

Understanding signals influencing on-farm change

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Abstract. The Our Land and Water (OLW) National Science Challenge has a vision for a future where catchments contain mosaics of land use that are more resilient, healthy and prosperous than today. To achieve this, a considerable amount of on-farm change will be required. OLW wanted to understand the signals (information from a range of sources) that are influencing on-farm changes. From the literature we developed a framework to identify external off-farm signals from farmers' operating environment and internal on-farm signals that provide information about the farming system. We used an inductive case study method, interviewing farmers and advisors to test the framework. The data revealed that no single signal prompted on-farm change. Instead, several signals appeared to influence decision making on-farm. These signals need to be considered by extension agents and policy makers. The framework provides a checklist for this. Refinement of the framework would be useful to determine how on-farm signals differ from intrinsic drivers and to refine the critical attributes of signals.

Keywords: signals, practice change, land stewards, farmers, extension, advisors.

Introduction

The Our Land and Water (OLW) *Toitū te Whenua, Toiora te Wai* National Science Challenge has a vision for a future where catchments contain mosaics of land use that are more resilient, healthy and prosperous than today. In this future, all New Zealanders can be proud of the state of our land and water and share the economic, environmental, social and cultural values that *te Taiao* (the environment that contains and surrounds us) offers. To achieve these outcomes, a considerable amount of on-farm change will be required from land stewards. Changes to New Zealand's farming systems will be required at the operational, tactical and strategic levels. This will involve changes to on-farm practices and land use. A particular focus for OLW is to enhance the production and productivity of the primary sector while maintaining and improving the quality of the country's water for future generations. To this end, OLW were interested in understanding the signals that are most important for eliciting a constructive response from land stewards to improve water quality. A constructive response refers to the changes on-farm required to achieve the vision of OLW for resilient, healthy and prosperous land use. Signals refers to information from the natural environment, culture and society, farm activities, industry group directives, markets and incentive schemes, regulations, prices, peers, advisors, policy makers and researchers. The term land stewards, refers to people making decisions about the use of land, especially farmers and land managers. In this paper, the terms land stewards and farmers have been used interchangeably.

Objective of the research

The objective of the research in this paper was to determine what were the signals that influence land stewards to change practices resulting in water quality improvement. While OLW provided a definition of signals as information from a range of sources, a framework for understanding signals was needed to consider the types of signals that influence farmers, whether from on- or off-farm.

Literature review

Factors influencing on-farm change

Understanding practice change amongst farmers has been a focus for researchers for many years. Rose et al. (2018) presents a recent review of the factors that influence on-farm practice change. They determined the following list of factors.

Personal factors These were factors such as age, gender, experience, attitudes, and beliefs. They reported that that older farmers were more resistant to technology adoption and that personal beliefs were the key factor in explaining levels of environmental management. Rose et al. (2018) also noted that negative emotions (e.g., anger or misery) could slow on-farm change.

Business factors These were factors such as farm size, cashflow, staff numbers, succession plans, and profitability. Examples included the influence of farm size on behaviour (e.g., larger farms may have more staff or a greater income to implement changes).

Family, peer and advisor networks These factors included the opinions of family, friends, peers and trusted advisors. Examples included formal and informal advice and social pressure.

Feeling in control of decision making These factors included the perceived level of autonomy over decision making. Rose et al. (2018) noted that this was sometimes associated with level of education as a higher education level provides a farmer with more confidence about implementing new ideas.

Relative advantage (incentives/rewards) As Rogers (2003) indicated, relative advantage in terms of time saved, reduced inputs, and economic or environmental benefits influence on-farm change. Rose et al. (2018) notes that profitability or other benefits must occur because of the change in behaviour for it to be considered desirable. Financial benefits were often considered much more of an advantage than environmental benefits.

Market or compliance-based rewards These factors included gaining higher prices or making an on-farm change that helped meet compliance requirements.

Information provision education (or extension) These factors were about the provision of good information combined with clear communication. Rose et al. (2018) noted that information provision and communication must be sustained over time so that land stewards are constantly supported.

Other researchers have referred to the factors outlined by Rose et al. (2018) as enablers and barriers (Eagle et al. 2016), principles (Vanclay 2004) or motivations for change (Turner et al. 2017). Rose et al. (2018) also identified behavioural change insights from outside the agricultural literature. Several had already been highlighted in the agricultural literature, namely attitudes/personal factors, influence of family, friends and peers, relative advantage, including incentives and provision of education. An additional factor was 'nudging', such as through positive messaging, pricing or other incentives (see for example Kuhfuss et al. (2016)).

