Co-innovation to improve profit and environmental performance of dairy farm systems in New Zealand

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Abstract. To increase the likelihood of developing successful options for future dairy farm systems, DairyNZ adopted a deliberate co-innovation approach for two topics: heifer rearing and nutrient management. Co-innovation activities differed between projects, but common principles were adopted: being inclusive, valuing and learning from different kinds of knowledge, and being flexible to stay attuned to the wider context. Stakeholders, including end-users, were involved from the start, and reflexive monitoring supported process management. The projects were successful in their engagement with farmers and were flexible to adapt to feedback and changing context. Difficulties were experienced with attaining legitimacy for farmer knowledge and engagement with commercial entities. These results are related to known enablers and barriers for co-innovation, as identified in literature. We suggest that the listed key principles, enablers and barriers, sourced from literature, provide a framework for regular reflection that will help to maintain a co-innovation approach and to define interventions or adjustments of project activities to improve impact.

Keywords: co-innovation, heifer rearing, nutrient management, dairy farm systems

Introduction

DairyNZ is an industry-good body aimed at securing and enhancing the profitability, sustainability and competitiveness of New Zealand dairy farming through research, training, extension, advocacy and policy development (www.dairynz.co.nz). DairyNZ wanted to investigate alternative approaches for its activities to improve their impact and therefore became involved in an AgResearch-led Primary Innovation project (Turner et al. 2016). This project aimed to foster co-learning and co-innovation principles in the New Zealand primary industry innovation system to increase cross-organisation and cross-sector collaboration which, based on science in the field, should improve the impact of the research (Botha et al. 2014).

The DairyNZ-led Heifer Rearing and Canterbury Nutrient Management projects were two of the six innovation projects within Primary Innovation (Coutts et al. 2016). The Nutrient Management project originated from an initiative of DairyNZ staff to coordinate their actions in the Canterbury region of New Zealand supporting farmers through implementation of upcoming water quality regulations. Nutrient management was considered an ideal issue and environment for co-innovation, with a complex problem (reducing the environmental footprint while maintaining production/profitability, which are in general opposing targets), a network of many parties that need to be part of solutions, and solutions requiring action from all levels (farm-level to national policy).

The Heifer Rearing project was initiated as a follow-on from an earlier herd reproductive performance project to increase productivity of young stock coming into the dairy herd. Heifer rearing was a suitable case study for co-innovation because the high level of underperformance in this area influences the dairy farming's production potential. McNaughton & Lopdell (2012) reported that 73% of dairy heifers were 5% or more below target. Four years later 69% of heifers were 11% below target liveweight (Handcock, Lopdell & McNaughton 2016). The financial impact to New Zealand dairy farmers is estimated to be over $500 million annually (estimated from results provided by Archbold et al. (2012) and Roche et al. (2014). Clearly, earlier extension efforts had not resulted in significant improvements. Also, although a few New Zealand research trials have been carried out, there is limited published information on good practice for achieving heifer liveweight targets, meaning that much of the knowledge is tacit knowledge held by farmers who rear heifers successfully. Other characteristics of the heifer rearing issue that made it suitable for a co-innovation approach were the diversity of stakeholders, reliance on other primary sectors, and the complexity of the farm systems in which heifers are managed, often mixed enterprises involving cropping and livestock including sheep and beef.

Primary Innovation was inspired by Dutch experiences with co-innovation (Klerkx & Leeuwis 2008; Klerkx, Van Mierlo & Leeuwis 2012) and used key elements for co-innovation identified by Nederlof, Wongtschowski & van der Lee (2011) to develop guiding principles for activities

instigated in six 'innovation projects', which functioned as longitudinal studies in Primary Innovation (Coutts et al. 2016). Co-innovation was defined as a collaborative approach to innovation to solve complex problems, i.e. problems with a diversity of stakeholders with different drivers and goals, and potential solutions that are not the same in different contexts (e.g. farm systems, regions) and frequently involve trade-offs and/or unintended consequences (Schut et al. 2015). Under these circumstances, it is widely believed that innovation should adapt to the situation as it develops throughout the duration of the project (Klerkx & Jansen 2010) and should involve multiple end-users instead of being the domain of science only, as with the linear view of technology transfer (Röling 2009), i.e. where knowledge is transferred from experts to end-users.

