no measurements were collected for N uptake from the grass crop. There appeared to be an over prediction of nitrogen (N) uptake for the maize crop but there is some uncertainty about the observations later in this crop. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

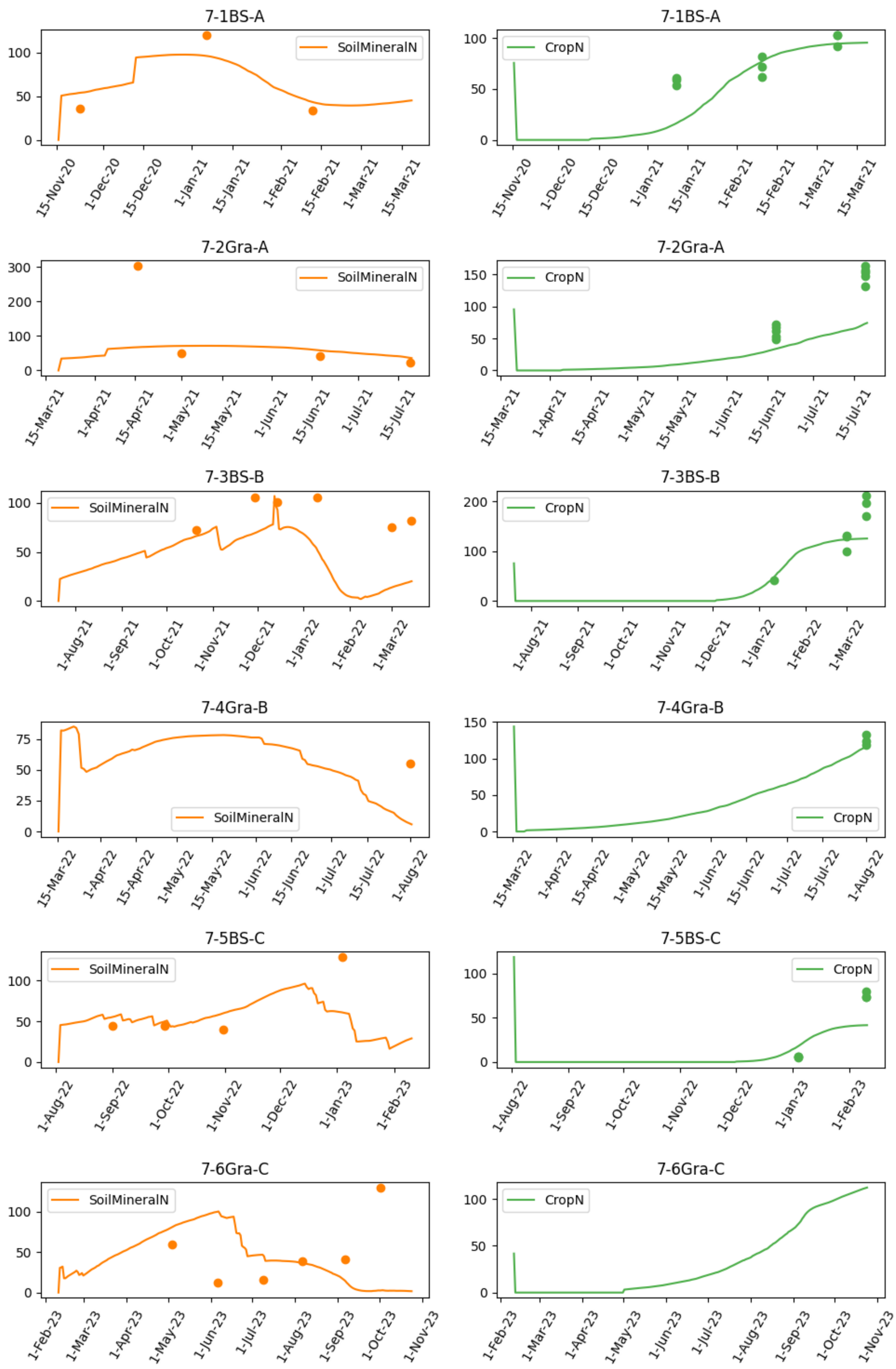


Figure 67. Site 7. We have an incomplete record of fertiliser nitrogen (N) inputs for this location so it is not possible to make judgement on the performance of the model. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg

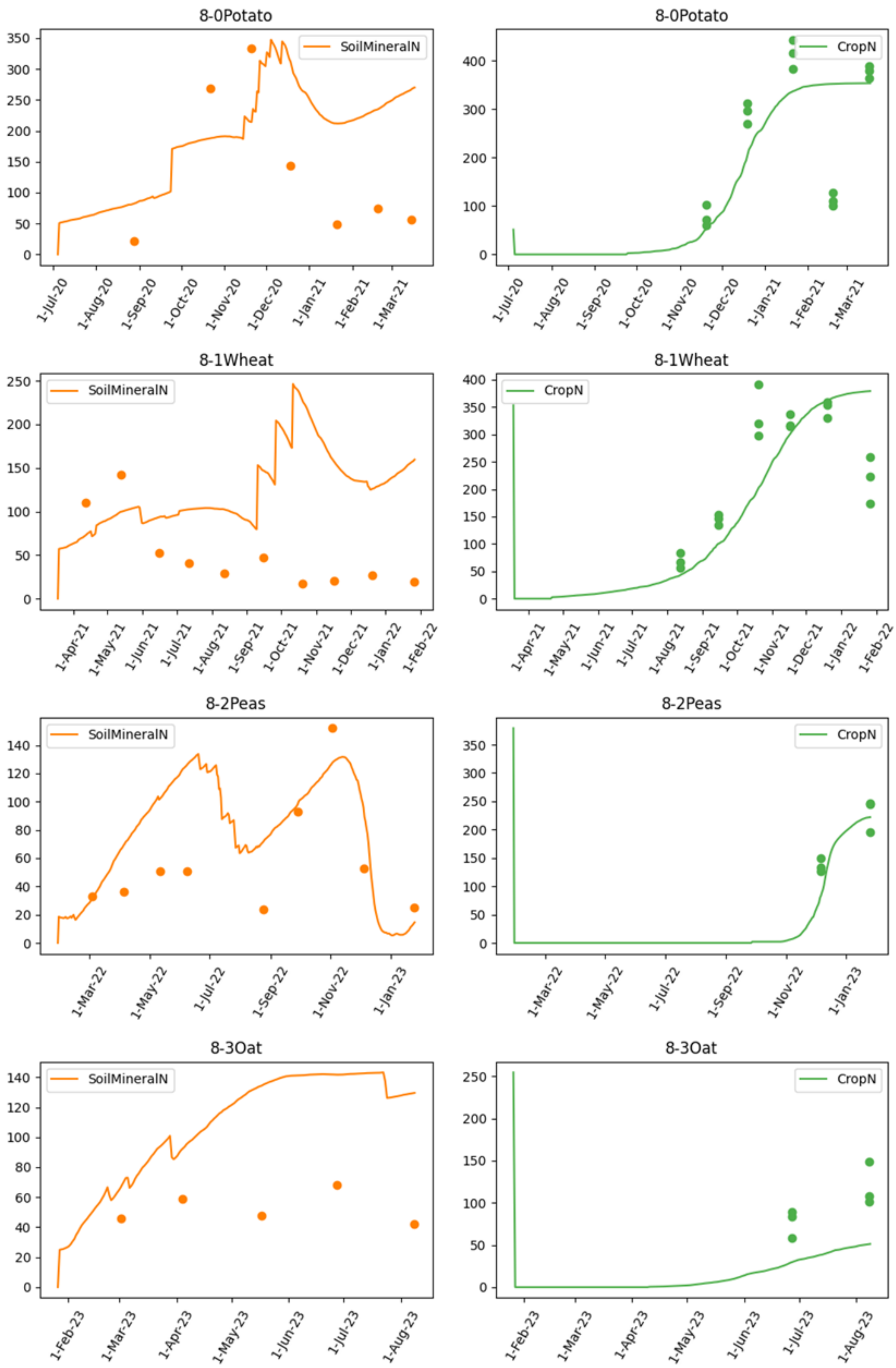


Figure 68. Site 8. The model gave good predictions of crop nitrogen (N) uptake at this location except for the oat crop which N uptake was underestimated. This is due to the model not accounting for luxury N uptake in this crop which has been explained earlier. There was a general tendency to over predict soil N which may be due to an over prediction of N mineralisation or and under prediction of losses. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

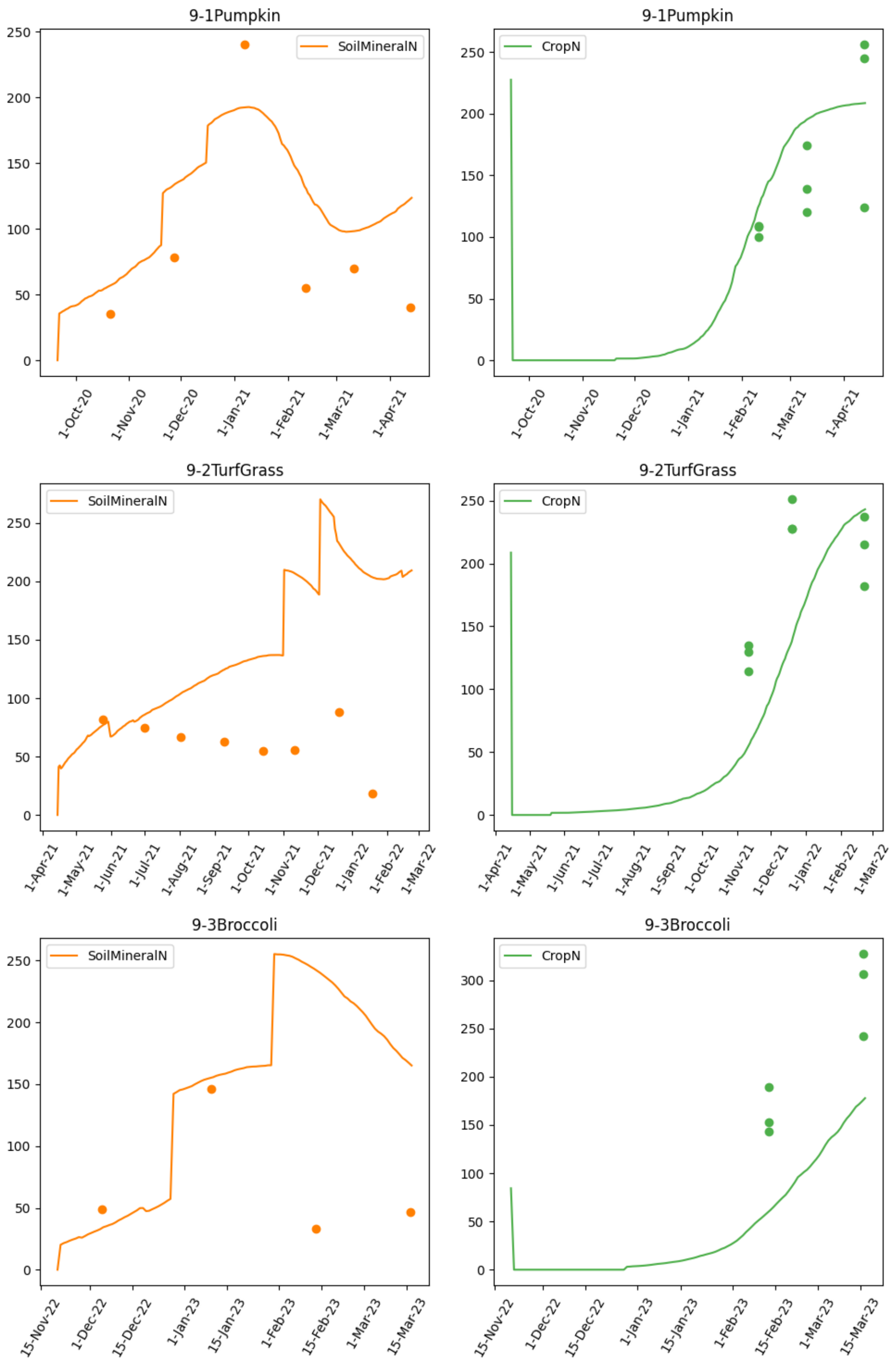


Figure 69. Site 9. The model gave an under prediction of nitrogen (N) uptake by broccoli at this location which could be due to an incorrect yield being used in the model configuration or incorrect coefficients for harvest index or N content in the model. There was also a tendency to over predict soil N which may be due to an overprediction of mineralisation or under prediction of losses. Plots on the left are soil mineral N levels (orange line and points), plots on the right are crop N uptake (green line and points). Lines indicate predicted values and dots indicate measured values. Units are in kg N/ha.

4.3 Tool development

Early on during the programme development stage of SVS it was recognised that any outputs from the project must be delivered to end users in an accessible way. Therefore, the development of a user-friendly tool was prioritised as a key output from the programme, with this taking the form of a web application that integrated the SVS model and combined this with additional outputs and management options. Development of the tool interface was entrusted to Rezare Systems (now Map of Ag AU/NZ), a software development company based in Hamilton.

4.3.1 Rezare Pathway Review

This section summarises the concept development work carried out by Rezare Systems after first being contracted to deliver the tool in 2022. Content from this section comes from Wilson D et al (2022), with the full pathway review available upon request. This review solidified the development pathway for the tool and underpins the strategy behind the tool's open-source design.

Introduction

A key deliverable for the project has been to support fertiliser decision makers through the development of a farmer-facing tool. The goal for such a tool was to support management decisions while also helping growers to consider and demonstrate how they will meet regulatory requirements (for instance, as part of their Farm Environment Plan evidence of GMP). Early project workshops identified a range of options for delivery of farmer facing solutions. These options could include embedding or linking to *OverseerFM*, supporting integration into third-party software, or delivery as a stand-alone tool.

In this context, Rezare Systems was asked to engage with the project team to identify potential options, explore the potential benefits of each to growers and their engagement, and inform the project team about likely comparative costs and risks of each approach.

Methodology

The methodology adopted by Rezare Systems was:

- to work with the PFR modelling team to understand how the model Is currently framed and constructed
- to interview the short list of stakeholders, including council, growers, and service providers
- to consider potential application or integration scenarios.

The interviews of stakeholders typically asked:

- what their organisation's area of interest was in nitrogen management within vegetable crops
- their view of how the SVS model should or would be used
- the benefits they hoped it would deliver
- the possible barriers to achieving those benefits
- who might use the model and why they might use it
- how the tool might be packaged (that is, standalone or integrated into another tool)
- to identify any potential issues.

In the final step, Rezare drew on their substantial experience in the development of decision support systems and delivery of mathematical models that support a range of farming systems in New Zealand and internationally. They considered the relative investment necessary to both implement and maintain each of the potential approaches and drew on their experience with how these approaches facilitate adoption and use across the industry.

Interview results

Interviews were conducted with the following people in Table 16.

Table 16. Rezare pathway interviewee description.