These factors have been incorporated into conceptualisations of change. The decision-making conceptualisation developed by Sutherland et al. (2012) comes from social psychology. Their decision-making cycle was derived from empirical data, but then grounded in existing theories beyond what was available through the research data. They posited that trigger events are needed to challenge the path dependencies of existing farm businesses. They outlined a five-stage cycle moving from (1) path dependency when (2) a trigger event prompts (3) active assessment of change and a decision to (4) implement an innovation (a new practice or technology), before (5) consolidation of skill development and resource investment as the innovation becomes embedded in the path dependency of the farm. The trigger event is important as it initiates change (Sutherland et al. 2012). It may be a single event or information source, or it may be the cumulation of information over time that initiates change (Murray-Prior & Wright 2001).

This decision-making conceptualisation reinforces the view that adoption is a multi-stage process from awareness to final adoption (Rogers 2003), or in innovation systems language, from the Trigger Event to Consolidation (Sutherland et al. 2012). This theory of change considers that individuals do not have the capacity to process all information in-depth and so tend to operate in routines most of the time (Murray-Prior & Wright 2001). They will only move to in-depth processing when required, i.e., there is a trigger event. A degree of path dependency and lock in (Goldstein et al. 2023) is expected in farming businesses dues to sunk costs such as investment in dairy sheds and irrigation, established skills (e.g. grazing management, dairy herd nutrition) and markets. These combine to make it more efficient to continue to invest along a consistent pathway, for example, remaining a dairy farmer with irrigation. Given the investment in resources and learning, farmers find it difficult to change direction because it is likely to require significant additional investment in both capital and learning. Advisors and systems of advice on traditional commodities can also reinforce these path dependencies.

While farmers are locked in path dependency (business as usual), they engage in peripheral processing of new information, giving this information superficial attention. However, it can also be stored for later use. In contrast, following a trigger event, farmers engage in active assessment, they focus attention on the problem at hand, seeking information and potential solutions and intentionally seeking advice (Murray-Prior & Wright 2004; Sutherland et al. 2012).

Signals

Signals is a ubiquitous term in several disciplines. Signals are means of conveying information (Shannon 1948). In contrast, noise is unwanted or irrelevant information (Haeckel 2004). Signals are used to describe a variety of information, from future trends or signs of what is coming (Malmgren 2016) to consumers' use of brand name, price and appearance to determine product quality (Dawar & Parker 1994). Signals can take on different meanings in different individuals

(Kasper et al. 2012). Signals are used extensively in organisational planning as a means of identifying actions that enable them to adapt to their environment (Choo 1999). The objective is to identify factors that could influence a system, as well as estimating their impact, and their effects on the system (Parra-López et al. 2021). One commonly used framework for environmental scanning is the PESTEL framework, which was originally conceived by Aguilar (1967). PESTEL was designed to be able to identify trends in the macroenvironment by classifying these into one of six categories: political, economic, social, technological, environmental and legal (making the acronym PESTEL). PESTEL is a means of identifying any key drivers of change and helps organisations consider strategies that may be required to deal with these (Johnson et al. 2006; Stanford-Billington & Cannon 2010).

In agriculture, signals have been used to explore the growth of the organic sector (De Bont et al. 2005; Wheeler 2006), the health and welfare of farm animals (Hulsen 2005; Tonson 2018; Lawal-Adebowale 2020), the effects of COVID-19 on diversified farms (Mastronardi et al. 2020), and policies designed to modify on-farm behaviour (Buckwell 1989; Greiner & Gregg 2011).

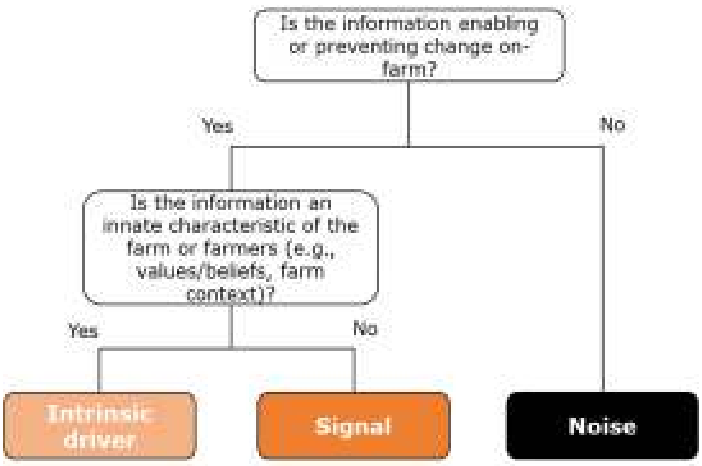
When considering on-farm change, three types of signals are mentioned in the literature. These are:

- Price or economic signals: There is an assumption in the literature that farmers are very responsive to price signals (Winter 2000). Boardman et al. (2003) note that price signals often do not consider impacts on the environment.
- Policy signals: Agriculture has been receiving policy signals for many years (e.g., through the EU Common Agricultural Policy framework as outlined in Curry (1997) and Porter et al. (1991))
- Market signals: Market signals alone were found to be insufficient to trigger widespread adoption of integrated pest management amongst European farmers (Falconer 1998).

