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Diverging and Converging Pathways

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Workshop 1.3: Using a co-innovation approach to improve innovation and learning

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New ways of supporting learning and innovation have become more acceptable over the last decade to better fit the new context within which research and development (R&D) for sustainable outcomes is practised. Co-innovation is a process-driven approach that aims to stimulate innovation and learning for sustainable outcomes. Co-innovation has been trialled as an approach to stimulating innovation and learning in New Zealand and other countries for several years in a variety of socio-cultural, economic and institutional contexts. Some of these experiments have been idealistic and theory driven, while others were pragmatic and inserted co-innovation principles through action research into more traditional models of learning and innovation, such as technology transfer. Our international team of social and biophysical scientists organises and ran a workshop on co-innovation during IFSA 2016 that explores co-innovation at the practical level through a range of presented papers, highlighting how theory was translated into practice. Generally a range of concepts like co-creation (Kukkuru, 2011); strategies for development of the co-innovation approach (Bossink, 2002), co-production (Klerkx and Nettle, 2013) and co-evolution (Kilelu, Klerkx and Leeuwis, 2013), are associated with co-innovation. In this workshop two concepts that were specifically explored were reflexivity (van Mierlo et al., 2010) and knowledge and innovation brokering (Bielak et al., 2013) because in New Zealand they have been found to be central to co-innovation. The workshop consisted of a series of papers on co-innovation that are grounded in theory but focus on knowledge gained from application in ex-post and action research case studies. We had a core of five papers from New Zealand and sought, through the open call for papers, additional papers on co-innovation that highlight the application of this approach, as well as the use of reflexive practice and brokering. The core of papers focused on:

- Developing a community of practice for understanding and using co-innovation, and the outcomes from this group at the agricultural innovation system level;
- Cost benefit analysis of co-innovation;
- A cross case analysis of the contribution of co-innovation to enhanced innovation and learning in the pastoral, horticultural and forestry sectors;
- Reflexive monitoring practice for implementing co-innovation;
- A Māori (indigenous people of New Zealand) perspective of co-innovation;
- Monitoring and evaluation for supporting co-innovation

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A co-innovation approach in family-farming livestock systems in Rocha - Uruguay: a three-year learning process

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Abstract: There are opportunities to improve livestock family farms' (LFF) sustainability in Uruguay by changing management practices and incorporating technologies using the co-innovation approach. To harness these opportunities, between 2012 and 2015 a research project was implemented in Eastern Uruguay, where three simultaneous processes occurred at three levels: farm, region and research team. At farm level, the work was carried out in seven LFF as case studies. Through monthly visits to the farms by a field agronomist the process followed three phases using the Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators (MESMIS) framework: (i) characterisation and diagnosis; (ii) re-design and (iii) implementation, monitoring and evaluation. As a result farmer farm management knowledge and skills improved and the farms increased their meat production and net income (by on average 23% and 56% respectively) while preserving natural resources. At regional level, a participatory approach to planning, monitoring and evaluating the project´s progress with regional stakeholders was adapted from a Participatory Analysis of Impact Pathways (PIPA) method. An interinstitutional network was consolidated, which developed a common vision and expected project outcomes and designed a communication plan to disseminate the results. At team level a Participatory Action Research (PAR) approach was carried out. A transdisciplinary team was consolidated through cyclic processes of research, reflection and action. Consensus on the objectives and methods allowed combining knowledge to solve practice-oriented problems. The three-year process demonstrated effectiveness in improving LFF sustainability, opening a learning space with stakeholders and contributing a novel model of rural development: co-innovation.

Keywords: Methodology, MESMIS, PAR, PIPA, systemic approach, monitoring and evaluation, co-innovation

Introduction

Twenty-one percent of the farms in Uruguay disappeared between 2000 and 2011 (Cortelezzi & Mondelli, 2014). Nowadays, there are more than 26,000 livestock farms covering more than 11.7 million hectares, most of which (60%) are family farms (Tommasino et al., 2014). In our work, and according to the definition of family-farming provided by the Uruguayan Ministry of Livestock and Agriculture, "family-farming" satisfies the following criteria: labour is mainly provided by the family while hired labour is limited, the family is directly responsible for the production and management of agricultural activities, the family lives on the farm or within a 50 kilometre radius, and the production is intended for self-consumption and marketing (Tommasino et al., 2014).

The traditional model of agricultural technology transfer has led to low adoption of improved agricultural technologies (Moschitz et al., 2015; Okali et al., 1994). On the other hand, the active participation of the farmers in the process of problem identification and development of alternatives may maximise the impact of the generated proposals (Leeuwis & Van der Ban, 2004). Accordingly, some advances have been observed in Uruguay by the National Agricultural Research Institute (INIA) while working together with organic farmers (Albicette, 2011), and by the Faculty of Agronomy of the University of the Republic with livestock and horticultural farmers (Dogliotti et al., 2012; 2014). This presupposes a research process paradigm shift, where the human factor is an integral part of the innovation process.

Most of the livestock family farms (LFF) in Uruguay apply low technology levels and consequently they present low production efficiency with substantial fluctuations between years (Pereira, 2003). At farm level, some opportunities can be identified to improve family-farm production efficiency and sustainability through an adequate selection and orientation of production activities and the use of appropriate technology and farming management skills. In line with this, technical information for natural grassland management (Soca et al., 2013; Altesor et al., 2011) and cattle and sheep management (Nabinger et al., 2011; Quintans & Scarsi, 2013) is available and known by end users. Farm sustainability cannot be solved by mere adjustments or modifications in isolated components of the system, which generally responds to disciplinary advances. To improve LFF sustainability, a systemic approach of LFF is needed, therefore implying changes in the quality and availability of production resources, along with changes in farm management. The latter includes certain changes in knowledge, skills, attitudes and abilities -KASA- (Rockwell & Bennett, 2004) of the family (Dogliotti et al., 2012; 2014). A Rapid Rural Appraisal (RRA) (Schönhuth & Kievelitz, 1994) was conducted during 2009 and 2010 in Rocha, Eastern Uruguay by INIA in collaboration with local farmer organisations (Sociedad de Fomento Rural-Ruta 109 - SFR-R109, Sociedad de Fomento Rural-Castillos - SFR-C), the national farmer union (Comisión Nacional de Fomento Rural - CNFR) and local government (Intendencia Municipal de Rocha - IMR). Through this RRA we confirmed a reduction of the number of family farms and an increase of average farmer´s age. We also identified knowledge gaps and misuse of the available technological alternatives related to low income. As a consequence, the strategy of the farmers was to intensify their production (i.e. use of external sources of feed, substituting natural grasslands by sowed pastures, increases in animal stocking rate), usually associated with inadequate technologies and practices. This posed a risk to natural resource preservation while affecting the present productivity and compromising sustainability for future generations (Capra et al., 2009).

The project "co-innovating for the sustainable development of family-farming systems in Rocha-Uruguay" aimed to contribute from the scientific research and the technological development standpoint to the improvement of family-farming systems sustainability, the development of this rural area and the improvement of farmer wellbeing using a co-innovation process. As defined by Coutts et al. (2014), co-innovation is a participative and interactive approach to fostering effective innovation across sectors and stakeholders. Within this project we proposed a methodological framework to design, implement and monitor and evaluate (M&E) an intervention strategy for improving LFF sustainability.

Materials and Methods

We implemented a co-innovation approach that combines complex systems theory, social learning and dynamic project M&E (Rossing et al., 2010) at three interconnected and simultaneous levels: farm, region and research team (Figure 1). The process occurred over three years (2012-2015) and involved two rural areas of Rocha - Uruguay: Castillos and the hilly areas delimited by roads 109 and 15 (Figure 2).

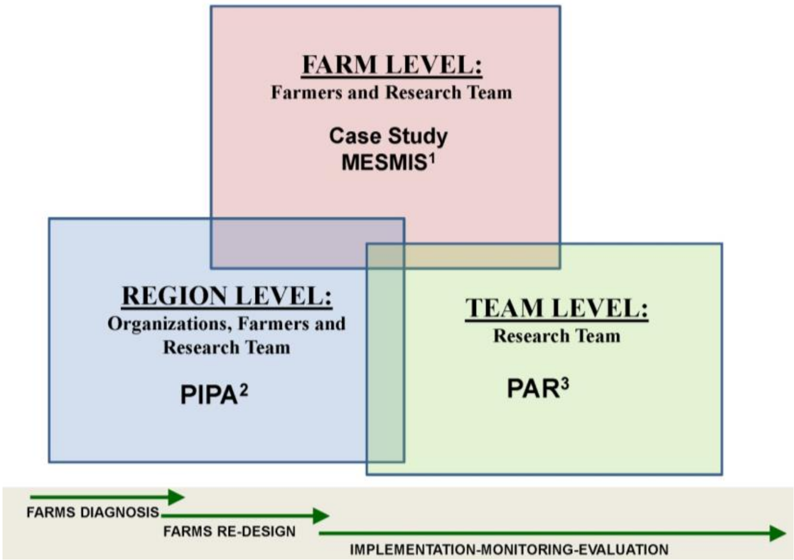

Figure 1. Project methodological approach. *The co-innovation approach was implemented at three simultaneous and interconnected levels: farm, region and research team. At each level specific methods/methodologies were used and supported the diagnosis, re-design and implementation, monitoring and evaluation of the introduced changes in the farming systems.*

[1] MESMIS: Framework for the Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators (Masera et al., 2000); [2] PIPA: Participatory Impact Pathways Analysis (Alvarez et al., 2010); [3] PAR: Participatory Action Research (Moschitz and Home, 2014).

Figure 2. Localisation of the rural areas where the project was implemented: Castillos and Rocha hilly area, Rocha, Uruguay.

Farm level

To improve LFF sustainability, we implemented a multiple case study (Yin, 2014) within the MESMIS framework (Spanish acronym for Evaluation of Natural Resource Management Systems Incorporating Sustainability Indicators [Masera et al., 2000]). Seven family farms were selected jointly by INIA researchers, extension agents of two grassroots local farmer organisations (SFR-R109 and SFR-C) and agronomists of the national farmer union (CNFR). The main activity of the selected LFF is livestock production (raising cattle and sheep) based on native grasslands.

Three phases were followed according to Dogliotti et al. (2014): (i) characterisation and diagnosis; (ii) re-design of the farming system and (iii) implementation and M&E of the proposed changes in the farming system. The field agronomist was responsible for supporting the farmer and the family to implement the proposed changes as well as monitoring the whole process. In order to carry this out the field agronomist visited each farm on a monthly basis. He also facilitated the connection between the farmers and the research team members responsible for collecting on-farm information regarding grassland and animal management, environmental indicators and social processes.

The **characterisation and diagnosis** at each LFF was undertaken by the farmer and his family along with the field agronomist and the research team. The status and operation of the production systems were described and the main problems of these systems were identified taking into account the family´s conception of sustainability. Finally, based on the MESMIS framework (Masera et al., 2000) the critical points were organised according to four groups of sustainable attributes (productivity, stability, reliability-adaptability-resilience and self-reliance) and the indicators to monitor them were determined (Table 1). During the **re-design** phase (strategic planning) of the LFF, different productive alternatives were proposed based on the resources available on the farm. After that, the proposals were evaluated by quantifying the expected physical and economic results, as well as the potential impact on farm management and on natural resources. After a learning process where the producer's practical knowledge and the scientific knowledge provided by the research team merged, one proposal was constructed by the family and the field agronomist in order to overcome the critical points. The last phase of the process was the **implementation** (tactical planning) and **M&E of the proposal**. The impact of the re-designed system was monitored and quantified with the selected indicators. Some unexpected difficulties arose as the process evolved so the original proposal was adjusted through continuous cycles of re-design and implementation.

Region level

The Participatory Analysis of Impact Pathways (PIPA) was designed to help the people involved in a project to explicitly present their expectations towards the project and to plan, implement and monitor activities together in order to fulfil those expectations (Alvarez et al., 2010). In our case, we used PIPA to support and disseminate the processes which took place at farm level, therefore we engaged regional stakeholders in a participatory learning process during interinstitutional workshops carried out twice a year. During these workshops participatory methods were selected from a toolkit (Knowledge Sharing Toolkit, 2009; UNICEF Bangladesh, 1993) and a facilitator guided the discussions and the reflection process. To keep continuity throughout the process, workshops activities were documented and systematised in minutes, which were sent to each participant to be used as memory refreshers and starting points for the succeeding meetings. As the project advanced and changes occurred, lessons learned were incorporated in real time. In the last workshop a written survey was conducted to evaluate the project performance and outcomes, both qualitatively and quantitatively. This survey was composed of 17 questions regarding global assessment, goals achievement, project performance, other topics and future impact of results, rated on a Likert scale ranging from 1 = very bad to 5 = excellent.

Team level

A multidisciplinary team (research team) was set up to elaborate and implement the project, to conduct M&E of the processes at farm and region levels and to answer specific research questions. The research team followed a Participatory Action Research (PAR) process. PAR presupposes a cyclic process of research, reflection and action where the researchers are both participants and learners (MacDonald, 2012). The research team had a varied range of backgrounds and expertise, e.g. farm management, pasture and grassland management, livestock production, soil sciences, environmental impact assessment and social sciences.

Two one-day workshops per year were organised aiming to achieve a common vision of the objective and methodology of the project, plan activities, reflect on the process and discuss partial results and how to communicate them. In these workshops participatory methods were implemented as previously described in the ***Region level*** section.

Finally, to evaluate the process within the team we implemented a quantitative survey designed to evaluate transdisciplinary research (Small et al., 2015). The survey consisted of 38 questions/statements accounting for the key process factors in transdisciplinarity, to be scored on a 1 to 7 scale (1 = very poor to 7 = very good) and included the possibility of adding comments regarding the addressed issue. In addition, researchers were asked to provide up to three lessons learned from the project. The survey was delivered by e-mail to the researchers and was answered anonymously.

Results

Farm level

During the first year (2012) each farm was characterised and the main weaknesses and strengths were organised into sustainability attributes and critical points according to MESMIS (Table 1). Among the weaknesses the following were identified: (i) low productivity associated with low family income and labour organisation; (ii) low use of improved technologies for animal, grassland and farm management and (iii) degraded natural resources, mainly native pastures and soil. On the other hand, the strengths were: (i) high degree of satisfaction with their livelihood and availability of family labour, and (ii) high biodiversity.

Considering the previous analysis, the second phase - re-design of the farming system -took place over the course of two years (2013-2014). Several proposals were elaborated for each farm and those which did not imply any incremental costs and used the on-farm resources were selected. After reaching an agreement on the production objectives the proposals focused on: (i) adjustments to the system´s stocking rate (total stocking rate and bovine/ovine ratio); (ii) use and application of technologies for cow-calf systems and (iii) grazing management using different paddocks according to pasture height and animal age.

The implementation of the proposals for the re-design of LFFs started in 2013. Over a period of two years, the impacts of the introduced changes were monitored by using a set of indicators accounting for the three dimensions of sustainability (Table 1). As for the economic dimension, the seven farms increased average equivalent meat production from 99 to 123 kg ha^{-1} $year^{-1}$ and their net income from 58 to 98 US$ ha^{-1} $year^{-1}$. Regarding the environmental dimension, the amount of standing spring biomass of natural grasslands increased from 1183 to 1868 kg DM ha^{-1}, while the diversity of birds as well as the labile organic carbon fraction of soils (760 mg C. kg $soil^{-1}$) were maintained in this environment. Finally, significant changes in the social dimension were observed: a 25% reduction in workload on animals and pasture management; an increase in use of the 11 proposed technologies from 39 to 97 %, and farmers shifted from ‘not planning' to starting ‘mid-term planning'. All of these advances were a result of changes in farmers´ knowledge and skills around how to understand and manage their LFFs, as expressed by themselves: “*we now know how to manage pastures and cattle”, “with less we can do things in a better way”, “now we have more clear production objectives, we know when to do things”*.

Table 1. Main critical points and indicators used to assess livestock family farms (LFF) performance, organised in four groups of sustainability attributes and sustainability dimensions, according to MESMIS.