Name	Title	Organisation	Type
Hamish Brown	Model developer	Plant & Food Research	Research
Bruce Searle	Science Team Leader	Plant & Food Research	Research
Waka Paul	Social Scientist	Plant & Food Research	Research (Social Science)
Jacquie Harper	Chief Scientist	Overseer	Industry tool
Allen Lim	Owner	Jade Garden	Grower
Stuart Davis	Sustainability Manager	Leaderbrand	Grower
Antony Heywood	General Manager	Vegetables NZ	Vegetable NZ Manager
Gavin Subritzky	Technical Specialist	FruitFed Supplies	Service industry
Tom Stephens	Principal – Integrated Catchment	Auckland Council	Regional Council
Ian McNab	Rural Advisor	Horizons Regional Council	Regional Council
Damian Diack	Programme Manager (Overseer Redevelopment)	MPI	Government

Prototype tool

The following summarises the state of the SVS Tool at the time of our interview with Hamish Brown (18 May 2022).

The existing tool is a prototype. The interface is designed to show everything, not what an end-user might see. It works field by field, and there are some default values. The eventual user experience should be designed based on the needs and intended use pattern of the end users.

Inputs include:

- crop and type
- yield and units
- moisture percentage
- percentage field losses
- percentage dressing losses
- location.

The model calculates total N requirements of the crop, produces a N uptake curve, and then partitions it into saleable yield, dressing losses, field losses, stover and root N. The previous crop history is stored so it can determine the stover and root residues coming in and mineralising during the current crop, as shown in Figure 70.

The tool has the same approach for the current and following crops so you can run the N balance into the following crop to see the outcome of the current crop and potential mitigations.

The prototype has four regional locations, each with a meteorological file behind them. The meteorological data used are long term averages on a daily scale because the tool is forward looking. Temperature data are the most important measure for the model now because while mineralisation is considered, N leaching is not modelled. Were N leaching to be added, then rainfall would become an important (but highly variable) input.

Some vegetable growers also grow arable crops, and the same model could be of benefit for arable use also.

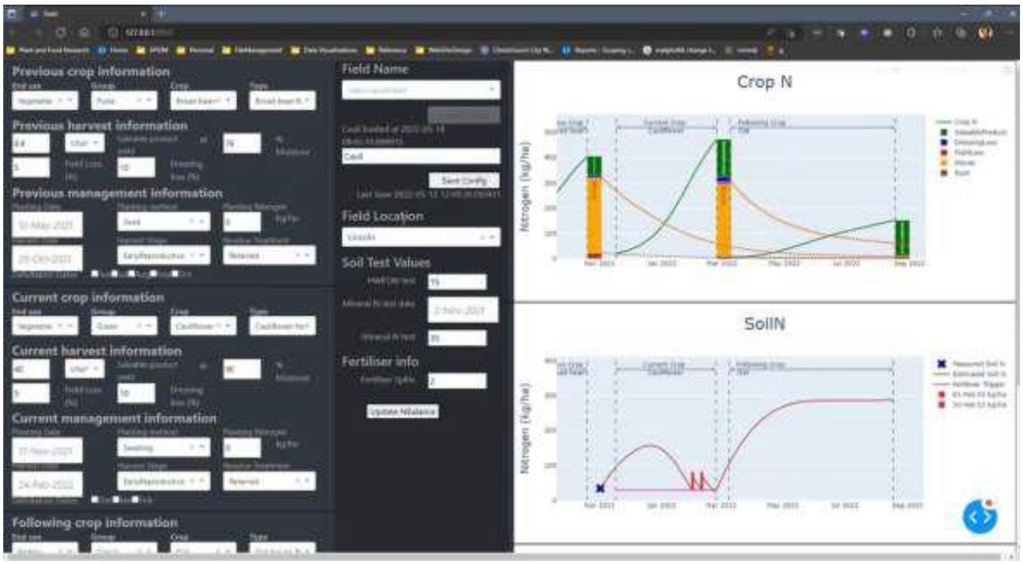


Figure 70. Screenshot from the prototype tool.

Stakeholder interviews

Most interviewees felt that the model could be beneficial to the industry. Three key benefits were identified:

- To understand what is happening with nitrate mineralisation, plant availability and uptake, and hence nitrate remaining in the soil for future crops or at risk of leaching. This could be considered an "education" outcome.
- To improve the planning of N fertiliser application, both quantities and timing, with potential economic and environmental benefits.
- To demonstrate that best practices of nutrient management are considered in the business (practices that support catchment outcomes without relying on a single leaching number).

There was significant discussion about nitrate losses due to leaching and volatilisation. These are not currently predicted by the model. Modelling leaching would require significantly more knowledge of the soil parameters, seasonal weather considerations (rather than long-term climate data) and could have issues of alignment with models such as *Overseer*. Some stakeholders expressed a desire to have visibility of leaching, but all stakeholders also wanted the model to be simple to use and did not like the idea of needing to provide more data.

Rezare asked about potential ways that the model could be used in the industry. If data entry was not too onerous, most interviewees felt that growers themselves (and even staff in their businesses) would be able to use the tool and would gain insights from its use. One grower suggested they would like to make it mandatory for their teams to use when planning crops. The intention in this context was that team members would consider appropriate practices to use.

Other potential users of the tool could include agronomists, consultants, fertiliser companies and seed companies. The tool could be used as part of fertiliser planning or crop planning in the latter contexts. It could also potentially be used or triggered when receiving lab results from the HWEON test.

Rezare discussed with interviewees how the tool might be delivered. Overall interviewees seemed to favour a standalone tool, with potential for the crop information to be automatically provided or integrated from other tools that growers might use. We suggested several existing packages (e.g. *ProductionWise, Muddy Boots*) that could build in the model. Apart from *NuPoint*, which was mentioned by one organisation, many New Zealand vegetable growers primarily make use of spreadsheets and whiteboards in their vegetable crop planning (along with electronic spray diaries), and this might be why a standalone tool was preferred.

Rezare looked at the potential hosting or integration of the model with *Overseer*. While *Overseer* Limited consider there may be some “shared IP”, the function and use of the model would be quite different from *Overseer*’s target. In particular, the model is a tactical tool that focuses on timing and best practice rather than a strategic tool.

Some growers and industry participants had a negative view of compliance with *Overseer*. This may be historical more than present reality, but that perception should be considered. There would however be benefits in sharing a common farm/growing data model across *Overseer*, SVS, and potentially other tools. This could dramatically reduce the amount of duplication of data recording growers needed to do across all tools.

There was some discussion about the use of SVS in the context of regulation and compliance. Strong fact-based evidence will be essential to allow growers to demonstrate their practices to both regulators and markets. Again, interviewees (including those associated with regional councils) argued that the model should support decisions about good practices rather than providing a single number which might be grasped for compliance. There is significant concern among growers about the potential for punitive outcomes from tools and it will be important to explicitly address this.

We explored how wide adoption might be achieved. Interviewees pointed out that many growers are time poor and under financial pressure. They are often working “in” the business rather than “on” the business. It will be important to respect their time, and to communicate the benefit SVS could provide.

Growers also look to industry champions as the leaders for innovation and practice change. It will be important to support adoption among these recognised leaders and publicise their use of the tool. Many interviewees noted the need to have a support framework for the tool. It needs to be able to adapt and growers need to build confidence in what the tool predicts. Increasingly the New Zealand primary industry is recognising that models need to fit into a wider ongoing support structure and cannot just be funded for development without longer-term success considerations.

Some practical considerations were raised:

- not all growers test for nitrate
- growers are increasingly concerned about market yield rather than absolute yield – language and intent matters
- growers are often concerned that lack of N means their crops may be rejected by buyers (too yellow) and will apply more nitrogen than is strictly needed for growth
- similarly, growers worry about heavy rain at key times removing nitrate from the soil. If growers are unable to access their fields to apply additional N at these times, they may lose the value of their crops
- growers recognise the importance of leaving crop residues on the fields, but residue is typically not evenly distributed. There is a concern that minimising additional N application may result in good outcomes in some areas of fields and poor outcomes in other areas. Similarly crop harvest timing may be selective. These sub-field spatial concerns impact soil tests, the model, and N applications.

Discussion

Based on both the interviews and Rezare's experience in models in arable, vegetable and livestock systems, they identified some key considerations.

1. The SVS Tool is a lightweight, simplistic model. It is not designed to give an absolute figure nor to handle nitrate leaching. Really it is designed to help people look at efficient use of their nitrogen fertiliser applications, particularly to think about not needing to apply it all in one dose at the start of planting. It provides learning and feedback on how you could operate your fertiliser policy differently. The tool provides visualisation to support a change in fertiliser application practises.

2. A few growers use crop production software tools like *ProductionWise* and *NuPoint*. However, apart from electronic spray diaries, many growers do not have crop management software tools. Rather, they may use *Excel* or whiteboards. There is no obvious single existing tool used by growers that the model could be built into.

3. The tool is not an obvious fit for long-term compliance and planning tools such as *Overseer* or the (under development) Ministry for the Environment *Risk Index Tool*. This is because the SVS model predicts short-term mineralisation and uptake and does not model leaching or other environmental losses. It is more suitable for practice optimisation tool than modelling impacts on the environment. However, the mineralisation and uptake curves should be made available to improve tools like *Overseer* if possible.

4. Several interviewees noted that if growers were to rely on the model it would need to be well supported. This would be a commitment by industry to do more than just develop the tool and push it out, but to maintain it for a longer term and provide support (either directly

to growers, or to companies who are supporting growers). Alternatively, industry could commit to supporting the model for a few years (3–5 years) and then accept that it had delivered the potential value and cease further investment.

5. Some participants noted that the intellectual property in the model, especially the equations, has been developed from industry-funded research. They were wary of this intellectual property being “locked up” with a single commercial product, or otherwise unavailable to benefit the industry.

Approaches considered

Rezare reviewed a variety of approaches that the SVS partners could consider to encourage adoption and use of the SVS Tool.

Publishing as Open or Shared Source

Publishing the SVS model as well-documented open-source libraries (technically termed “repositories”) would support its use by a wide variety of potential organisations. A well-documented open-source library also represents a significant way of publishing research results, albeit without formal peer review.

There is an immensely “long tail” of open-source projects however, many of which have very low engagement by software development and user communities. Source code is also only accessible to those with the technical skills to access this, such as software developers, commercial software businesses, and technology enthusiasts. This does not directly address the desired outcomes for growers. It’s likely that open-source publishing would need to be used alongside other activities to incentivise uptake. Documenting and preparing an open-source data exchange might cost in the order of $25–30,000.

Intellectual property rights and considerations also need to be considered in open-source publishing. If the SVS model depends on significant intellectual property input from research or other organisations, or if the SVS partners desire to restrict access (for instance, to businesses delivering benefits to New Zealand growers only), then a completely open-source model will not be appropriate.

However, a shared-source model where access is granted to approved organisations or after execution of an intellectual property agreement could be effective. Even an open-source model will still need to be maintained to stay relevant. An open source “maintainer” will typically respond to questions and suggestions from developers, and ensure the solution stays up to date with current development tools and frameworks. In most years this would be a relatively “light touch” arrangement, with occasional more substantial work required.

Standalone visual model

While the current iteration of the SVS tool was not intended for widespread use, it has the characteristics of a visual user interface that allows growers and advisors to adjust the relatively simple set of parameters, and to visually see the curves of N mineralisation and uptake, along with potential application dates. This visualisation provides a substantial part of the benefits of using the tool – increasing understanding of nitrate flows relating to vegetable crops, and the options (which still may or may not be logistically feasible) for distributing N applications.

Current software technologies would usually see the user interface developed using a browser-based technology (such as React or Angular), with the model itself delivered through a back-end service (an Application Programming Interface or API).

Development effort for a standalone model would vary. A very simple user interface that did not attempt to store user inputs would be substantially simpler than one that provided the ability for growers to login, maintain their list of fields and crops, and produce printable output. Providing a mobile application that could be used offline would similarly increase complexity of development and testing.

Partnering with Solution Providers

One of the adoption routes we considered for the SVS model was delivery through existing software solution providers who might be providing agronomy, crop planning, or job management solutions to growers and advisors.

The benefits of this route are attractive: software solution providers already have the capability to integrate a model such as SVS (particularly if it is packaged appropriately for their use), and they can deliver an integrated user experience by integrating the functionality into the appropriate place in their existing tools.

Rezare's interviews with growers and industry participants revealed that the use of these software tools is very limited. It seems that the vegetable industry may be similar to livestock and arable industries internationally, with about 10-20% of growers making regular use of agronomic software tools (a much larger majority of growers will make very effective use of software such as spreadsheets and financial software). Nevertheless, Rezare recommended engaging with New Zealand tools that were mentioned by interviewees – *NuPoint* job management software, and *ProductionWise* [no longer available – 2024] crop planning and recording software. Other tools should be considered too. Encouraging adoption by solution providers will require a deliberate approach and appropriate resource.

In addition to the task of convincing solution providers that the SVS model will add value to their business and their customers, appropriate technical documentation will need to be developed, and collaboration with the providers is advised to ensure the model is being used appropriately and that growers will understand what the inputs and outputs mean. The SVS model itself can be supported into solution providers through an open-source repository or packaged as a hosted API.

Partnering with Agronomy and Testing Companies

An alternative route to deliver the SVS model to growers might be through agronomy providers (particularly seed and fertiliser input organisations that also provide advice) or through soil test providers.

These providers might choose to implement the SVS model in their own systems to support advice, or in the results or recommendations they provide to growers (where these are delivered online).

Unlike software solution providers, engaging with agronomy and testing companies is a two-step process, which requires convincing these companies of the benefits of delivering the SVS model, and then providing equivalent support to their software developers (often third parties) to that contemplated in the previous section.

Providing a hosted Application Programming Interface (API)

The SVS partners may also consider providing a hosted API that would allow a range of third parties to use SVS and which would also support a visual interface.

A hosted application programming interface or API is a version of the model running on a back-end web server (hosted "in the cloud") and providing a programmatic interface for use by software solution providers. A solution provider could pass the parameters to the model and receive the results back, including the time-series data that supports display of the mineralisation and uptake curves and nitrogen applications.

A hosted API service would support:

- A visual user interface
- Third-party developers including software solution providers, or developers
- Providing services to agronomy or testing companies.

Conclusions and recommendations

Rezare recommended that the SVS partners consider leveraging several approaches in concert.

1. Documenting the SVS model well and publishing it as an open-source repository (or alternatively, a protected shared-source repository if greater IP control is required) is the lowest cost way of ensuring that the outcomes of the SVS research is available for industry.

   We recommend that a shared or open-source approach is used, regardless of which of the other options is also considered.

2. Developing a visual tool that growers can use (as per the *Standalone visual model* section) is among the most expensive options but does ensure that the model is available for growers, and without the extensive lead time to convince software solution providers or agronomy or testing providers that they should develop an interface. If the SVS partners want to be sure that a tool can be delivered into the hands of growers to support best practice, this option should be considered.

3. If a visual tool is developed, Rezare recommended that an API is developed in the same project. Developing the API and visual tool in concert will lower the combined cost and will support use of the API by other solution providers.

The combination of technology approaches above balances the ability to make the SVS model broadly available to both growers through a visual tool and publishing the model for use by the technology and research community. Clearly, a commensurate level of investment will be required, both for delivery (including encouraging uptake by partners) and supporting the model and its use over its lifetime.

4.4 The SVS Tool

Following the tool concept developed by the programme team in collaboration with Rezare systems, the SVS Tool was developed in stages from mid-2022 onwards.

4.4.1 SVS Tool Launch

The eventual output is shown through the example screenshots in Figures 71-73. The SVS Tool is accessible through www.svstool.co.nz and consists of two primary views.