Each of these types of signals are external to the farm. However, OLW defined signals as information from the natural environment, culture and society, farm activities, industry group directives, markets and incentive schemes, regulations and prices. This definition includes both on- and off-farm signals. This perspective on signals meant we needed to consider the types of signals farmers received from their farming system.

To do this we began with the factors as outlined by Rose et al. (2018) and considered which of these could be potential signals. However, some of these factors are not information as defined by OLW, but a characteristic of the adopter (Pannell et al. 2006; Kuehne et al. 2017). The characteristics of the adopter are naturally existing and/or relatively long-term characteristics of a farmer such as their goals which can encompass economic, social and environmental outcomes (Pannell et al. 2006), age, gender, experience, attitudes, beliefs and perceptions of control (Rose et al. 2018; Fahad et al. 2023). Some researchers also include the context of the farm, such as location and climate (Kaine 2009). According to Greiner and Gregg (2011) these characteristics are intrinsic drivers of change. Researchers agree that different factors combine to influence on-farm change (Pannell et al. 2006) although the influence of these factors might vary. This is demonstrated in the models developed to predict change where different factors are weighted depending on the characteristics of the innovation, the target population and the relative advantage of the innovation (Kuehne et al. 2017). To help differentiate an intrinsic driver from a signal, as well as clarifying noise, a logical flowchart was developed (Figure 1).

Figure 1: Flowchart to identify signals versus intrinsic drivers and noise.



Signals framework development

To develop a framework for exploring signals, we first reconsidered the definition of signals in the context of the literature review and the definition from OLW. This identified a suitable framework for identifying off-farm signals (PESTEL) but highlighted the need for a framework for on-farm signals.

The Community Capitals Framework (CCF) (Flora et al. 2015) was developed as a means of analysing communities and community development efforts from a systems perspective. Seven capitals were identified: natural, cultural, human, social, political, financial and built. This framework reveals the interactions between parts of a community and provides a means of enabling a community to measure current resources and identify the potential for improvements (Jacobs 2007). The seven capitals mirrored the type of information, and therefore the types of signals that could be received from on-farm. The CCF framework provided a means of categorising information about the state of those capitals on-farm.

The chosen typology for the signals themselves is derived from these two existing frameworks, namely the PESTEL (Parra-López et al. 2021) and CCF (Emery & Flora 2006). The resulting framework for this project has thirteen types of signals, comprised of six types of off-farm signals and seven types of on-farm signals. A brief definition and description of the signals identified with this framework is provided below, specific to the context of influencing a constructive response from a land steward.

Off-farm signals (signals from farm operating environment)

- Political signals are defined as information coming from proposed government policies or actions. These signals will include other signals from government such as spending on R&D in the environmental space.
- Economic signals are defined as information about macro-economic factors such as exchange rates, interest rates, inflation, business cycles and economic growth. These signals will include information about market drivers and product and input prices.
- Social signals are defined as signals that come from people, culture and demographics, for example the ageing populations in many Western societies. This includes information about the perceptions and views of society, and global and consumer trends.
- Technological signals are defined as signals about innovations such as the internet, nanotechnology, or the rise of new composite materials. In the farming context, these signals would include information about new innovations and technologies relevant to agriculture.
- Environmental signals are defined as information from the natural environment. These signals could include the state of the local catchment, and district, regional, and NZ wide environmental states. These signals include information about global climate change, as well as 'green' issues, such as pollution and waste.
- Legal signals are defined as information about legislative constraints or changes, such as health and safety legislation or restrictions on company mergers and acquisitions. This includes off-farm signals coming from regulatory requirements (e.g., health and safety, product safety) and laws (e.g., employment law) from the district, regional or national level.

On-farm signals (signals from the farm system)

- Natural capital signals are defined as information about the natural capital of the farm. Natural capital (natural resources and environmental features) will include information about the climate and weather, the state of the water and soils on the farm including the state of the farm waterways and wetlands in terms of water quality, plant and animal life.
- Human capital signals are defined as information about the quantity and quality of labour on-farm. This includes their attitudes, skills and abilities including leadership.
- Social capital signals are defined as the information about the connections the land steward has among people and organisations, and within the community.
- Financial capital signals are defined as information about the financial resources available to invest in the farm, support entrepreneurship, and to accumulate wealth. We have said this includes the profit and debt levels on-farm.
- Physical capital signals (also known as built capital) are defined as information about the type and age of the infrastructure on farm, as well as the livestock and pastures, i.e. any improvements to the basic natural capital of the farm including soil fertility, artificial drainage and so-on.
- Cultural capital signals are defined as information about the traditions, language and the influence that different individuals or groups may have on the land steward.
- Political capital signals are defined as information about the land steward's access or connections to power or power brokers.

