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Sustainable vegetable systems – understanding grower and agronomist perspectives: Interviews and focus groups

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This report summarises work conducted by The New Zealand Institute for Plant and Food Research Limited (PFR) within Workstream (4) of the Sustainable Vegetable Systems (SVS) programme.

The purpose of this report was to gather the thoughts of growers and agronomists around nutrient management practices to inform tool development and help develop effective communication and engagement processes with growers. This is part of a wider strategy in supporting growers' nitrogen use decision making through data-based decision systems and support, and a transition of vegetable production to more sustainable systems.

Several interviews and focus groups were completed online in 2021 involving individuals from Pukekohe, East Coast (Gisborne – Hawke's Bay), Ohakune, Manawatu-Horowhenua and Canterbury.

Both growers and agronomists signalled a keenness to try new tools and practices if they are proven to be successful. There is currently no single tool that covers all aspects of nutrient management. These tools/practices need to consider the depth of soil tests and speed at which a result is given, ease of use, ability to use data from other tools, ability to adapt to different crops (both vegetable and cover crops), ability to adapt to different environments, and accuracy in terms of calculating nutrient availability. For adoption of any new tool or practice, it will be important to consider whether it is a standalone tool/practice or is packaged with other tools/practices to optimise effectiveness.

Growers and agronomists recognised several areas where more research is needed. These included the mineralisation of nitrogen, the effect of cultivation on nutrient availability and a better understanding of cover crops. Also key to improving nutrient management practices are the relationships that exist between growers, agronomists, researchers, industry representatives and policy makers. More transparency is needed in this space.

Overall, there is an openness to try new tools and practices as long as both growers and agronomists are included in the decision-making processes.

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1 Introduction

Understanding what is enabling and useful for both growers and agronomists in nutrient management, particularly when it comes to the use of nitrogen, is a key focus of the Sustainable Vegetable Systems (SVS) programme. There is little value in designing the perfect tool or process if it does not suit the needs of growers or agronomists, as this will result in non-use and an associated non-result in the key change area of improving nutrient management practices for better environmental, and in turn, economical outcomes. Getting the foundations right in the SVS programme is essential to achieving this change space. The views, values and practices both growers and agronomists have regarding nutrient management will provide the base upon which to overlay the design and communication of the tools and information developed within this programme. Specifically, this information will inform SVS Workstream 3, which focuses on modelling and seeks to develop a tool fit for grower and agronomist use.

This work follows on from and was influenced by the FOLKL *Vegetable Grower Baseline Survey* conducted under the guidance of Potatoes New Zealand Incorporated, Ministry for Primary Industries, Vegetable Research & Innovation Board (VR&I) and Horticulture New Zealand. (FOLKL 2021).

This report begins with an exploration of theories around decision-making processes and the dynamic mechanisms that influence adoption pathways. This leads into a discussion of the methodology behind the fieldwork of this report and the outcomes of the research. It then concludes with recommendations for the Workstream 3 modelling team.

2 Adoption literature: a landscape review

It is pertinent to explore some theory around the adoption of innovations at this early stage of the project where the development of a tool fit for farmer practice is sought. An important place to start is with the recognition that an individual's decision to change what they do or to adopt a practice/technology is not an instantaneous act, but rather a process that happens over time and is influenced by multiple touchpoints of experience, information, and actions (Rogers 2003). It is this accumulation of interactions that creates the confidence and risk assessment for change that exists regardless of whether you are an early or late adopter. From pre-adoption, through to awareness and information seeking to support a decision, to actual decision making and adoption, the grower undertakes a process of investigation to consider the actions they will invest in (Wisdom et al. 2014).

Influential aspects of this process have been broadly themed into five key attributes by Rogers (2003), which resonate with many grower-centric examples of adoption. The five key attributes are:

Relative Advantage: In what way is the innovation/technology/practice better than what is already being used, or other options that are available to the grower? When considering relative advantage, a grower will be weighing up their options between choices including aspects of (but not limited to) cost, utility, time requirements and benefits. Interestingly, research has shown that while profit drivers are influential, assumptions made that these will negate social and cognitive considerations (values and beliefs) of adoption are risky and depending on the innovation of focus, prone to creating lower levels of adoption (Weersink & Fulton 2020).

Compatibility: In what way is the innovation/technology/practice a good fit for what we already do or use in the growing system? Compatibility is a recognition that there are already many processes that are undertaken to produce the crops that work well for the grower, and there has been previous investments into technology or innovations that a grower would want to continue to take advantage of. When something new is in contrast; will disrupt or supersede what already exists; or is in conflict with existing values or previous experiences of the grower, this can challenge the uptake of the innovation being explored. When a grower's values or experiential knowledge is not compatible with the new opportunity being explored, this can be a considerable obstacle.

Complexity: Is the innovation/technology/practice difficult or easy to understand and use? How complex the process is to use, or how difficult it is to understand the output produced (for example data or numbers) is an important aspect of adoption. However, it may be countered by either good co-design with end users or via the use of an intermediary such as a consultant who could take the complexity load on for a grower. A good example is the translation of soil test results into a bespoke fertiliser recommendation. While some farmers may be willing to tackle this, many seek expertise to negotiate this process, reducing the complex stage, and producing the product that they can then use i.e. a fertiliser recommendation.

Trialability: Can the innovation/technology/practice be experimented with on a limited basis to test its applicability and how well it works in the field? Growers often want to see how something will work in their own, or similar, settings to gain the confidence that it will fit in their production system and importantly for land users, in their environmental settings. The term "try before you buy" is an excellent descriptor for this attribute.

Observability: Are the results of this innovation/technology/practice obvious or visible to others? Growers and farmers are known to 'looking over the fence' at the activity of their neighbours. Technologies are said to have both a hardware aspect and a software aspect. Hardware is often easy

to see, it has a physical form and therefore easier to observe, e.g. a new piece of equipment for precision farming. In contrast, software aspects are often less observable, and emphasis is required to make observable the outcome that results from utilising the software, e.g. a process in the grower's system. This attribute is closely linked to the trialability attribute in the way that growers would seek to see the innovation in action or the impact or change state that results from its implementation.