The first page that users are taken to after signing up or logging in is the **manage enterprises and crops** page (Figure 59). This page is designed to allow users to set up their enterprises at the operation point, and then individual paddocks, and from there individual crop rotations.

The intention behind this page was to simplify the user management experience and to also turn the SVS Tool into an operational tool for assisting with daily management decisions, as opposed to a simple detached calculator for individual scenarios. The programme team felt that the former, a complete crop N management tool, would receive far greater uptake and consistent and continued usage than the latter.

From the manage enterprises and crops page users are then able to navigate to the main page (Figure 60). This page contains all the calculation functions and outputs of the tool and is where users will spend most of their time after initial paddock setup. The main tool page consists of two primary areas. To the left side of the screen is the input area, where users can enter crop information, soil test data, and other useful information required for accurate N balance modelling. The input options available to the user are dependent on the input level selected, with the default option (**Basic**) allowing users to overwrite the default data presented for the chosen crop with the most easily accessible data – that being crop type, planting, and harvest date (anticipated dates if used for current crop or for future crop planting), and yield (or anticipated yield). The intention behind locking off a majority of inputs was to allow users with less crop and soil test information to receive a useable modelled output without being overwhelmed or put off by the quantity of more advanced input options that they may not have to hand. However, the other inputs are still visible (though greyed out and locked) even at the basic level, with the philosophy behind this design was that natural curiosity would take over and drive users to acquire some or all of the missing data through greater use of soil testing and more advanced assessment of yield and field losses.

The “but that doesn’t apply to me” drives people to the more advanced levels that allow the model to be better tuned to the grower’s situation.

The next input point available to the user in the dropdown list at the top of the main tool page is **Soil N tests**, which, as the name suggests, allows the user to enter soil N test results. There are two test categories that can be entered into the SVS Tool, **Soil mineral N Test Results** and **Potentially Mineralisable Nitrogen (PMN).** The former allows the user to enter mineral N in the form of laboratory mineral N test results or as Nitrate Quick Test results. Both inputs have a significant effect on the accuracy of the modelled outputs, with the soil mineral N test results in particular acting to “ground-truth” the model to the actual soil N concentration at a specific time in the rotation. This input also allows the user to enter their actual N fertiliser applications, helpful when reviewing prior crops and also when assessing the fertiliser schedule for a current or future crop. It is hoped and anticipated that the majority of users will engage with this level of the tool, with the largest increase in modelled guidance accuracy occurring when entering inputs at this point as well as the greatest practice changes (increased soil N testing) being incentivised at this point.

The final and most comprehensive input stage is labelled **Crop Rotation** and allows the user to input crop details for prior and future crops in the rotation, as well as to specify more advanced crop information, such as establishment stage, moisture content, and dressing and paddock losses. This input point reflects the systems component of the Sustainable Vegetable Systems programme, encouraging growers and other users to look at N management from rotation perspective rather than on a crop-by-crop basis. Over time, this may be reflected in adjustments to rotation planning, better use of crop residues, and changes to crop and paddock management.

The SVS Tool also allows users to save their scenarios both within the tool and as downloaded PDF or Excel CSV files. An example of the PDF report generated from the SVS Tool is shown in Figure 72. While regulatory or commercial compliance was not the main objective when designing the tool, allowing users to easily manage their paddocks and crops and store their scenarios will allow operations to store bodies of evidence against which they can provide as evidence in their Farm Environment Plan (FEP) or other commercial sustainability schemes (particularly for supplying certain export markets).

The SVS Tool can therefore help users with N decision support, crop management, meeting regulatory and commercial requirements, as well as research and experimentation, both on the farm and through industry groups and research operations. By being a multi-use tool, the SVS web application will secure its continued use throughout the industry.

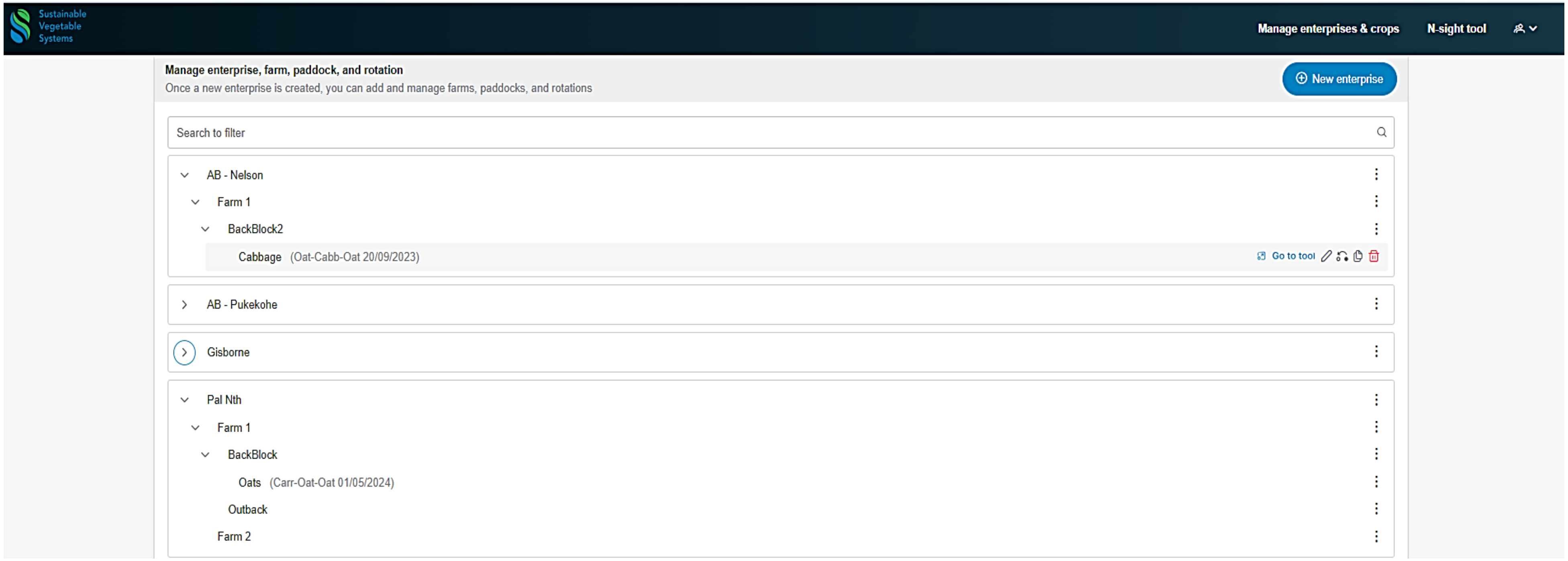


Figure 71. Paddock and crop management screen of the Sustainable Vegetable Systems (SVS) tool.

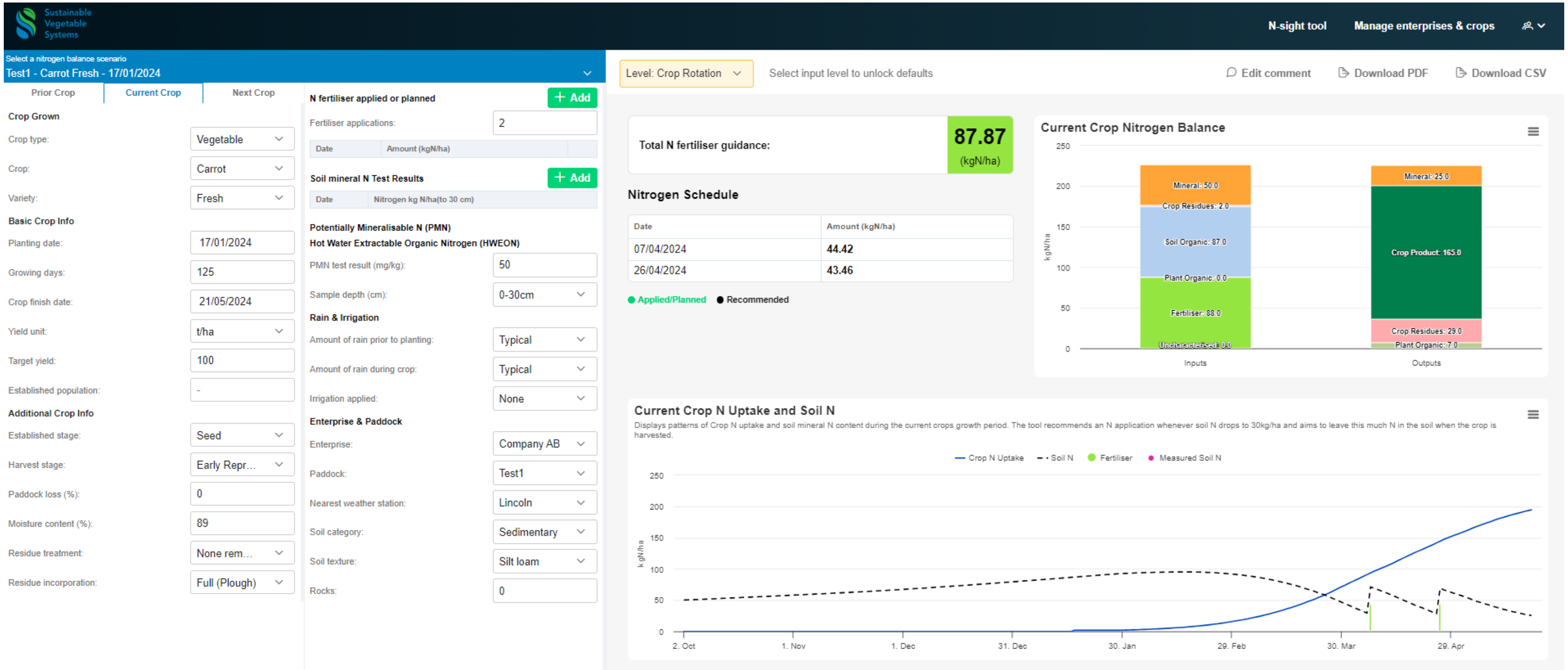


Figure 72. Sustainable Vegetable Systems (SVS) tool main user interface.

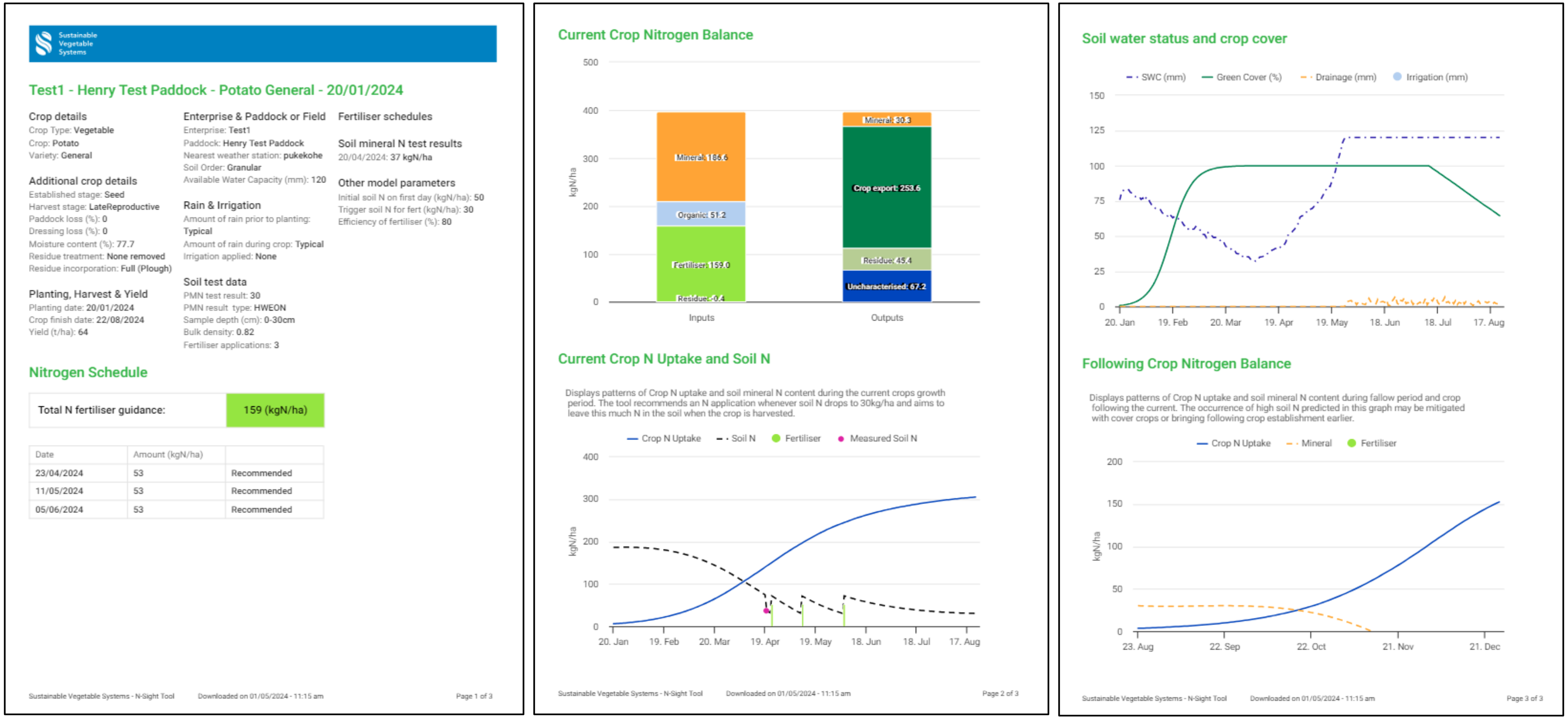


Figure 73. Sustainable Vegetable Systems (SVS) tool PDF output.

4.4.2 Tool user metrics

Tool users as of June 2024:

- Number of users: 76
- Number of enterprises: 24
- Number of scenarios: 101

For other metrics, like number of times a user has logged in and the length of time they are logged in for, Rezare has advised that they will need some tracking data to report this. As the tool has not yet been launched, this ability to track was given a lower priority in the development pipeline. Rezare have a solution that can be implemented through Google Analytics.

4.4.3 The Nitrogen Risk Assessment Tool (NRAT): Tracking change

The NRAT has been developed with NZGAP, industry, and Horizons Regional Council. This is a tool that can be used to track practice change and consequently N loss risk.

The SVS Tool will reduce grower managed diffuse N discharge risks associated with commercial vegetable production, managing multiple N sources, including from crop residue, total soil N, and fertiliser.