Methodology

Research was undertaken using an inductive qualitative case study approach. A conceptual framework (the signals framework) was developed from the literature, and this was used to gather data (Boeije 2010). A case study approach meant that we could develop an understanding of signals. The case is extension design and delivery in the New Zealand farming sector. Advisors and farmers were interviewed to gain an understanding of whether signals were used in extension design and delivery, as well as exploring which signals they believed were important and how they influenced change.

Eighteen interviews were conducted between September 2022 and January 2023. Eleven farmers who had taken part in an extension programme and made changes on-farm were interviewed, along with seven advisors who had experience in the design and implementation of extension programmes. Interviewees were identified through project team connections. The interviews had an average duration of about one and a half hours for each advisor interview and half an hour to an hour for each farmer interview. The methodology for these interviews was approved by the Scarlatti ethics committee.

Farmers were asked about the journey they took when considering and undertaking a change on-farm, in relation to the extension programme, including what may have influenced these decisions. This was undertaken without prompting for any influences, to see what they mentioned naturally. They were then asked about the influences they identified and the relative strength of each of these influences. Finally, they were asked about the support that could have enabled on-farm change.

Interviews with the advisors typically began with a high-level discussion to understand the advisor's approach to designing and implementing extension programmes. This was undertaken without prompting to see which steps were mentioned naturally, and what on- and off-farm information was assessed. Advisors were then asked what they thought influenced the land stewards they worked with. The interviewer then explained the term signals and showed the advisor the signals framework. Finally, they were asked for feedback on the value of using this framework in the development of an extension programme.

Each interviewer took notes. Notes were compared to find themes and insights following a process of qualitative analysis (Lacey & Luff 2001). Signals mentioned were identified using the framework and a short outline of the interview was written, including identification of the signals to demonstrate the influence of these signals. This analysis was iterated using the concepts from the literature. Excerpts from interview notes and interview outlines were used to illustrate these insights and these have been anonymised.

There are limitations to doing case study research. Interviewees were selected based on project team connections. Farmers were selected because they had made an on-farm change and had been involved in extension. Advisors were selected for their experience in extension design and/or delivery. The number of interviewees was limited and as such it is likely that not all influences on decision making were included. Further diversity in terms of influences of change on-farm could exist in terms of the types of decisions being made. The decisions focused on a mix of operational and tactical decisions. There could be strategic decisions that will have different influences. As such, it is likely that not all influences are captured. It was also outside the scope of this research to explore innate characteristics of farmers' and how this influenced their decision making.

Farmer interviewees were asked to describe what had influenced a change on-farm post the decision. Generally, a relatively small number of factors contribute to a decision (Gigerenzer & Gaissmaier 2011). However, other influences can be added as a means of rationalisation for the decision. Advisor interviewees were also asked to reflect on previous decisions and their perceptions of farmers decision making introducing further bias.

Findings

Interviewing advisors involved in extension design and delivery and farmers taking part in these programmes provided a range of data highlighting different influences for on-farm change. Using the framework enabled the identification of a range of off- and on-farm signals influencing land stewards. The data revealed critical attributes of signals that enhance the influence of different signals.

Off-farm signals

The advisors identified a range of signals for bringing about practice change with farmers in relation to improving water quality. These are outlined in Table 1. Advisors felt that the most important off-farm signals influencing change on-farm were political and legal signals, social signals and economic signals. For example, Advisor G has been involved in a dairy focused extension programme in Northland. When reflecting on the farmers he worked with as part of that programme, he felt that the most positive signals were regulatory pressures from both current and forthcoming regulations [legal and political signals]. On-farm change was also influenced by hearing positive comments about a change from other farmers and industry [social signals]. For example, statistics provided by industry highlighted how much fencing had been done. This provided a benchmark and motivation when farmers compare themselves to what other farmers were doing. Advisor G thought incentives [economic signals] were also important for influencing change on-farm and something Fonterra uses well. Advisor E emphasised the importance of social signals. She specialises in irrigation and water management in Canterbury. When she reflects on what influences farmers changing their practice on farm in relation to water quality, she highlights that production is very important. When providing information or advising farmers, she always needs to give assurance that [production] won't be negatively impacted, thus providing a social signal to farmers about the impact of the technology or practice.