In alignment with the adoption attributes defined by Rogers above, there are other wider constructs that influence the environment of adoption. Although there is no 'one size fits all' solution for identifying which constructs will be influential for any one adoption situation, some notable ones include socio-political and external influencers, organisational characteristics, innovation characteristics, staff/individual characteristics, and user characteristics (Wisdom et al. 2014). Without sinking into too much depth with each of these constructs, there is value in noting that each innovation/technology/practice comes with its own 'baggage'. This will be something that a grower accounts for as they assess the support available, whether it is a push or pull opportunity (voluntary or enforced), and any potential politics that may surround or be embedded in it.

Holistically, the innovation/technology/practice and the grower sit within the innovation ecosystem.

"An innovation ecosystem is the evolving set of actors, activities, and artefacts, and the institutions and relations, including complementary and substitutes relations, that are important for the innovative performance of an actor or a population of actors" (Granstrand & Holgersson 2020, p. 90).

In short, for a grower to perform well in terms of their problem/need and potential innovations/technologies/practices, the larger context in which that actor and the innovation sits, as well as the attributes that are closer to the action within the production unit. These must be accounted for and mitigations or adaptions developed to create a successful change space.

2.1 Dynamic adoption

Often we talk about adoption as one process, when in fact it is a very dynamic activity fraught with ebbs and flows across the continuum of time (Figure 1). For example, moving through stages of awareness and trialling through to adoption is a process that looks successful, but within a cohort of growers the result could look quite different. Some growers may have never been aware of the innovation or may have never adopted it. Some may adopt then adapt, or adopt and maintain use, or adopt then dis-adopt.

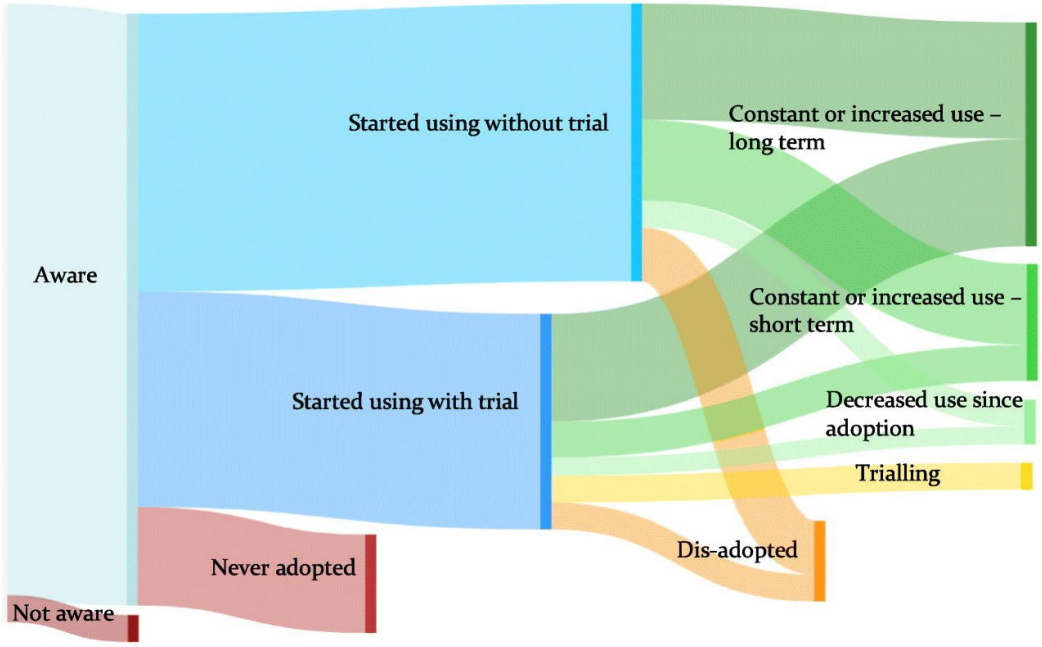

Figure 1. Adoption pathways analysis for agricultural practices. Source: Montes et al. 2021

Montes de Oca Munguia et al. (2021) explore this dynamic in greater depth; however, for the purposes of this research, it is important for the research team to think about this concept with some critical reflective questions early in the development process. The findings from grower interviews and focus groups will help inform the project team's thinking about this dynamic space. Examples of reflective questions include:

- How do we ensure growers and agronomists are aware of the innovation/technology/practice we are developing?
- Why would a grower or agronomist not want to adopt this innovation/technology/practice?
- How do we ensure sustained use and benefit for the grower and agronomist from adopting this innovation/technology/practice?
- Under what circumstances is non-sustained practice suitable?

3 Methodology

Aligning with the work of Workstream 1 (Field experiments) and Workstream 2 (Regional monitoring), five key locations and a shortlist of growers and agronomists in those locations were given to the social science team of Workstream 4. These locations were Pukekohe, the East Coast (Gisborne through to Hawke's Bay), Manawatu-Horowhenua, Ohakune and Canterbury. Thirty individuals were contacted for 1-on-1 interviews, with 10 agreeing to participate. The location and role of these ten individuals can be seen in the table 1 below.

Table 1. Interview and focus group participants.

Location	Interview		Focus Groups	
	Grower	Agronomist	Grower	Agronomist
Pukekohe	3	1	0	2
East Coast	2	0	0	2
Ohakune	0	0	1	0
Manawatu-Horowhenua	1	1	0	0
Canterbury	1	1	1	0

Nine of these interviews were done online via Zoom while the tenth was completed via telephone. These discussions were 0.5–1 hour in length. Interviews were completed during September and October 2021. Questions were co-designed with input from members of Workstream 1 (Field experiments) and Workstream 3 (Modelling), and focused on the interviewee's history in horticulture, their knowledge around nutrient management tools and practices, what crops they (the growers) produced or (agronomists) assisted growers in producing, and what has been a barrier to better nitrogen use.