Sustainability attribute	Critical point	Indicator (unit/scale)	Sustainability dimension
Productivity	Low productivity	Equivalent meat production [1] (kg ha^{-1} $year^{-1}$)	Economic
	Low family income	Net income (US$ ha^{-1} $year^{-1}$)	Economic
Stability	High level of satisfaction with family livelihood	Subjective life quality [2]	Social
	Low labour organisation	Workload on animals and pasture management (h $year^{-1}$)	Social
	Low use of improved technologies	Implemented improved technology (%)[3]	Social
	High biodiversity	Birds Richness [4] and Birds diversity (Shannon Index=H) [5]	Environmental
	Degraded natural grasslands	Spring biomass of native grassland (kg DM ha^{-1})	Environmental
Reliability/ Adaptability/ Resilience	Degraded soils	Labile organic carbon (mg C. kg $soil^{-1}$)	Environmental
	Availability of family labour	Proportion of workload provided by the family on animals and pasture management (%)	Social
Self-reliance	Low farm management skills	Mid and long term planning [6]	Social

*[1] Equivalent meat production ha^{-1} = (kg meat + 2.48*kg wool)/grazing area; [2] According to family perception, from 5 = very satisfied to 1 = not satisfied; [3] Proposed production technologies: 100% means common 11 technologies proposed to all farmers for the re-design of the LFF (e.g. adjustment in stocking rate, animal allocation according to pasture biomass, pregnancy diagnosis); [4] Number of species; [5] Shannon Index $H= -\Sigma p_i \ln p_i$, where p = the proportion of species, r = total of species, and i varies from 1 to r; [6] Scale from 5 = value and apply long-term planning to 1 = not valued and do not apply planning.*

Region level

An interinstitutional network of several actors in relation to rural development was generated. The actors were the seven above mentioned families, the research team and representatives of the farmer organisations and union (SFR-C, SFR-R109 and CNFR), the University, local/national government and local extension services (Albicette et al., 2016).

During the first interinstitutional workshop participants developed a shared view of what their expectations were at the end of the project (the vision) regarding: (i) contribution to enhancing sustainability of the farms in the region; (ii) improvement of interactions among farmers; (iii) promotion of knowledge acquisition and development of abilities for farm management; (iv) increasing networking towards LFF development and (v) dissemination of the acquired knowledge through field days and mass media. The participants discussed the impact of several pathways and proposed strategies, outputs and outcomes to achieve that vision. A communication plan (CP) for the project was elaborated considering its strategy. During the following PIPA workshops the research team members shared the implemented project´s activities and obtained results so that anyone could follow the process. Participants reflected upon results and progress achieved so far, considering the elaborated strategy and using participatory methods and suggested changes for better impacts. This was seen as the M&E process of the PIPA. Activities and workshop results were documented in minutes which were used for linking the workshops together. The CP aimed to effectively disseminate project results and promote learning considering different groups' objectives: farmers; professionals involved in rural development and organisations. As an example, we present the strategy plan for farmers (Figure 3) and for professionals involved in rural development (Figure 4). Specific activities were defined annually during PIPA workshops.

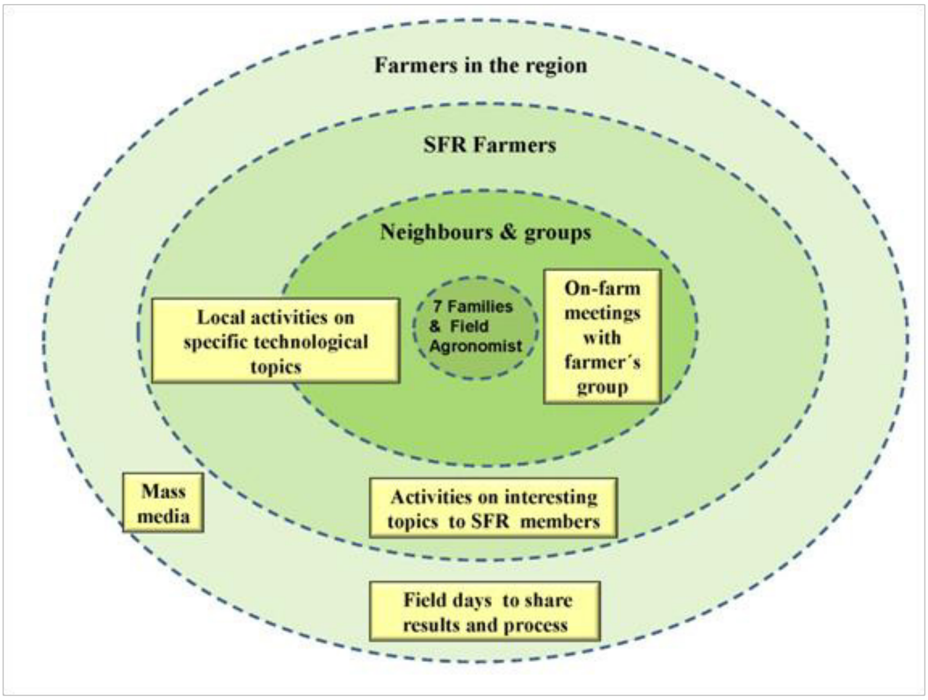

Figure 3. Communication strategy for farmers

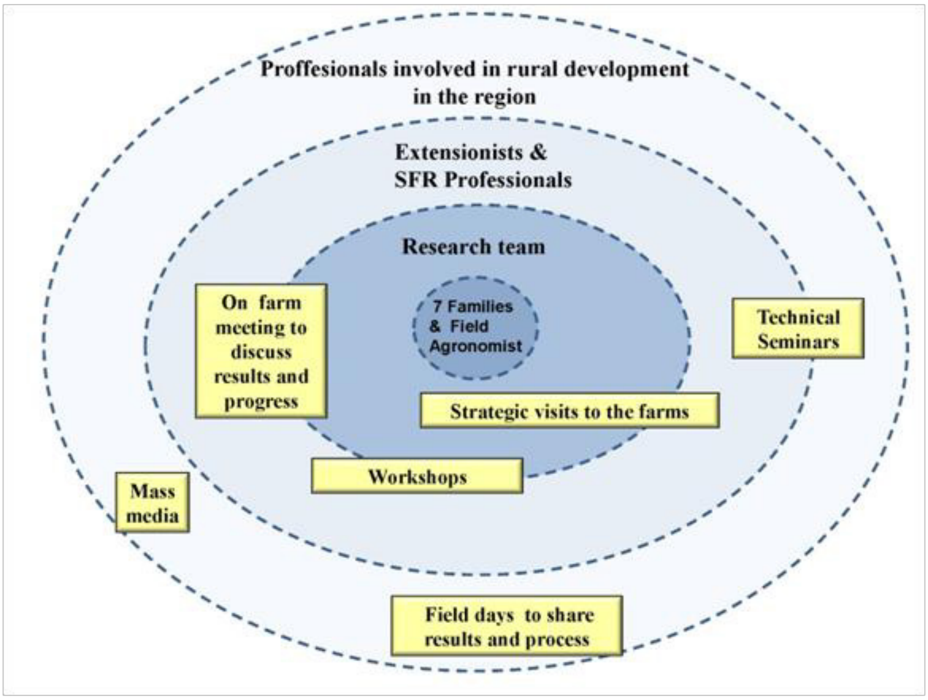

Figure 4. Communication strategy for professionals involved in rural development

During 2014 and 2016 several activities according to the designed plan took place. Five field days were organised and supported by the interinstitutional network, involving more than 600 participants. In December 2015 almost 200 people participated in the final field day where the research team, farmers and members of the interinstitutional network exchanged results and lessons learned with the participants. The evaluation of the activity was completed by 98 people with 65% being farmers. The field day was scored as 'very good' or 'excellent' by 93% of the respondents and 83% considered that the technological proposals were useful for the farm on which each worked. At the end of the field day a session with members of national organisations reflected on the project's results and exchanged ideas for the future of Uruguayan LFF[1]. The Rural Development Director of Ministry of Livestock stated that the results of this project had shown that in LFFs it is possible to undertake an intensification process along with increasing sustainability and adapting to climate change. He also stated that : "*This is not a minor result: with this rigorous scientific data the country's productivity and the competitiveness of livestock family production could be improved*". Similarly, the representative of CNFR said: "*We valued this way of working and we are looking forward to reaching out to more farmers. Fifteen days ago, we presented a project based on this methodology, which will allow us to obtain funding to reach other regions and farmers".*

[1] *For more information about the 2015´s field day: http://www.inia.uy/estaciones-experimentales/direcciones-regionales/inia-treinta-y-tres/hacia-una-ganader%C3%ADa-familiar-sustentable-jornada-final-del-proyecto-co-innovando-en-rocha-2012-%E2%80%93-2015*

The final evaluation of the three-year process, in which all were asked to score certain project related issues, was answered by 18 stakeholders (excluding INIA participants). The global project was valued as ‘very good’ with a mean value of 4.22 out of 5. The relevance of the changes that occurred on the seven farms was valued at 4.28. Two main topics were highly valued, the methodology used to work with farmers (4.44) and the incorporation of suggestion during the project (4.17). The less valued topics were related to the information available in the region on the project results (3.61) and the impact of these results on the near future (3.4).

Team level

We consolidated a research team with 25 members including 17 researchers and 8 assistants. A PAR methodology advanced our understanding of the progresses in different areas (economic-productive, environmental and social), guided from the beginning by different disciplinary researchers. It took six workshops of the whole research team to understand the research problem, as well as the methodological approach, and several interdisciplinary meetings for discussions guiding the research process. As the process advanced the workshops focused on analysing the strengths and weaknesses of the project´s implementation, which allowed for the incorporation of lessons learned during the project.

Transdisciplinarity emerged as a new property of the project team integrated by researchers, farmers and local actors. Transdisciplinarity was validated through a survey implemented according to Small et al. (2015), where process success factors were valued as positive with an average score of 5.40 out of a maximum of 7.00. The survey was answered anonymously by 21 members of the research team in 2015.

Discussion and final considerations

To develop sustainable agricultural practices researchers need to collaborate with end-users of technology (Akpo et al., 2015; Dogliotti et al., 2012). Consequently, joint definitions of problems and opportunities among the seven farmers and the research team, and considering family’s needs and resources, were key elements in the development of the ongoing re-design of proposals. The results at farm level showed that all the farms improved sustainability when evaluated through a combination of several indicators (Table 1), with the MESMIS method including social quantitative indicators (as pointed out by Astier et al. 2011). Learning occurred based on the data obtained from the indicators that were measured and analysed. Some economic and environmental indicators were reaffirmed in importance, and new social indicators were designed and used to better understand changes and learning processes in family farming systems (Astier et al., 2011).

Changes on farms took place thanks to the co-working between farmers and the research team, especially the field agronomist, mixing their knowledge of farming systems and learning together. A strong relationship between them generated confidence and trust (Rossi, 2011) as well as contributing to the rapid response of farmers to understanding the use of technology, improving their knowledge, abilities and skills (Rockwell & Bennett, 2004) and innovating on their farms (Klerkx et al., 2012). Furthermore, they all have new aspirations to deepen the process of improving farm sustainability. As mentioned by Drechsel et al. (2001)

changes in KASA are a prerequisite for the adoption of an innovation if other conditions are favorable.

Local actors were involved in a three-year project process, considering the seven farms and generating an interinstitutional network that was capable of designing a common vision of what was expected from the project, as well as the planning to make changes happen (Alvarez et al., 2010). The communication plan elaborated by the network defined activities that helped to disseminate the experience and contributed to local development. The vision, the project´s strategies and the activities had been changed during the process to some extent, based on the M&E process and on what had been learned (Douthwaite et al., 2003). The participatory process continued as an experiential learning cycle that can be compared with that described by Douthwaite et al. (2002). The most remarkable results considering the regional level were: (i) government and policy makers now know about the project strategy and results and consider it as an inspiring approach towards implementation of LFF policies and (ii) key organisations related to rural development such as CNFR are now using this methodology in their development projects with farmers. Considering all that, the project directly contributed to enhancing LFF sustainability and rural development.

The PAR methodology (Moschitz & Home, 2014) used by the research team resulted in a novel way of addressing agricultural complex problems by INIA. Furthermore, transdisciplinarity can be seen as a new avenue for generating knowledge along with farmers, representing an institutional innovation (Klerkx et al., 2012; Moschitz & Home, 2014). This approach challenges the research institutions to face practice oriented problems, demanding further development and adaptation according to the needs of other research teams.

Finally, the process of changing towards more sustainable LFF systems in Rocha-Uruguay was achieved by applying a co-innovation approach (Rossing et al., 2010). A three-year learning process jointly implemented by farmers, researchers and interinstitutional network members was based on: (i) working with a systemic view aimed at solving real problems felt by farmers; (ii) combining three levels of action - farm, region and team; (iii) considering an adequate period of time to allow changes and their assessment; (iv) M&E of the process encouraging a learning process among stakeholders and (v) and allowing flexibility to incorporate lessons learned and to make adjustments during the project. The results presented in this work demonstrate that the approach used to address complex systemic challenges and to solve practice-oriented problems by using/applying participatory approaches/methods was effective at enhancing LFF sustainability and contributing to rural development, albeit on a small scale. However, this is an ongoing learning process that needs to continue and improve.

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Evaluating a space for co-innovation: the practical application of nine principles for co-innovation in five innovation projects

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Abstract: Primary Innovation is a five year collaborative initiative demonstrating and evaluating co-innovation, a systemic approach to innovation addressing complex problems, in five 'innovation projects' (active case studies) in different agricultural industries. In defining the elements of co-innovation, Primary Innovation has emphasised nine principles (based on those from Nederlof et al., 2011) which guide activity in the innovation projects. To understand how useful the nine principles were in guiding practice, and their influence on co-innovation, innovation project participants assessed and reflected on: how the principles were applied in practice; issues that arose; how each influenced the project; and how important each principle was perceived as being in influencing project outcomes. Data were captured and summarised in an on-line survey. While each principle added an important element to each innovation project, different contexts and barriers to implementation required them to be applied in different ways and to different degrees. The nine principles should be understood in each individual project's context because their appropriateness and usefulness were affected by the type of problem being addressed and the stage of the project. It was also evident that they need to be built into the process from the start.

Keywords: Co-innovation, principles, practice, innovation projects, barriers

Introduction

The need to innovate and how co-innovation fits the requirement

Agriculture is of importance to New Zealand's economy and one of the six key drivers needed to achieve the government's ambitious goal of doubling the value of New Zealand's exports is increasing business innovation (Ministry of Business Innovation and Employment, 2014). It was this driver that helped make the case for a new approach to innovation in the New Zealand agricultural sector. As a result the New Zealand government is now investing significantly in strengthening the innovation system through a programme called *Co-learning and Co-innovation to Achieve Impact in New Zealand's Biological Industries*, which is referred to as Primary Innovation (Botha et al., 2015).

Primary Innovation

The technology transfer approach, which encourages the adoption of agricultural research findings, has failed to address increasingly complex problems (Botha et al., 2014). Earlier attempts in New Zealand to encourage adoption of more systemic approaches such as farming systems and Agricultural Knowledge and Information Systems (Klerkx et al., 2012; Reid et al., 1993) were of variable success (Reid & Brazendale, 2014; Turner et al., 2016).

Primary Innovation was therefore designed to demonstrate an alternative approach in New Zealand's primary sector that could successfully address complex challenges in modern agriculture. The intention is that problems are addressed through a co-evolution of technologies, practices, policies and market changes undertaken in processes of collaboration and negotiation involving multiple stakeholders in the problems. This is also referred to as 'co-innovation' (Dogliotti et al., 2014; Hall et al., 2001; Klerkx et al., 2012). Co-innovation is considered to be the result of a process of networking and interactive learning among a heterogeneous set of actors, such as farmers, input industries, processors, traders and researchers. There is an emphasis on organisational change (Kilelu et al., 2013), where: innovation is 'co-produced' by many stakeholders; researchers become part of a broader network of actors; and innovation is an emergent property of their interaction.

Primary Innovation has five innovation projects that are embedded in different primary industries, dealing with issues of differing complexity. The projects, in order of estimated complexity from least to most complex, are (Coutts et al., 2014): (i) Heifer Rearing Project (HR) - focused on improving the rearing of dairy heifers by third-party graziers; (ii) Tomato Potato Psyllid (TPP) – which is a vector of the bacterium *Candidatus Liberibacter solanacearum* (CLso) - with the aim to develop economically and environmentally sustainable control solutions for the TPP/CLso complex; (iii) Timber Segregation Project (TS) - working along the forestry value chain to better match forests to markets; (iv) Irrigation Water Use Efficiency (WUE) Project focused on provision of climate and soil moisture data to farmers to support water use decisions; and (vi) Nutrient Management Project (NM) – focused on increasing the implementation of farm nutrient management plans.