Table 1: Overview of identified off-farm signals using the signals framework

Signals framework	Farmer interview data	Advisor interview data
Political signals	Upcoming rules or regulatory changes from government	Upcoming rules from government
Economic signals	Requirements to supply (e.g., Fonterra requiring stream fencing to supply milk) Funding (e.g., for planting)	Incentives (such as processors paying more for a product produced using specific practices) Cost of water (for an irrigation scheme) Funding to cover the costs of changing (e.g., consultant time)
Social signals	Trusted sources of information (e.g., via an extension programme, peers or advisors)	The influence of others, peer pressure Trusted sources of information (advisors providing information on the impact of a technology or practice) Benchmarking data
Technological signals	Alternatives to current management (e.g., herd home or composting barn)	Science-based information
Environmental signals	Water quality monitoring data from water bodies near farmers (e.g., lake, stream)	The contrast between the past and current state of the local environment
Legal signals	Regulations/rules from the Regional Council	Current rules from the Regional Council

Farmers identified some off-farm signals that influenced their decisions in relation to improving water quality. Economic and legal signals influenced their decision making in relation to improving water quality. For example, Farmer D runs a large dairy farm on the West Coast. He uses winter crops such as swedes, kale, turnips and rape, but he does not feed out supplementary feed in the current farm system. Typically, a small number of cows were wintered on a stoney stand-off block adjacent to a waterway, with the remainder going off-farm to graziers. Recently, the grazier used by farmer D increased the charge for grazing. Because of the higher price for grazing off-farm [economic signal], the farmer undertook an investigation into other wintering options. Based on this, he is now considering becoming fully self-contained. Alongside this change, farmer D has had to consider how to manage his winter grazing because of the intensive winter grazing regulations [legal signal]. The previous system of having some cows wintered on-farm on a stand-off block is no longer allowed under the new regulations.

The different signals that were identified by advisors and farmers as influencing practice change in relation to improving water quality are outlined in Table 1. Similar political and legal signals, and some social signals were identified by farmers and advisors. However, farmers and advisors talked differently about economic, technological and social signals, providing slightly different details in these categories. For example, advisors felt that technological signals came from research. In contrast, when farmers talked about technological signals, they mentioned specific innovations or practices. Social signals farmers reflected on focused on trusted sources of information. Advisors also mentioned this but talked about the influence of others as being a strong social signal. These differences could reflect the different views of the interviewees, but also the focus of the interviews. Farmers were asked about their individual journey when considering and undertaking a change on-farm while advisors were asked to consider a range of farmers and what they felt influenced them.

We note that during the time this research was undertaken there were a range of policy changes that were impacting farmers. This could have been reflected in responses from both farmers and advisors where current signals influencing decision making was retrofitted to prior decision making. However, this reinforces the influence of these signals.

On-farm signals

Farmers were able to readily identify some on-farm signals that they believed influenced decision making on-farm. Farmers provided details about on-farm signals, revealing their awareness of the importance of on-farm signals because of their influence on their decision making in relation to practice change. The importance of these on-farm signals varied across farmers and depended upon the individual farm context.

Farmer D, a dairy farmer on the West Coast mentioned above, highlighted that a physical capital signal, combined with other signals, prompted them to change their farming practice. He has trialled several crops to diversify their farm system. However due to 4.5 meters annual rainfall and the prevailing wind, many crops failed [physical capital signal]. When D considered other wintering options such as herd homes or composting barns [technological signal], it became apparent that due to the need for supplementary feed, these options are not feasible for D. The cost of bringing in supplementary feed (silage) is considerable [economic signal], and it is quite difficult to access experts (e.g., farm advisors) because of where they are located.

Farmer W a Canterbury farmer who recently moved from another region, highlighted that social and cultural capital signals in combination with other signals helped them as they made on-farm changes. They were doing their Farm Environmental Plan (FEP) and participated in an extension programme run by Environment Canterbury. As they were settling into farming in a new region, they wanted to gain a Canterbury perspective and hear about 'how other farmers do things here' [social signal]. They felt it was rewarding to hear from other farmers and learn about a new region. Farmer W wants to be a community leader and so is keen to do 'the right thing', leading by example. To do this they wanted to understand the farming culture in Canterbury and the practice norms (Minato et al. 2010) or the practices farmers in the region typically used [social and cultural capital signals].

In contrast, advisors spoke more about intrinsic drivers than on-farm signals. This is not surprising given that studies have shown that advisors when working with clients spend a lot of time understanding their farm context before providing advice that is tailored to their specific situation (Rogers et al. 1996; Gray et al. 1999, 2017). For example, Advisor N in Canterbury highlighted the need to consider who you are talking to, the time of year and the season. Advisor A, also in Canterbury, echoed this, emphasising that it's about people, people, people; the person being asked to change is central. Advisor G thought that before addressing any issues, you needed an initial visit with a farmer to understand a farmer's drivers and goals. Then any changes could be addressed in the context of knowing what was important to them.