Individuals who did not participate in 1-on-1 interviews were also contacted to be part of a series of focus groups discussing the same topics from the interviews but at more length. Individuals who completed the FOLKL Vegetable Grower Baseline Survey (2021) were also invited to participate in these focus groups. From the 30 individuals contacted, in addition to the invites sent to FOLKL survey participants, six people agreed to participate in the focus group discussions. These focus groups were co-hosted by the lead social science researcher as well as SVS team leader Andrew Barber and Workstream 4 team leader Gemma Carroll. Two focus groups were held online via Zoom and were both between 1 and 1.5 hours (November 2021). The locations and roles of these six individuals can be seen in the table above.

Both the interviews and focus groups were influenced by workshops held in 2021, hosted by the Workstream 3 modelling team involving growers, agronomists and industry representatives. These conversations brought to the forefront concerns both growers and agronomists have when it comes to nutrient management, the information needed by Workstream 3 to improve or create the tools and practices necessary, and ways forward in terms of improving the relationships between growers, agronomists, researchers and policymakers.

There were limitations to this study. The presence of COVID-19 in New Zealand meant that face-to-face interactions were impossible to hold safely, leading to online alternatives being initiated. This situation had both a positive and negative impact on the research. Positive in that what was said through Zoom and over the telephone was accurately reflected in this report, but negatively in that this limited the pool of potential candidates and the ability to better connect with participants. The timing of this project along with technological difficulties were also issues as it made growers and agronomists less able to participate.

A further bias to the study was that both growers and agronomists invited to participate in the research were identified by the project team. While this approach to identifying participants does create a bias as it limits participation to known growers and agronomists, it is recognised that the New Zealand vegetable industry is not exhaustive in size and is dominated by a few larger businesses, limiting numbers available. Further, this explorative study sought to understand growers' views from the outset of the programme development and will have continued grower touchpoints as it progresses. Overall, the knowledge gathered from the 10 interviewed individuals and 6 focus group participants provided good insight into what does and does not work when it comes to vegetables, nitrogen use and general nutrient management.

4 Research findings

4.1 Tools and practices

Growers and agronomists use a variety of tools and practices to gain a better understanding of what is happening in the soil and the amount of nutrients required for their crops. Crops grown vary depending on factors such as location, business connections, consumer demand and land availability. A grower from the East Coast region, for example, noted that crop selection had been affected by the decision to sell some of his land because it became too expensive to use. Whereas a grower from the Manawatu-Horowhenua region stated that consumer demand along with current business relationships were dominant factors in deciding which vegetables to grow. Pukekohe growers were also influenced by demand, noting that they were already preparing potatoes for the following (2022) Christmas period. The most common vegetables across the regions were potatoes, onions, broccoli, lettuce, cauliflower, squash and pumpkin.

Tools and practices are also affected by factors such as location and geology. Growers gave examples that included: soil type and profile, e.g. having clayish soils, having a high level of naturally present phosphate and land susceptible to wet weather conditions. Participating growers and agronomists identified several strategies that they are currently using for assessing N and other nutrients in their growing system. These include but are not limited to (table 2):

Table 2. Strategies currently being used by participating growers and agronomists to assess nitrogen and other nutrients.

Tools and practices	Examples					
Testing period	Soil testing once a year in summer	Soil testing every 3 years	Soil testing new ground		Before planting and after harvest	Soil testing every paddock
N tests and tools	Nitrate Quick Test	Potentially mineralisable nitrogen (PMN)	Petiole test		Crop removal models	Hot water extractable organic nitrogen (HWEON)
Monitoring	Soil and moisture probes	Nitrate sensors	Weather stations		Historical database + maps	
Management	Software, e.g. Hawkeye, Trimble, Cool Farm Tool	Nutrient budget tools / calculators	Fert Rep. recommendations		Environment plans	
Growing practices	Irrigation, slurry applicators	Cover crops, Base dressing	Fertigation	Crop rotation	Precision Machinery	Wet (liquid) / dry (solid) fertiliser

Also affecting tool choice and use is the amount of time required to get a result and the level of effort necessary to produce data. In the business of growing vegetable crops, time is critical, and growers feel that when it comes to making nutrient management decisions in a timely manner, current tools are not always a good fit.

4.2 Time, depth, effectiveness

"No grower wants to wait two weeks to get a soil test result back for nitrogen" (Hawke's Bay agronomist). "*A 6-week wait is too long*" (Horowhenua grower).

Growers indicated that they are seeking quick results to fit the pace of their own production system decisions. The feedback from growers is that tools that require a lot of effort can be difficult to work with and off-putting. This result indicates that any tool that is aimed at growers must fit with the diffusion attributes mentioned earlier. The wider range of adoption levels of the 11 nitrogen loss strategies and the barriers to adoption identified in the earlier survey is reflective of this (FOLKL 2021, pp. 16, 22). Compatibility with not only the physical growing system but the processes and timeframes the grower is working with, in addition to being easy to use and understand in a timely way, are important considerations.

One of the key uncertainties that was identified through the interviews was the importance of depth and size when it comes to doing soil tests. Regarding size, "*growers are sceptical about how a teaspoon of soil can give you a representative sample of your whole paddock*" (Gisborne agronomist). Regarding depth, three growers mentioned a keenness to go beyond the standard 15 cm depth use by tools such as the PMN test, which uses an algorithm to calculate what is happening beyond those 15 cm. This was considered an issue for some because several vegetable crops tend to use nutrients at much deeper levels. Growers do not want to miss out on information available at deeper levels that they feel could improve their nutrient management practices. For that reason, nitrate quick tests were considered an important solution*. "Cropping guys want something easy and that is why we're really pushing this quick N test as a solution … For any deep-rooting crops we go down to 30cm, and any winter or shallow-rooting crops we go down to 15cm"* (Gisborne agronomist). But there is also concern that 30 cm may also be too shallow, which led to two growers and an agronomist mentioning the possibility of completing tests at a 60 cm depth. Two other agronomists stated that doing so would generally lead to an increased workload and muddled results, and for that reason, had not maintained the adoption of this process.