Each of the innovation projects sought to operationalise co-innovation to test the extent to which it enabled progress to developing successful solutions to each of the five problems being addressed (Coutts et al., 2014). The practice of co-innovation has been informed by social research (Hall, 2005; Klerkx et al., 2012; Nettle et al., 2013), systems research (Adner, 2006; Adner & Kapoor, 2010; Rohrbeck et al., 2009) and business management research (Hueske et al., 2015; Rufat-Latre et al., 2010; Smart et al., 2007; Traitler et al., 2011) on how to tackle complex problems. This research has sought to understand the factors associated with successful (and unsuccessful) attempts to address complex problems in agriculture and natural resource management.

However, implementing co-innovation in practice does have challenges (Botha et al., 2014). Firstly, there is still not agreement in the literature on the specific characteristics of co-innovation, for example when operationalised as innovation platforms (Nederlof et al., 2011). Secondly, much of the literature on co-innovation is retrospective case study analysis (e.g. Amankwah et al., 2012; Batterink et al., 2010; Botha et al., 2014; Dogliotti et al., 2014; Klerkx & Nettle, 2013), i.e., diagnosing what co-innovation looked like in specific circumstances. These insights from specific cases (e.g. improving family farm profitability in Uruguay (Dogliotti et al., 2014)) need to be translated into practices for use in each new context (Thiele et al., 2007), such as the innovation projects described above, for the lessons to be operationalised. Thirdly, challenges to implementing co-innovation have been considered as simply barriers to progress instead of a major focus of research (Beratan, 2014). As a consequence there is limited insight into co-innovation practice in the face of barriers, such as insufficient resources, time or capabilities.

Co-innovation is therefore best described in terms of principles, as its practice is still being defined. Co-innovation is context-specific and adaptive, i.e., how co-innovation is implemented must be tailored to the particular situation, which will also change over time (centre of Figure 1) (Hall, 2005; Klerkx et al., 2010; Schut et al., 2014). In Primary Innovation, key principles for co-innovation were identified from the main principles identified by Nederlof et al. (2011) for agricultural innovation platforms. These were adapted for the context of innovation in the New Zealand primary sector based on the project team's previous experience of co-innovation in the New Zealand context. We used these nine principles to conceptualise the space within which actors can negotiate how co-innovation is implemented in practice over time in specific cases (Figure 1). The nine principles are listed and described briefly below.

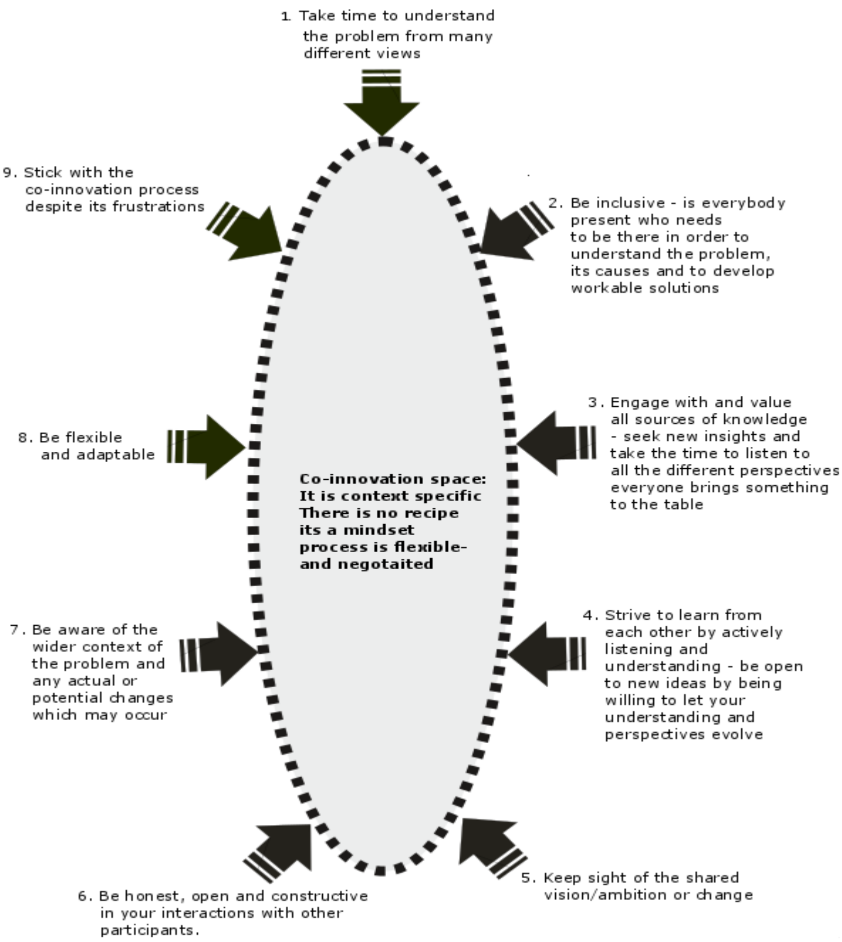

Figure 1. A space for innovation project participants to co-innovate, defined by the practical implementation of nine principles

Take time to understand the problem from many different views

By taking the time to fully understand the nature of the problem, and building a shared vision (or ambition for change) solutions will be more likely to succeed. If you begin by assuming you understand the problem and already have a preconceived solution you may not get the changes you desire. Be prepared to consider a variety of solutions.

Be inclusive – ensure everybody is present who needs to be there in order to understand the problem, its causes and to develop workable solutions.
Ensure everyone is there who can help to understand the nature of the problem and its causes and influence the implementation of any potential solutions. Include those who take ideas to the market or create the rules, as well as those who may potentially block solutions. It is easier to develop a solution together than to try and sell a solution after it is formed.

Engage with and value all sources of knowledge – seek new insights and take the time to listen to all the different perspectives – everyone brings something to the table.
Be respectful of other views, experiences and ideas, while at the same time challenging ways of thinking in a constructive manner. Sources of knowledge could be local and tangible or scientific but are not limited to these sources.

Strive to learn from each other by actively listening and understanding - be open to new ideas by being willing to let your own understanding and perspectives evolve.
How we work together and the roles we have may change over time. Active listening is a way of listening and responding to another person that improves mutual understanding. Over time, learning goes to a deeper level, where mutual understanding can impact on attitudes and values and views on what is important.

Keep sight of the shared vision or 'ambition for change'.
Agree on the nature of the problem, its causes and the desired outcome of the project, and regularly review this outcome and progress toward achieving it.

Be honest, open and constructive in your interactions with other participants.
Remember we are all in this together and no one group can solve this problem on their own.

Be aware of the wider context of the problem and any actual or potential changes which may occur.
We may need to change our solutions and goals as a result of external influences (natural disaster, legislative changes, world markets, unexpected setbacks).

Be flexible and adaptable.
How we work together and the roles we have may change over time**.**

Stick with the co-innovation process despite its frustrations.
Be prepared to be uncomfortable and for setbacks to occur – we may have to work through historical tensions, current tensions and although this is not fun it is a necessary part of negotiating shared and workable solutions. Things will take time, but this investment will pay off.

Figure 1 illustrates how these principles together create a 'space for co-innovation' in innovation projects. The concept of 'learning spaces' and 'collaboration spaces' have been used elsewhere to describe either characteristics of physical environments that encourage social learning (Kolb & Kolb, 2005; Matthews et al., 2011; Temple, 2008) or online platforms for collaborative activities, such as software development (Geyer et al., 2001; McComb et al., 2010; Morán et al., 2004). Here we conceptualise a 'co-innovation space' as being characterised by the extent to which combinations of the nine principles are present. We hypothesis that when more of these principles are perceived by actors in an innovation project as present and strong, co-innovation is more likely to occur, leading to successful innovation.

Aim of the paper

With Primary Innovation in its final stages, research was undertaken on how well the nine principles were perceived as being applied in practice in the five innovation projects, how these principles were adapted to each project's context, and the extent to which the project teams believed the principles influenced innovation and impact. This paper presents the results of this inquiry and provides grounded experiences in the use and usefulness of these nine principles and also raises questions for on-going theory development around the practice of co-innovation.

Methodology

This paper is based on the results from a survey of the five Innovation Project teams' use of the nine principles. Each of the project teams was made up of three to five individuals, including the project leader, a Reflexive Monitor, researchers and extension agents, who together implemented co-innovation principles in the project. Each of the project teams were facilitated as a group by the second author in a structured discussion of the questions on the use of the 'nine principles' and a group consensus of responses recorded. During the group process responses were directly inputted into a web-based survey format to reduce double handling of the data and to enable quick access for analysis. Sessions were audio recorded to enable the research team to return to the conversations for any points of clarification. The questions asked in relation to each principle were:

1. How have you applied this principle?
2. What difficulties/issues have you encountered in trying to apply this?
3. How did you address these difficulties?
4. How do you feel that this principle has benefited/added to/changed the project?
5. From your perspective, to what extent have you applied this principle in relation to what you think would be ideal for your project? [rating 0-10]
6. From what you have found to date, how important would you rate this principle in terms of its contribution to a successful project outcome [rating 0-10]
7. General comments about the principle

Data were collated and the authors analysed the data in a group workshop with the purpose of developing a succinct summary of the feedback around each principle. The rating data was also analysed to provide a context around the qualitative feedback. Synthesised lessons from application of principles were also drawn across the five cases.

Results

The results are organised by each of the nine principles, with each described in terms of: (i) was the principle perceived as important to the outcomes of the innovation project and what were the benefits of applying the principles; (ii) to what extent was the principle applied in each innovation project; (iii) how was the principle applied in practice in the innovation projects; and (iv) what were the barriers to putting the principles into practice and how were these barriers overcome?

Understand the problem from different views

Perceived importance and benefits

This principle was rated as highly important to outcomes by all projects, however there was some variation in extent to which projects were able to implement the principle in practice. The

TPP project for example found it more difficult to implement this principle as it has a strong science focus and the project was contracted and planned before co-innovation was considered. The NM project reported that, by seeking these wider views, "*It has got people on board and given them an opportunity to have more conversations*." It was also noted that they employed a more controversial way to include different views: "*Ignored nay-sayers and organised meetings anyway – they now are supporters*". They also acted to bring newcomers 'up to speed' noting that ongoing nurturing was needed.

Application, challenges and responses
The projects focused on farmer practice – WUE and HR – on the other hand deliberately brought in farmers' views early in the project. The WUE project posed the question 'how could we manage irrigation better' rather than 'irrigation is not well managed'. This resulted in expanding the project focus from soil moisture and irrigation to include a soil water drainage element. In the HR project results from farmer focus groups were combined with advice from a technical reference group and input from the funder. This resulted in a broader scope looking at regional differences and non-traditional solutions – moving from weight-gain contracts as the only solution to HR to a broader emphasis on relationships between dairy farmers and graziers.

Although the HR project tried to incorporate different views it did not mean that the stakeholders were always willing to understand each other's views: "*Initially the technical advisory group sort of made their own solutions, they were not really interested in what we were doing and in how we were arriving at solutions.*" And to find out which views to include sometimes took a while as the HR project did not have graziers involved from the start. The TS project experienced similar difficulties with getting people on board and understanding each other's views, taking the project a year to consult with stakeholders and set up 'clusters' for stakeholder input. The clusters consist of a mix of growers, academics, processors and suppliers and were described as providing an opportunity for taking time to listen to others' views – and to put a focus on the timber customers rather than just the grower (seen as a 'game changer'). It was noted that "*this is the first time that some of the growers and processors have sat in the same room together to have these conversations*".

Be inclusive

Perceived importance and benefits
Inclusiveness was rated as very important by the HR project (10) and less important by the others (range from 7-10) with the NM and TS projects rated the lowest (7). This engagement with stakeholders helped researchers to understand operational challenges and provided a greater legitimacy to the innovation project. Role modelling inclusiveness, as well as persistence of the project team, helped to capture the interest of researchers and science managers and convinced them that being inclusive could be beneficial to them and the project later on.

Application, challenges and responses
Science based research projects found it particularly difficult to achieve (score 6) because scientists preferred to work in the traditional mode and there were difficulties with getting everyone together and increased contestability associated with increasing the number of stakeholders. In contrast, in the project with a small number of participants (WUE) it was easy to include all participants through face-to-face interactions. In two projects, TS and HR, value

chain analysis and stakeholder analysis were used to help ensure all stakeholders were identified and included. Commercial interests in the dairy industry made it hard to include some stakeholders, while in TPP many scientists did not believe an inclusive process was beneficial or necessary to achieve project goals.

In the NM project one-on-one conversations were used to deal with commercial sensitivities and being respectful helped to get and keep stakeholders on board, while in the TS project a strong mix of one-on-one and group interactions helped to address the difficulty of getting all stakeholders in the same room. The HR project experienced challenges around the practicality of including everyone and observed how participation changed over time due to disagreements.

Engage with and value all sources of knowledge

Perceived importance and benefits
This principle was rated as 'central' to the innovation projects, with an average score of 8.5/10 regarding importance. Most teams were able to invite a wide range of stakeholders into the project, because they valued the knowledge others would bring in terms of understanding the nature of the problem and co-developing solutions. The commitment to this principle was reported widely to result in different stakeholders effectively engaging with and listening to each other, broadening understanding of the issues.

Application, challenges and responses
In practice several challenges arose. First, how to navigate the relative value placed on science knowledge and experience based or industry knowledge, e.g. "*Our scientists use experiments and others' experience*" (HR). Reconciling these views when working towards solutions has been difficult because of what different groups believe constitutes 'data' or 'evidence' or demonstrates cause and effect. In the TPP Project "…*there are not too many people that are engaging with people outside of their science bodie*s" meaning dialogue with stakeholders was a new way to operate.

Second, creating bridges between different disciplines or practices to promote understanding also posed challenges: "*We had difficulties understanding what each other were on about*" (HR). The TS project mentioned that "*you often trade away a bit of control as well as some budget and resource as the number of collaborators has increased*." The solution for all cases was "*just do it anyway and let everyone be heard*" (NM) largely through creating forums for dialogue.

Strive to learn from each other

Perceived importance
Providing platforms and processes for interaction, discussion and sharing experiences was seen as important to the learning process with resulting changes to planned actions. Teams in the innovation projects felt that they had been doing a lot of listening as part of their projects, and were then able to adapt future actions.

Application, challenges and response
However they identified that the link between listening and learning was tenuous if people involved already felt they knew what the problem was. In the HR project the team explained; "*We listened at the focus groups, we took it away, developed a strategy and then went back*

into the regions and said this is the strategy we'd come up with, is this what you meant, is this right? What the focus groups told us did not align with our ideas - we were willing to let our own understanding evolve. It ended up being wider than what we started with." In comparison, the NM team commented; "*People can be respectful but actually still not listening… which makes it hard to actually achieve … this is something that will be noticed over time*." The TS project continued in this theme; "*This is one of the harder ones for the sector and academics to implement. They have to be willing to change their practices of the past and these can be quite entrenched*." Moreover organisational boundaries and people's personal comfort zones could get in the way of learning too (TS).

Keep sight of the shared vision or 'ambition for change'

Perceived importance and benefits
Innovation project teams agreed that having a shared vision or ambition for change was important. While a shared vision was important there were tensions about the means of achieving the vision.

Application, challenges and response
There were some tensions apparent in this principle as not all innovation projects had a shared vision. The innovation projects that had a shared vision had some mechanisms for helping the project teams keep it 'top of mind'. For example, the NM team have a series of management group discussions informing the vision, and milestone and deliverables based on this vision to keep track of what is happening. The TS team commented "… *the way change should occur was much more contested".* For the HR project, there was a process of getting to a shared vision, where the vision was refined until they *"… ended up with one that is a win-win for everyone*".

Be honest, open and constructive

Perceived importance and benefits
Team members across the projects felt that this principle required on-going work. It started a process of building trust, with the long term aim of getting those within the project to a point where they could be honest, open and constructive.

Application, challenges and responses
Some teams did this by utilising the structures that had been put into place, for example in the TS project the team commented that "… *having a levy that supports research has levelled the area – everyone gets equal value from science*". Most projects struggled initially to build trust, the TPP project for example were working on building trust "… *by suggesting that more interactions would be good*", but at the same time they also noticed that "*Sometimes there are honest comments but not always put across in a constructive way.*" A particular challenge for a number of projects was the need for hidden agendas to be brought into the open so that real interactions could take place. In the NM project the team said, "*You never really know what the hidden agendas in a group may be*". In the HR project the commercial competition between some stakeholders initially stood in the way of building trust, and this remains an ongoing issue.