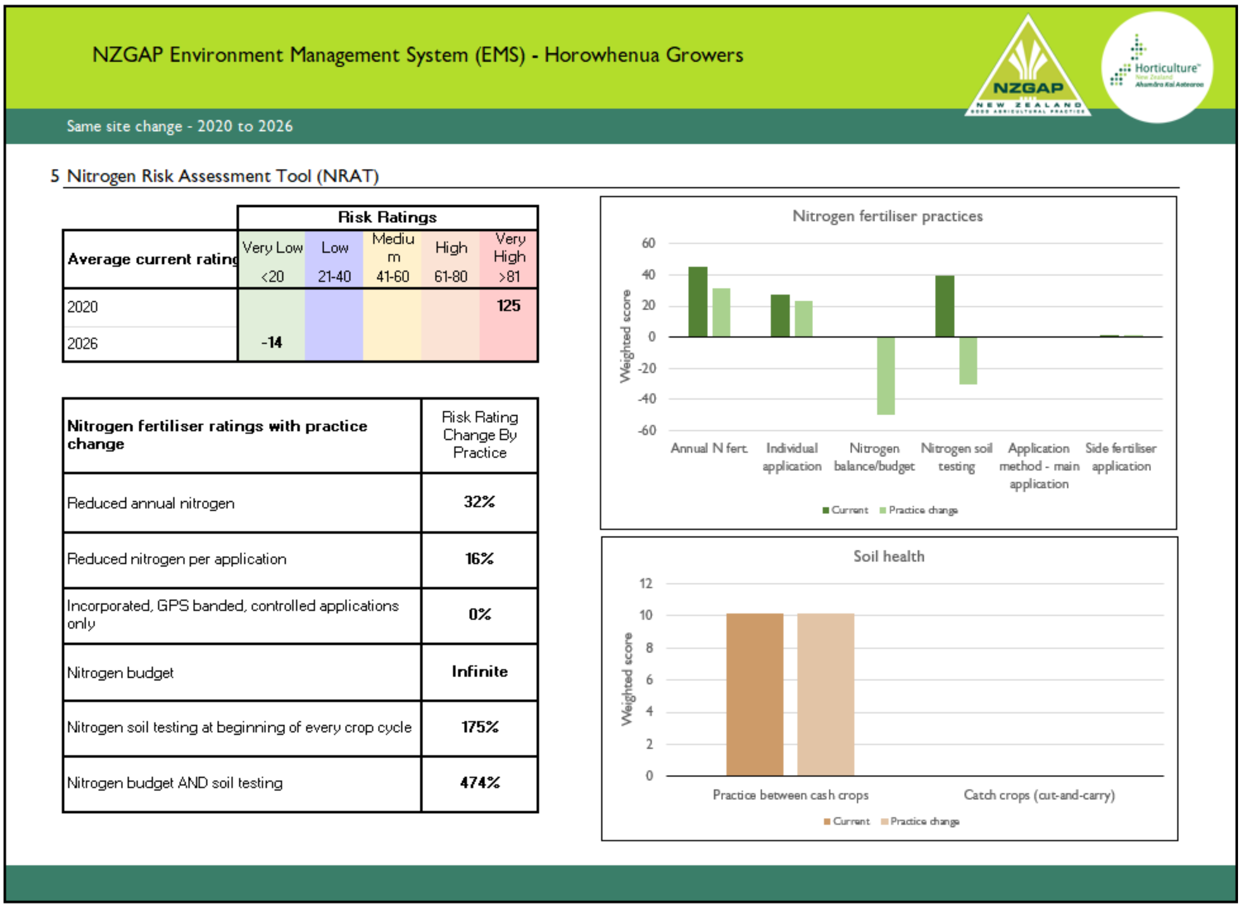
Growers have used the NRAT and we have projected how the metrics can be used to track change in the future. All scores are unitless. The higher the score the greater the N fertiliser intensity and the higher the risk. In our example the grower currently has a N intensity score of 77, which in the future when they have reduced their fertiliser use by 15% their score has lowered to 63. Nitrogen fertiliser practices produced a current score of 130 and over time through the implementation of N budgets and soil testing their score is lowered to -15.

Table 17 shows the example of a grower now and with future practice change.

Table 17. Projecting the Nitrogen Risk Assessment Tool (NRAT) grower scores with future practice changed compared to current day.

		Now	Future	Future
	Future scenario practice changes		No N change N budget, Once a year test	15% lower N, N budget, N test start of each crop
	Nitrogen intensity score	77	77	63
Nitrogen Fertiliser Practices				
a	Annual N fertiliser	50	50	36
b	Individual application	27	27	27
c	Nitrogen balance/budget	0	0	-50
d	Nitrogen soil testing	50	0	-30
e	Application method - main application	0	0	0
f	Side fertiliser application	3	3	3
	Total	**130**	**80**	**-15**

The NRAT sore and its associated practices can be displayed through a Dashboard. In Levin the average score in 2020 was 125 (calculated retrospectively as the NRAT was developed in 2023). With the implementation of the proposed practice changes and an approximately 25% reduction in fertiliser use, this drops to -14. The Dashboard in Figure 74 shows these results.



	Risk Ratings				
Average current rating	Very Low <20	Low 21-40	Medium 41-60	High 61-80	Very High >81
2020					125
2026	-14				

Nitrogen fertiliser ratings with practice change	Risk Rating Change By Practice
Reduced annual nitrogen	32%
Reduced nitrogen per application	16%
Incorporated, GPS banded, controlled applications only	0%
Nitrogen budget	Infinite
Nitrogen soil testing at beginning of every crop cycle	175%
Nitrogen budget AND soil testing	474%

Figure 74. Example of the Nitrogen Risk Assessment Tool (NRAT) dashboard.

The NRAT and Dashboard can be a very public facing platform that is driven through NZGAP as part of their Environmental Management System (EMS) (Farm Environment Plan).

5 Workstream Four: Extension

Extension work was fundamental to the programme design, with Workstream 4 dedicated to communicating results and learnings back to the industry and promoting education for growers on soil and crop nitrogen.

5.1 Workshops and conferences

Presenting results and learnings directly to growers in the form of workshops and conference presentations was one of the most effective ways of promoting grower engagement with SVS.

Despite initially being limited by restrictions resulting from the COVID-19 pandemic, dozens of workshops were held across the country over the course of the programme. In addition, a stand was set up and presentations given at the HortNZ and Potatoes NZ conferences.

Workshops and conferences organised or attended:

- HortNZ Conference, 1st-4th August 2023. A stand featured an overview of SVS and was presented by Programme Manager Andrew Barber (Figure 75)
- Potatoes NZ Conference 22 August 2023. A stand featured an overview of SVS and presented by Programme Manager Andrew Barber. There was also a session during the conference on SVS. Papers presented were:
    - Andrew Barber – Sustainable Vegetable Systems Introduction
    - Bruce Searle and Trish Fraser – Soil and crop nitrogen dynamics in vegetable cropping systems
    - Trish Fraser and Bruce Searle – Residues in vegetable cropping systems
    - Hamish Brown – Nitrogen management tool(s) for minimised leaching
- Vegetable Roadshows. These were held in 9 different regions of Aotearoa – NZ, and the SVS tool was presented and discussed.

Region	Date
Dargaville	21 February 2024
Nelson	19 March 2024
Pukekohe	3 April 2024
Gisborne	9 March 2024
Hawkes bay	11 April 2024
Christchurch	16 April 2024
Invercargill	17 April 2024
Ohakune	30 April 2024
Manawatu	1 May 2024

Figure 75. Horticulture New Zealand Conference SVS stand.

5.2 Other extension

Several resources were developed and distributed at workshops, conferences, through the NZ Grower magazine and online.

5.2.1 Factsheets, handouts, and posters

Several factsheets, handouts, and posters were prepared throughout the programme to summarise relevant information, clarify points of confusion, or direct growers to additional resources. Material prepared included:

- Soil nitrogen test factsheet: A 4-page handout with a summary of the key testable fractions of total soil nitrogen and soil test request forms and result reports from each of the three main commercial laboratories.
- Nitrate Quick Test instructions: A series of laminated pictorial instructions on how to perform the nitrate quick test. QR codes on the instructions linked growers to websites to purchase the necessary equipment.
- Posters: A series of eight A1 posters for display at the HortNZ and Potatoes NZ conferences. Content on the posters included explanations of the soil nitrogen cycle, components of a nitrogen balance, and graphs showing changes in mineral nitrogen in cropping soils.
- Case studies: These were developed as both a tool development and feedback loop, with the learnings also captured as written case studies (see Case studies section) designed for publication and use as handouts at workshops and conferences.

5.2.2 Workstream 2 grower reports

One of the immediate priorities within the regional monitoring workstream was communicating sampled data back to the participating growers in order to keep them informed and engaged with project developments. Alongside regular communication with the growers through telephone calls and emails, an individualised report was developed for distribution at regular quarterly intervals (Figure 76).

This report summarised the main data collected through the regional monitoring, with a focus on changes in soil mineral nitrogen status at the monitoring site. These changes are best represented by the main graph in Figure 65, which shows fluctuations in mineral nitrogen levels over time by depth range in shades of green. Background colours denote what crop was in the paddock at that time, while black lines indicate fertiliser applications. The orange dotted line plots crop nitrogen uptake along the same axis as mineral nitrogen change. In the example shown in Figure 77, it is apparent that mineral nitrogen decreases as crop uptake increases, with it again increasing after harvest due to breakdown of residue and increased mineralisation during summer.

Figure 76. Example of Workstream 2 individualised report.

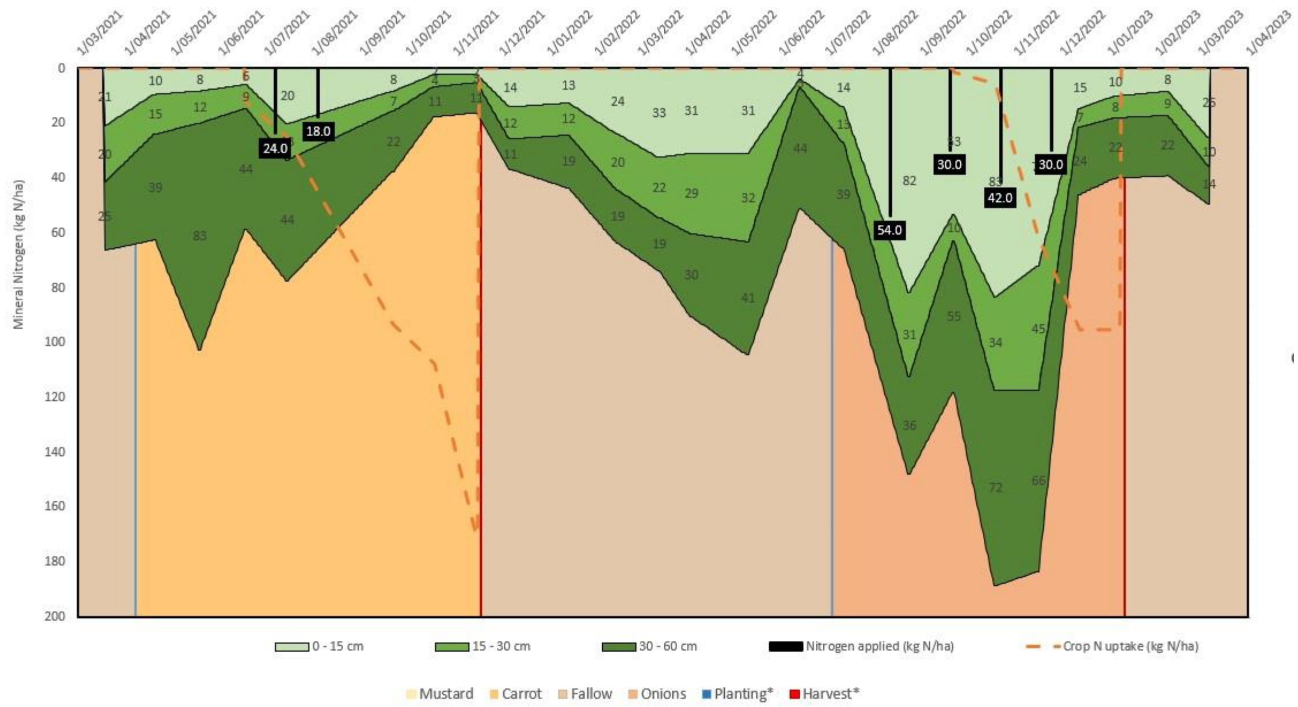


Figure 77. Example of Workstream 2 individualised report's mineral nitrogen graph.

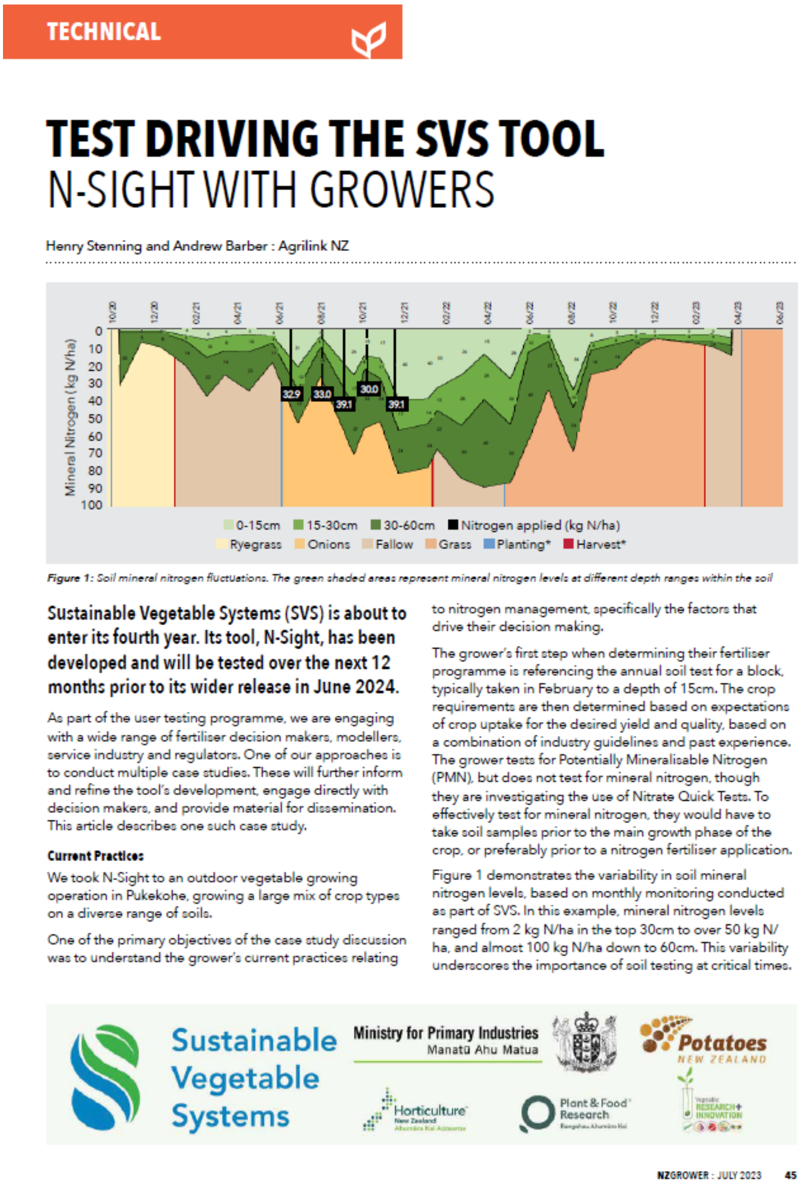
5.2.3 NZ Grower articles

One of the best ways to communicate with the industry at large is through the industry magazine NZ Grower. Throughout the programme, articles were contributed from multiple programme stakeholders to the NZ Grower, with a total of twenty-three articles published between September 2020 and April 2024, for an average coverage of one SVS related article in every two editions of the NZ Grower. This strategy helped ensure that the SVS programme was kept in the front and centre of growers' minds. Figure 78 shows an example of an SVS article published in the NZ Grower magazine.