The practical application of a co-innovation approach includes (adapted from Nederlof, Wongtschowski & van der Lee 2011):

- Formation of groups of relevant participants to jointly identify key questions associated with important issues, to interactively learn to co-create knowledge addressing the question and to develop and refine potential solutions. This follows an action learning approach (Van Mierlo et al. 2010; see below) and acknowledges that innovation emerges as a result of the co-innovation process, i.e. the outcome is not known at the start of the process.
- Active cooperation and coordination by all participants, which requires participants to partially give up their independent positions to develop and coordinate change with others.
- A process that values alternative views and knowledge (e.g. local or tacit knowledge and science) as legitimate and relevant to developing potential solutions. Managing power relationships to ensure all stakeholders are active participants is important to achieve this.
- Involvement of roles that have not traditionally been identified e.g. innovation brokers who are independent individuals or organisations focused on enabling all stakeholders involved to actively participate in co-innovation. Mechanisms for observing group processes and suggesting appropriate changes to facilitate effective interaction and learning.
- Innovations that are a complementary mix of technological, practice, market, social and policy changes. These changes evolve together through an iterative process of practical actions and experiments that challenge the current way of doing things.

Based on these practices, Primary Innovation developed a list of principles and behaviours that outlined the way participants in a co-innovation project were envisaged to work, and these principles have subsequently guided the innovation projects (Coutts et al. 2016): (1) Take time to understand the problem; (2) Be inclusive; (3) Engage with and value all sources of knowledge; (4) Listen actively, let your understanding and perspectives evolve; (5) Keep sight of shared vision; (6) Be honest, open and constructive; (7) Be aware of the wider context; (8) Be flexible and adaptable; (9) Stick with the co-innovation process. These behaviours are important to build and maintain respectful interpersonal relationships in groups that co-create solutions to complex problems. Indeed, the existence of social capital is a key indicator for successful innovation networks (Morrar 2015).

Additionally, co-innovation is influenced by institutional settings, such as the predominant investment and funding systems, culture of rewards and recognition, rules of collaboration, and legitimacy of non-traditional roles such as innovation brokers or reflexive monitors. Nettle, Brightling & Hope (2013) evaluated innovation initiatives in the Australian dairy sector and describe barriers encountered due to Australian institutional settings that favour traditional technology transfer. A multi-stakeholder programme approach emerged in different domains of the dairy sector that provided governance for combinations of research-led and demand-pull activities that enabled innovation and change. Klerkx & Nettle (2013) compared the Australian approach with Dutch initiatives, and noted that in The Netherlands the brokers or facilitators have become specialists, working in organisations dedicated to this role. However, in both countries sustained resourcing of this role is often lacking.

The Nutrient Management (NM) and Heifer Rearing (HR) projects implemented a range of activities designed to practically apply the principles and practices outlined above. This paper describes the main activities in the first three years of the projects (2013 to 2016) and how they were, or were not, successful. Institutional and networking enablers and barriers for co-innovation are drawn from literature to identify reasons for these successes and difficulties, thus providing key lessons learned and a framework for continuous evaluation that will support new co-innovation projects.

Methods

Capturing data – reflexive monitoring

Social scientists in a reflexive monitor role were provided for each of the innovation projects. The process of reflexive monitoring is to stimulate integration and coordination of projects and uses

an action learning cycle; observe, analyse, reflect and adjust activities, generating iterative learning and action of the project team (Van Mierlo et al. 2010). Reflexive monitors facilitate project team reflections on values, goals, assumptions, structures, and bottlenecks in the project and wider innovation system. Ultimately reflection should enhance learning and more dynamic innovation (Van Mierlo & Leeuwis 2006). The reflexive monitors provide substantive feedback for adjustment of project activities to increase the potential impact of the project, take part in the decision making about adjustments and facilitate adjustments. The project team ultimately makes the decisions and actions the adjustments (Van Mierlo et al. 2010). The reflexive monitors' role in the innovation projects also included collecting data to contribute to the science of co-innovation, part of the pre-defined objectives of Primary Innovation.

Reflexive monitoring data were used throughout the lifetime of the innovation projects. Data were gathered in project meetings and workshops (meeting notes and minutes), event feedback questionnaires were used after each workshop and reports collated after each event, reflective discussions were had in various settings with notes taken, and quick feedback loops with the project teams led to adjustments during the projects. Information from the reflexive monitoring, meeting minutes, quarterly reports from project teams and interviews provided the data to describe and evaluate the activities in the innovation projects as presented here.