Be aware of the wider context of the problem

Perceived importance and benefits
This principle allowed the projects to remain anchored in reality and provided a "…*much wider perspective of what the findings meant and what it meant for different people - kept the system in perspectiv*e" (WUE).

Application, challenges and responses
An awareness of the wider context within which the project operates was obtained largely "…*by involving all the stakeholders and valuing their points of view", by doing this "you naturally end up looking at the wider context*" (WUE). The principle was seen as important because it "…*informs the project as it develops and we understand if priorities change. Need to be aware that things can change and that projects will need to adapt*".

The changing context affecting an innovation project is demonstrated both within the HR and the NM projects, both led by DairyNZ, a dairy farmers' levy based organisation. Lower global prices for dairy products resulted in a reduced pay-out to farmers triggering an internal reprioritisation of DairyNZ resources towards efficient financial management campaigns. At the project level, this meant greater constraints on staff time and resourcing. Each project team recognised this and altered their plans to suit. For example, the HR project slowed the pace of the project and openly discussed the challenges with other stakeholders.

Be adaptable

Perceived importance and benefits
Flexibility and adaptability was rated as very important by all the projects with scores varying between seven (HR) and ten (NM). However, both projects indicated that they had applied the principle very well with scores of nine and ten respectively.

Application, challenges and responses
Projects overall described the application of the principle in a range of ways. For example, team adaptability and flexibility while being faced by inflexible research goals (TPP), changes to how the project was run (NM), changes in participants' perspectives (WUE and TS), and project role and participation changes that had occurred over time (HR).

Research focused programmes experienced difficulties in being flexible and adaptable because of predetermined research contracts, goals, deliverables and budgets that lead to lock-in and disciplinary silos. Changing contracts have significant implications for researchers and cause hassles for science and contract managers which discourage flexibility and adaptability. In one project, difficult relationships contributed to inflexibility and reluctance to change. Continuously communicating openly with funders and participants was mentioned in research focused projects to promote flexibility. In the HR some participants left the project because they felt confronted by the requirement to change. The NM team reported that applying the principle created the "…*ability to respond to new knowledge and changes in context*." Better utilisation of resources occurred because "…*you don't waste resource on things that don't work, for example, we have introduced new tools that weren't thought of at the start of the project*" was an advantage to the TS project. The WUE team indicated that the principle "…*has underpinned the project and the way it has evolved*," and it also created buy-in from farmers and engaged "other players" like the regional council.

Stick with the co-innovation process despite its frustrations

Perceived importance and benefits

Most projects reflected that this was an important principle that all were implementing because they "*are still doing it*". However, it was not seen as necessarily easy with the nine principles all being closely connected and so the need for co-innovation to be "a mind-set not a recipe". The HR project argued that context was critical rather than persevering with all principles once they have achieved their benefits.

Application, challenges and responses

The TPP project spent effort adapting the co-innovation approach to the context that worked for the different stakeholders – in terms of language and methods. The TS project reported that while they remained committed to active engagement through innovation clusters, they were aware of a need to be flexible, e.g. moving from six monthly to twelve monthly meetings to avoid 'meeting fatigue' and using distance communication tools. The NM project reported the need to deal with setbacks and "…*working in spaces where we are out of our comfort zones and keeping the shared vision in front of us*". A number of projects referred to how application of the principles resulted in "…*slowing down the process"* and a loss of some control by researchers. However, TPP noted that the approach has "…*put the team in a better place for other projects going forward (*trust building)", and "…*it's an investment in the future*".

Discussion

Relevance or importance of principles

All of the innovation projects rated all of the principles highly (on average 8.6/10, range across principles 8.2-9.4) in terms of their importance to achieving outcomes regardless of context. The highest rating of 9.4 was being honest, open and constructive (6).

A common theme on how these principles benefited projects, was that they created buy-in by a wider group of stakeholders and improved problem understanding. The TS project's reference to a mix of stakeholders in the room focusing on the timber customer was described as a 'game changer'. Other projects reported that this facilitating conversations with different groups and seeing stakeholders effectively engage with one another resulted in a broader understanding of what was needed. There was consistent feedback about how this inclusion 'got stakeholders on board' with what the project was trying to achieve.

Improved problem understanding as a result of being inclusive, valuing multiple sources of knowledge and striving to learn from each other also reshaped solutions. For example: the HR project moved from a focus on 'contracts' to that of strengthening relationships between dairy farmers and contract 'rearers'; the WUE project moved from a focus on water application only, to the inclusion of soil moisture monitoring that highlighted drainage issues; the TS project included new timber processing tools that weren't thought of at the start of the project; and the NM project was able to stop some planned activities because they were wasting resources.

Some principles were rated much lower by individual projects. The HR project for example, rated sticking with the process (9) and engaging with and valuing all sources of knowledge (3) as only 5/10 each. In their case, the problem area was a lot more defined with the focus on the two groups with a stake in the problem. It seemed that from their perspective once the issue had been teased out and an alternative approach identified, on-going and broad engagement was less needed.

Even though all principles were rated as very important by the projects, the average rating of the extent to which they had applied the principle was lower at 7.8/10 – with flexibility (8) having the lowest average rating (7/10). Comments around flexibility related to the context issues raised earlier – contracts already in place; timelines and milestones already set; and lack of resources. This was particularly the case with research focused programmes – and particularly where the attempt to implement co-innovation occurred after the project had commenced. Application of adaptability (8); wider context (7); and different views of the problem (1) were rated in one project as two, three and four out of ten. There was flexibility in the way different projects applied and adjusted implementation of the principles. For example, the NM project focused on individual farmer collaborators while the HR project used farmer focus groups to gain input and feedback.

Challenges encountered

A number of projects made reference to the process of applying the principles around engagement as having 'slowed the process down'. The need to communicate, negotiate, organise meetings, follow-up and other logistical issues around engagement added cost in terms of time and resources. This was particularly an issue where contracts and timing and milestones were in place and there was little scope to act on what emerged from the extra engagement. One project that also reported this 'slow down' as well as some loss of control by the project team saw long term benefits of the process in positioning the research team 'in a better place for projects going forward.'

There were also issues around mind-sets and agendas that some individuals/groups brought with them to the table – and skill was needed to develop a truly collaborative/cooperative approach in some instances. This impacted on gaining the 'shared vision' (5), but also on the way that the vision was enacted. This raises the question about the extent to which all stakeholders need to share the same specific vision.

Conclusions

The responses to the survey showed that the nine principles should be understood in the context of the individual projects. Teams provided examples of where they have applied these principles, where they have had problems applying them and how they view them in terms of influence on outcomes. Despite the apparent overlap, each principle added a different aspect around the underlying application of co-innovation. Although there is scope to review these principles and consolidate some, care needs to be taken not to lose each specific facet of the diamond.

The application of these principles within these innovation projects demonstrated that their appropriateness and usefulness were affected by the type of problem being addressed and the stage of the project. Clearly, it is difficult to meaningfully bring in broader perspectives, flexibility and extra engagement when contracts have already been written with explicit activities, outputs and tight deadlines. Also, where projects are directed at very specific management practices or boundaries, there are limits to the value of broader stakeholder involvement and slowing down a process for little gain. It is clear that they need to be built into the process from the start – with the appropriate room to move within the project time frame. Also, the application of these principles needs to be considered in the context of the complexity of the problem or scope of the opportunity and recognise that not all projects require the same degree of application.

The principles have been shown in these examples to assist in implementing co-innovation in practice, and appear to have supported project teams in reflecting on, learning about and improving their own co-innovation practice. The principles in themselves though do not ensure that project teams have the skills or tools they need to be able to apply them. It was evident that when engaging a broader group of stakeholders' skills such as facilitating learning, negotiation (with funders and stakeholders) and conflict management are needed. Tools are also needed to support teams in terms of selecting the stakeholders with whom to engage (for example, stakeholder analysis, social network analysis), in capturing complexity (for example, systems mapping), looking at alternatives and in evaluating progress. Extra time and resources are also needed to fully enact some of these principles.

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Hitting the bull's-eye: the role of a reflexive monitor in New Zealand agricultural innovation systems

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Abstract: Reflexive monitors (RMs) are vital to the success of co-innovation approaches in Agricultural Innovation System (AIS) projects. While the practices utilised by RMs have been examined in various contexts, links between their roles and the theoretical frameworks they straddle is limited. This paper will address this gap in terms of explaining the case-specific behaviours that have been utilised in seven different New Zealand (NZ) AIS projects. More importantly, however, it will place the role of the RM in a framework that incorporates AIS, Actor-Network Theory (ANT) and broader Agricultural Transition Theory (ATT). Qualitative data from interviews with six RMs will be used to argue that RMs are a key component in the co-innovation process and are required to play diverse roles depending on project circumstances to enhance system innovation – for example devil's advocate, project supporter, consensus seeker, conflict mediator, critical enquirer or encourager. The findings have implications for how RMs should be chosen, the characteristics that make a good RM, and how they report on the practice of monitoring a project reflexively.

Keywords: Reflexive monitoring, co-innovation, actor-network theory, agricultural innovation systems, agricultural transition, New Zealand

Introduction

The theoretical framework within which the Reflexive Monitor (RM) role sits in primary industries is the co-innovation approach utilised within the systems innovation and Agricultural Innovation System (AIS) literature. In a seminal resource on applying reflexive monitoring van Mierlo et al. (2010b, p. 11) provide the following definition regarding the position of a RM in a project:

> [A RM] "encourages participants to keep reflecting on the relationships between the key items: the *ambitions* of the project, usual *practices* and the way they are embedded in the institutions, plus the *developments* in the system that offer opportunities for realising the ambitions of systems innovation".

While this task in itself may seem like a significant effort, Arkesteijn et al. (2015) report that there are various forms a RM position can take at certain points in time. These include observer, facilitator, or even criticiser that works to link ambitions, practices and subsequent project developments (Arkesteijn et al., 2015). Importantly, in regard to the workload of a RM, it is also a requirement that they do not fulfil many other tasks within the project so they can maintain focus on broader systemic change (van Mierlo et al., 2010b). Figure 1 shows a continuum from 'appreciative inquiry' through to 'critical analysis' to highlight the extremes of where a RM can act depending on project circumstances, although it should be noted that RMs can sit anywhere along the continuum and their positions might be altered by changes over the project lifetime. Appreciative enquiry involves encouraging the project team to build momentum. On the other hand critical enquiry involves questioning the project team and the barriers to project outcomes. Both are examples of facilitation techniques (Kristiansen, 2014).

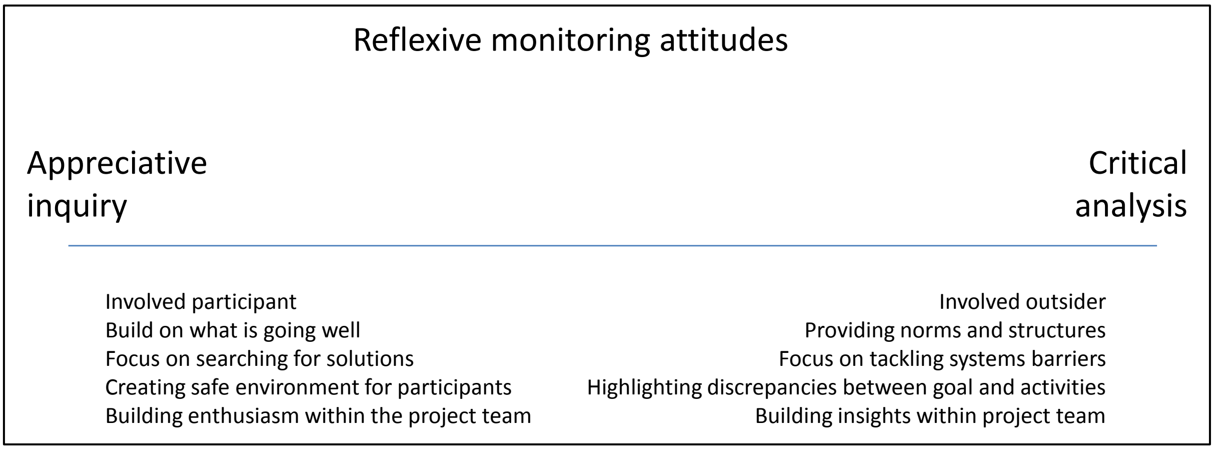

Figure 1. Spectrum of reflexive monitoring attitudes and differences according to approach (*Adapted from: van Mierlo et al., (2010b)*).

In the context of this paper, AIS is used to frame the institutional interactions of primary industry networks and the impacts of those interactions in addressing a key problem in each innovation project. We aim to build on the AIS literature, as well as to contribute to the broader literature concerning actor-network theory (ANT) (Latour 2005), and agricultural transition theory (ATT) (Wilson 2007). By analysing one actor of an AIS, the RM, we contribute to the application of the co-innovation approach, highlighting the actual roles taken on by RMs in New Zealand (NZ).

This paper examines the RM role in regard to six NZ innovation projects using a participatory action research approach (Chevalier & Buckles, 2013). Early within the initial analysis phase of the research programme that included these innovation projects a gap was identified between theory and practical applications of the RM role in NZ, particularly in the experience and tools being used by RMs and complexity in regard to the expectations of the RM role within each project (Rijswijk et al., 2015). In this context it was hypothesised that ANT and ATT could be useful frameworks to inform and situate the practice of reflexive monitoring due to the emphasis on reflection and participation in applied research and practice and the subsequent transitions that manifest. The role of RMs in NZ are analysed through the eyes of RM practitioners and develop two conceptual models; one to expose the factors that influence the RM's ability to function within an innovation programme and a second to explore how the RM may operate in practice.

This paper thus aims to report on the practical application of RM roles in co-innovation approaches to innovation projects. Firstly, the broad theoretical framework the paper utilises is presented. The research method will then be described before the results are presented to answer the primary research question: what roles are RMs performing in the context of NZ primary sector co-innovation projects? Finally, links back to literature will be made in order to increase the relevance of the findings and encourage debate in broader AIS work.

Theoretical framework

Klerkx et al. (2012) examine the evolution of AIS in relation to understanding agricultural systems and key enablers for innovation. The concept of co-innovation became a mechanism to link collaboration and innovation in order to solve complex problems (Lee et al., 2012). The concept of co-innovation can be thought of as one end of the continuum from direct technology transfer at the other. Co-innovation involves understanding that each actor has a role in designing their future, as opposed to the technology transfer approach (Mylan et al., 2015). Reflexive monitoring in action (RMA) is already practised in the European context (van Mierlo et al., 2010b), usually across multiple industries, however, formal RM use within a NZ AIS context is only beginning to emerge (Rijswijk et al., 2015).

It is also important to define what is meant by ATT. Here the term is used to broadly encompass the work that has been done in mapping the transitions of agricultural regimes through various processes. For example, Robinson (2004) used the term 'food regimes' to discuss the evolution of agriculture, whilst other important work has encouraged transitions from agricultural bio-economies to eco-economies based on more agro-ecological principles (Marsden, 2012; Marsden, 2013a; Marsden, 2013b). Although it is generally recognised in this work that there is a need for productivist agricultural outputs, for a number of reasons it is increasingly important to value the multiple functions of agricultural land use (Wilson, 2007; Wilson, 2008). The underlying assumption of these varying, yet related, fields of scholarship is that, as a society, we should aspire to increase the diversity (biological/economic/social or people/profit/planet) of our agricultural systems. It could be argued that within the vast expanse of ATT work, a contribution from ANT may help decipher the trajectory of any future change. This is made possible by Latour (2005, pp. 64-65) asserting that '*for ANT, we now understand the definition of the term is different: it doesn't designate a domain of reality or some particular item, but rather is the name of a movement, a displacement, a transformation, a translation, an enrolment'*. In many cases, broader ATT argues for *change* in the way society conducts agriculture, while ANT can provide an alternate view of this transformation, whereby the resources traditionally dissociated with the social (commodities, scientific research, agricultural policy, or genetic modification to name but a few) become 'actors' in the game, not just '*hapless bearers of symbolic projection'* (Latour, 2005, p. 10). These principles are broadly shared with AIS, which points to AIS, ATT and ANT sharing an ambition for change that it could be possible to bring together to increase the strength of such a movement.