It is notable that only 6% of growers considered deep N testing below the root zone to be a method of greatly reducing N loss, with a total of 28% of surveyed growers using this tool (FOLKL 2021, pp. 16, 21). Opinions on the effectiveness of the Nitrate Quick Test varied from growers/agronomists depending on soil profile and region. In the Gisborne area for example, where soils can be heavily clay, Nitrate Quick Tests are viewed to be less effective on their own*. "We're working with some pretty heavy clay around the farm. Leaving samples just to set by gravity didn't work for us so we bought a centrifuge and I definitely recommend it if using the quick N test"* (Gisborne agronomist). Effort required was also a factor identified with participants from the Pukekohe region, which has led to growers using alternative tools such as petiole testing to get a better understanding of nitrate levels. These examples indicate that practices often require extra commitment, effort, and at times extra equipment investment. Where this is incompatible with growers' ways of working, and the perceived return value they will receive from this investment (time and money), then adoption and sustained adoption will always be challenging. Another adoption aspect highlighted here is the synergy between different adoption methods. In the Gisborne example, two technologies were adopted: the Nitrate Quick Test and a centrifuge. For adoption of any new tool or practice it will be important consider whether it is a standalone tool/practice, or if it comes packaged with other tools/practices to optimise effectiveness.

The cost of testing and specifically targeting nitrogen were also issues raised. A grower in the Canterbury region felt that it was better to test for phosphates and to some degree magnesium in his region, for nitrogen testing results can be inconsistent. A similar sentiment expressed by agronomists in the Pukekohe region: "*every paddock we have soil tested, but not for nitrogen because we have found it unreliable and hard to interpret. Depends what nitrogen you are looking at and when*". Regarding the cost of testing, participants from the Gisborne region felt that although regular testing can be fruitful in terms of the information received, it can also be economically difficult. "*You can't soil test every five minutes and foliar test every five minutes; it is too expensive*" (Gisborne grower). "*We do tests once every three years. We don't have enough resources to sample everything once a year*." (Gisborne agronomist). One resource they do have plenty of, is the knowledge they have gained through years of working with the environment. Knowledge they fall back on to help overcome any form of nutrient management difficulties.

Every grower and agronomist interviewed has been in the horticulture industry for at least 5 years, with many having been involved in vegetable growing in some form for 10 or 20 years. This is a decent amount of time to build up a wealth of place-based knowledge around the most appropriate tools and practices that can be used for their selected locations and crops. *"There's a lot of work to do with a lot of these tests and that's why I'm saying that a lot of the applications at the moment are still based on historical knowledge; crop knowledge and/or paddock/block knowledge; What has been in that paddock in the past because it's all about matching release with demand, or availability with plant demand and that's the very difficult part"* (Hawke's Bay agronomist).

This reliance on historical data when it comes to decision making was a common message throughout the discussions and reflects the SVS grower survey, which found that 58% of growers surveyed rely on their own historical knowledge to inform nutrient/fertiliser decision making (FOLKL 2021, p. 10). As one agronomist noted, *"We do a nutrient budget but I'm finding that most of the applications are occurring based on historical preferences as opposed to what we say they require, particularly nitrogen"* (Hawke's Bay agronomist). A key challenge for shifting growers towards new tools or practices is the existence of practices that embed a recipe approach to growing as opposed to a bespoke approach. Recipe approaches are stable and familiar for growers but are at risk of not optimising the nutrient management opportunity. A challenge that is apparent to many of the agronomists who were interviewed: *"some of the older growers are stuck in their old ways. Old gear and old methods"* (agronomist).

Whether stuck in old ways or seeking out change, crops, tools, and practices have continued to transform as more knowledge becomes available on topics such as plant needs, sustainability, and fertiliser application rates, and as the quality of the fertiliser, tools and practices used also sees improvement. Knowledge that both growers and agronomists have used to improve their decision-making processes.

4.3 Drivers

"*When it affects your business and affects your profit, you learn in a hurry that this is not what you do*" (Pukekohe grower).

Gross margin and bottom line were common drivers among all participants when it came to nitrogen use and general nutrient management. Many expressed a concern with the overuse of nitrogen due to its effect on quality, yield, and the ability to meet consumer demand. Factors varied in importance depending on the interviewee and the crop.

'Efficiency' and 'practicality' were key words for growers in the Canterbury region, expressing the importance of quality over yield due to the need to meet consumer expectations. Whether overused or underused, *"there is a very fine line between just enough and too much nitrogen. It is a tough balance between nitrogen in the soil and meeting consumer demand"*. A sentiment also expressed in the Pukekohe region, with growers stating that *"there are no shortcuts when it comes to nitrogen use. A lesson that has been learned the hard way for several growers. […] We can't afford to put on more than what we need because it is costing us money"*. No matter how much tonnage is acquired at the end of the harvest, *"if the quality is not there, it costs more to sort out the good produce from the bad produce."* Whether it be the effect it has on crop quality or the effect it has on profit, many of the growers interviewed commented on the dangers of the misuse of nitrogen.

Being compliant with environmental regulations and satisfying the market by proving to be more sustainable in practice are also key drivers in grower decision-making. A message expressed across all five regions. Just as the crops and technologies have changed, so too have attitudes towards growing practices and environmental sustainability. *"Things have certainly changed in terms of nutrient management from 15/16 years ago. Whether it is growers or service industries or whoever, they are much more aware of environmental concerns and strategies for mitigation are right up there"* (agronomist). A grower from the Manawatu-Horowhenua region recognised that more work needs to be done in this space and was concerned that perhaps not everyone in the industry was pulling their weight as there is no pressure to prove green or sustainable practice. Growers in the East Coast region were all for sustainable practices but were concerned with how sustainability is measured, sharing concern that perhaps not everyone has the same understanding of sustainability. A similar thought Canterbury growers had when it came to efficiency; *"what exactly is efficiency? People are defining it in different ways"*. Pukekohe growers made it clear that they *are "here to help, not hide. We understand [that] as growers we need to look after the environment"*. The comments made here by growers are clear signals of the importance of those organisations of influence in the N management space to have a clear and consistent approach, including clarity of definitions used and identification of practices that fall within those definitions. The development of any new tool or practice in nitrogen management will need to bring not only growers on the journey of change, but also industry, policy and even markets to gain the consistency of messaging and communication to support grower confidence to engage and adopt.