Evaluation of project activities

The lead members from each innovation project assessed how their project implemented aspects of the co-innovation approach as described by Nederlof, Wongtschowski & van der Lee (2011). A list of enablers and barriers for co-innovation was derived from published manuscripts on co-innovation (Klerkx, Aarts & Leeuwis 2010; Klerkx, Van Mierlo & Leeuwis 2012; Hermans et al. 2013; Klerkx & Nettle 2013; Nettle, Brightling & Hope 2013; Table1). The lead members from each innovation project then assessed for their projects the presence or absence of these enablers and barriers. This was recorded and discussed with other team members, including the reflexive monitors, to verify validity of the observations and discuss implications for the progress reported by the projects.

Results

Heifer Rearing and Nutrient Management deliberately undertook activities that brought a range of stakeholders together to co-create solutions to complex problems faced by the dairy industry. Active cooperation was sought, with coordinated group work that invited a diversity of viewpoints and knowledge. Adding the role of a reflexive monitor to the project team ensured that the group processes were monitored and regular reflection on progress occurred to identify next steps.

The following sections describe the main activities in detail, followed by an assessment of which enablers or barriers influenced the success or difficulties encountered.

Formation of groups of relevant participants to jointly identify key questions

Nutrient Management – Jointly developing a logic framework to clarify required activities

Nutrient Management was focussed on the dairy industry's requirement for dairy farmers to develop nutrient management plans for their farm business, as part of the Sustainable Dairying: Water Accord (https://www.dairynz.co.nz/), and to manage their nitrogen (N) loss to limits set out in proposed regional policy plans. Reductions of N loss from dairy farms of 30-45% below levels at good management practice in the Selwyn and Hinds catchments in Canterbury, New Zealand, were proposed. Therefore, substantive changes on farm were going to be needed.

The DairyNZ team based in Lincoln, Canterbury, decided to develop a joint plan for policy, research, development and extension to ensure information, tools and infrastructure would become available for farmers to adapt to the upcoming regulation. A logic framework was developed in several meetings in 2011 and 2012, and used to define the critical activities, including identifying key individuals and most affected regions, defining good management practice, research into options to mitigate nitrogen leaching, establishing a network of farmers demonstrating good management practice and co-developing new mitigation options, and capability building amongst DairyNZ staff and rural professionals.

Capability building was taken care of in various initiatives, notably the Nutrient Management Advisor Certification Programme in the Primary Growth Partnership programme (http://www.nmacertification.org.nz/) and the NZIPIM Certified Dairy Farm Systems Consultants scheme (https://www.nzipim.co.nz/). A social network analysis was conducted to identify key individuals influencing dairy farming in Canterbury and this was used to set up an industry advisory group to assist DairyNZ directing and executing local activities. The industry advisory group became pivotal in decision making around dairy industry input for the Matrix of Good

Management project which developed tools for local environmental policy (Pinxterhuis, Kuhn-Sherlock & Dennis 2015; Williams et al. 2015; Environment Canterbury 2016). Good Management Practice was defined in this project (Canterbury Matrix of Good Management Project 2015) and used by DairyNZ to develop the template for Sustainable Milk Plans. By March 2017 a total of 522 Sustainable Milk Plans were developed between consultants and farmers in Canterbury, with another 136 scheduled to be completed in 2017. The remaining 550 dairy farms in Canterbury (Edwards et al. 2016) had/will have their farm environment plan organised by others, e.g. their irrigation scheme or milk company.

Heifer Rearing – Scoping a project with focus groups

Heifer Rearing's goal was to increase the number of heifers that achieve their target liveweight pre-calving and subsequently influence the future reproductive performance of these animals. In August 2013, the project team coordinated an industry advisory group of mixed stakeholders in relation to heifer management. The group comprised researchers, extension programme managers, grazing companies, genetics companies, a milk company, dairy farmers and contract heifer graziers. The purpose of the group was to explore what the underlying causes of undergrown heifers could be and to develop the programme, gaining shared ownership of the outcomes.

Farmer representation in the advisory group was low and there was a risk that programme design would not resonate with the wider farmer target group or address specific regional issues. As a response eight focus groups were run across the country. The groups had multi-stakeholder representation, with an emphasis on a farmer presence: dairy farmers, contract graziers, dairy support farm managers, agriculture bankers, an accountant, farm consultant, veterinarians, stock agents, grazing companies, and an NGO.