Method

In regard to this paper, primary data were gathered using semi-structured interviews with the five RMs in each of the six innovation projects in a NZ research programme called Primary Innovation (one interviewee acts as RM for two projects). The innovation projects included: a project examining heifer rearing in the dairy industry; an integrated forestry sector project; a nutrient management project involving the dairy industry; an irrigation scheme project; a project aiming to reduce a pest in tomato and potato crops; and a project looking at broader systemic change within NZ AISs. Interview questions were developed depending on the project the RM was involved in. The questions asked were altered to suit the RM being interviewed allowing them to talk more specifically about significant issues relating to the relevance to each innovation project in a more reflexive manner (Beers & Bots, 2009; Lamprinopoulou et al., 2014).

The following seven steps provide a timeline for the events that have led to the composition of this paper. Of primary importance is the iterative process that has been utilised in order to enhance learning and increase the alignment of the project tasks with the meeting of project aims. Simultaneously, significant effort has gone into the utilisation of more developed theoretical understandings of the RM role in the Dutch context, utilising expertise from the Wageningen University and Research Centre (WUR) and subsequently applying that knowledge to the NZ AIS cases.

1. Research programme begins with six projects requiring RMs (October 2012): initial confusion, questioning of the RM role.
2. Regular monthly meeting of NZ RMs begins (April 2013).
3. Barbara van Mierlo visit to NZ (August 2013) providing a key question for RM practice: ‘what is the ambition for change for the project?’
4. RM trip to WUR (April 2014), including RM workshop with Barbara van Mierlo: highlights diversity in RM role and similar questions from others working in co-innovation space.
5. Projects renamed ‘innovation projects’ (July 2014): key shift in thinking for the whole of the research team, reflected in terminology.
6. NZ RM workshop (July 2014): bull’s-eye diagram developed and ‘RM guide’ started.
7. Reflection from RMs via interviews (late 2014/early 2015).

Results

Applying RM principles to decision making

RMs can analyse and reflect on co-innovation projects based on the steps of the action learning cycle (van Mierlo et al., 2010b) (Figure 2 inset). Reflection and action should be structured to assist the project team achieve their ambition for change by mitigating systemic failures (van Mierlo et al., 2010a; Nederlof et al., 2011; Wieczorek & Hekkert, 2012). The RM cycle in Figure 2 is also useful for deciding when a RM should intervene in a project to uphold co-innovation principles.

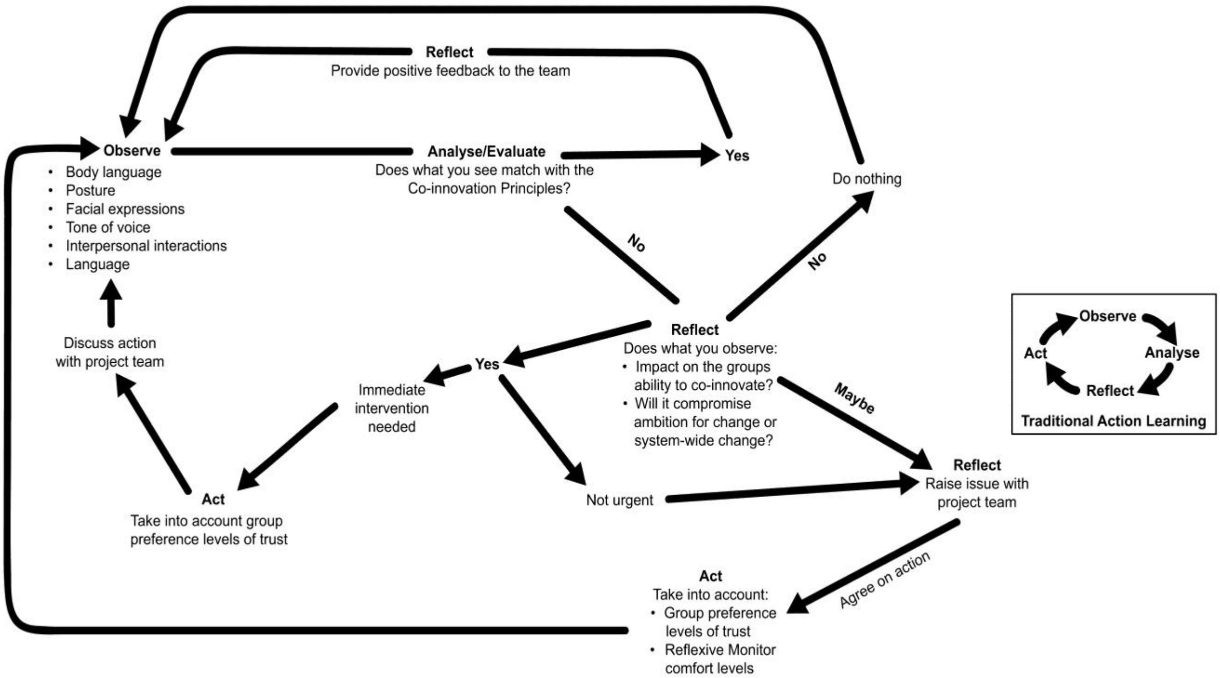

Figure 2. Action learning cycle that could be implemented by a RM.

At each stage of the RM cycle a process can be followed to determine how a RM might act.

1) **Observe:** the process of observation draws on multiple forms of evidence from body language, facial expressions, tone of voice, interpersonal communication, language used, content of the conversations, short interviews, conversations, structured participant reflections and secondary data sources (Dick, 1991; Forester, 1999; Kitchin & Tate, 2000). van Mierlo (2013, pers. comm.) found that successful RMs were typically experienced facilitators. As a consequence, they are familiar with structuring small group processes of dialogue and decision making.

2) **Analyse and evaluate**: all the data collected during the previous stage can undergo thematic analysis (Flick, 2009). The depth of analysis depends on the speed at which the cycle is moving; the faster the cycle the quicker the thematic analysis. The key questions during analysis are:

   - are these behaviours and actions consistent with the co-innovation principles? (i.e., will it assist the project to overcome/change any potential barriers to success within the system?)
   - what will the likely impact of the observed behaviours, actions or practice be on the ambition for change if no intervention occurs?
   - what is driving the observed behaviour, practices and action?

   van Mierlo et al. (2010b) and Nederlof et al. (2011) provide insights into what behaviours and system characteristics are desirable and what may hinder systemic change. This literature and the RM's previous facilitation experience provide a reference point against which to evaluate behaviours and activities within the project.

3) **Reflect:** once the data has been analysed, reflection can occur on how behaviours, practice or activities could be altered (or current practice strengthened) to enhance the change ambition or generate systemic change. Each option should be carefully evaluated based on the benefits and costs of its application. Who is involved in the refection will depend on the speed at which the cycle is moving; the faster the cycle is moving the less people will be involved. If the cycle is occurring rapidly, the RM may be the sole reflector. Reflection should be structured to assist the project team achieve their ambition for change by mitigating systemic failures (van Mierlo et al., 2010a; Nederlof et al*.,* 2011; Wieczorek & Hekkert, 2012).

4) **Act:** all actions and interventions should be undertaken by the most suitable person and will depend on the nature of the issue. For example, it may be the RM in a meeting setting or the project manager in consultation with other project members. How these actions occur will need to be negotiated with the project team at an early stage of the project. There is a wealth of literature and practice which may inform the choice of action and the benefits and trade-offs associated with each alternative (Dick, 1991; Chambers, 2002; Chevalier & Buckles, 2013).

What does a RM in NZ do?

This section addresses the primary research question in terms of the roles of RMs in the context of six NZ innovation projects. Based on the experiences of those operating as RMs in the seven cases it was clear that there is no one size fits all definition or approach to reflexive monitoring, as there were examples across the entire spectrum identified by van Mierlo et al. (2010b) (Figure 1). All of those interviewed agreed that the role is about supporting the project manager and team to achieve the project goals; *"a supporting role but a critical supporting role"* and is *"a role that doesn't get much recognition".* Other aspects of the role are identified in Table 1. As one RM noted: *"you adapt your skills to the role, and RMs require certain personality traits and mind-sets rather than particular skills… [they must be] open to other viewpoints, [have a] strong team mentality and want to see collaboration and co-learning outcomes".*

Over the life of the research programme there have been shifts in thinking about the RM role. At the beginning of the project there was confusion and questioning as to whether the RM was essential and how it was different to a good facilitator. As the programme began and there was interaction across projects and with other RMs (notably workshops with Barbara van Mierlo from WUR) there was acceptance of the RM role, albeit with some confusion about how exactly it was to be undertaken in specific projects. van Mierlo (pers. comm. 2013) provided an initial question to help guide RMs; 'what is the ambition for change?'

Table 1. Definition of a RM by current RMs.

Tasks	Description
Supporting role (supporting project manager and wider project team)	*- "Support work done by project team"* *- "Find ways to get the group to agree, not everyone will agree but everyone has to be able to live with it"* *- "There to help take temperature gauge, let the project leader know how the process is going"* *- "Picking up different things from what a project manager would pick up"*
Get the project team where it needs to go	*-"It doesn't have to be a straight line, it can be a bit wobbly, because it will be, constantly assessing against what you've said you want to achieve and how are we going towards it"* *- "Always asking why"* *- "Asking the question 'is the project on track?'"* *- "If the direction is changing, do they realise?"* *- "Keeping them on track towards the goal"*
Identifying conflict	*-"Don't get involved in the conflict between members…highlight conflict to project manager"* *-"Mediate conflict…if that's what project manager wants from you"*
Data collector / Evaluator	*-"Making sure the project is tracking along"* *- "Figuring out what is causing blockages"*
Facilitator	*- "Facilitate project meetings"*
Providing feedback	*- "Two different parts, devil's advocate and pushing hard and looking for positives and building support"* *- "Offer opinions, throw things back at them to think about"*
Identifying the right stakeholders to be involved and valuing their knowledge	*- "Making sure everyone's knowledge is continually included"* *- "Making sure the right people are involved at the right time"* *- "Having everyone's knowledge heard"* *- "If someone is missing ask why"*

RM Influence and challenges

During the most recent workshop involving NZ RMs (step 6 of the list in the method section) it was found that not all characteristics identified in Table 1 have the same level of influence to the RM role as others. A diagram was subsequently developed through discussion of the question: 'what influences the way we work and our ability to have impact as reflexive monitors?' Each RM contributed their personal list of items. The workshop was used to identify similar issues and highlight which of these were under the control of the RM. The resulting 'bulls-eye' diagram is presented in Figure 3. In the centre bull's-eye are the aspects that the RM has the most control over, as the circles expand the RM has decreasing influence on these aspects of the role and may find it can be unproductive to attempt to address these concerns (Figure 3). The central controllable aspects of a co-innovation project are of primary importance in regard to choosing individuals to take on a RM position. Follow up interviews (after the most recent workshop) revealed that RMs believed the most important requirements for the role were:

- *personal skills*
- *a good relationship with project manager*
- *having a support network*
- *having a clear job description*
- *having freedom to experiment*
- *meeting expectations of the project team*

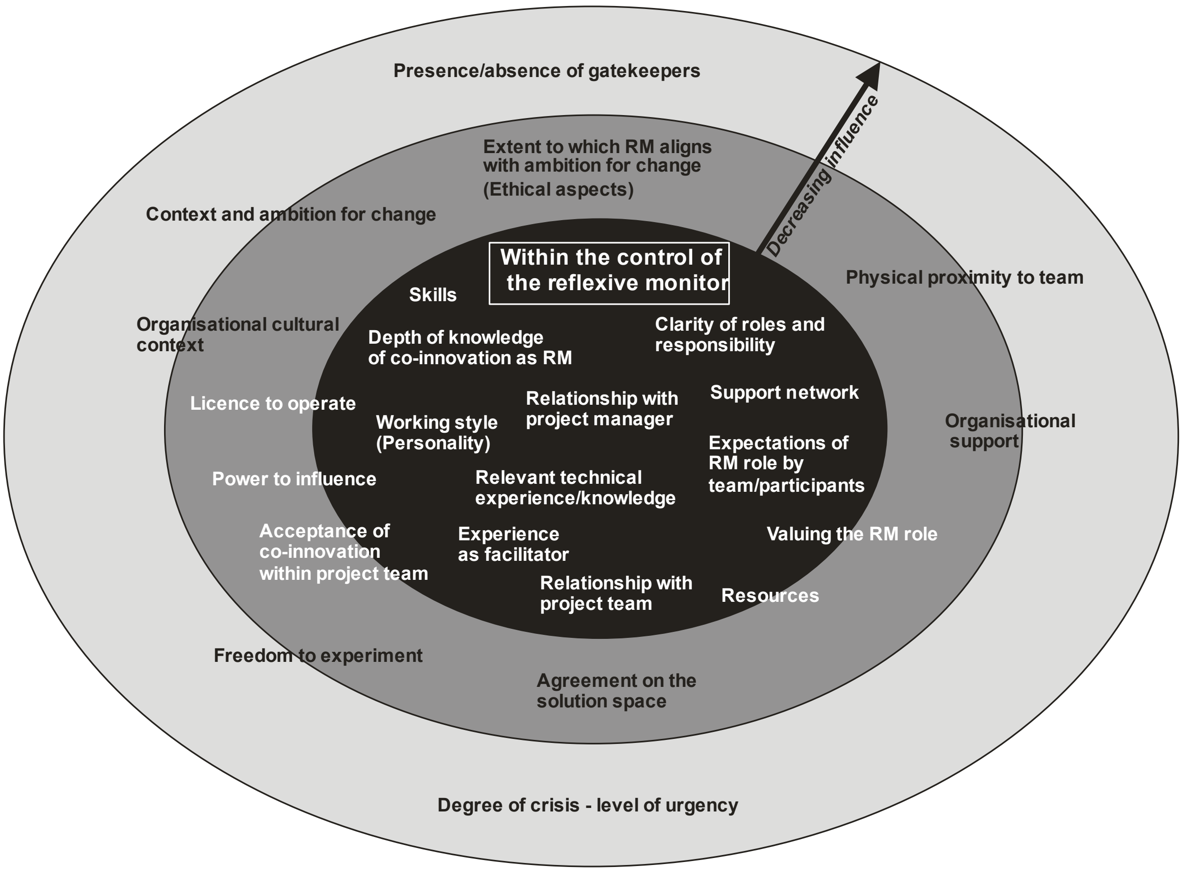

Figure 3. The bull's-eye highlighting things a RM can control with decreasing influence.

Similarly, although the RM has less of an influence over the outer rings (Figure 3) these aspects of the project can still present concerns. For example, the challenges a RM will face in the role will be influenced strongly by the:

- Project they are involved with:
  - the project might go against the RM's own principles (e.g. personal concerns about genetically modified organisms)
- Project leader and their expectations of the role:
  - how the project leader defines the role
  - what the project leader expects of the RM (e.g. interventionist role, sit back and observe or somewhere in between?)
- RMs personality:
  - may not be comfortable taking on an interventionist role or being passive/reserved
- RM having another role in the project (e.g. they also provide technical expertise or are conducting social research):
  - this may cause tension between how the RM is seen by the project manager, the project team and how the RM sees the role
- RM working in the same organisation as the project leader:
  - may make it harder to be objective or critical
- RM working in a different organisation to the project leader:
  - may not be aware of the political climate the project leader is operating in
  - may not understand how the project leader's organisation works
  - may be working with different company structures and hierarchies
- Physical proximity to the project team:
  - it may be expensive and time consuming to attend all meetings
  - it may take longer to build up trust
  - there can be a lack of opportunities for informal interaction

Although some of these challenges may be out of the control of the RM, those that cannot be controlled need to be managed in a way which assists the project team and its partners to achieve their ambition for change. It is extremely important as an RM to reflect on all these factors in order to inform practice and identify potential future risks to the project. The primary focus of the RM should be on what they can do to encourage and support the application of co-innovation principles within their projects (van Mierlo et al., 2010b). These principles were built from previous work and are based on taking time to understand, being inclusive, valuing various sources of knowledge, being open and honest, sharing a vision, sticking with the process, being flexible and being aware of the wider context (van Mierlo et al., 2010b; Nederlof et al., 2011).

The literature and results suggest that RMs collect data, provide feedback, support the project and are critical when required. The 13 lessons learnt in Table 2 also make this point quite clear. At all times RMs are required to foster relationships with various actors using components of a broad toolkit which can now be found online (AgResearch Limited, 2016). It is also important to consider the role of a RM and the findings from this work, in relation to a discussion of the theoretical concepts introduced earlier.