Table 2 provides an overview of on-farm signals identified by land stewards and advisors as enabling change on-farm. Both farmers and advisors identified similar natural capital and physical capital signals. Farmers went on to provide a range of other on-farm signals, although neither advisors nor farmers identified any political capital signals. This could be an indication of the need to review the framework or that the decisions farmers and advisors reflected on were not influenced by these types of signals.

Table 2: An overview of identified on-farm signals based on the signals framework

Signals framework	Farmer interview data	Advisor interview data
Natural capital signals	Life in the water (e.g., the bugs in the waterway) State of soils	Results of water testing, soil testing
Human capital signals	Farm team On-farm labour	None identified
Social capital signals	Skills and experience of farm team/labour	None identified
Financial capital signals	Costs Productivity/profitability	
Physical capital signals	State of feed (e.g., pasture, crops, bought in feed) Current infrastructure Production levels Stock health Stock shelter	On-farm observations (e.g., plant and soil conditions, animal behaviour)
Cultural capital signals	Practice norms in a region	None identified
Political capital signals	None identified	None identified

The attributes of signals

The interview data also revealed some of the attributes of signals that could influence land stewards. The attributes highlighted in the study were relevance, certainty, consistency, trusted sources and on-going support for change. Each of these is discussed in turn.

Relevance To bring about change, the signal needs to be considered relevant to the land steward. For example, Farmer P on the West Coast was looking for a way to increase production on the farm to pay off debt without having to necessarily intensify. He did not want to intensify his system because one of his important goals was to spend adequate time with his family. He had identified an important weakness with his current farm system where his stock were pugging and compacting their soil over the winter and early spring. This was affecting pasture health and production and the physical and financial performance of his farm [natural and financial capital signals]. As such, Farmer P felt that it was worth exploring options such as composting barns and herd homes because one of the benefits of these technologies was that they reduce pugging and soil compaction [physical capital signals]. Hence, the farmer considered these signals relevant to his decision making. One advisor, Advisor A, emphasised this need to understand what was relevant to farmers. They felt this was critical to providing support for successful change on-farm.

In another example of the relevance of signals came from Farmer R. Farmer R is a farm manager in Canterbury who participated in Environment Canterbury's Shed Talks. He has been planting riparian areas with native plants. One of his policies as a manager of a farm is that he aims to always leave a farm in a better state than when he first took over the property. He believes that this is important when seeking new managerial positions as he develops his career as a farm manager. Farmer R wanted to understand what actions to take on-farm that would restore and enhance the biodiversity of his farm. He was receptive to signals that were relevant to this goal. That is, he wanted to implement practices that would help him leave the farm in a better state.

Certainty To bring about change, the signal needs to provide certainty. Advisors felt farmers will not change if they are uncertain, as any potential regulation that requires investment and/or a systems change is risky. Data revealed that this attribute of a signal often prevented change on-farm. Examples of this were provided by Farmer R in Canterbury and K and I on the West Coast. Farmer R feels that a strong positive regulatory signal drove him to act [legal signal]. However, now that there are uncertainties about future environmental regulations [political signal], this has slowed down his decision making. Farmer R feels that uncertainty about carbon sequestration [political signal] prevents him from making decisions about planting riparian margins and increasing the area planted in native vegetation on-farm. This is because it has an impact on investment. If a farmer is not clear about the minimum area to plant to claim carbon credits, then this will prevent them investing in tree planting.

Similarly, up until the wintering regulations for livestock were clear on the West Coast, Farmers K and I felt there had been too much uncertainty about regulatory changes [political signal]. This had pushed out the timeframes for making a change on-farm. Their investment decisions in relation to improving their stock wintering systems had been delayed because of this uncertainty.

Consistency from different sources The data also showed that consistency in relation to the message a signal was providing was important for farmer decision making in relation to practice change to improve environmental outcomes. Advisors talked about the need for '*consistent messaging*' when considering change on-farm. Consider Farmer M who was confused by signals from an unexpected source. The Regional Council had a time bound rule for requiring farmers to fence their waterways to exclude livestock. The farmer's cooperative, Fonterra, made this rule a requirement farmers must meet if they wished to continue supplying milk to the cooperative. Farmer M was not sold on the need for the fencing of waterways but felt he did not have a choice. The farmer's cooperative had challenged his autonomy. This meant he felt negatively about the policy at first. He felt that it was the Regional Council's job to impose this policy, not his cooperative's. He felt that Fonterra had signalled urgency on the need for the fencing of streams, but the Regional Council had not. Their signals or messages were not consistent.