Both growers and agronomists signalled a keenness to use new tools and/or practices if they helped in the better use of nitrogen and were able to identify the best practices that would help achieve environmental sustainability. However, growers pointed out that currently, no such single tool or practice exists that meets all these requirements – a point also reinforced in the survey (FOLKL, 2021 p. 21). Requirements that can marginally differ from grower to grower and region to region. These tools and/or practices must first be proven and need to be able to help growers strike a balance

between understanding the amount of nitrogen in the soil and meeting consumer demand. A capability that requires a lot of trust.

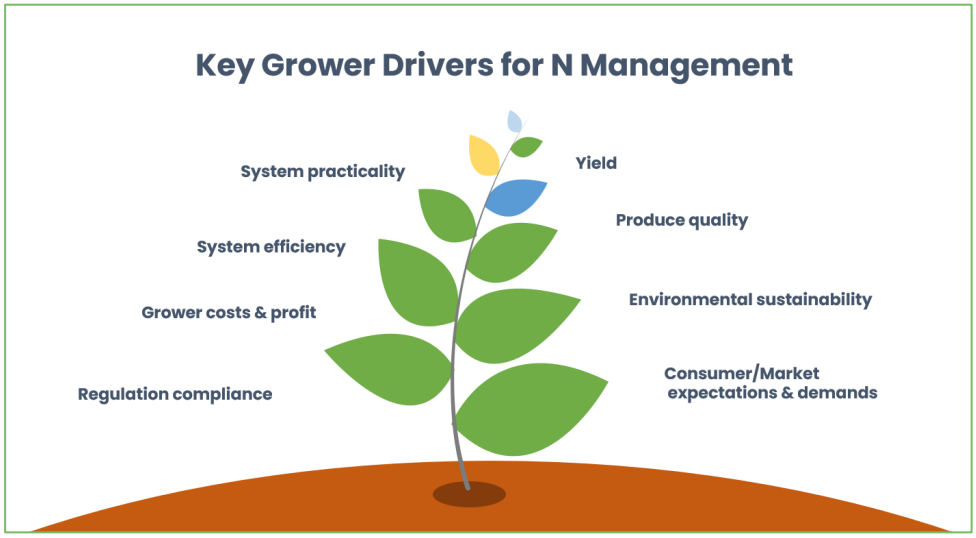

Figure 2. Summary of key Grower drivers identified for Nitrogen management.

It is pertinent to pause here to reflect on the synergies from the SVS grower survey results and these interviews/focus groups. The survey asked growers what they felt the greatest barriers were in terms of reducing nitrogen loss further. The top five barriers identified were: reduced marketable yield (43%); access to the right tools/technology/testing (29%); access to sufficient land or natural resources, e.g. water (22%); lack of knowledge (20%); and too costly (19%) (FOLKL 2021, p. 22). Both from this section on drivers (Figure 2), and the themes highlighted below, the grower voice provides greater grower context to these survey results.

4.4 Confidence and trust

Trust is important when it comes to growing vegetables. Trust in the regulations; trust in the grower's own experience; trust in the science; trust in the tools and practices being used; and trust in the knowledge of agronomists.

Most growers interviewed relied heavily on agronomist input when it came to nutrient management and the use of nitrogen, particularly when it comes to cultivating new land for vegetables[1]. It is a relationship that gives growers reassurance and support with their everyday decisions, and a relationship of importance when it comes to implementing new methods that aim to improve nutrient management. As one East Coast grower said*: "understanding the complexity of nutrient management is not easy; having that confidence to make decisions is important*".

[1] Note the earlier SVS grower survey found that 33% of growers surveyed used farm consultants as a source for their fertiliser advice/recommendations (FOLKL 2021, p. 10).

There is some hesitancy in trusting tools and practices that are new to the industry due to past occurrences of tools becoming unreliable a few years after their launch. "*There are a lot of tools that come out and then few years down the track you use them and they're really not providing good information*." (Ohakune grower). This hesitancy can also be linked to tools being associated with individuals that growers/agronomists do not trust. When there is this lack of trust, growers again rely on the confidence that comes from the knowledge and experience they have gained through many years of toil with their environment. A relationship with the land where they have learned a lot about what works and what does not. *"Growing vegetables outside is not as easy as somebody giving you a textbook that says, 'this is what your plant requires, and this is what you need to grow a good crop'. […] It is a challenge, but most growers are pretty experienced"* (Pukekohe grower).

One of these challenges is being able to consistently produce the same result and maintain acceptable levels of sustainability. In response to a question regarding his thoughts on nutrient management in the vegetables sector, one agronomist felt that growers, overall, are:

"*Somewhere in the middle between confident in what's going on in the soil with nutrient management and a guessing game. Most people are trying to do the right thing but there's still an element of the industry out there who are possibly putting a bit too much on or at the wrong times. Most people are fairly aware of it but there's a step there around the execution of it that we don't always get right*".

There is also concern that some growers see fertiliser as a form of insurance and the easiest solution when it comes to assisting struggling crops; *"If in doubt, chuck more on"* is how one agronomist reflected on this mindset. The interviews made it clear that this notion of 'the more that is applied, the more likely that total yield goals will be attainable' is a mindset that is still lingering in the industry. This mindset goes back to comments growers made around sustainability, moving forward as an industry, and holding everybody accountable. There is an eagerness to try and solve this dilemma but convincing growers that more is not always the best decision has been a challenge for agronomists: "*The quicker I can give someone an answer backed by data, the better I'll be able to convince them to reconsider applying more fertiliser because the data suggests otherwise*." (Gisborne agronomist). These quotes emphasise the importance of building trust in the industry to ensure that all growers are aware of where the industry wants to be in terms of environmental sustainability and how to achieve it. The more that future tools can provide this data quickly, the better.