Articles published in the NZ Grower magazine:

- Gemma Carrol. Potatoes New Zealand. *The future looks brighter when we work together*. September 2020.
- Glenys Christian. NZ Grower. *Nitrogen efficiency increased*. March 2021.
- Gemma Carrol. Potatoes New Zealand. *Sustainable Vegetable Systems: project progressing despite a year of pandemic disruption*. June 2021.
- Gemma Carrol. Potatoes New Zealand. *Robust models mean the best farmer-facing tools*. July 2021.
- Gemma Carrol. Potatoes New Zealand. *Sustainable Vegetable Systems: Connecting with growers*. August 2021.
- Dan Bloomer and Luke Posthuma. LandWISE. *Soil fertility sampling*. October 2021.
- Trish Fraser. Plant & Food Research. *Understanding soil nitrogen*. December 2021.
- Andrew Barber and Henry Stenning. Agrilink. *Sustainable Vegetable systems: Progress and mineral N tracking reports*. February 2022.
- Bruce Searle, Trish Fraser, and Jo Sharp. Plant & Food Research. *Nitrogen balance – understanding management and environmental implications of nitrogen use in crop production.* April 2022.

- Gemma Carrol. Potatoes New Zealand. *Understanding grower and agronomist perspectives*. May 2022.
- Andrew Barber. Agrilink. *N-Sight: Making the invisible*, visible. June 2022.
- Andrew Barber and Henry Stenning. Agrilink. *Monitoring wins over leaching model*. July 2022.
- Andrew Barber and Henry Stenning. Agrilink. *Nitrogen management and farm environment plans*. August 2022.
- Andrew Barber and Henry Stenning. Agrilink. *Sustainable Vegetable Systems programme update*. November 2022.
- Andrew Barber and Henry Stenning. Agrilink. *Soil mineral and mineralisable nitrogen: acknowledging and reducing variability*. December 2022.
- Andrew Barber and Henry Stenning. Agrilink. *SVS tool development update*. March 2023.
- Andrew Barber and Henry Stenning. Agrilink. *SVS tool development update*. April 2023.
- Anne Hardie. NZ Grower. *Using green cover crops to increase yield.* June 2023.
- Andrew Barber and Henry Stenning. Agrilink. *Test driving the SVS tool N-Sight with growers*. July 2023.
- Chris Hosie. Fruition Horticulture (South Island). *Applications of continuous soil moisture monitoring technology for industry best practice nutrient management*. September 2023.
- Andrew Barber and Henry Stenning. Agrilink. *Untangling soil nitrogen testing*. February 2024.
- Kate Truffit. Potatoes NZ. *SVS project is a successful investment*. April 2024.
- Andrew Barber and Henry Stenning. Agrilink. *Preview the SVS tool with an online or workshop demo*. April 2024
- Andrew Barber and Henry Stenning. Agrilink. *Integrating soil N testing with the SVS tool.* May 2024.



TECHNICAL

TEST DRIVING THE SVS TOOL N-SIGHT WITH GROWERS

Henry Stenning and Andrew Barber : Agrilink NZ

Figure 1: Soil mineral nitrogen fluctuations. The green shaded areas represent mineral nitrogen levels at different depth ranges within the soil

Sustainable Vegetable Systems (SVS) is about to enter its fourth year. Its tool, N-Sight, has been developed and will be tested over the next 12 months prior to its wider release in June 2024.

As part of the user testing programme, we are engaging with a wide range of fertiliser decision makers, modellers, service industry and regulators. One of our approaches is to conduct multiple case studies. These will further inform and refine the tool's development, engage directly with decision makers, and provide material for dissemination. This article describes one such case study.

Current Practices

We took N-Sight to an outdoor vegetable growing operation in Pukekohe, growing a large mix of crop types on a diverse range of soils.

One of the primary objectives of the case study discussion was to understand the grower's current practices relating to nitrogen management, specifically the factors that drive their decision making.

The grower's first step when determining their fertiliser programme is referencing the annual soil test for a block, typically taken in February to a depth of 15cm. The crop requirements are then determined based on expectations of crop uptake for the desired yield and quality, based on a combination of industry guidelines and past experience. The grower tests for Potentially Mineralisable Nitrogen (PMN), but does not test for mineral nitrogen, though they are investigating the use of Nitrate Quick Tests. To effectively test for mineral nitrogen, they would have to take soil samples prior to the main growth phase of the crop, or preferably prior to a nitrogen fertiliser application.

Figure 1 demonstrates the variability in soil mineral nitrogen levels, based on monthly monitoring conducted as part of SVS. In this example, mineral nitrogen levels ranged from 2 kg N/ha in the top 30cm to over 50 kg N/ha, and almost 100 kg N/ha down to 60cm. This variability underscores the importance of soil testing at critical times.

Sustainable Vegetable Systems
Ministry for Primary Industries Manatū Ahu Matua
Potatoes New Zealand
Horticulture New Zealand
Plant & Food Research
Vegetable Research + Innovation

NZGROWER : JULY 2023 45

Figure 78. Example of SVS focussed NZ Grower article.

5.2.4 SVS videos

To further engage growers, a video series was produced in collaboration with Wanderly Media Ltd. This video series consisted of four videos on the SVS programme:

- Video 1: Programme Overview
- Video 2: Case studies and monitoring sites
- Video 3: The Science Story
- Video 4: How to perform the Nitrate Quick Test.

These videos were uploaded to YouTube.com and viewed a total of 551 times as of June 2024.

They can be accessed here: https://www.youtube.com/@potatoesnewzealandinc.8524/videos.

Figure 79 shows some stills from the first video in the series.

Figure 79. Stills from Video 1.

5.2.5 Case studies

User testing was a key component of tool development, with feedback from growers and other industry professionals (agronomists, fertiliser representatives, researchers, etc.) sought out for integration into the end product. Early-stage user testing was captured through the development of case studies, which were then converted into published material for distribution around the industry.

The following case studies were undertaken in the first half of 2023, using a prototype test version of the tool:

- Outdoor vegetable grower case studies (Pukekohe, Canterbury, 2x Nelson, Gisborne)
- Green manure research case study
- Service industry case study (Pukekohe)
- Interview with fertiliser representative
- Cost analysis case study
- Regional monitoring case study.

These case studies enabled in-depth discussions with growers and gave some key members of the industry a detailed look at the programmes intended outcomes while still under-development. Feedback from these case studies was instrumental in improving the SVS Tool and aligning it with user expectations.

Published case studies were distributed at the Hort NZ conference and at several workshops. An example is provided in Figure 80.

Figure 80. Outdoor vegetable grower case study – Pukekohe.

6 Literature

6.1 Literature prepared for SVS

A significant quantity of supporting papers, articles, reviews, and updates were prepared over the course of this programme. Key material is listed below:

- Hosie, C. 2024. *Potatoes New Zealand – Sustainable Vegetable Systems Project: Site soil moisture and nutrient characteristics – final review*. Fruition Horticulture.
- Michel A, Fraser T, Searle B, Adams C. 2021. *Review of nitrate leaching data from New Zealand vegetable crops*. Plant & Food Research.
- Searle B, Brown H, Khaembah E, Sharp J, Maley S, Dellow S, van der Weyden J, Arnold NA, Sorensen I, Husband E, Beare M, Husheer. 2024. *Sustainable Vegetable Systems – annual report 2024*. PFR SPTS No. 26449. Plant & Food Research.
- Searle B, Brown H, Sharp J, Husheer S. 2023. *Sustainable vegetable systems – quarterly report October – December 2023*. PFR SPTS No. 25067. Plant & Food Research.
- Searle B, Michel A, Fraser P, Brown H, Khaembah E, Sharp J, Maley S, Dellow S, van der Weyden J, Arnold N, Sorensen I, Husband E, Waka P, Husheer S. 2023. *Sustainable Vegetable Systems – annual report 2023*. PFR SPTS No. 24028. Plant & Food Research.
- Searle B, Fraser T, Brown H, Michel A, Maley S, Dellow S, George M, Arnold NA, van der Weyden J, Sorensen I, Tan Y, Khaembah E, Thomas S, Cichota R, Paul W. 2022. *Sustainable Vegetable Systems – annual report 2022*. PFR SPTS No. 22510. Plant & Food Research.
- Stenning, H. 2023. *Workstream 2 - Potentially Mineralisable Nitrogen Data*. Agrilink.
- Stenning, H. 2022. *Workstream 2 – Nitrate Quick Test Measurements*. Agrilink.
- Wilson D, Cooke A, Cathcart L. 2022. *Sustainable Vegetable Systems: Rezare Pathway Review*. Rezare Systems.

6.2 Supporting literature

A variety of literature was used to support research and dissemination work undertaken during the SVS programme. Due to the length of the programme and diversity of work taken throughout each workstream, an exhaustive list has not been provided here. However, key material that was prepared outside of the SVS programme but formed a critical foundation to work undertaken has been listed below:

- Beare M, Lehto K, Peterson M, Curtin D. 2023. *Determining Potentially Mineralisable Nitrogen (PMN) based on analysis of hot water extractable C and N in soils*. Plant & Food Research.
- Beare M. 2022. *Guidelines for Soil Nitrogen Testing and Predicting Soil Nitrogen Supply*. Plant & Food Research.
- Mathers D, Norris M, Hunt A, Dellow S, Liu J, Trolove S. *The Nitrate Quick Test Mass Balance Tool – User Guide*. Foundation for Arable Research, Plant & Food Research.
- Reid JB and Morton JB. 2019. *Nutrient Management for Vegetable Crops in New Zealand*. Plant & Food Research.

- McLellan EL, Cassman KG, Eagle AJ, Woodbury PB, Sela S, Tonitto C, Marjerison RD, van Es HM 2018. The nitrogen balancing act: tracking the environmental performance of food production. Bioscience 68(3): 194-203.
- Misovic M, Momirovic N, Brocic Z, Radosevic Z 1997. Effect of interrow distance on growth and yield of different potato cultivars for processing. VIII International Symposium on Timing Field Production in Vegetable Crops 533. Pp. 187-196.
- Rocha KF, de Souza M, Almeida DS, Chadwick DR, Jones DL, Mooney SJ, Rosolem CA 2020. Cover crops affect the partial nitrogen balance in a maize-forage cropping system. Geoderma 360: 114000.
- Rozas HRS, Echeverría HE, Barbieri PA 2004. Nitrogen balance as affected by application time and nitrogen fertilizer rate in irrigated no-tillage maize. Agron J 96(6): 1622-1631.
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- Searle B, Michel A, Maley S, Dellow S, George M, Fraser P, Arnold N, van der Weyden J, Sorensen I, Khaembah E et al. 2022. Sustainable Vegetable Systems – Quarterly report October–December 2021. A Plant & Food Research report. SPTS No. 22021.
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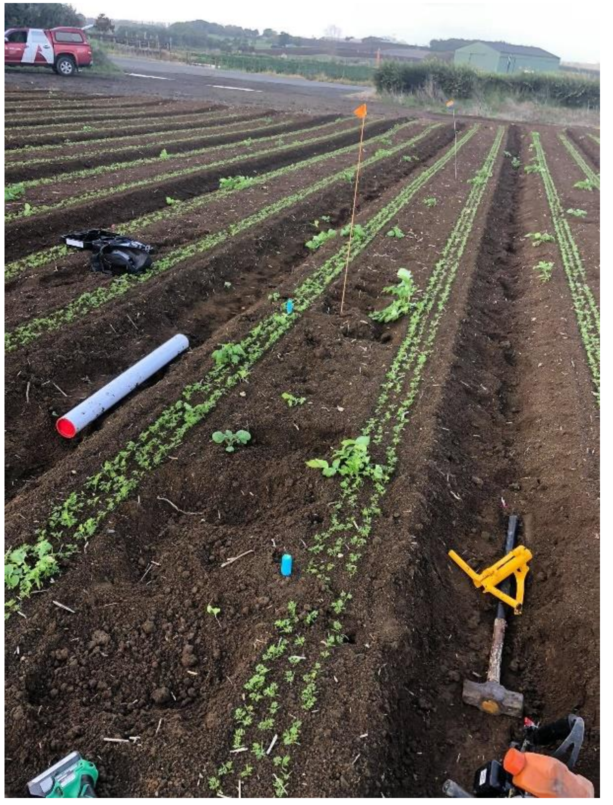
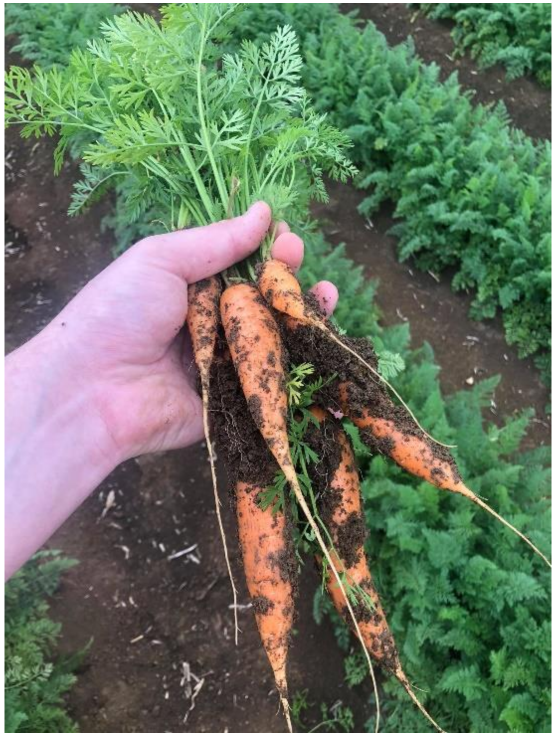
Appendix A: Workstream 2 site photographs