Trusted sources of a signal The advisors in this study highlighted that land stewards generally only listened to trusted sources. Advisor G said that if farmers don't trust the advisor or the advice, then no action will happen, or not enough will happen. Similarly, Farmers P and M on the West Coast highlighted the need for this, seeing other farmers as trusted sources of information. Farmer P suggested that farmers need to look at how others are doing things and get advice from them to make sure 'you get it right for your system'. This was what they saw as a support network. They also felt having economic information on the cost-benefit of different systems was useful. Farmer P wanted to understand operational costs like trucking in feed, because it is critical to know that the system would cover its costs. Farmer M contacted farmers around the country who he had heard were running similar systems to what he wanted to introduce, and arranged to visit them in their part of the country to see how they were doing things, and to hear from them about what the benefits and challenges were.

On-going support for change In most instances, signals only brought about on-farm change where there was on-going support. Farmer M found that being able to get expert help made a difference (e.g., for the reticulated water supply, they used a contractor to do research on the technical specs like tank capacity, pump capacity, and set up). They also believed that seeing other farms in the project and what they were doing to get the farm team aligned before implementing a change on-farm, was really helpful. They believe that hearing from other farmers makes an on-farm change an 'easier sell'. The advisors echoed this, with Advisors E and A explaining that extension is iterative. 'You tailor the approach to address this [where people are at] so that you can get people on the journey'. Advisor A believes that the key to successful extension is making it a two-way communication process by 'genuinely asking how you can help, and not just telling people'.

Discussion and conclusion

What were the most signals influencing practice change with farmers in relation to improving water quality?

The objective from OLW for this research was to determine what were the signals influencing practice change with farmers in relation to improving water quality. The literature on signals indicated that price or economic signals were strong drivers of on-farm change, but these signals often did not account for environmental impacts (Boardman et al. 2003). To help answer this question, we developed a framework to help identify external off-farm signals from farmers' operating environment and internal on-farm signals that provide information about the farming system monitored by farmers. The framework drew on literature that identified several external signals, namely economic and price signals, policy signals and market signals, and used PESTEL (Parra-López et al. 2021) as a means of classifying these signals. We added on-farm signals into the framework using the CCF from Emery & Flora (2006). The framework helped us identify a range of signals that advisors and farmers felt influenced on-farm change.

The data revealed that no single signal prompted on-farm change. Instead, several signals appeared to influence decision making on-farm. This is consistent with the practice change literature where different factors combine to influence on-farm change (Pannell et al. 2006). Researchers have used this perspective to develop models to predict change where different factors are weighted depending on the characteristics of the innovation, the target population and the relative advantage of the innovation (Kuehne et al. 2017). As outlined by Rose et al. (2018), the data also showed that having support for change on-farm was important, rather than relying on signals alone. This is a critical consideration for extension design and delivery. It requires building an understanding of the networks around farmers to be able to draw on these to support change.

Understanding the networks around farmers is part of the concept of the micro–Agricultural Knowledge and Innovation System or micro-AKIS (Sutherland & Labarthe, 2022). The micro-AKIS is defined as

> the knowledge systems that farmers personally assemble, including the range of individuals and organisations from whom they seek services and exchange knowledge, and the processes involved in the formation and working of the system, including the way farmers translate these resources into innovative activities (or not) (Sutherland & Labarthe, 2022, p. 461).

The micro-AKIS concept draws on the decision-making conceptualisation developed by Sutherland et al. (2012). The concept of micro-AKIS and the decision-making conceptualisation reinforces the view that adoption is a multi-stage process from awareness to final adoption (Rogers 2003), or in innovation systems language, from the Trigger Event to Consolidation (Sutherland et al. 2012).