The notion of 'not always getting it right' was a common theme among growers. Not for a lack of effort in trying to keep on top of nutrient management, but rather a nod to several factors that can influence their ability to be consistent. Factors such as the effect weather conditions can have on planning ahead and nutrient leaching; the rules and regulations that exist around environmental sustainability; and the ways in which this sustainability is measured. The last two points appeared to be an area where trust from the growers is waning.

"The most complex thing about growing nowadays is not the growing. It's having to deal with all the rules and regulations. Which is what the feedback is from growers" (Canterbury grower). There is a feeling of disconnect at times, particularly from growers, around how these policies are made and the way in which sustainability is measured. Some felt that there is a lack of understanding of the unique complexities that exist with different vegetable growing systems. Complexities that involve factors such as crop rotation, soil profile, cover crops, and the effect weather has on fertiliser use. When discussing the beginnings of his horticultural business, one Canterbury grower noted that one of the first issues they had was regulators not understanding their farming system. A sentiment also expressed in the Pukekohe region*; "people who are making these decisions, it would be nice if they could actually practice what they preach. Borrow some land off me if they want and let them grow a crop how they want us to grow a crop"* (Pukekohe grower). This disconnect is also felt through what grower's feel is an inconsistency in how policies are implemented regionally and the lines of communication that exists between growers and policymakers. "*There is a fine line between helping a person and telling me what to do. Legislation and regulations can be forced sporadically around the country*" (Gisborne grower).

Sentiments such as these are important to consider when thinking of the relationships between growers, agronomists, policymakers, researchers, and the science that will inform future management practices. Given the adoption of previous tools into the regulatory system (for example the Overseer tool) for farmers and growers alike, there is caution about how new tools will be or might be used in policy settings. "*We need to be careful with these tools that we develop. That they're not just picked up like Overseer and slammed on us as a regulatory tool because they're not there for that reason. There are so many factors to factor into these tools that you're never going to cover everything. It's not a one size fits all*" (Ohakune grower). It will be important as new tools and practices are developed, to ensure clear communications about their role in current and potential future regulatory processes so to build the foundations upon which growers can begin to have confidence and trust in their use. Whatever model the industry decides to develop, both growers and agronomists want the transition to be as easy as possible. *"It would be good if things could be compatible, and data could be exported from one platform to another. Growers find that you get pulled in a lot of directions and you don't want to have to enter information 2/3 times just to produce a different report for somebody*" (Pukekohe agronomist).

Both growers and agronomists had confidence in the knowledge developed through science, but how that knowledge was applied was a point of contention; especially when it came to a discussion around measuring what is in the soil versus the models and theories used for nutrient management. Some agronomists felt that perhaps some of the modelling available today could be better in terms of the predictions they give. Growers felt that more modelling is needed, especially around understanding nutrient availability. And there is also some hesitancy about relying on models and theories when it comes to nutrient decisions. As one grower put it; *"if you can measure, why would you want to model?"*

It is evident that having science-backed information, tools and practices is important, but these conflicting views signal the importance of finding a balance to ensure that any new nutrient management tools or practices are robust regarding the biophysical and modelling science and are clearly communicated. What growers are sure about is a need for future tools and practices to better measure and explain the reasons why nutrients are leaching.

4.5 Measures of success

"*If there was a tool that could be used that is successful, I think yes, growers will use it. Until now, there hasn't been one that is successful, and what I mean by successful is, it's going to tell you that if you put on too much fertiliser in one hit, this is what the problem is going to be*" (Pukekohe grower).

From a grower's point of view, success is the ability to be able to quantify the amount of nitrate leaching occurring in the soil and the reasons for that leaching. Success is also the ability to collect data from tools and then tweak current practices to reduce nitrate loss. And success is being able to quantify the amount of nitrogen available in the soil and have a sense of when that nitrogen may become available to future crops. If future tools and practices can help achieve these goals, then both growers and agronomists feel that they can be more successful.

A common message expressed by all participants is that nutrient input is easy to keep on top of but what comes out the other end can be difficult to measure. Precision machinery, satellite imagery, plant knowledge, fertiliser quality, irrigation, and application rates can all play a role in staying one step ahead of plant requirements, but there are other factors that can negatively affect and reverse a lot of the good work that goes into growing. The equation may seem simple on the surface, but the actual art of day to day growing, and the ability to correctly calculate both actual yield and what has been left or lost in the soil can be difficult to measure.

"It's about nutrients in and nutrients out, what you take off the farm. [But] it's that change from day-to-day to week-to-week that is really hard to account for" (Canterbury grower). One of the key factors influencing these changes is weather, which was frequently mentioned as affecting grower ability to keep on top of nutrient management. *"Since we can't control the weather, we will always get some leaching … We've got probes in the soil hopefully telling us what it is we're doing. We've changed our processes as a result"* (Pukekohe grower).

Underlying these difficulties is the message that good nutrient management activities do not always achieve great results. *"When you've got no control over anything; temperature, weather, whatever, you get a hailstorm, and it ruins everything. Crops start to go backwards and to go forward again, it needs that extra feed"* (Pukekohe grower). There is always the possibility that something can go wrong; a message that participants from both focus groups felt needs to be remembered. Growers interviewed felt that what would be useful is if future tools could indicate a range within which good practice can be accomplished. If it can take into consideration inputs such as the crops planted, field history, weather events, and fertiliser use, and indicate why a certain practice may cause leaching, it would go a long way to helping both growers and agronomists be successful. *"There needs to be some explanation around why it's leaching. Is it because we put in on and it wasn't supposed to flood, and we got a flood? Which, again, nobody can tell us. If the weather people can't get it right, how do you expect growers to get it right?"* (Pukekohe grower)

These difficulties underline the message given by both groups that more knowledge is needed to improve nutrient management practices. Knowledge that will help growers and agronomists feel more in control over what is happening in the soil.

4.6 Knowledge and control

One phrase that was prevalent throughout the interviews and focus groups was 'more research'. Both groups felt that there are several gaps in the current knowledge base, and it would be beneficial to both if any new or updated tool or practice addressed these challenges.