Table 2. Lessons learnt from the experiences of RMs.

Lesson	Examples
Build a relationship with project manager	- "*Need honest conversations around expectations*" - *"Regular communication"* - *"Need their buy-in"* - *"Help facilitate you into the group"* - *"Establish a relationship of trust and rapport with the project leader, tough and very direct discussions will come up"* - *"It's a hard road to get the project leader to realise things need to be done differently – there is a fine line between being seen as helpful and being seen to be interfering"*
Define the role	- *"Work with project manager to define the role and what their expectations were"* - *"Important to ask this as there to help them"* - *"Don't go in and say what you think, project manager has to have buy-in"* - *"Need a clear definition of the role at the start"* - *"You must remain disconnected from the project – it is not your project, you need to remain apart from it in order to see it clearly"* - *"Must have the skills to 'speak the truth kindly' and remain dispassionate when those who are personally involved get defensive when you touch a nerve"*
Use accessible terminology	- *"Jargon doesn't work…is a barrier…use laymen terms"*
Be flexible in your approach	- *"Activities you try"* - *"Be willing to try any approach – think creatively about methodologies"* - *"Takes a lot of time – more than you think*"
Have open communication channels	- *"Always be willing to see another point of view, and encourage others to see other points of view also"* - *"Things won't happen the first time you bring it up – keep telling the same consistent message until they are heard"* - *"Give consistent messages"*
Have a support network	- *"To talk to and off-load"* - *"Don't necessarily need solutions from them"*
Monitor and evaluate	- *"Part of your role"* - *"Helps you understand/track what is going on"*
Provide feedback	- *"Two different parts, devil's advocate and pushing hard and looking for positives and building support"* - *"Can only identify change, you cannot make change happen"* - *"You point out the behaviours needing change and actions that must be taken, but cannot make them change, only support them to change"* - *"If change isn't occurring, or they disagree, then you need to be able to self-evaluate and accept that you might be wrong on this one"*

Specific training is required	*- "Facilitation training"* *- "Conflict resolution"*
Build trust	*- "With the project manager"* *- "With project team members"*
Use different strategies according to participants	*- "Interview team members individually, as this allows them to get across the real institutions and attitudes that are driving the team culture, as well as highlighting what they believe the key problem or ambition for change is"*
No right way to do the role	*- "Best advice I got was from another RM – just make a start, just do something…it is very difficult to know what to do as an RM, so it is literally taking a step out and hoping a stepping stone presents itself so you can go forward"* *- "Context specific – approach role differently based on a number of factors"*
Have a buddy	*- "Someone to learn from"* *- "Talk things through with…doesn't mean giving you answers"*

What do the lessons learnt mean for AIS, ANT and broader ATT?

Firstly, it is important to understand that RMs fit within AISs that can be conceptualised in numerous ways. For example, an AIS could form part of a socio-ecological system (SES) approach to a problem, where resources are separated from individual actors and the relationships between these groups form the SES (Lebel et al., 2006; Ostrom, 2009; Weible et al., 2010; Bardsley & Bardsley, 2014). Although this might be a useful framework to address some issues – particularly regarding the resilience of systems and their adaptive capacity (Walker & Salt, 2006; Olsson et al., 2014), in this context it is argued that the AIS literature, and particularly the RM role, sit more readily within conceptualisations of ATT and ANT.

As discussed earlier in the theoretical framework section, AIS projects are based on the recognition that all stakeholders need to be receptive to constant change in the current climate (supporting the ANT thesis of transformation). As found in the results, the RMs role in an AIS project is to be a guiding voice in regard to following the principles of co-innovation by reflecting on where the project is going. Latour (2005, pp. 11-12) calls on social scientists to no longer "*limit the range of acceptable entities, to teach actors what they are, or to add some reflexivity to their blind practice. Using a slogan from ANT, you have 'to follow the actors themselves' that is to try to catch up with their often wild innovations in order to learn from them what the collective existence has become in their hands.*" This highlights an important social science role that RMs must play.

The practical lessons learnt from RMs in the innovation projects in NZ provide evidence of the changing nature of approaches to tackle complex problems by reflectively considering the actions of those involved throughout an innovation project (Table 2). There is 'no right way' to be a RM, you need to be flexible, strategic, work on relationships and have support in place. Theoretically the RM role within the framework of RMA could be seen as central to the AIS project, an actor itself in ANT, and contributing to broader ATT by altering the direction of agricultural regimes from inside these networks (Figure 4 shows a simplified diagram of this).

There are also broader implications for trans-disciplinary research in general, particularly in regard to linking threads of theories that share similar traits. Although we do not have scope to discuss those in this paper future work will aim to tighten these gaps in knowledge and merge theoretical understanding.

The RM in each project allowed for the actors involved to create space where they could enact their own collective transitions toward project outcomes (Audet, 2014). This work highlights the important role of a RM in regard to encouraging innovation and shifting the mind-sets of project stakeholders. As Cohen and Ilieva (2015, p. 201) explain, the "*complexity and uncertainty of a transition make it difficult, if not impossible, to deliberately engineer*". Conceptually this work built on important literature to provide both practical suggestions for future RMs and began to thread the 'actors' that are these theories, in the encompassing ANT use of the term, into a larger theoretical meta-database (Latour, 2005; Wilson, 2007; Klerkx et al., 2010; van Mierlo et al., 2010b; Marsden, 2012).

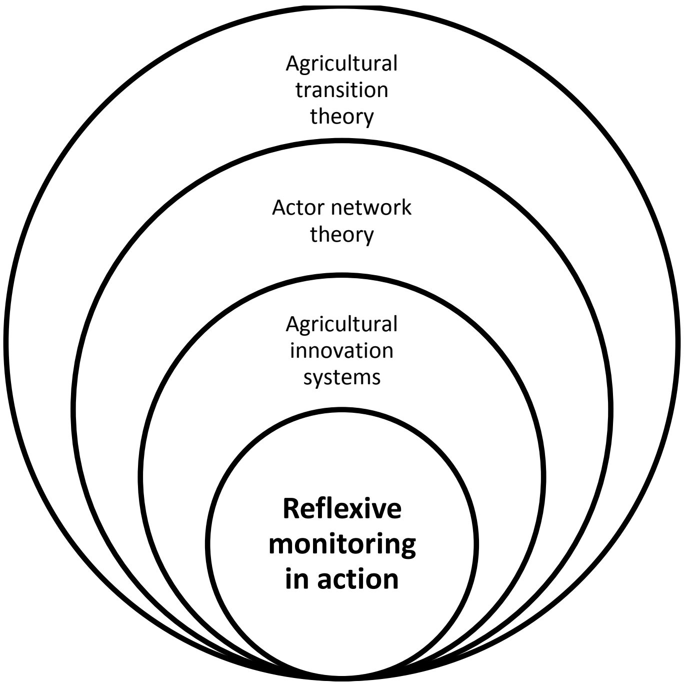

Figure 4. How RMA fits within existing socio-agricultural conceptualisations

Conclusion

This paper analysed the role of RMs in regard to six NZ innovation projects. In response to the research question it was found that a RM is required to be prepared for various situations, depending on the individual project, the stakeholders involved and the broader context in which the project sits, as they will influence the actions that can be taken. Simultaneously a RM should focus primarily on the aspects of a project they can influence (the middle of the bull's-eye in Figure 3) as that will be most productive and hence most likely to alter the agricultural regime they are embedded in. This study strengthened the scholarship around the practical application of reflexive monitoring in AIS and also introduced relations with ATT and ANT. This study found these concepts have potential in regard to taking this work further, particularly as co-innovation through AISs is increasingly recognised as an appropriate approach to tackle problems with ever-increasing complexity.

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Multi-scale modelling as a tool for sharing the perspectives of researchers, practitioners and farmers on beneficial management practices to be adopted in an intensive agricultural watershed

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Abstract: Canadian agricultural production systems are facing issues related to maintaining high crop yields and profitability while adopting beneficial management practices (BMPs) that mitigate their impact on the health of the environment. Since 2014 Agriculture and Agri-Food Canada (AAFC) has been collaborating on the development of an open innovation platform, namely the “L'Acadie-Lab” living laboratory, initiated by an interactive community of farmers, practitioners and researchers to increase the adoption of BMPs in the L'Acadie River watershed, in southern Quebec Canada. So far, workshops have been held featuring farmers, practitioners, scientists and other stakeholders. These workshops have revealed a disconnect between farmers’ expectations and research organisations' ability to provide a consistent array of practices and knowledge. To get new knowledge and technology adopted, consistent choices between various practices that interact on a range of spatial and temporal scales have to be proposed to the users and the economic and ecosystem benefits have to be demonstrated. In response to these issues, the authors propose the development and use of a participatory modelling approach as a tool for sharing the perspectives of researchers, practitioners and farmers on innovative practices to be adopted. The approach links the knowledge of researchers and certain modelling tools at the plot level or the farm level with ecosystem services simulation models at the landscape level to produce quantitative or semi-quantitative results. Farmers and advisors will play a special role in defining the scenarios to be simulated to ensure that their situations and concerns are reflected and to increase the commitment to innovation.

Keywords: Beneficial management practice, open innovation, knowledge and technology transfer, participatory modelling, intensive agricultural watershed.

Introduction

Issues for Canadian agriculture

The agricultural systems in eastern Canada and notably Quebec and Ontario are dominated by intensive crop production, mostly maize and soya, which use large quantities of inputs.

These systems have many environmental impacts such as water quality deterioration, loss of biodiversity, soil erosion, deforestation and greenhouse gas emissions.

Research and development agencies have developed and promoted beneficial management practices (BMP) for more than two decades. In particular, advances have been obtained in knowledge pertaining to BMPs related to fertilisation, soil conservation practices, hydrological infrastructures and integrated pest management (AAFC, 2015). However limited success has been seen in their implementation in farmers' fields (Groulx-Tellier, 2012; Bibeau & Breune, 2005). In fact the implementation of the BMPs faces two significant issues in Quebec:

- the difficulty in getting a critical mass of farmers to participate, in particular for developments that have an impact on the landscape;
- these programmes often fall short in sustaining the adoption of the BMPs.

Current programmes of development of the BMPs have made it possible to favour the adoption of agro-environmental practices among those farmers who were already the most convinced of their importance (pro-environment attitude). A large proportion of farmers that have a less environmentally friendly attitude thus remain to be convinced and the extent of their participation in these programmes is therefore critical for the success of implementation of the BMPs. It is also often observed that once the financial support has come to an end, the mobilisation of the agricultural community starts to weaken. In other words, the developments that are done in the field are not all maintained or preserved once the project is over. This situation calls for a new way of thinking around the transfer of BMPs to the farming community. In fact, the most recent literature supports this need for a shift in thinking on the research-development-transfer continuum.

New ways of seeing innovations

Innovation theory generally distinguishes two categories of innovation processes (Leeuwis & Aarts, 2011): linear processes, most commonly given by the experts or by the technology to be promoted; and systemic processes. The theoretical conception of innovation that is most familiar to governments is the top-down approach, where innovation follows a linear path from the initial idea to adoption by the end user, who is a receiver of information (ENRD, 2013). Initially developed for the transfer of so-called 'hard' technologies and marketable products, this type of linear process is today considered inadequate for knowledge and technology that concern the introduction of beneficial management practices and sustainable production systems in the farming landscape (Dolinska & Aquino, 2016; ENRD, 2013; Anandajayasekeram, 2011). This inadequacy stems from the fact that agriculture is based on management decisions made in a complex context of biophysical, ecological and socioeconomic interactions, and that the knowledge and technology cannot be directly adopted; each farmer has to adapt them to his specific context (Martin et al., 2015; McIntyre et al., 2009). Moreover, the public research and development organisations tend to produce individual and partial sets of knowledge and technology (silos), which the farmer or even the agricultural advisor finds difficult to integrate (Anandajayasekeram, 2011). Finally, the success of linear innovation is very dependent on the capacity of research to design tangible results that are relevant for users (ENRD, 2013). In a system where local conditions are preponderant factors in the adoption of knowledge and technology, the innovation approach must sometimes incorporate the contribution of the users into the creation process, for which the linear model was not designed. Esparcia (2014) frames the importance to innovation of combining local and expert knowledge with a wider network of support from the public sector.

Systemic innovation models were proposed in the early 1990s to take into account the fact that in agriculture, innovation does not arise from a single source of knowledge, but from multiple sources (e.g. researchers, practitioners, users, NGOs, etc.) and that every generation of knowledge and technology occurs in a certain political, economic, agroclimatic and institutional context (Anandajayasekeram, 2011). Today, Canada's strategy "Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation 2014" (Government of Canada, 2014) recognizes that "innovation is a complicated process that is neither defined by a simple formula or playbook, nor easily measured," and that sometimes, "innovation comes directly from advances in science and technology, but it can also stem from other sources." According to Berthet et al. (2015), innovation in such an agro-ecosystemic context will depend on changes in the nature of the knowledge, which will be both agricultural and ecosystemic, and on the social interactions inherent in the reduction of the knowledge by the various stakeholders, which suggests a need for a participatory approach.

Following these statements, the authors of this paper have initiated a new dynamic in a region situated in the South West of the Quebec province, in a river basin that concentrates the environmental issues related to agricultural systems impacts. This dynamic takes the form of a living laboratory that is presented in the next section.

The living lab approach

Fundamentals of living labs

Since 2014, the authors have been collaborating with agricultural and environmental organisations of the L'Acadie watershed on developing a knowledge and technology transfer platform (Umvelt, 2015; Gariépy et al., 2015). This living laboratory, called L'AcadieLab, requires the commitment of all actors, and seeks to address the issues of rehabilitating agroecosystems and creating attractive living environments within the territories with intensive farming.

The L'AcadieLab relies on an open innovation approach, inspired by living laboratories and involving a community of agricultural producers, practitioners and researchers. This approach:

- is based on the process of co-creation and experimentation of new agro-environmental practices with the end users (the farmers) in real conditions (a specific watershed);
- is carried forward by the users. It involves the farmer both as stakeholder in the processes of co-creation and as beneficiary of the positive outcomes of these processes;
- is based on a collaborative partnership that brings together the whole agro-environmental innovation chain from the research to the extension and professionals of farming.

Through this approach, the knowledge provided by the farmers is every bit as important as the knowledge coming from the other stakeholders (e.g. the actors in the agro-environmental innovation chain and the researchers). It is, above all, a way of being and doing in the project. For example, instead of proposing a priori a new integrated development model for watersheds, it offers an opportunity to establish a dialogue among existing models, and attempts to create synergies among them in order to ultimately arrive at a new or combined approach and at development tools integrated by the co-creation among the stakeholders.

L'Acadie River watershed

The L'Acadie River flows north over 82 kilometres in the Montérégie region, on the south shore of the St. Lawrence River, in Quebec, Canada. Its source is located near the municipality of

Hemmingford (45.038N/73.558W). It runs north through Napierville and L'Acadie to its mouth at Chambly Basin (45.476N/73.287W). It is the main tributary of the Richelieu River which is home to more than 50 species of fish, some of which (such as copper redhorse, river redhorse and lake sturgeon) are considered threatened or endangered,

The L'Acadie River flows through a number of small towns as well as agricultural and forest areas (Figure 1). Its drainage basin covers an area of 41,336 hectares (ha), including 30,884 ha (75%) under cultivation - mainly grain corn, soybean and vegetables. More than 10,000 ha are cropped under the supervision of local agri-environmental advisory clubs. An AAFC experimental farm also operates in the watershed. The area has major issues pertaining to surface and subsurface water quality as well as soil conservation and habitat rehabilitation.

Considering the type of land use and intensive anthropogenic activity within the watershed, as well as the commitment by farmers to agricultural beneficial management practices, the L'Acadie River watershed offers a suitable context for the implementation of a living lab aimed at improving the development and adoption of knowledge and technology.