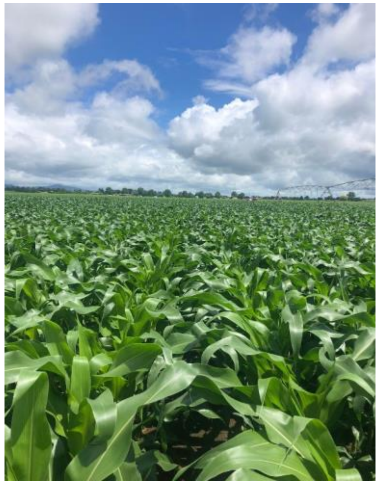







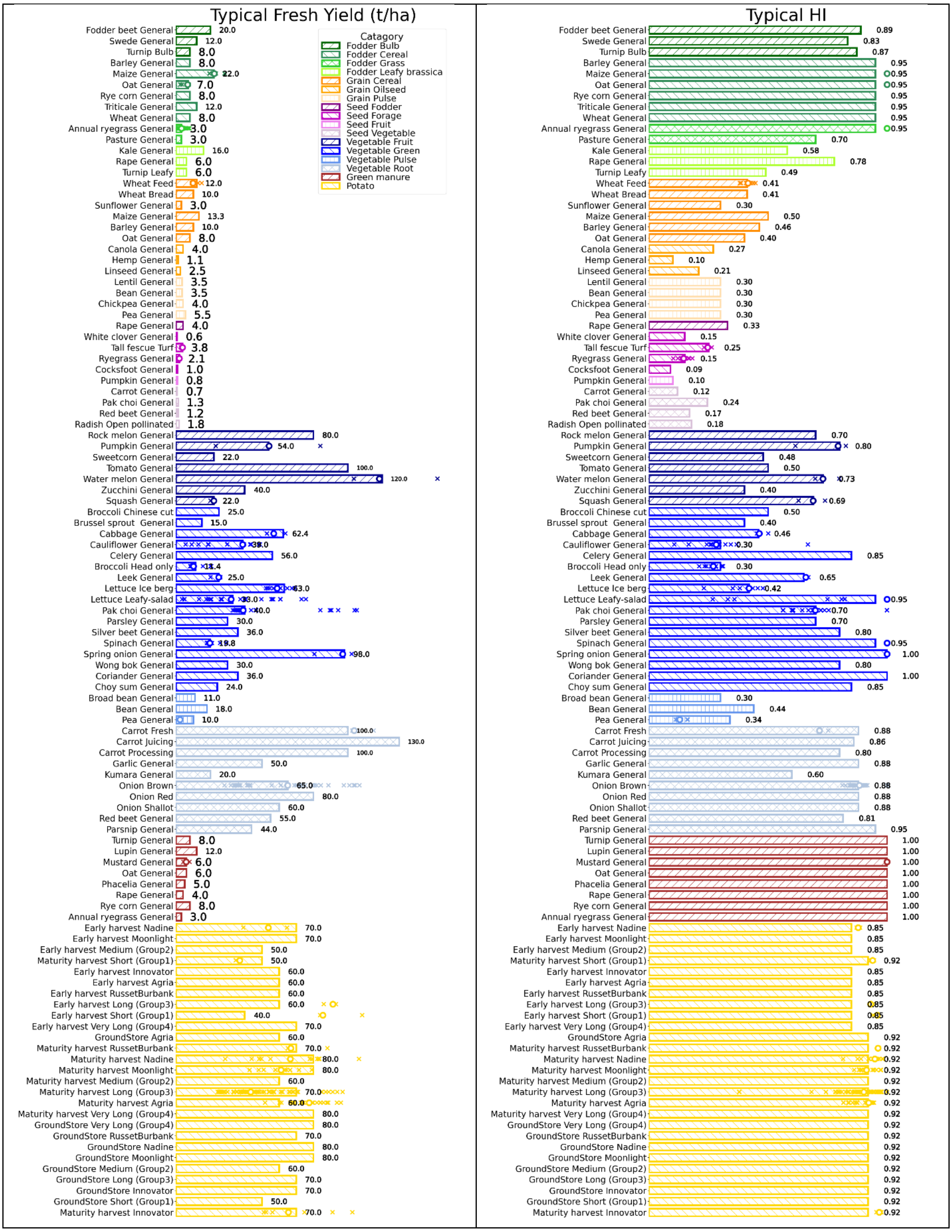




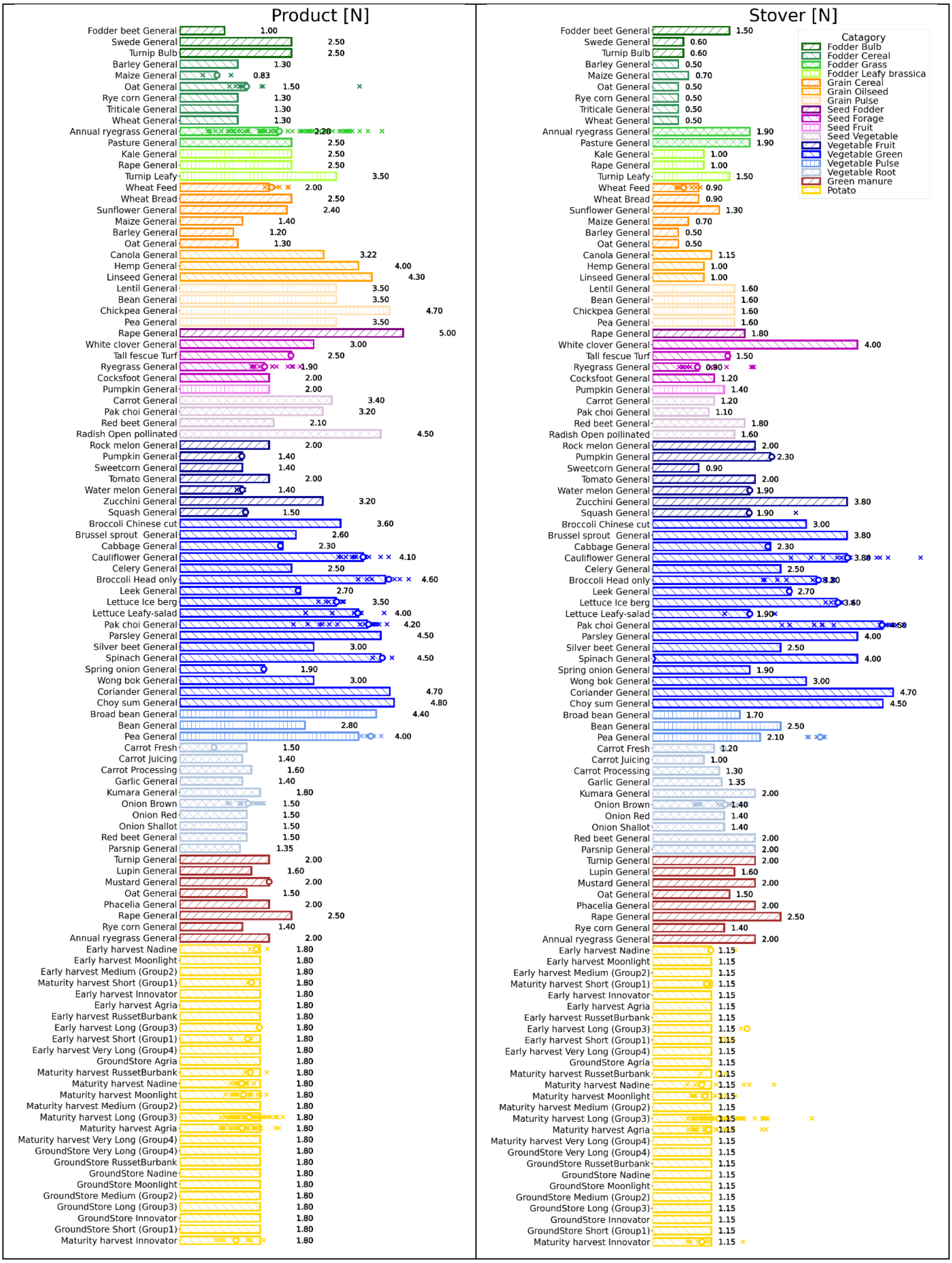





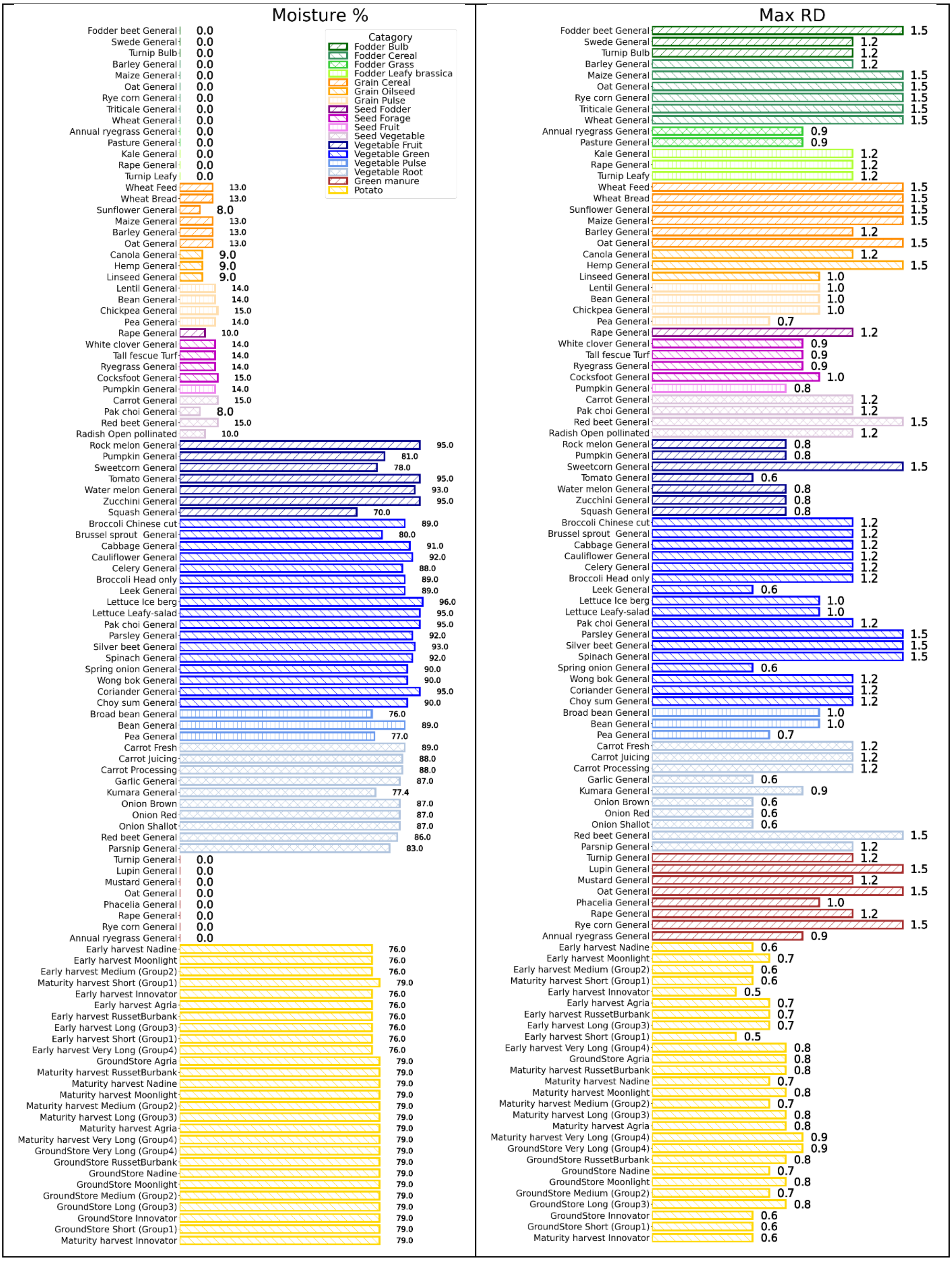
Appendix B: Workstream 3 model coefficients



Typical fresh product yields (t/ha) and harvest index values for crops included in the SVS tool. Where values were measured in SVS they are plotted as a ‘x’ against the respective crop and the median value of observations is plotted as a ‘o’.



Nitrogen concentration (% N) in product and stover components for crops included in the SVS tool. Where values were measured in SVS they are plotted as a 'x' against the respective crop and the median value of observations is plotted as a 'o'



Moisture content and maximum rooting depth for crops included in the SVS tool. Note that the SVS Tool models the nitrogen balance in the top 30 cm. The nitrogen below 30 cm is part of the uncharacterised component in the budget. This is an area that has been identified as requiring further investigation, however it is considerably more complex and variable.

Appendix C: Frequently Asked Questions

Nitrogen in cropping soils

Q. Why is nitrogen special and why should I account for soil nitrogen levels?

A. Nitrogen is one of the primary macronutrients utilised by plants, which use it to build amino acids and chlorophyll, the compound through which plant convert sunlight energy, carbon dioxide, and oxygen, into sugars. Nitrogen is often the limiting factor for crop growth, insufficient nitrogen available for plant uptake leads to reduced crop yield (actual and marketable), and in some cases total crop failure (actual and marketable).

Nitrogen, specifically in the form of nitrate-nitrogen, can also have adverse effects on the environment and human health when levels become elevated in waterways and other drinking water sources such as aquifers. Nitrate-nitrogen is highly soluble and does not form strong attachments to soil surfaces, resulting in a propensity to fluctuate rapidly in quantity within the soil over short timeframes, unlike other nutrients that typically increase or decrease at a much slower rate. The movement of nitrate-nitrogen through the soil is referred to as *nitrate leaching*.

Because nitrogen is a key requirement to producing a successful crop, growers must ensure that nitrogen supply will always meet crop demand. Historically, this has not always taken into account the magnitude of potential losses from nitrate leaching and from other loss pathways. However, with increasing scrutiny being placed on vegetable production from regulators and customers, growers are facing pressure to demonstrate that they are operating in a sustainable way and following good agricultural practices.

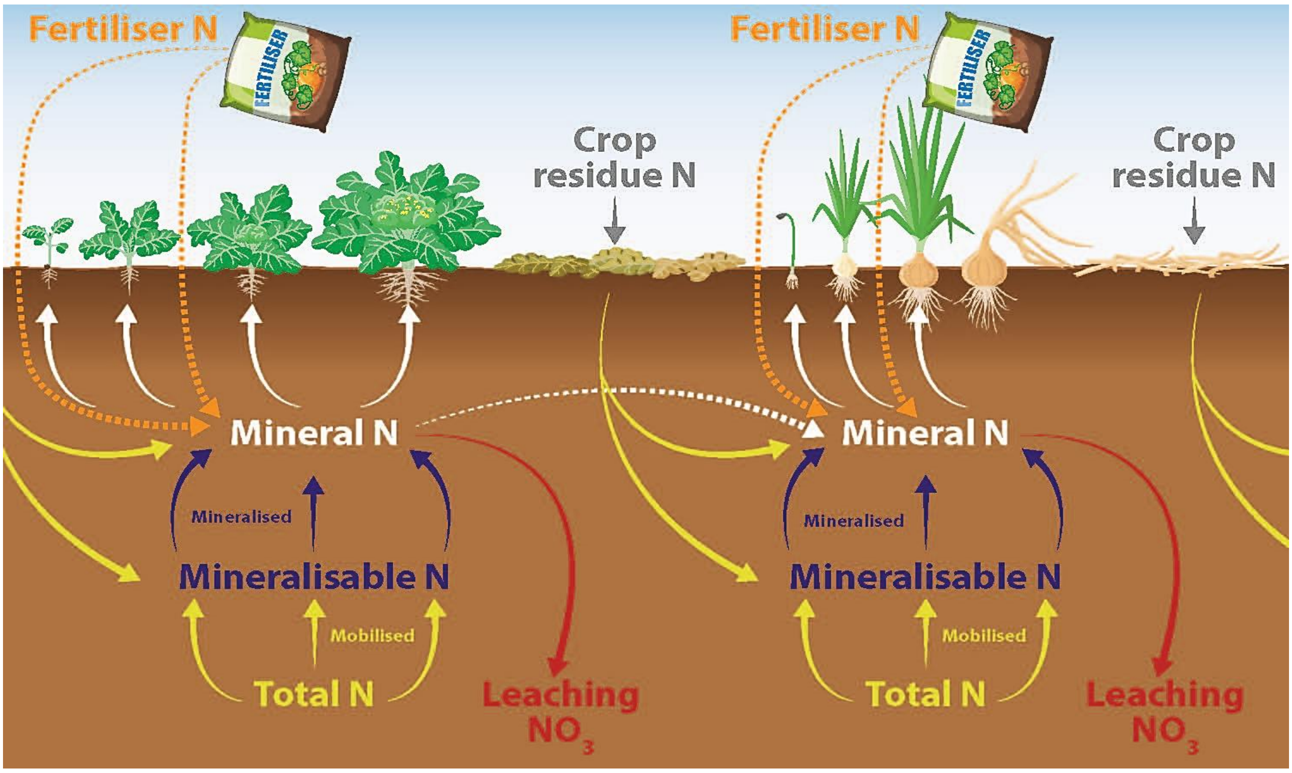
Therefore, growers want to ensure that they are using fertiliser and planning their crop rotations in a way that optimises nitrogen use, by matching nitrogen supply to crop demand as closely as possible. Accounting for current and predicted future levels of soil nitrogen through a combination of soil testing and modelling can assist growers optimise their nitrogen use efficiency, increasing the sustainability of their operations, reducing costs, and further building knowledge.