The biggest question marks for those interviewed were around understanding nitrogen mineralisation, understanding nitrogen availability, understanding cover crops and organic matter, and how to accurately measure what is left in the soil. Calculating the level of nutrients available after a harvest was a key issue for growers in the Canterbury region. *"Estimated average for what is left behind is quite difficult because we have quite a wide harvest window for many of the crops […] Say you bypass a patch of green vegetables because it just doesn't look good enough for the consumer. By the time you finish, you just have no idea what is left in the paddock"* (Canterbury grower).

That bypassed patch will eventually be cultivated and prepared for future vegetables. But the impact that cultivation has on future crops, whether it be ploughing in vegetables or ploughing in cover crops, is a challenge that both groups are having difficulty with. "*We need more research on the effects of ploughing in, cultivating cover crops and the effect it has on the following crop […] There's a lot of hesitancy and scepticism around cover crops and how we deal with the residue at the other end and what effects it's going to have on the next crop*" (Hawke's Bay agronomist). A sentiment shared by growers in the Gisborne region; "*We need to know the breakdown release times of N. If you're ploughing a green manure crop, when is that nitrogen going to be available to the plant - is it next year? Important particularly in a tight vegetable rotation".* (Gisborne grower). The conversion of organic N into inorganic forms is one of the harder challenges for both groups when it comes to nutrient budgeting. "*Mineralisation of nitrogen, the availability of that on a curve, month by month, aligned with rainfall, that's probably the hardest thing I would find in terms of our nutrient budgeting*" (agronomist).

There was also interest in better understanding the impact temperature, aeration and moisture levels have on growth in the wake of cultivation activities. *"If you cultivate a paddock and the temperature is right, you're going to get a flush of growth after that cultivation, and whether that's due to increasing soil temperature or aerating of the soil, or reducing soil moisture content, I don't know"* (Hawke's Bay agronomist).

These are some of the key questions that came through in this study, much of it focusing on the happenings in the soil. To combat these challenges, agronomists are being proactive by having a good understanding of what is and what is not in their control. In the Hawke's Bay region for example, nitrate sensors are being used to monitor what is coming out of drainage systems relative to weather and management events. This knowledge is then being combined with data collected from PMN tests to calculate how much nitrogen may be in the soil and when might it become available over the next 4 months. "*You cannot control that 100ml of rain weather event, but you can control your 35-meter irrigation event.*" (Hawke's Bay agronomist).

Parallel with the theme of trust, control is key to motivating the industry to adapt better tools and practices for nutrient management. By providing a chance to be more in control of what is happening in the soil, more focus can then put on issues such as nitrate leaching and environmental sustainability. If future tools and practices are proven to assist in this area, that will go a long way to building trust between growers, agronomists, researchers, and policymakers. Relationships that are key to better nutrient management.

4.7 Relationships

Thinking again about dynamic adoption, one of the reflective questions asked was: 'how do we ensure growers and agronomists are aware of the innovation/technology/practice we are developing? Key to answering this question are the relationships that exists between grower and grower, grower and agronomist, growers and the industry, and growers and policymakers. For SVS to be successful, these relationships need to be maintained and improved upon.

Growers would like to see more cohesion between small and large growing enterprises and more openness when it comes to the sharing of knowledge around nutrient management practices. "*I feel there's a difference between what's happening with the smaller grower and what's happening with bigger growers. You have to take the smaller growers with you as well"* (Ohakune grower). Some growers feel that there can be a 'disconnect' at times between the goals of the industry and equal access to knowledge. *"Are we actually moving forward as an industry? If we're doing this for the benefit of the environment and benefit of the industry, well what's the point of being secretive about managing our nutrients better?"* (Gisborne grower).

Communities are a central part of this industry. A collection of individuals who rely on one another for expertise and support. And so, when thinking about implementing changes to nutrient management, rather than a blanket, one size fits all approach, it is important that we think about these communities and the best approach for each one. Groups of people that can be so specific to a region. Whether it be growers, Council staff, scientists, agronomists, or other members of this industry, ensure that communities such as those in the Ohakune, East Coast, Manawatu-Horowhenua, Pukekohe, and Canterbury areas are aware of the happenings in their area and know who to turn to for support. Their strength as a community will contribute greatly to the industry moving forward as a whole.

5 A possible pathway ahead

Academic behaviour change theories can help us understand the dynamics of change for those involved, but in themselves, they cannot bring about behaviour change (Prager 2012). Different approaches are required for different complexities of innovation (Figure 3). Where very simple solutions are required, the science behind it is known and the environment is not complex, then the old school approach of tech transfer will often be sufficient. Undertaking exploration of end-users needs and constraints, however, can provide early on in a programme, the opportunities for more integrated approaches. The SVS programme has explored adoption needs and constraints in the earlier grower survey followed by these interviews and focus groups. Based on this, and its direction of travel, it is recommended that the project consider what level of co-design and collaboration it wants with growers as the end-users for the nutrient management tool it aims to develop.