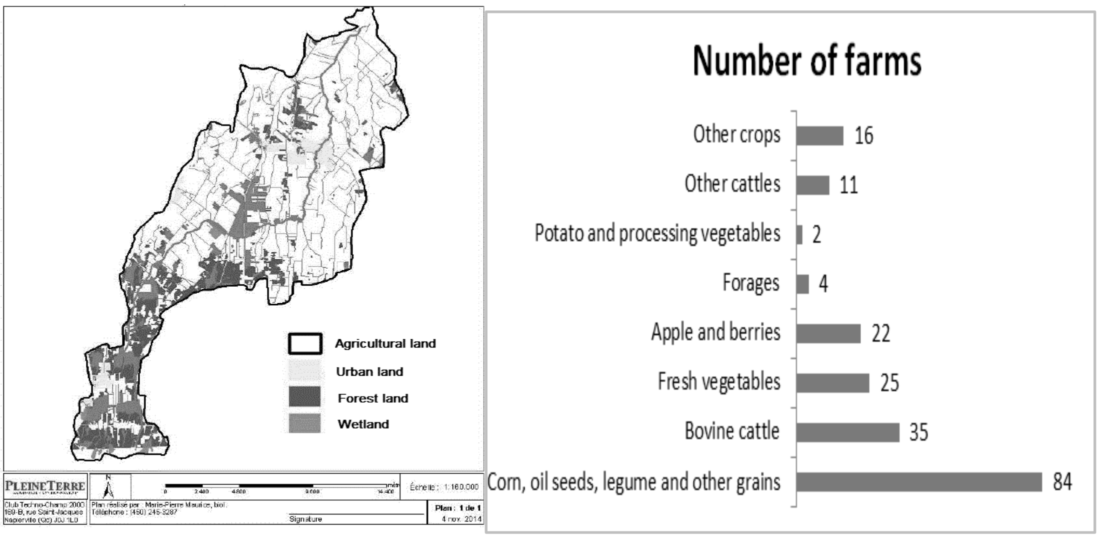

Figure 1. L'Acadie watershed land use and number of farms per category of production

Activities conducted and results achieved in the L'AcadieLab so far

In 2014 to 2015 a series of meetings were held to lay the foundations of collaboration and to identify BMPs to be implemented. Researchers, local partners, community stakeholders and 55 farmers have participated in this start-up and mobilisation phase. Ten BMPs with the potential to maximise the positive environmental benefits of the projects to rehabilitate agricultural systems have been listed and analysed collectively to identify the most promising. It is on this basis that the cycle of co-creation and exploration has been developed. The following paragraphs highlight the gap between the farmers and the researchers' perceptions with regards to the gain and effort pertaining to specific BMPs.

Farmers' perception of the usefulness and credibility of the BMPs
Figure 2 illustrates the evaluation done by local agriculture stakeholders (mainly farmers and agricultural advisors) of the effectiveness of the proposed BMPs. In the opinion of the participants who were invited to evaluate the proposed BMPs, it seems that measures such as the riparian buffers, the two stage channel and the wet-retention ponds are perceived as unattractive measures. These measures require an effort on the part of agricultural producers that is considered to be excessive in relation to their perception of the environmental gain and of the satisfaction of their needs that such measures could produce. On the contrary, integrated pest management, direct seeding and controlled drainage seem to be of proven value in terms of gain. Moreover, SCAN (a tool for optimising fertilisation) and cover plants seem to be less difficult to adopt for the producers. Apart from the evaluation by the local agriculture stakeholders, what we observed was their high capacity to establish a consensus on their perceptions of the potential gains and required efforts associated with each practice.

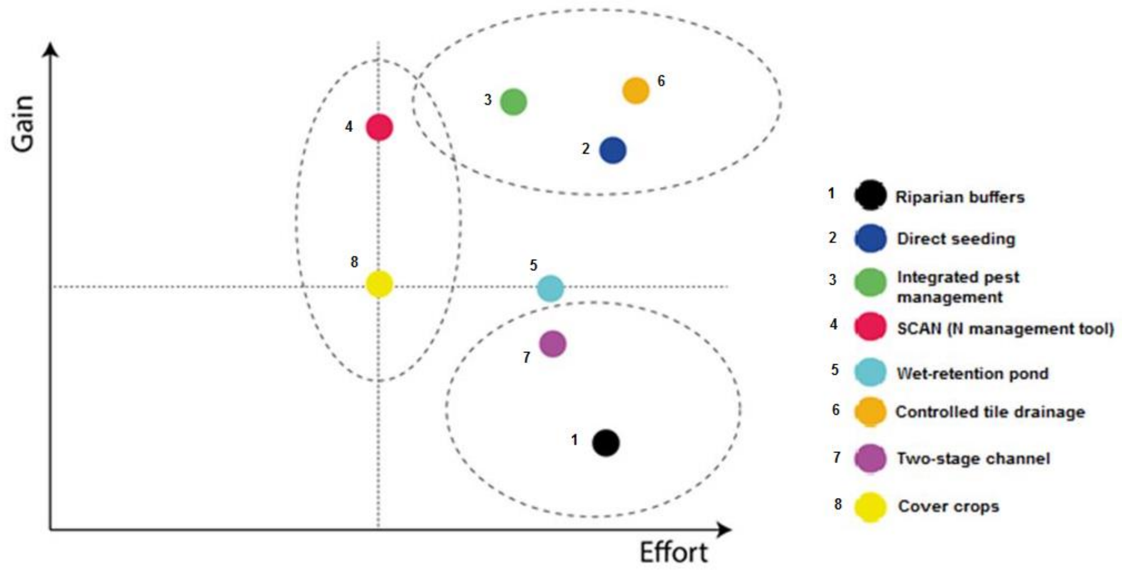

Figure 2. Perceptions of local agriculture stakeholders of the effectiveness of the proposed BMPs. Each point represents the consensus obtained among farmers, agricultural advisors and stakeholders participating in the workshop.

Support of researchers for an open innovation approach: a challenge yet to be met
A similar exercise was carried out with the researchers from different research institutions that could be involved in the future of the L'AcadieLab. In Figure 3 each point represents the vision expressed by one or more researchers. Although the same exercise was proposed to the farmers and researchers, a consensus was not reached within the community of researchers concerning the potential gain and effort that the implementation of the BMPs would require in real conditions.

There is therefore a clear difference of perceptions between the farmers and local stakeholders, and the researchers. For example, the riparian buffer is seen by local participants as a BMP with a low potential gain while the researchers considered that the gains related to the adoption of this measure would be medium to high. To get new knowledge and technology adopted, consistent choices between various practices that interact on a range of spatial and temporal scales have to be proposed to the users and the economic and ecosystem benefits have to be demonstrated. Further information about the BMPs, their usefulness, advantages and drawbacks, and contribution to the sustainability of the farming systems and of the region is needed.

Consequently, even in a collaborative approach are there major challenges that lie ahead if we want farmers to adopt innovative practices stemming from research, including: building the capacity of stakeholders to make consistent choices between various practices that interact on a range of spatial and temporal scales; and establishing methodologies for assessing the economic and ecosystem benefits for farmers and society in adopting new knowledge and technology. In response to these issues, the authors propose the development and use of a participatory modelling approach as a tool for generating the needed knowledge and for sharing the perspectives of researchers, practitioners and farmers on innovative practices to be adopted.

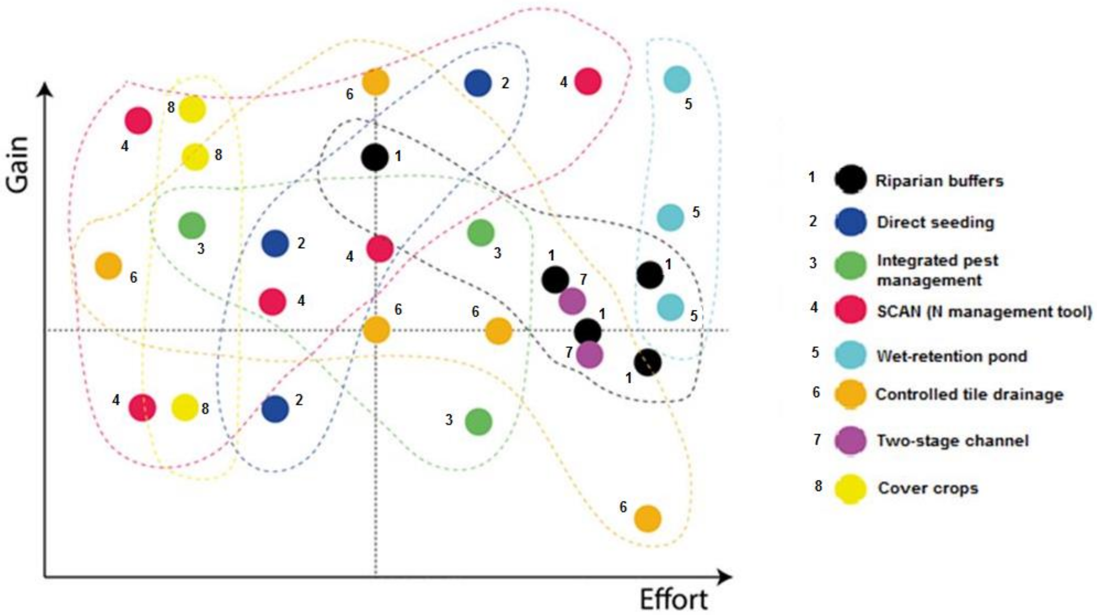

Figure 3. Perception of researchers questioned about the effort and the gain produced by the BMPs. As the researchers did not reach a consensus, their different visions are represented (each vision is represented by a point).

Proposition of a framework for scenario development

Rational

Through the development of participatory modelling, the project team is seeking to address three major scientific and management issues relating to the establishment of the L'AcadieLab and to the BMPs:

- the improvement of the capacity of the stakeholders to make a coherent choice among various scenarios for adopting the BMPs introduced at various spatial scales (parcel, farm, landscape or watershed) and temporal scales (e.g. impact of climate changes, changes in markets;.
- the development of a methodology for evaluating the consequences of adopting these BMPs for the farmer and society, in particular through indicators of sustainability, which will

immediately be used to evaluate the sustainable nature of the systems and modes of production;
- the acquisition of a scientific understanding of how to optimise and quantify ecosystem services as a result of the possible introduction of new knowledge and technology into agricultural systems.

Many methodologies have been developed and implemented to bring together the actors in research and development projects (Bos et al., 2009; Neef & Neubert, 2010). Participatory approaches, in partnership, possibly with the creation of multi-actor platforms, have been imagined and tested for the diagnosis of existing and innovative systems and the co-construction and evaluation of scenarios (Giampietro, 2003; Kok et al., 2007; Etienne, 2011; Meynard et al., 2012; Bewsell, 2013). The farmers and local actors of the L'Acadie River watershed, AAFC researchers and partner institutions will also be closely associated with this work of evaluating innovative systems and formalising possible futures, for at least three reasons:

- the actors in a territory bring knowledge of the biophysical and socioeconomic characteristics of their environment, which are relevant for evaluating agricultural systems (Scoones & Thompson, 1994), and for co-creating innovative systems (Salembier et al., 2015);
- their knowledge can influence the choice of evaluation criteria, and even bring in new criteria and act on the definition of the level of detail necessary for quantifying indicators, so that they will put their trust in the indicators and be able to use them for negotiations or decisions (Delmotte et al., 2016);
- some actors in a territory (for example, agriculture advisors, farmer associations' representatives) have the capacity to make the changes required to improve the economic and environmental performance of the agricultural systems (Martin et al., 2015).

For these reasons, our plan is to use, together with the actors, a diversity of models to design and assist developments of agricultural systems. The simulation models will be used to evaluate the anticipated consequences of the transfer of knowledge and technology and of projected innovation in terms of the sustainability of the agricultural systems and of goods and services offered by the agricultural territory of the L'Acadie River watershed. However, so that the knowledge and technology can be jointly developed and shared with the local actors (e.g. farmers, agriculture advisors, farming and environmental associations), it is appropriate to mobilise them through a participatory approach.

Methodological approach

The project's methodological approach consists of associating the knowledge of the scientists and cropping and farming modelling tools with one or more simulation models of ecosystem services on the territorial scale.

The implementation of the methodology will involve two phases: (i) an initial phase of diagnosis, making use of the farming system sustainability analysis method (the IDEA method – Vilain, 2008), in order to better understand and prioritise the issues that concern the agricultural systems in the region; and (ii) a second phase, more forward-looking, that will use the models to develop and assess scenarios.

Initial diagnosis

In recent decades, many conceptual frameworks have been developed for evaluating the sustainability of agricultural systems on the basis of multi-criteria evaluation (Munda et al., 1994; Lopez Ridaura et al., 2002; Parra-López et al., 2009; Koschke et al., 2012). However, in many cases, these frameworks have a primarily scientific perspective and have not been designed, in terms of field studies operationality, for and with the local actors in agricultural systems. However, some recent studies, in particular in Canada (Bélanger et al., 2012; Thivierge et al., 2014) and in Europe (Delmotte et al., 2016; Sadok et al., 2009; Barbier & Lopez-Ridaura, 2010; Zahm et al., 2015) have proposed methods and tools for adapting these frameworks to particular contexts.

In the first phase of the project it will therefore be appropriate to adapt the existing conceptual frameworks to the situation of the L'Acadie River watershed. To do this the above-mentioned works will be mobilised - in particular the potential of the IDEA method developed in France and of other similar approaches such as the DELTA method (Bélanger et al., 2012; Thivierge et al., 2014) will be analysed. IDEA is a method for diagnosing the sustainability of farming operations that is already operational. Its implementation also encourages thinking about the criteria and indicators of sustainability that must be adapted to the context of the farming operations and of the study region. This method has the advantage of very quickly providing a result for the participating farmer and, by carrying out some diagnosis, to establish a summary diagnosis of the current situation and major issues for the region.

It will therefore be adapted to:

- provide a diagnosis of the current situation, which will be used as a benchmark for comparison with the scenarios where the BMPs would be implemented. This step will also make it possible to complete the existing data on the farming operations, with a view to modelling them;
- reflect collectively on the major issues relating to the sustainability of the agricultural systems of the L'Acadie River watershed that it will be necessary to take into account in the various modelling tools available.

This implementation of a multi-criteria evaluation method will be part of the on-going work in the basin of the L'Acadie River using the participatory approach. This shared diagnosis will therefore be constructed collectively. This approach should help to define the indicators of sustainability to be quantified by models or, as the case may be, to be further developed in a more qualitative way.

Modelling and scenario assessment

In the second phase, the simulation of scenarios for the adoption of practices will provide food for thought for participants in the L'AcadieLab platform concerning the advantages and disadvantages of the various innovations in terms of the sustainability of the systems and the ecosystem services offered by the farming landscape. Workshops will be organised in order to co-construct, with the local actors, scenarios for developing the region's agricultural systems, and for thinking about BMPs and other innovations that could be implemented in the context of these scenarios and the farming operations of the region. The use of modelling will also make it possible to take into account the impact of climate change scenarios on the choice of practices and agricultural systems. Two models will be considered for agricultural systems analysis: STICS (multidisciplinary simulator for standard crops) and IFSM (Integrated Farm

System Model). Moreover a model of ecosystem services will be used at the regional level. The models are described in the next sections.

Modelling agroecosystems at the level of the parcel and the farm

Simulation models of agroecosystems are particularly useful tools for evaluating the impact of agricultural practices and climate changes on the operation and performance of agricultural systems, and thus for supporting decision-making at the farm level. These models operate on different spatial scales, from the individual agricultural field to the whole farm or watershed. The crop model STICS (Simulateur mulTIdisciplinaire pour les Cultures Standard [multidisciplinary simulator for standard crops]) simulates the growth of plants and the carbon, nitrogen and water balances of a field (Brisson et al., 1998; 2008), taking into consideration the interactions among the different modes of crop management, the soils' properties and the climate. This model has recently been calibrated and validated to simulate growth of several field crops in Canada (spring wheat, corn and soybean in particular) and more particularly in the Montérégie (Jégo et al., 2010, 2011). STICS has also been coupled with a snow cover simulation model (Jégo et al., 2014) in order to improve prediction of water and nitrogen balances in fields under the climatic conditions of Eastern Canada (short growing season and long snow cover period).

On a larger spatial scale, the IFSM model (Integrated Farm System Model; Rotz et al., 2015) has also been recently adapted to simulate the growth of the main perennial and annual crops used in Eastern Canada (Jégo et al., 2015). This model allows simulation of the agronomic (productions), economic and environmental (water, nitrogen, carbon and phosphorus) balances of a farm. Several dairy farms representative of three regions of Canada (including two in Quebec) were defined in the model in a previous project. Although the IFSM was initially developed to simulate the operation of dairy farms, the most recent versions of the model also make it possible to simulate the farms involved only in producing field crops, which are present in the northern part of the L'Acadie watershed.