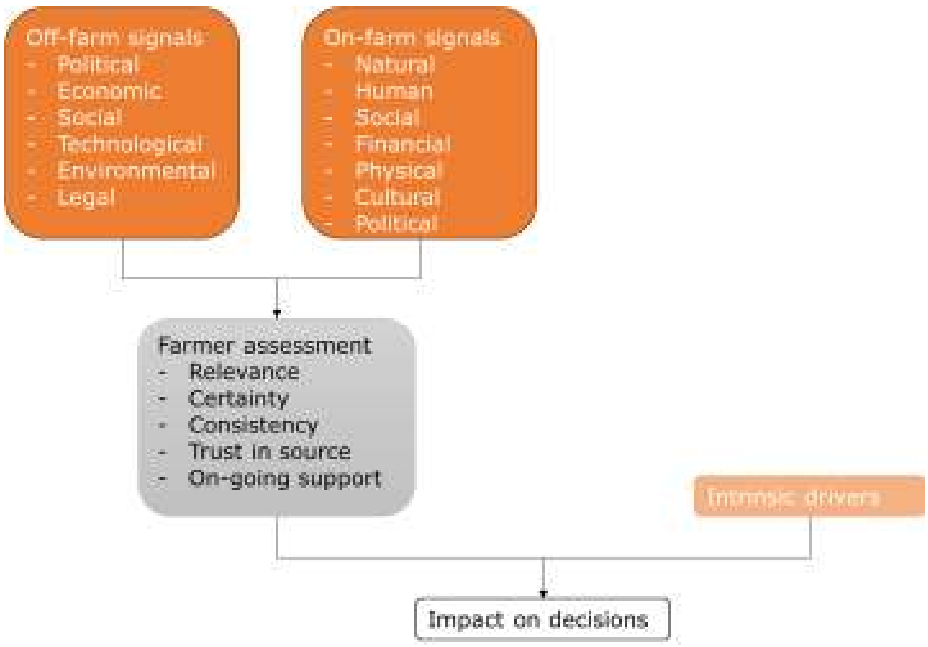
Our definition of a signal means this trigger event could be a signal or multiple signals over time. Information is then used to assess options for change, plan and execute the implementation of the change and consolidate (evaluate, refine or discontinue the change) the change (Sutherland et al. 2012). As such, signals could play a wide range of roles in the process and a range of different types of advisors may be important sources of signals throughout the process. In addition, the work outlined by Sutherland & Lararthe (2022) shows that different farmers use different networks to source information. Their research suggests there is a diversity of different networks used by farmers. This provides some ideas for the range of ways in which support for on-farm change could be provided.

The study identified several important attributes of signals; relevance, certainty, consistency, the trustworthiness of the source and that they provide on-going support for change are important as they appeared to amplify signals. These attributes amplify a signal, whereas if a signal lacks these attributes, it will be weakened and have less impact on on-farm practice change. Advisors who recognised that both intrinsic drivers and signals influenced on-farm change made sure that they were incorporated into their extension design and delivery. Trusted sources of information are also important to help enable land stewards to respond constructively to signals. Trusted sources can act as brokers, translating and amplifying signals. Advisors spend a lot of time understanding their clients and their farm context before providing advice tailored to their specific situation (Rogers et al. 1996; Gray et al. 1999, 2017), often acting in that brokering role. Advisors can also provide the on-going support required for change on-farm. Our research indicates that the consideration of signals in the change process is an area where training and support could be provided for advisors. This would help increase the effectiveness of extension design and delivery.

Using the signals framework

The signals framework developed in this study contributes to practice in several ways. The framework helps separate signals, the information that farmers receive, from intrinsic drivers. It also provides a way to categorise signals to help advisors and policy makers as they reflect on the signals being received by farmers. In the context of extension programmes, this is useful as encouraging practice change means considering all possible signals, to ensure they support a consistent message. The study has also highlighted that to be effective, a signal requires several important attributes that need to be considered by extension agents and policy makers. In effect, the framework can be a checklist to help this process. Figure 1Figure 2 illustrates the integration of the framework, pulling together the different types of signals and their attributes, alongside intrinsic drivers, which then impact decision making.

Figure 2. Integration of the signals framework



Refining the signals framework

Some of the interview data revealed the shortcomings of our signals framework and definitions. The framework is useful as it forces the consideration of how a range of signals and intrinsic drivers will influence on-farm change. However, it is not always clear whether information is a signal or an intrinsic driver as some of the on-farm signals may be a signal in one context, but an intrinsic driver in another. Many of our findings were based on intrinsic drivers acting as signals. We considered a farmer's debt levels to be an on-farm financial capital signal, although this could also be considered a characteristic of the adopter and thus, an intrinsic driver. Similarly, the number of staff on a farm was considered a human capital signal, but it could also be considered a characteristic of the farm and therefore a possible intrinsic driver. The definition of intrinsic drivers needs to be revisited if using a signals framework. Spence (1973) distinguishes signals from 'unalterable attributes' and signals as information that is subject to manipulation and change. However, a given factor may be a signal in one context, but an intrinsic driver in another. For example, if a farmer's debt levels were considered an intrinsic driver but there was an economic signal that interest rates were going to rise, debt level could become a financial signal for the need to change.

Ideally the framework for signals would clearly identify each signal type. While there could be multiple signals being received by a land steward, these are more easily identifiable when considering off-farm signals than some on-farm signals. Further research will be required to help determine whether all the currently defined on-farm signals are relevant and useful for the signals framework. Future research could consolidate the signals framework further, by:

- Refining the list of signals, particularly to determine how on-farm signals differ from intrinsic drivers, or determining under what circumstances the distinction is important.
- Conducting research that refines the critical attributes of signals.
- Determining whether an exercise to quantify the importance of different signals for different farms, land stewards and wider contexts would provide useful information.

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