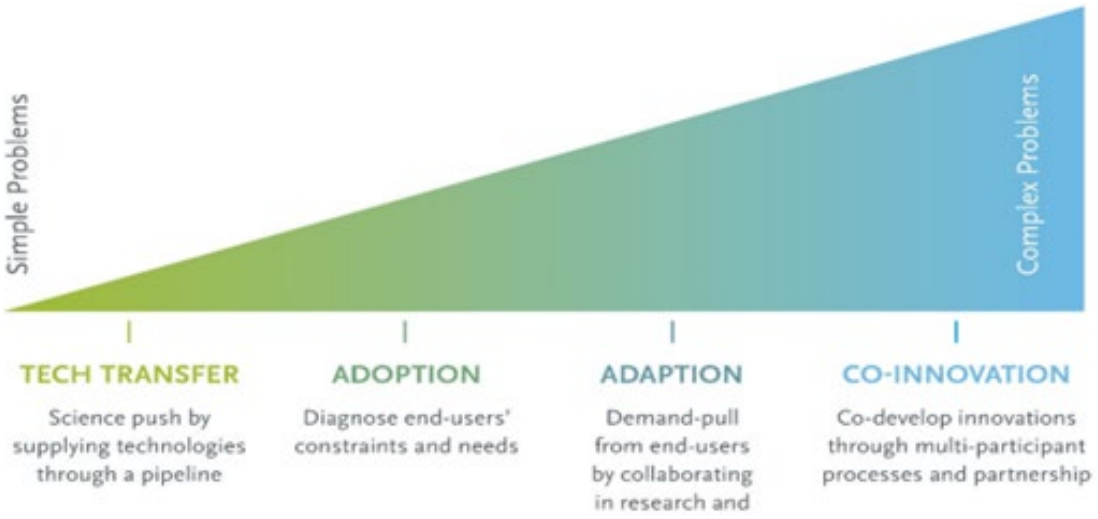

Figure 3. The co-innovation continuum, showing that complex research problems are most suited to co-innovation approaches. Source: Boyce et al. 2016, p. 2.

The SVS programme is already on the pathway to a co-innovation approach; however, it is the decisions that are made at this stage of the programme that will enable timely grower interactions to be embedded to support a truly co-innovative approach. As an example of this approach in action, the NIWA-led Irrigation Insight Programme sought high-resolution weather forecasting, production potential and drainage estimations for on-farm (dairy) water management. In short, this team sought to make the invisible (water movement in the soil profile) visible to the farmer to enable better decision making about irrigation need and use on farm (Srinivasan et al. 2022).

Irrigation Insight

"Inefficient use of irrigation in New Zealand pastoral farms is widespread and the uptake of irrigation scheduling tools to improve efficiency is poor. Recent studies suggest that end-user inclusive participatory approaches to developing tools and practices could improve the uptake, contributing to improved economic and environmental outcomes. Using a co-learning based participatory approach, we (researchers) worked with a group of pastoral farmers, water resources regulators and industry professionals, to develop an operational irrigation scheduling support tool that would facilitate improved water use. The key engagement principles used were taking time to understand the problem from multiple (stakeholder) perspectives; applying equal value to all sources of knowledge; providing an atmosphere that fosters learning among stakeholders (co-learning); staying aware of the wider (problem) context; and remaining flexible and adaptable. The co-learning approach revealed over-lapping, yet distinct, perceptions of improved water use: for farmers, it meant pasture growth unimpeded by available soil water; for regulators, reduced irrigation-drainage and consequent leaching of nutrients from rootzone; and for researchers, justified use of water based current (crop) demand and forecast (rainfall) supply. The co-learning guided operational tool combined near-real time soil water monitoring (demand) and short-term (two to six days) rainfall forecast (supply), to support on-farm irrigation scheduling decisions. The tool included biophysical (data type and synthesis), structural (data format, presentation, and visualisation) and technological (instrumentation and data collection protocols) features that incorporated the diverse perspectives to water use. Uptake of the tool by the pilot study farmers was high, and their irrigation practices evolved because of the information it provided. Inclusion of multiple stakeholder perspectives throughout the tool development process revealed unexpected insights and resulted in improved outcomes for all stakeholders." (Srinivasan et al. 2022).

For further information on this programme visit the Irrigation Insight page on the NIWA website.

The Irrigation Insight team (of whom Toni White from PFR was a member) worked with a core group of farmers to understand what was important to them, and what they needed to know or see to be able to make good decisions about when and where to use on-farm irrigation. They used participatory methodologies to interact and co-learn with farmers to envision what this could look like, and what information needed to be included to make the digital tool practical, useful, and easy to interpret and use.

The similarities of what SVS is seeking to do within nutrient management, making the invisible visible, and developing a tool that is easy to use, integrate into existing systems and enable timely decision making is pertinent. An opportunity exists to invite MS Srinivasan from NIWA (project leader) to present to SVS on the process they undertook, the way they worked and the outcome they achieved to explore if this resonates as an approach SVS might consider.

6 Conclusion

Overall, both growers and agronomists are interested in improving their nutrient management practices if it means better opportunity to meet consumer demand, better control over what is happening in the environment, and improvement regarding environmental sustainability.

Both groups recognised a variety of issues with current tools and practices and were keen to consider developments that would give them a relative advantage. This process, however, requires a lot of trust in both the tools being developed and the relationships surrounding them. One of the key issues has been the connection between environmental policy, vegetable growing practices and the ways in which environmental sustainability is measured. Growers would rather have a tool that helps drive them towards best practice than one that is governed by the regulatory system. Growing is not a perfect process and policy makers need to recognise that.

Developed tools and practices need to be compatible with what is already in use. Growers and agronomists use a variety of tools/practices and rely on them heavily in their decision-making processes. If what is developed can incorporate the outputs from other tools and practices, both groups are more likely to make that transition. Familiarity and ease of use is key.

Ideally, this tool is malleable in terms of the locations it can be used in and the way in which it can be experimented with. People are unique, environments are unique, and crops are unique. If this tool can understand those environmental differences and still be easy to use, that will go a long way in terms of adoption. Then there are issues around cost, time for a result, soil depth and testing frequency. It is recommended that Workstream 3 continues to work with growers and agronomists in this space.

It also needs to be recognised that people are at different stages of adoption (figure 1). Some people need to be convinced while others will jump at the opportunity to try out new tools and practices. Agronomists are a key group to think about in this space as the level of trust they have with growers will help many consider transitioning to different tools/practices. There also needs to be more emphasis placed on improving relationships at the regional level and initiating more conversations between agronomists and growers. Both groups were appreciative of the opportunity to have a say in this programme and a chance to discuss with others the tools and practices they thought were successful.

Another key relationship that could see some improvement is that between growers/agronomists and researchers. Growers/agronomists mentioned a keenness to better understand covers crops and organic matter, calculating the level of nutrients avaialble after a harvest, and a better understanding of nitrogen mineralisation. There may be litereature that already exists covering some or all of these topics, but they have not been made aware of their existence.

Now that growers and agronomists have started this conversation around better nutrient management, it is important that they continue to be involved in the process.

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