In the focus groups the following questions were discussed:

- What is currently happening with heifer management in the region?
- What would a better future look like?
- What is stopping us from being better?
- What do you think should be done to improve on how things are currently?

From the results of the focus groups four common themes were identified as barriers to improvement:

1. Absence of leadership in the area for the industry
2. Relationship management barriers for heifers grazed on contract
3. Limited access to stock management information
4. Lack of economic information when choosing grazing enterprises.

The most common issue that the groups identified as a barrier were challenges in relationship management between stock owners and contract graziers. The groups also defined tools and resources in each of the areas that would assist them to address these barriers, and requested on-farm events to meet with other farmers managing heifers and observe and discuss farm systems for heifer management.

A project plan was jointly developed and subsequently reviewed and approved by farmers during March-May 2014. At the conclusion of the project planning process, the industry advisory group was disbanded, and representatives were allocated to relevant working groups to help design and review the resources and tools to be developed. A steering group was formed with three key industry-good organisations (DairyNZ, Livestock Improvement Corporation, Beef and Lamb New Zealand), a dairy farmer, and a contract grazier to guide the implementation of the project plan and ensure that diverse views were incorporated.

The outcomes of the regional focus groups aligned with the causal analysis completed by the industry advisory group, but the regional focus groups broadened the scope of the project and broadened the vision of the work, thereby altering the trajectory of the project plan. Due to the results of the focus groups, the project's aim shifted from 90% of New Zealand heifers achieving their liveweight targets to win-win outcomes for everyone, i.e. from emphasising a benefit for the dairy sector only to aiming for a wider industry result. The project plan was also reformed from emphasizing a liveweight gain payment system for heifers to a programme offering that created opportunities for capacity building for all stakeholders.

The initial concept of the project was to provide an industry standardised reward/penalty payment system of $/kg of liveweight gained by heifers in contract grazing relationships. This technology development is just one of the three legs of the Capacity Building Ladder from Coutts & Roberts (2003). They argue that extensionists need to use a range of complementary activities to build

their clients' capacity. The three legs of the ladder are: making information accessible, developing technology and facilitating the process of empowerment. Ongoing specific training and iterative consultant/mentoring support provide the rungs of the ladder. The focus groups identified gaps in information access and facilitation of empowerment. The commercial market provided the mentors/consultants, but in the absence of information, training modules could never have been developed. By taking the time to facilitate focus groups for scoping the project, the project design and outputs led to a more comprehensive set of resources and activities being delivered than what otherwise would have been accomplished.

Active cooperation and coordination, valuing alternative views and knowledge

Nutrient Management – Establishing a monitor farm network

Based on the logic framework developed in Canterbury described above, a nationwide research programme was established to research and co-develop practical options to mitigate nitrogen leaching: Forages for Reduced Nitrate Leaching (FRNL). The FRNL programme logic was described in Edwards, Pinxterhuis & Bewsell (2015). An impact monitoring and evaluation plan was developed, and a reflexive monitor was assigned to the programme to support implementation of co-innovation principles and monitoring and evaluation of progress.

A key aspect of FRNL was the cross-sectoral monitor farm network (Edwards, Pinxterhuis & Bewsell 2015). The goal of farmer participation was to provide input for research, in terms of research direction, practicality and existing knowledge through experiences and innovation on-farm. The farmers also assisted in identifying barriers to adoption of nutrient management strategies, in terms of risks, unintended consequences, new skills and the resources required. The monitor farmers demonstrated current practice and changes through monitoring and reporting on farm performance, including financials and nutrient budgets. Earlier projects incorporated a similar approach and were successful in establishing meaningful collaboration between farmers, researchers, developers and extension (Pinxterhuis et al. 2013).

The process of selecting farmers to collaborate in the FRNL programme was an inclusive process with input from researchers, extension staff and rural professionals. Terms of Reference were jointly developed, outlining the purpose of the monitor farm network, planned activities and role of farmers, and criteria to assess suitability of the farm and farmer, e.g. access to and willingness to share key information on farm management and performance, good communicator, willing to host extension events, operating at good management practice and willingness and scope for improvement of environmental impact.