Q. What are the main forms of soil nitrogen?

A. Nitrogen in the soil occurs in many distinct forms, though for practical considerations can be divided into two principal fractions.

The first of these is the fraction that is immediately available for plant uptake through the roots. This is referred to as *mineral nitrogen*. Mineral nitrogen can be further divided into *nitrate-nitrogen* and *ammoniacal-nitrogen*. Nitrate-nitrogen is typically the dominant fraction and is prone to rapid movement through the soil profile as it is highly soluble and does not form strong attachments to soil surfaces – a phenomenon called *nitrate leaching*. This is one of the factors that drives rapid changes in mineral nitrogen levels within the soil.

The second fraction is organic nitrogen, which constitutes the vast majority of total soil nitrogen. Nitrogen components of soil organic matter are not immediately available for plant uptake until the organic matter has been broken down within the soil and then converted into mineral forms of nitrogen by soil microbes – a process known as *mineralisation*. Within the organic nitrogen pool there is a sub-fraction of organic matter that has been broken down to a point that it is accessible to soil microbes, this sub-fraction is called *mineralisable nitrogen*. Knowing the quantity of mineralisable nitrogen can help to predict the quantity of mineral nitrogen that will be supplied by the soil over a certain period of time.



Q. What causes soil nitrogen levels to change?

A. The level of mineral nitrogen in the soil that is accessible to a crop at any given time is the balance of the total quantity lost against the total quantity added.

Historically, the focus has predominately been on the loss side of this equation with the largest two drivers of mineral nitrogen decrease being:

- *Crop uptake:* nitrate-nitrogen and ammoniacal-nitrogen drawn up into plant tissues through the roots.
- *Nitrate leaching:* Nitrate-nitrogen that has moved below the rootzone due to excess drainage of water. Eventually this nitrate-nitrogen will enter ground or surface water.

Other loss pathways include:

- *Immoblisation*: the reverse of mineralisation. Mineral nitrogen becomes locked up in soil microbes or soil organic matter. Typically driven by high carbon:nitrogen ratios, rates can be increased following incorporation of high carbon:nitrogen ratio crops (e.g., cereals).
- *Denitrification*: the conversion of nitrate-nitrogen by soil microbes to nitrogen gas, which escapes the soil into the atmosphere.
- *Volatilisation*: Ammoniacal-nitrogen (often from urea-based fertilisers or compost) conversion to ammonia gas, which escapes the soil (typically at or close to the surface) into the atmosphere.

Pathways that increase mineral nitrogen levels within the soil include:

- *Fertiliser*: the addition of mineral nitrogen directly through fertiliser, this has been the major mechanism by which growers supply crops with nitrogen.

- *Mineralisation*: the conversion of mineralisable organic nitrogen into mineral nitrogen by soil microbes. This can often contribute large quantities of mineral nitrogen, especially during warm and wet periods.
- *Residue breakdown*: Residues from prior crops are broken down by soil microbes, increasing the soil organic nitrogen pool and also providing direct increases to mineral nitrogen as residues are mineralised.

Depending on the history of the field and the climate, the balance between addition and subtraction of mineral nitrogen from the plant accessible pool may be very different. In general, winter months see more losses through leaching and less addition through mineralisation, while summer months see the opposite. The only way to know for sure however is to take a soil mineral nitrogen test.

Q. How can I account for soil nitrogen in my crop nutrient planning and when planning my crop rotations?

A. The best way to account for the amount of mineral nitrogen present in the field at a particular point in time is to take a test. This can be done using commercial laboratories (*Mineral N test*) or done yourself using the *Nitrate Quick Test*.

Good times to take a mineral nitrogen test include:

- Immediately prior to crop planting: to help inform the base N fertiliser requirement and overall crop N programme.
- Prior to side dressings: to help determine if a side dressing is required or the rate to apply.
- After significant rainfall events: to help determine if a large leaching event has occurred and the crop may need more N fertiliser to get to harvest.

In general, it is not recommended to take a mineral nitrogen test shortly after fertiliser applications, as this can provide a misleading result (extremely high if sampling through fertiliser band, artificially low if sampling avoided fertiliser band).

Using mineral nitrogen test results in conjunction with the SVS Tool can help calibrate the model to current local conditions and will result in significantly more accurate fertiliser N guidance.

In addition to knowing what nitrogen is currently in the soil and plant available, you will likely also want to know what nitrogen could be supplied to the plant through the soil via mineralisation.

As with mineral nitrogen, the best way to account for this background supply of mineral nitrogen from the soil is by taking a test. The test to determine this value is usually referred to as the *Potentially Mineralisable Nitrogen* (PMN) or *Hot Water Extractable Organic Nitrogen (HWEON)* test. From a practical perspective these tests are essentially the same and will provide you with the same information, that is, the amount of mineral N supplied by the soil over a set period of time. To make best use of this test, you will need to integrate this result into the SVS Tool, which converts the result to the amount of mineral N supplied by the soil over the course of your crop growth period under your locations average climate for that time of year.

This will provide the model with a specific estimate of how much mineral N will be available for crop uptake over the course of its growth period, with estimated mineralisation calculated on a daily basis to best match predicted crop uptake.

The PMN test can be taken alongside your regular soil tests, once per year or once every few years, as its value does not usually change rapidly.

Soil nitrogen test methods

Q. What do I need to test for?

A. The table below shows the key nitrogen tests for crop production and use with the SVS Tool. All three tests require conversion to kg N/ha for practical use – the SVS Tool does this for you.

Testing for	Test name	Tested by	Frequency	Information provided	Result units
Mineral nitrogen	Min N or Deep N	Commercial laboratories	Close to decision making – (e.g., crop planting, fertiliser applications)	Quantity of nitrogen immediately available for plant uptake – i.e., what is in the soil currently.	mg N/kg
Mineral nitrogen - nitrate	Nitrate Quick Test	Yourself		Quantity of nitrate-nitrogen immediately available for plant uptake – excludes ammonium but in most cases is a good and conservative proxy for laboratory Min N test.	mg NO_3-/L
Mineralisable nitrogen	Potentially Mineralisable Nitrogen (PMN) or Hot Water Extractable Organic Nitrogen (HWEON)	Commercial laboratories	Annual or bi-annual	Quantity of nitrogen that may be mineralised over a certain time period – i.e., what is likely to be supplied by the soil during crop growth.	Mg N/kg

Q. What equipment do I need to take a soil test?

A. The table below shows the essential equipment for soil testing.

Equipment	Description	Associated test type	Examples
Auger/corer/probe	For taking soil samples. Different styles and lengths suited for different ground conditions. (E.g., step probes work better on lighter soils, while augers work better on heavy clay soils).	All tests.	Groundtest: Augers https://tinyurl.com/GroundtestAugers Amazon: 30 cm step probe https://tinyurl.com/AmazonStep-probe Hill laboratories: 15 cm step probe https://tinyurl.com/HillLabsProbe ARL: 30 cm step probe Contact ARL.Lab@ravensdown.co.nz
Safety equipment	Gloves, correct footwear, high-viz.	All tests.	-
Bucket(s)	For containing and mixing soil prior to taking a sub-sample.	All tests.	-
Ice packs	For keeping mineral N samples cool to prevent mineralisation.	Laboratory Min N & Nitrate Quick Test	Supplied by laboratory.

Insulated boxes	Polystyrene or other boxes with ice packs to keep sample cool during transport to lab or test location.	Laboratory Min N & Nitrate Quick Test	Supplied by laboratory.
Essential Nitrate Quick Test equipment	Nitrate Quick Test strips, calcium chloride, test tubes.	Nitrate Quick Test	https://tinyurl.com/LabSupply-QuickN
Optional Nitrate Quick Test equipment	Equipment that can help with processing Nitrate Quick Test samples and interpreting results.	Nitrate Quick Test	Nitrate Quick Test colour scale & MQuant measurement app. https://tinyurl.com/MQuantStripScan Vortex shaker for mixing samples. Centrifuge for separating suspended sediment.

Q. How do I take a soil sample for nitrogen testing?

A. The first consideration when taking a soil sample is ensuring that you have the right equipment, including storage for your sample. If you are taking a soil sample for a laboratory mineral nitrogen test or for a nitrate quick test that you plan to conduct later, ensure the sample is kept cool with ice packs to prevent excessive mineralisation. Failure to do so may lead to an artificially high reading.

When taking samples, ensure you are following a transect that is representative of the field and avoid only sampling the edge of the field. The transect should ideally take the form of a V or W pattern to cover as much of the field as possible.

You will also want to consider the depth of the sample you are taking and specify this depth on sample request forms. For most vegetable crops, 30 cm is a good standard sample depth, though samples to 15 cm can also be taken if the crop is particularly young, shallow rooting, or if ground conditions make taking deeper samples difficult.

Take a minimum of 10 samples per field. The more samples you collect the more representative your test results will be, with some laboratories requesting 15-20 samples be taken per field. All samples from the same field and depth range should go in the same bucket and be thoroughly mixed. A sub-sample can then be taken for sending to the lab or testing yourself (if performing the Nitrate Quick Test).

For more detailed instructions, please refer to this thorough guide on soil nitrogen testing from Plant & Food Research -

https://www.plantandfood.com/en-nz/article/soil-nitrogen-testing-and-predicting-nitrogen-supply

Q. Once I have taken a soil sample, what do I do with it?

A. This depends on what you are testing for.

For mineral nitrogen tests (including the Nitrate Quick Test) you must immediately keep the sample cool using ice packs and a chilly bin.

If sending to the lab, send the sample in an insulated box (e.g., polystyrene) and with either plenty of ice packs or frozen overnight prior to sending. Use courier delivery options and try your best to drop the sample off as close to courier pick up as possible (i.e., do not leave it at the post office at 9 am when the only collection time is at 5 pm).

If you are planning to conduct a Nitrate Quick Test on the sample, either test within a few hours of sample collection or keep the sample refrigerated until you take the test. These steps are necessary to prevent excessive mineralisation of the sample resulting in artificially high-test results.

For Potentially Mineralisable Nitrogen (PMN, aka Hot Water Extractable Organic Nitrogen), keeping the sample cool is less important. As PMN levels change slowly overtime, testing can be more infrequent and as such you are likely to request this test alongside your regular annual or bi-annual soil test. You do not need to collect a separate sample or treat the sample any differently to how you normally would.

Q. What laboratory tests should I request?

A. Mineral nitrogen (i.e., the amount of nitrogen that is immediately available to plants) is tested for by labs using a *KCl extraction*. Different labs use different names for this test, including Mineral Nitrogen, Min N, and Deep Nitrogen.

Potentially Mineralisable Nitrogen (PMN, i.e., the amount of nitrogen that could be released by the soil during the breakdown of organic matter) is tested for by labs using the *Hot Water Extractable Organic Nitrogen (HWEON)* test. These terms are sometimes used interchangeably but essentially refer to the same thing.

If in doubt about what to test to select on the request form, please contact the lab directly. See the soil testing guide developed by SVS.

Q. How do I perform the Nitrate Quick Test on my soil sample?

A. The Nitrate Quick Test can be performed in the field or back at your workspace. The process is shown in this video https://www.youtube.com/watch?v=UrY8yAvtVvY. The test consists of the following steps:

- The soil sample is collected, mixed, and sub-sampled.
- The sub-sample is then passed through a sieve to ensure uniform particle sizes. For heavy clay soils this may require grating the collected soil instead.
- A solution of distilled water and calcium chloride is prepared, with 30ml volumes of solution portioned into test tubes.
- The sieved soil is added to the test tube until there is 40ml of soil-water-calcium chloride solution in each tube.
- Each test tube is thoroughly shaken for 1 minute each to ensure all of the soil particles have been in contact with the solution.
- The soil is allowed to settle to the bottom of the test tube, leaving a clear layer of solution at the top.
- The Nitrate Quick Test strip is dipped into the clear layer of solution for 1 second and then withdrawn. A timer is set for 1 minute while the colour develops on the strip.
- After 1 minute, the strip is compared to the colour scale on the side of the bottle. The user can then match the colour to the closest colour or interpolate a result between two colours. The result is displayed in mg NO_3^-/L of solution, which will be converted by the SVS Tool to kg N/ha.

For more detailed instructions, including on how to manually convert the result to kg N/ha if not using the SVS Tool, please refer to the following guide – developed by the FAR: https://www.far.org.nz/resources/quick-test-mass-balance-tool-user-guide

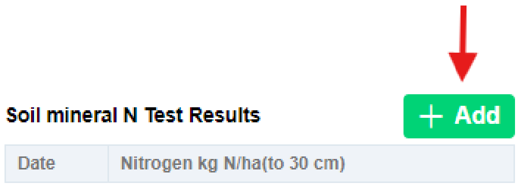
Soil nitrogen test result interpretation

Q. How do I interpret a Nitrate Quick Test result and how do I enter it into the SVS Tool?

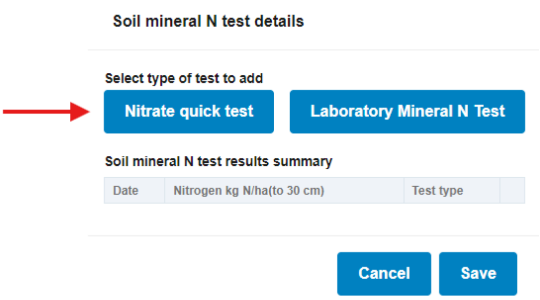
A. Most users of the Nitrate Quick Test will obtain their test result by comparing the colour on the test strip to the colour scale on the side of the test strip bottle. Another option is an app (MQuant® StripScan) that can be used in conjunction with a colour card to read the result on the strip. Whatever option you choose to use, the result will be shown as mg NO_3-/L of solution, a rather meaningless unit for most practical growing purposes. This unit will therefore need to be converted to kg N/ha.

There are two ways you can accomplish this conversion. The first and simplest option is to enter the test result directly into the SVS Tool:

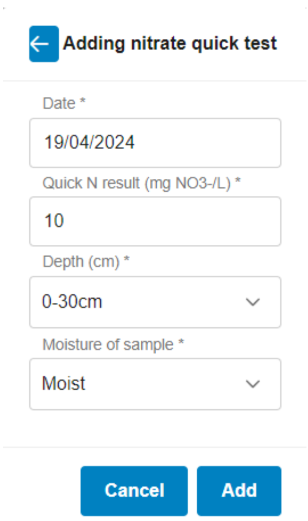
Step 1.



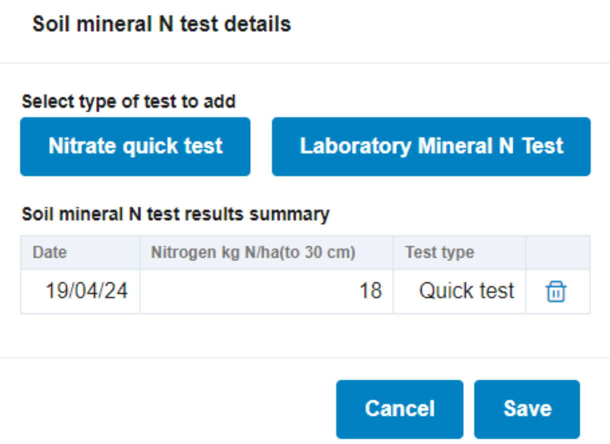
Step 2.

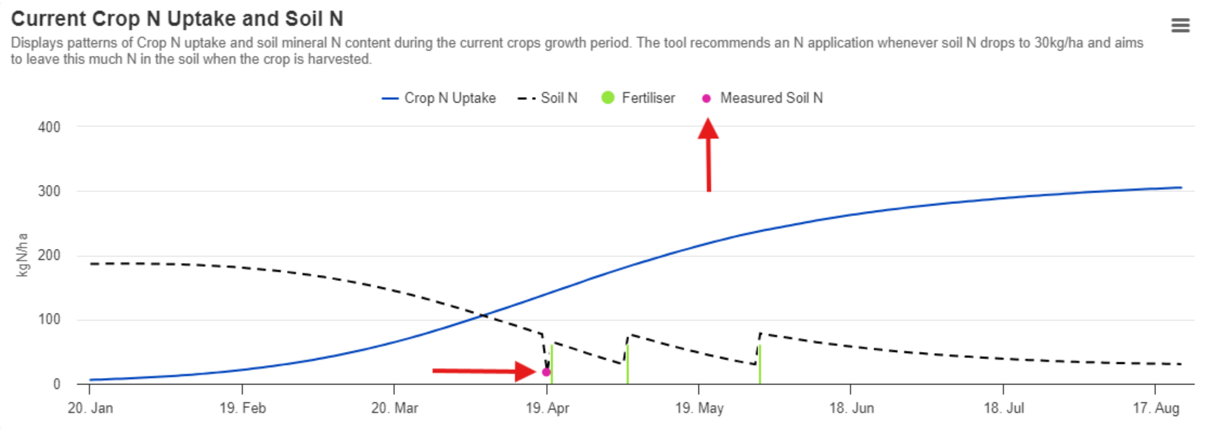


Step 3.



Result.





The second option is to calculate it yourself with a simple equation. The equation and calculation steps can be found in the following guide – developed by the FAR: https://www.far.org.nz/resources/quick-test-mass-balance-tool-user-guide.

Q. How do I interpret a laboratory Mineral Nitrogen result and how do I enter it into the SVS Tool?

A. Laboratories report mineral nitrogen test results in units of mg N/kg. Examples:

Hill Laboratories

Analysis		Level Found	Medium Range*	Low	Medium	High
pH	pH Units	5.7	5.4 - 5.8			
Olsen Phosphorus	mg/L	23	30 - 60			
Potassium	me/100g	0.30	0.50 - 1.00			
Calcium	me/100g	7.9	4.0 - 10.0			
Magnesium	me/100g	0.60	1.00 - 3.00			
Sodium	me/100g	0.09	0.00 - 0.50			
CEC	me/100g	16	12 - 25			
Total Base Saturation	%	57	35 - 75			
Volume Weight	g/mL	1.00	0.60 - 1.00			
Boron	mg/kg	0.6	1.0 - 2.0			
Ammonium-N*	mg/kg	11				
Nitrate-N*	mg/kg	7				
Mineral N (sum)*	mg/kg	18				
Organic Matter*	%	4.4	7.0 - 17.0			
Total Carbon*	%	2.6				
Hot Water Extractable Organic Nitrogen*	mg/kg	152				
Potentially Mineralisable Nitrogen*	mg/kg	149				
Dry Matter*	%	78.3				
Moisture*	%	21.7				
Sample temperature on arrival*	°C	8				
Soil Sample Depth*†	mm	0-300				
Soil Type*†		Sedimentary				

ARL

SOIL ANALYSIS

Lab Number	Sample Name	Temperature oC	Core Length	Nitrate-N mg/kg DM	Ammoniacal N mg/kg DM	Mineral N mg/kg DM
		oC	cm	mg/kg DM	mg/kg DM	mg/kg DM
		7.0	15	22	2	24
		3.0	30	13	1	15
		4.0	60	7	< 1	7
		5.0	90	10	< 1	10

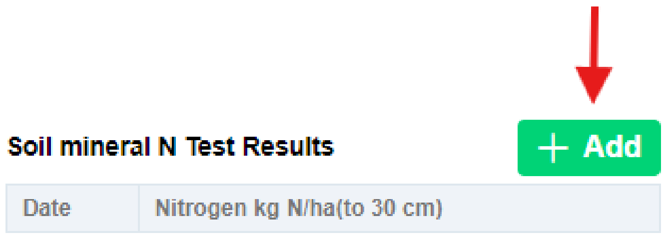
Eurofins

SOIL TEST RESULTS		Units	Results	①Soil Range	①Soil Fertility Desired
NU015	pH	pH units	6.5	6~6.5	
① NUD09	Effective Cation Exchange Capacity	cmol+/kg	15	12~25	
NU362	Total Nitrogen	%	0.19	0.3~0.5	
① NU355	Total Carbon	%	1.9	4~10	
① NU259	Organic Matter	%	3.2	7~17	
① NU065	Carbon to Nitrogen Ratio	Number	10	10~15	
① NU284	Potentially Available Nitrogen	kg N/ha	16	100~150	
① NU027	AMN to Total Nitrogen Ratio	%	1	2~4	
① NUE76	Ammoniacal Nitrogen	mg N/kg	2		
① NUE77	Nitrate Nitrogen	mg N/kg	0		
① NU220	Mineral Nitrogen	mg N/kg	2		
① NU227	Moisture Content	%	32		
① NU04X	Hot Water Nitrogen	mg/kg	50	100~200	
① NU0FN	Hot Water Soluble Inorganic Nitrogen	mg/kg	11		
① NU0FP	Hot Water Soluble Organic Nitrogen	mg/kg	39		

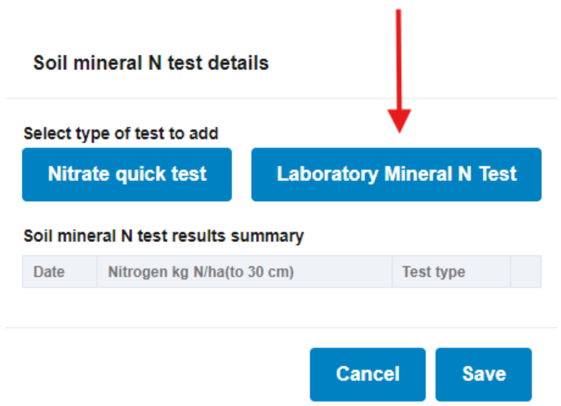
To put these results in practical context within your soil-crop nitrogen budget these results must be converted to units of kg N/ha. As with Nitrate Quick Test results there are two ways to accomplish this.

The first is to enter the result in the SVS Tool:

Step 1.



Step 2.



Step 3.

← Adding laboratory mineral N test

Date *

20/04/2024

Laboratory test result (mg N/kg) *

15

Depth (cm) *

0-30cm

Cancel | Add

Results.

Soil mineral N test details

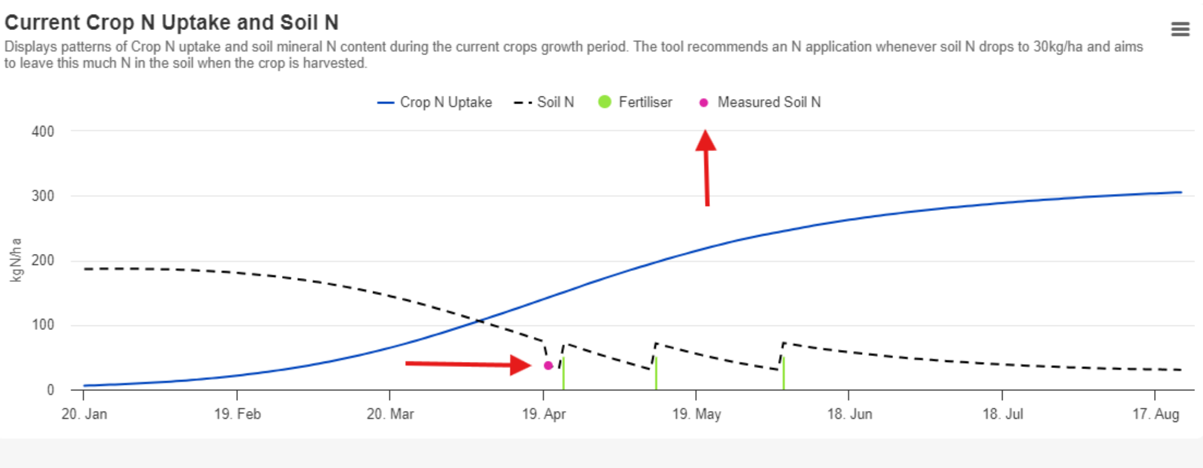
Select type of test to add

Nitrate quick test | Laboratory Mineral N Test

Soil mineral N test results summary

Date	Nitrogen kg N/ha(to 30 cm)	Test type	
20/04/24	37	Lab test	

Cancel | Save



The second method is to convert the test result yourself using the following calculation:

Test result (mg N/kg) x soil layer depth (cm) x 0.1 x bulk density of your soil = kg N/ha

Example: *15 mg N/kg x 30 cm x 0.1 x 0.82 g/cm*^{3} *= 37 kg N/ha.*

Q. How do I interpret a laboratory Potentially Mineralisable Nitrogen result and how do I enter it into the SVS Tool?

A. The Potentially Mineralisable Nitrogen (PMN) test is designed to show how much nitrogen within the soil may become available to plants through the natural mineralisation process. Laboratories determine this by calibrating their test results to a fixed time frame while tested under fixed laboratory conditions – obviously, these conditions and timeframes are not always relevant to a crop grown in real-world conditions, and so to use this result to predict the quantity of nitrogen likely to be mineralised during the growth of a specific crop, it needs to be converted to account for:

- The length of time the crop is grown for (a longer crop = a larger amount mineralised, and vice versa).
- The climate and soil the crop is grown in (more nitrogen will be mineralised during warmer and moister soil conditions).

Fortunately, the SVS Tool does this conversion for you, maximising the value you can obtain from this test.

However, interpreting the PMN test result itself can sometimes be confusing as different labs use different names for the same test and sometimes report the results using different units. The two key things to remember when using the PMN test with the SVS Tool are:

- Use the test result called Potentially Mineralisable Nitrogen (PMN). If there is no test result by this name, then use the result called Hot Water Extractable Organic Nitrogen (HWEON). Do NOT use any other test results (e.g., Potentially Available Nitrogen or Anaerobically Mineralisable Nitrogen).
- Only input test results in units of mg/kg. Do NOT input results in units of kg N/ha.

Examples of lab PMN results are shown below:

Hill laboratories

Analysis		Level Found	Medium Range*	Low	Medium	High
pH	pH Units	5.7	5.4 - 5.8			
Olsen Phosphorus	mg/L	23	30 - 60			
Potassium	me/100g	0.30	0.50 - 1.00			
Calcium	me/100g	7.9	4.0 - 10.0			
Magnesium	me/100g	0.60	1.00 - 3.00			
Sodium	me/100g	0.09	0.00 - 0.50			
CEC	me/100g	16	12 - 25			
Total Base Saturation	%	57	35 - 75			
Volume Weight	g/mL	1.00	0.60 - 1.00			
Boron	mg/kg	0.6	1.0 - 2.0			
Ammonium-N*	mg/kg	11				
Nitrate-N*	mg/kg	7				
Mineral N (sum)*	mg/kg	18				
Organic Matter*	%	4.4	7.0 - 17.0			
Total Carbon*	%	2.6				
Hot Water Extractable Organic Nitrogen*	mg/kg	152				
Potentially Mineralisable Nitrogen*	mg/kg	149				
Dry Matter*	%	78.3				
Moisture*	%	21.7				
Sample temperature on arrival*	°C	8				
Soil Sample Depth*†	mm	0-300				
Soil Type*†		Sedimentary				

ARL

SOIL ANALYSIS

Lab Number	Sample Name	Core Length (cm)	pH	Olsen Sol. P	Calcium	Magnesium	Potassium	Sodium
			.	ug/mL	QTU	QTU	QTU	QTU
		15	6.2	37	10	24	15	3
		15	6.1	35	9	23	10	4

Lab Number	Sample Name	Core Length (cm)	Potentially mineralisable N	Potentially mineralisable N	Organic Matter	Total Nitrogen	Total Carbon	Carbon/ Nitrogen
			mg/kg	kg/ha	% w/w	% w/w	% w/w	Ratio
		15	99	133	3.1	0.16	1.8	10.8
		15	81	113	2.8	0.15	1.6	11.3

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SOIL TEST RESULTS		Units	Results	①Soil Range
NU015	pH	pH units	6.0	6~6.5
① NUD09	Effective Cation Exchange Capacity	cmol+/kg	15	12~25
NU362	Total Nitrogen	%	0.20	0.3~0.5
① NU355	Total Carbon	%	2.1	4~10
① NU259	Organic Matter	%	3.7	7~17
① NU065	Carbon to Nitrogen Ratio	Number	11	10~15
① NU284	Potentially Available Nitrogen	kg N/ha	37	100~150
① NU027	AMN to Total Nitrogen Ratio	%	1	2~4
① NUE76	Ammoniacal Nitrogen	mg N/kg	3	
① NUE77	Nitrate Nitrogen	mg N/kg	15	
① NU220	Mineral Nitrogen	mg N/kg	18	
① NU227	Moisture Content	%	31	
① NU04X	Hot Water Nitrogen	mg/kg	67	100~200
① NU0EN	Hot Water Soluble Inorganic Nitrogen	mg/kg	24	
① NU0FP	Hot Water Soluble Organic Nitrogen	mg/kg	42	
① NU388	Volume Weight	g/ml	1.06	

①Soil Fertility Desired

Or Potentially Mineralisable Nitrogen *(if present)*

Entering the PMN test result into the tool is straightforward, simply enter the result (in mg/kg) and select the depth of the sample. Adjusting the rainfall and irrigation quantities (relative to the average weather at your location) will impact the prediction of nitrogen mineralised, as does changing the weather station and soil details. The latter two factors can have a significant impact on the prediction of nitrogen mineralisation for the test result provided.

Potentially Mineralisable N (PMN)

Hot Water Extractable Organic Nitrogen (HWEON)

PMN test result (mg/kg): 21

Sample depth (cm): 0-30cm

Rain & Irrigation

Amount of rain prior to planting: Typical

Amount of rain during crop: Typical

Irrigation Applied: None

Enterprise & Paddock

Enterprise: No.1 Farm

Paddock: Lettuce Trial

Nearest weather station: Pukekohe

Soil category: Volcanic

Soil texture: Clay loam