In the course of 2012, the Terms of Reference were discussed with a large number of people, mostly connected through the industry advisory group and nutrient advisors' group, and names of potential candidates were collected. A cross-check revealed which farmers were mentioned repeatedly and these farmers were visited and interviewed. Through this process nine farmers across Canterbury were selected and agreed to be part of the programme: four dairy farmers, two arable farmers, two mixed livestock farmers and one farmer with a mixed arable/dairy farm.

Throughout the FRNL programme, workshops were conducted with the monitor farmers, researchers, extension staff, programme management and governance members. In the third year of the programme rural professionals were included in the workshops. For each workshop, run sheets were developed with input from the reflexive monitor, to clarify purpose, methods and resource requirements. Workshops were aimed at different outcomes, e.g. to increase understanding of monitor farm systems, operational and strategic management issues of monitor farmers, research methods and results, and information requirements for decision making; or to co-develop research plans and consider opportunities for programme redesign/reprioritisation to improve impact. Event feedback questionnaires were used throughout to evaluate if the workshop aims were met and which questions remained for participants. The results of these surveys were input data for analysis of co-innovation implementation by Primary Innovation, and were used to define next steps in the FRNL programme or elsewhere.

The monitor farm network engaged with research and extension in several ways. Detailed farm system and management data were collected, nutrient budgets and economic reports developed, scenario studies conducted, workshops held to discuss research plans and results, and farms and farmers participated in various communication and extension activities.

From the start of the FRNL programme, there has been great interest from the media, farmers and rural professionals, not in the least due to having the monitor farmers involved in the programme and results being applicable to current farming practice. Three years into the programme, 66 articles had appeared in rural media, twice the programme featured on national radio and 91 times the programme results were presented at scientific or industry conferences,

workshops and field days. Monitor farmers have made changes to their farm system or management, feeling empowered by the greater availability of data and support. They hosted field days and farmer discussion groups, and think that these kinds of activities greatly assist extension of results of the programme:

> I think the farmers tend to take notice or listen harder or think about using it on their own farms if they know of someone who's doing it and it's actually working, rather than going to a research farm somewhere (FRNL monitor farmer A 2016).

> It's that connection from the research or development into actual practical implementation that you would struggle with if you just said "hey, this is what researchers are saying". You wouldn't get the uptake the same way, you'd have to have the farmers involved (FRNL monitor farmer B 2016).

Rural professionals were also positive about the role and potential success of the monitor farm network, as reported in Edwards, Pinxterhuis & Bewsell (2015) and illustrated by feedback provided by a rural professional who attended one of the workshops in the second half of 2016:

> The current monitor farms are a good example of getting buy in from key and influential farmers.

Researchers also appreciate the interaction with the monitor farmers, e.g.:

> Farmers provided great grounding of thinking.

Heifer Rearing – Establishing multi-stakeholder groups

Based on the project strategy there were different types of knowledge required to deliver on the Heifer Rearing project plan. Some of the information needed was based around "soft skills", such as contract negotiation, while stock management and target setting information was preferably sourced from published research.

Four cross-stakeholder groups were established to design and influence each stream of work: Leadership, Economics, Relationship Management and Knowledge Synthesis. The Leadership group focused on establishing common terminology to use in the project and its output, reviewed targets for heifer liveweight and defined the value of well grown heifers or the cost of an undergrown heifer. This group also defined metrics to evaluate the impact of the project. The Economics working group gave input and feedback on the design of three calculator tools: grazing heifers at the dairy farm vs. contract grazing; a grazing enterprise comparison; and pricing guidelines based on services provided. The draft tools were then presented at field days with feedback gained from multi-stakeholder attendees.

The Relationship Management working group developed six resources to support the relationship cycle of contract grazing and provided input into an industry standardised contract that is provided and serviced by an external organisation. The resources were then designed by the project team, reviewed by the working group and used at field days and events. The Knowledge Synthesis group had the most fragmented development process. Initially a multi-stakeholder group drafted an outline of information that needed to be sourced and management practices defined, then the responsibility moved to the project team to execute the scoped work. Although scientific knowledge existed for technical aspects of heifer growing, there were many knowledge gaps for regionally relevant heifer rearing systems. Many New Zealand-based studies assessing animal growth, however, were component studies estimating feed eaten with grazing in situ. Only one controlled trial, completed in the 1990s, assessed if high or low growth rates of dairy heifers (due to feed allocation) influenced the subsequent milk production performance. Therefore, the project team believed information on good management practice of heifer rearing systems needed to be sourced from science and farmer experience. The chosen methods for knowledge collection were:

- Establishing heifer management focus farms on contract graziers' properties to collect data and demonstrate regional good practice.
- Reviewing literature of animal growth trials in pastoral grazing systems.
- Conducting semi-structured interviews with dairy farmers and contract graziers across the country.
- Consulting and requesting feedback from scientists.

The project manager/resource developer was involved in all the field days, reviewed the literature, and completed the interviews and consultations. The developer then collated the information in extension resources, which were reviewed externally by a dairy farmer who also worked in contract grazing. Once finalised, the resources were submitted for DairyNZ science review.

Despite the co-development and project review process, the resources were not approved for publication. Feedback focused on the legitimacy of different types of evidence, science versus

farmer experience. The resources are now rewritten following substantial review, and will reference appropriate scientific evidence to balance science versus farmer experience.

Observing group processes and suggesting appropriate changes to facilitate effective interaction and learning

In the innovation projects, the reflexive monitors had the role of observing group processes and suggesting appropriate changes to facilitate effective interaction and learning. To fulfil their roles, reflexive monitors needed to be part of the project teams and participate in many of the projects' meetings and workshops. In Nutrient Management this was enabled by the reflexive monitor being involved in the organisation of the workshops, providing input for agendas, work forms and feedback questionnaires, and taking on the role of facilitator for selected workshops. It was felt that this facilitating role provided the monitor with the mandate to be present, observe and ask hard questions of the project team; in effect being an involved participant. In Heifer Rearing the reflexive monitor took a critical observer role in the meetings, focusing on asking individuals for feedback. The reflexive monitor in this project felt there was insufficient trust to ask hard questions in a group environment.

In both projects, project leaders assisted by reflexive monitors implemented the action learning cycle throughout the lifetime of the projects, and activities were tailored to the apparent needs of each project. In Nutrient Management this resulted in frequent requests for variations to the original contract. While this behaviour was seen by some as not delivering to agreed outputs, the funders, governance and management of the programme were supportive, enabling a flexible programme that responded to results becoming available and adapted its activities to maximise potential impact (Botha et al. 2014; Vereijssen et al. 2017).

Evaluation of enablers and barriers for co-innovation

Table 1 lists enablers and barriers for co-innovation as identified in the literature. For each innovation project it was noted which of these enablers and barriers had an influence on the projects. While both projects were instigated by the same organisation, the projects encountered different enablers and barriers, especially where networks were concerned.

Discussion

The Heifer Rearing and Nutrient Management projects were instigated in an organisational environment that is supportive of collaboration with farmers and other end-users, but co-innovation approaches where farmers are full partners in the work are sparse. While the Primary Innovation project fosters external innovation champions (E9), institutional policies have previously been based on a linear approach to knowledge, with science, development and extension working to a great extent in isolation. Currently this is being addressed by developing large programmes of work across the organisation to better link and collaborate within the organisation (E11) and with end-users (addressing B2 and B16) and to increase flexibility to better adapt to changing context (addressing B15). It is still unclear to what extent this will support co-innovation and, therefore, achieve a connected range of technological, practice, market, social and policy solutions for dairy farming's main challenges.

The evaluation of Nutrient Management and Heifer Rearing shows that the two projects encountered very different enablers and barriers where networks were concerned (Table 1). Nutrient Management spent much time building networks and trust amongst parties to collaborate on reducing environmental impact of agriculture (E3, E4, E5, E7). This led to a formalised collaboration between six organisations and a network of farmers (the Forages for Reduced Nitrate Leaching programme), with agreed procedures for programme governance and management and Intellectual Property management (E3, E14). Experiences with having agreed procedures to jointly solve problems encountered by team members have been positive to date, as evidenced by the reported open discussions at programme management and governance level. Sometimes this resulted in taking a different course of action, with associated variations to the contracts to ensure the overall goals could be met. However, interactions within the programme need continuous attention, and with more research results becoming available and monitor farmers implementing more of the new forage systems, demand for communication and extension activities has been growing and must be managed appropriately. For example, there is a need to have sufficient resources available for development of supporting material and to bring in new people with appropriate skills, thus avoiding requiring an unreasonable amount of time and/or effort from people currently involved in the programme.

Table 1. Enablers and barriers for co-innovation and whether they were experienced in the innovation projects Heifer Rearing and Nutrient Management

	Enablers	NM	HR
	Funding and Resourcing		
E1	Investment policies that foster co-production	☺	😐
E2	Adequate resourcing for sustainability of project management	☺	
	Networks		
E3	Functioning networks: trusted, agreed working procedures, co-learning, managing conflict, and intellectual property management	☺	
E4	Getting the right network of stakeholders together focused on the right things: scanning, scoping, filtering, and partnering	☺	😐
E5	Establishing a legitimate position that does not take over being the expert in the area and overruling stakeholder contributions	☺	
E6	Ability to influence and upscale on an organisational and outscale on an inter-organisational level	☺	
E7	Stakeholder involvement based on desire to be co-dependant or work in a different way	☺	
E8	Interdependence as criteria for stakeholder participation	>	
E9	External innovation champions	☺	☺
	Policies		
E10	Institutional settings that provide incentives for engaging with co-innovation		
E11	Institutional incentives for linking and collaborating		
E12	Policy environment that focuses on using knowledge not just creating it		
E13	Organisational attitudes to prepare for future change	>	>
E14	Governance arrangements that give stakeholders the authority to act on behalf of the organisation they represent		
	Roles and Responsibilities		
E15	Defined roles: Innovation broker and facilitator functions	☺	☺
E16	Decentralization of innovation management	☺	☺
	Vision		
E17	Well-articulated visions for: technology, knowledge, funding, policy, and problem diagnosis	☺	☺
	Barriers		
	Funding and Resourcing		
B1	Brokering and facilitating comes on top of an existing role	☹	☹
B2	Difficulty altering funding mechanisms to enable co-innovation	☹	😐
B3	Stakeholders fail to carry the ownership of the success or failure of the project		☹
	Networks		
B4	Stakeholders fail to carry a sense of responsibility to the success or failure of the project		☹
B5	Seen as a competitor to researchers or advisors		☹
B6	Lack of contact, disturbed or dysfunctional contact, conflict, and/or uncertainty in the innovation network		☹
B7	Conflict between differences in local indigenous knowledge/management and formal scientific knowledge		☹
B8	Network failure: locked relationships, weak networks, and lack of balance between openness and getting closure		☹
B9	Failing to understand past initiatives and historic conflict between stakeholders		☹
B10	Failing to engage stakeholders that can represent their sector		☹
B11	Difficulty aligning mindsets and competencies of stakeholders and project team	😐	
B12	Defining involvement of stakeholders based on time, returns, competencies, ambition for change, and the complexity of the innovation	😐	☹
B13	Lack of stability in stakeholders as interests and need for inclusion change		☹
B14	People that must implement the innovation concepts are not involved in the vision setting, leading to hesitant interaction with the project	😐	☹
	Policies		
B15	Difficulty altering pre-set agendas to be adaptive and responsive		
B16	Current arrangements only support consultation for stakeholder engagement	☹	☹
B17	Failing to define boundaries for interventions		
	Roles and responsibilities		
B18	Leadership is traditionally assigned to science or disciplinary leaders which may not be the most effective in leading across organisations	☹	

☺ = positive influence; ☹ = negative influence; 😐 = some influence; > = increased influence
Enablers and barriers derived from Klerkx, Aarts & Leeuwis 2010; Klerkx, Van Mierlo & Leeuwis 2012; Hermans et al. 2013; Klerkx & Nettle 2013; Nettle, Brightling & Hope 2013.

Clearly, the co-innovation approach is not able to include all individual end-users or intermediaries, and achieving learning and practice change with a larger group of end-users tends to fall back on traditional linear approaches to extension. However, discussions are ongoing to ensure the chosen methods are using co-innovation principles, e.g. learning networks that provide support to end-users implementing proposed farming systems and practices.

The Rural Professionals group, including farm consultants, was infrequently involved in FRNL, and in small numbers (B14). This group is an important intermediary for taking results to a larger group of farmers. Wadsworth (1998) stated that problems develop in action research when four parties are not closely linked in the inquiry process: researchers, the researched, those researched for with the direct problem and those researched for that support people with the direct problem. This fourth group has been consulted and presented to, but only a few members have been actively involved in FRNL to date. Collaboration in a co-innovation project takes considerable time and effort, and many of the people in this group do not consider this to be sufficiently worthwhile to forgo income from consultancy and prefer to simply have updates on the project work. Some consultants were able to fit FRNL involvement in their annual action plan and therefore their time was in fact paid for by their company (staff from industry-good bodies DairyNZ, FAR and Beef and LAMB NZ); others could gain credits for the workshops towards their certification. It has been proposed to pay for involvement of consultants to overcome this problem, but this has not been actioned because it is known this could be counterproductive, with people being involved for the wrong reasons (Nederlof, Wongtschowski & van der Lee 2011). In 2017-2019 more development and extension resources will be aligned to FRNL to support farmer uptake of the most successful options researched in FRNL, and paid involvement of consultants can be reconsidered (dealing with B2 and B10).

The Heifer Rearing focus groups exposed field extension staff to the project design process and farmers' needs (E4). As the project progressed and resources were developed, the extension network was engaged and ready to use these resources with their clients. No additional "buy-in" was required since those engaged with the process could see their ideas being put into practice and in project outputs. By having multiple focus groups, the ideas were validated across the country and the resulting activities and outputs were end-user oriented.

There were challenges in getting shared ownership with commercial companies in Heifer Rearing (B5, B9, B10). They were not paid participants in the project and industry-wide agreed positions could put some of their commercial positions at risk, removing the opportunity for brand differentiation. Also, any need for industry-wide agreement was not achieved, in the absence of a crisis or some other motivation to unite. Leeuwis & Van den Ban (2004) identified that equal opportunity for input does not mean equal opportunity for critiquing and claiming the project outputs. This is a contributing factor to competition between stakeholders and failure to gain shared ownership. However, shared ownership between many parties is not always needed, and collaboration between research and one company can lead to significant progress for the common good.

Nederlof, Wongtschowski & van der Lee (2011) suggest that a main principle of innovation systems is to build on 'sticky' information, i.e. tacit knowledge, local and specific to the information owner and not easily available to others. Through Heifer Rearing this type of information was actively sought and collected, looking for consistencies between farmers across regions that could be translated to good management practice, and integrated in the developed resources. However, the first iteration of these resources was not approved due to doubts about the validity of farmers' knowledge (B7). The resources will need to be revised to make a clear distinction between different types of knowledge, e.g. scientific and farmer's experience. For example, Cornelissen et al (2009) classified their results using the source of knowledge: 1 = Based on peer reviewed scientific publications; 2 = Based on handbooks or originating from practical, expert knowledge; and 3 = Based on both scientific and expert knowledge. Engaging with and valuing different sources of knowledge for the development of decision and management support resources will be encouraged. Achieving recognition for their voices in project outputs is important for stakeholders to see how they contributed and it is important that institutions are committed to the outcomes of the interactive process for both industry-support and for effective use of funds (Leeuwis and Van den Ban 2004).

Farmers and field extension staff have been accepting of the concept of starting with the farmers to develop information because they have a shared understanding of adaptation of principles in practice and the difference between a research environment and commercial farming. The importance of acknowledging this difference and valuing the farmer's knowledge was also voiced by the FRNL monitor farmers and rural professionals.

For the purposes of this paper we have evaluated our experiences in both projects using a list of enablers and barriers found in literature. While this clarified possible reasons for successes and difficulties, similar projects could benefit more from this exercise when it is included in timely evaluation that can lead to actions to resolve problems or make the most of opportunities during the projects, i.e. being part of an action learning cycle within projects. This is exactly the purpose of reflexive monitoring. We suggest using the list of enablers and barriers alongside the Primary Innovation principles in reflexive meetings and define SMART actions (specific, measurable, assignable, realistic and time-bound) for optimal benefit. These actions are project-specific and cannot be predetermined in the proposal stages of the project, therefore flexibility during the project is crucial.

Conclusion

While both the Heifer Rearing and Nutrient Management innovation projects implemented principles and practices of co-innovation, their activities were distinctly different and tailored to their goals, stakeholders, resources and ability of the teams. This illustrates that co-innovation cannot be as simple as following a recipe, but requires deliberate implementation of the action learning cycle and institutional support to adapt project activities to ensure co-innovation principles are enacted and meaningful progress is made. Many already published enablers and barriers to co-innovation were recognisable in the two projects, which influenced the progress of the projects. We recommend that others who aim to implement co-innovation principles and practices in their work, utilise our table of enablers and barriers and the Primary Innovation principles when designing their activities and regularly thereafter to reflect on their progress and assess which areas need attention in their projects or organisations.

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