Modelling ecosystem services

Evaluating the consequences of developing innovations on the scale of a farming landscape or watershed makes it possible to take into account sustainability issues other than those evaluated at the level of the field and individual farm (Mitchell et al., 2015). Some aspects of the impact of agriculture on the environment can only be measured and quantified at these scales. The concepts of ecosystem services aim to evaluate the benefits derived from the operation of the ecosystems. Use of these concepts in connection with agricultural systems is recent and is now the subject of many pieces of research work, which aim in particular to produce the tools required to quantify these ecosystem services (Dupras et al., 2013). A model was developed to allow evaluation of ecological services at the level of the territory (Mitchell et al., 2015). This model makes it possible to evaluate, in addition to supply services (agricultural production, forest production), regulation services such as pollination, the natural regulations of the predators of crops, the quality of water or storage of carbon in forests, and also such sociocultural services as the aesthetic quality of the landscape or the region's farm tourism potential. This model has been developed for the territory of la Vallée du Richelieu (RCM), which is geographically a very close neighbour to the watershed of the L'Acadie River. This RCM has characteristics that are very similar in terms of land use to those observed in the L'Acadie River. It will thus be possible to use this model in connection with the project to support decision-making for the adoption of BMPs and production systems.

Conclusion

An open innovation platform, the “L'Acadie-Lab” living laboratory, was instigated in 2014 by an interactive community of agricultural producers, practitioners and researchers to increase the adoption of beneficial management practices (BMPs) in the L'Acadie River watershed, in southern Quebec, Canada. A gap has been observed between farmers’ expectations in terms of economic and ecosystem benefits of BMPs and research organisations' ability to provide a consistent array of practices that interact on a range of spatial and temporal scales. In response to these issues, the authors propose the development and use of a participatory modelling approach as a tool for sharing the perspectives of researchers, practitioners and farmers on innovative practices to be adopted. The approach links the knowledge of researchers and certain modelling tools at the plot level or the farm level with ecosystem services simulation models at the landscape level to produce quantitative or semi-quantitative results. Simulation models will be used to evaluate the anticipated consequences of the transfer of knowledge and technology and of projected innovation in terms of the sustainability of the agricultural systems and of goods and services offered by the agricultural territory of the L'Acadie River watershed. Farmers and advisors will be mobilised through a participatory approach and will play a special role in defining the scenarios to be simulated to ensure that their situations and concerns are reflected and to increase their commitment to innovation.

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Just-in-case to justified irrigation: applying co-innovation principles to irrigation water management

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Abstract: A pilot study using a co-innovation approach to identify the opportunities to improved irrigation management is underway in five farms in an irrigation scheme in New Zealand. Through a process of co-learning, a group of on-farm and off-farm stakeholders defined the problem of on-farm water use efficiency and developed solutions to enhance farmers' ability, desire and capacity to adopt improved irrigation practices. To enable informed decision-making, participants were supplied with current soil water demand (measured on farm) and 2 to 15 day rainfall forecasts as a daily email update. We conducted several one-on-one formal/informal meetings and annual workshops with stakeholders to evaluate the farmers' ability to integrate the updates into their current irrigation practices. Some of the key learnings are: (i) on-farm irrigation decisions are influenced by on-farm and off-farm hydrological, climatic, infrastructural and regulatory factors, thus we need to develop a wider view on irrigation management; (ii) for successful uptake, it is important to understand the external stimulants that, directly and indirectly, conflict or align with proposed practice changes;(iii) introduction of stakeholders with conflicting perspectives needs to be carefully managed; (iv) with co-learning, project objectives continuously evolve in response to ongoing monitoring, review and reflection on the processes, thus it is important to build flexibility into the implementation pathway; and (v) when scaling up from five farms to the wider irrigation scheme, opportunities such as collective learning and reflection at end-user focused workshops may become more challenging owing to stakeholder size, thus other co-learning opportunities need to be identified.

Keywords: Irrigation, co-innovation, co-learning, stakeholder management, agricultural innovation system, water use efficiency.

Introduction

The limitations of science-driven technology transfer approaches in which agricultural innovation is seen as a linear process of development, dissemination and adoption become apparent in the context of complex or 'wicked' problems (Botha et al., 2014; Klerkx et al., 2012; Leeuwis & Aarts, 2011; Smits, 2002; Rittel & Webber, 1973). This lack of success has been attributed to their insufficient attention to multi-actor processes and perspectives, lack of acknowledgement of non-scientific knowledge and not viewing innovation as a combination of technical, social, economic and institutional changes (Turner et al., 2016; Klerkx et al., 2012; Leeuwis & Aarts, 2011; Smits, 2002). Agricultural Innovation System (AIS) addresses these limitations by arguing for a holistic, transdisciplinary, multi-stakeholder approach that encourages participants to collectively identify and address problems and instigate technical, social and market changes (Botha et al., 2014; Klerkx et al., 2012).

Irrigation management in New Zealand (NZ) presents a case study for a complex problem in need of a systems approach such as AIS. On-farm irrigation management in NZ is influenced by several layers of technical, hydrological, climatic, societal, environmental, economic, regulatory and cultural factors, which individually and collectively impose controls and constraints on farmers' ability and desire to adopt efficient irrigation practices. IrrigationNZ, an industry body for irrigators in NZ, forecasts that irrigation in this country will expand from the current 0.75 million hectares (ha) to 1 million ha by 2025, and urges the need for developing validated irrigation practices and tools that will enable farmers to become 'water-wise' (IrrigationNZ, 2016). They indicate that current irrigation efficiency can be improved by as much as 20% through improved irrigation practices. Historically, there has been limited success with technology transfer of irrigation management tools and practices. Uptake of technology such as soil moisture sensing to schedule irrigation has been stagnant over the last three decades (Davoren, 2015, HydroServices; personal communication), though the area under irrigation has been doubling every twelve years since 1970 (IrrigationNZ, 2016). Previous technology transfer approaches have tended to be farm specific, ignoring wider issues to water management such as water limits, multiple water users and community aspirations for improved water use efficiency (WUE). Here we define WUE as scheduling irrigations by taking account of current soil water demand and forecast rainfall.

Theory on learning through co-innovation

The AIS perspective promotes multi-actor processes to explore technological, social and structural needs and visions; to build trust, to agree on working procedures and to foster capacity building, learning and (intellectual) resource management (Klerkx et al., 2012; Leeuwis & Aarts, 2011; Botha et al., 2014). Stakeholder engagement has been associated with benefits such as increased knowledge, insights, experiences, networks, resources and creativity, improved 'ownership' of the innovation, empowerment and improved livelihoods, and a way of legitimising research and innovation projects (Leeuwis, 2004). However, it can also present challenges in terms of rules to be followed, resources required, power relations and political agendas (Leeuwis, 2004; Schut et al., 2014). Taking into consideration the context-specific nature of successful co-innovation (Neef & Neubert, 2011), the irrigation WUE case study is built on nine co-innovation principles, adapted from Nederlof et al. (2011), and described in detail in Coutts et al. (2016).

In this paper, our objective is to highlight the key learnings from applying a co-innovation approach to improving WUE on NZ farms. We have linked these learnings to the nine, adapted co-innovation principles. Through the use of co-learning we identified opportunities and barriers to improve the uptake of previously poorly used irrigation management tools and practices. Although existing literature provides relevant insights, "learning by doing remains essential in operationalising co-innovation" (Botha et al., 2014, p. 219). Accordingly, this paper provides insight into the implications of applying co-innovation principles in an irrigation case study in NZ. Considering the length of the paper, we have limited ourselves to the co-learning among the stakeholders and have not included any of the biophysical data collected during the study.

The project

The five-year duration WUE study was initiated in 2012 in the Waimakariri Irrigation Scheme (WIS), a run-of-the-river irrigation scheme located north of Christchurch, South Island, NZ. In this scheme irrigation practices are strongly influenced by the reliability of river flows which are currently at about 74% (Walton, 2015; WIS Executive Manager, personal communication).

Irrigators tend to use a 'just-in-case' approach where irrigations are applied whenever supply is available, even when demand is low. Very few farmers use the alternative practice, deficit irrigation, which is a 'just-in-time' approach where irrigation is scheduled based on water demand, rather than supply.

The project was based on the premise that a proactive irrigation management that matches current irrigation demands against forecasted (2-6 days) rainfall would lead to desirable economic and environmental outcomes for farmers and wider society. Accordingly, the project researchers aimed to support study farmers in their irrigation decisions by providing them with customised information on current demand (measured soil moisture) and forecast rainfall. This pilot study was focused on five farms (four dairy/one cropping) within WIS. They were selected because of their enthusiasm for the project and current (significant) water use. The farms are geographically scattered across the irrigation scheme (5-15 km apart from each other), and have varying soil types (varying soil water holding capacities to support crop growth), rainfall supplies and evaporative demands, and thus varying irrigation demands. Each farm was equipped with a soil moisture sensor that measured soil moisture (a proxy to irrigation demand) at 20 cm depth and a rain gauge that measured irrigation and rainfall. Data were recorded at 10 minute intervals and shared with participating farmers via a daily email. Farmers were also given 24/7 access to real-time soil moisture, rainfall and irrigation data via a secure, customised website. Additionally, farmers were provided with 2-, 6- and 15-day weather forecasts that included rainfall, air temperature, relative humidity and wind speed and direction, enabling them to schedule irrigations based on forecast rainfall. These data were included in the daily email update. To encourage a collective approach study farmers were provided with access to data from all pilot farms which enabled them to compare their conditions and practices against others as well as make useful observations of others' practices.

Methodology

Data collection

Individual meetings with pilot study farmers took place periodically during the irrigation season (September – April) to explore current irrigation practices, to provide training on data interpretation and irrigation scheduling, and to gain feedback on the project and support provided by researchers. Several formal and informal one-on-one meetings, email communications and telephone conversations took place with other stakeholders (irrigation scheme manager, researchers, regional regulatory authority, local catchment committee and local and national government officials) to involve them in the project and to obtain more information on links between on-farm water management and wider water management policies, strategies and perceptions. At the end of each irrigation season a workshop was held to debrief on the season just finished and to plan ahead for the season ahead, with participation of pilot farmers, scheme managers, irrigation professionals, regional councils (local government bodies tasked with regulating environmental resources and outcomes) and researchers. Workshop discussions aimed to (i) develop a shared understanding of WUE and solutions, (ii) guide the development and uptake of irrigation management tools, practices and processes and (iii) discuss the benefits, risks, barriers and opportunities of using a weather-based irrigation management. Feedback from workshops was used to review and refocus the process and information being generated and sought. To date, three such workshops have been held: Workshop 1 in May 2013; Workshop 2 in May 2014; and Workshop 3 in May 2015. Each of these workshops have been held in the WIS; firstly at one of the pilot farms, then moving to a local hall as the size of the stakeholder group grew. Workshop 1 was attended by pilot study farmers, irrigation scheme managers and researchers. In addition to workshop 1 attendees, workshop 2 was attended by the regional council and members of the local catchment management committee who advise the regional council on resource management. In addition to workshop 2 attendees, workshop 3 participants included farmers from WIS but not currently part of the project, managers from neighbouring irrigation schemes and the project funders.

There were a range of data collection points within the project. Each interaction, whether individually based or in a workshop setting, provided opportunities to obtain rich descriptive data, capturing individual and collective decision making, individual and collective reaction to information and the co-innovation processes being used. During the irrigation season individual discussions with farmers and other stakeholders were recorded in the form of notes and narratives to determine management changes, training needs and the usefulness of the co-innovation approach. At the end of each workshop a feedback sheet was used to collect data on each participant's response to the workshop. In February 2016 the project leader and the reflexive monitor reflected on the first 4 years (December 2012 – February 2016) of the project.

The biophysical data on rainfall, irrigation and soil moisture conditions present a record of the irrigation practices of each participant (i.e. when and how much irrigation was applied) during the season. These data were thus used at the workshops as a launching pad to initiate a discussion among stakeholders around examining the barriers and opportunities to changing irrigation practices.

Results

In this section we highlight three prominent learnings from the project that distinguish the co-innovation approach from the conventional technology transfer approach used to disseminate irrigation tools and practices in the past. These learnings were derived from a review of the biophysical data and reflection on processes and practices by stakeholders at the one-on-one meetings and annual workshops.

Lesson 1: broadening the context of the initial project into an innovation space

The primary aim of the study was to improve irrigation WUE in the pilot farms through the use of weather forecast based irrigation practices. As opposed to the 'just-in-case' and 'just-in-time' irrigation practices described earlier, we term this 'justified irrigation' as the irrigations are justified based on current soil water demand and forecast supplies (rainfall). To ensure the problem defined and solutions identified are consistent and fit with the perspectives of the wider stakeholder community that is relevant to water management, we involved both on-farm and off-farm stakeholders in the co-innovation process. In this way we conceptualised an irrigation landscape that extended far wider than the farm (see Figure 1). Through stakeholder interactions we mapped the controls, barriers, constraints and opportunities to irrigation management in NZ farms.

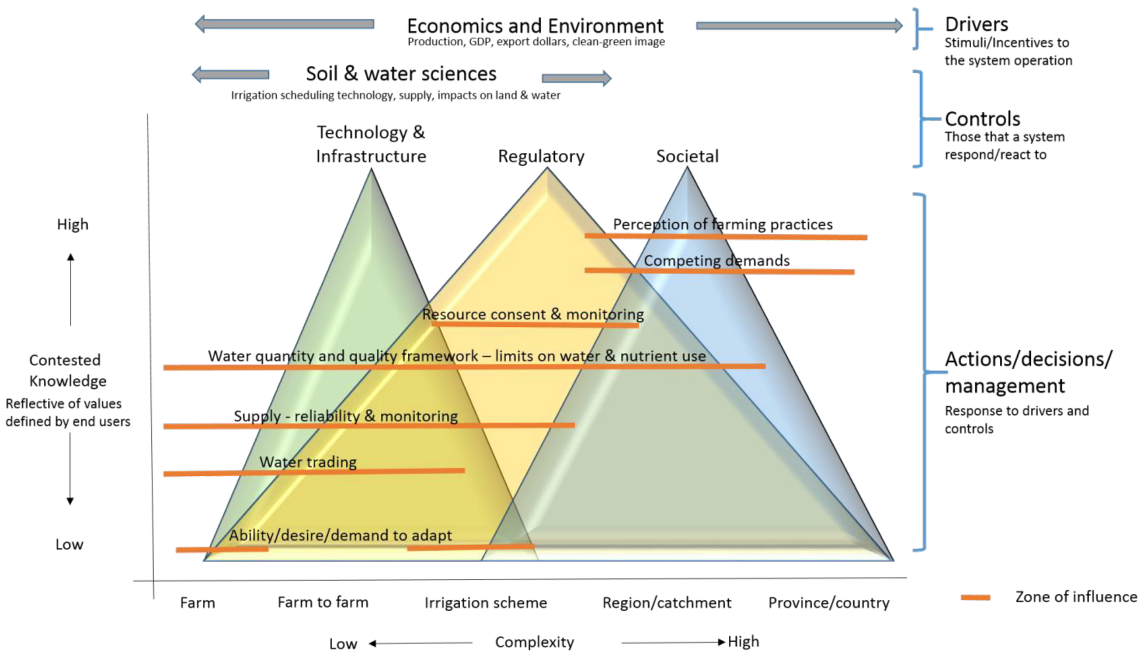

Figure 1. An overview of on-farm irrigation water management landscape in New Zealand, developed as context for the water use efficiency study being undertaken in the Waimakariri Irrigation Scheme (*adapted from Srinivasan et al., 2015*).

While an individual irrigation event may appear to be a stand-alone on-farm activity, the ability of farmers to implement it efficiently relies on several factors – from on-farm infrastructure to scheme and regional scale controls shown in Figure 1. These factors were identified at various stakeholder meetings and workshops. On the farm, the ability of a farmer to efficiently manage irrigation practices is primarily reliant on the availability of suitable irrigation infrastructure, access to a reliable water supply, accurate knowledge of soil properties, crop irrigation demands and access to a reliable weather forecast. Between farms, additional issues such as water trading and dynamic resource consenting rules (rules that control water abstraction and use) may influence irrigation decisions. At the irrigation scheme level the efficiency of on-farm irrigations can be influenced by environmental limits placed on nutrient losses and water use, and the ability of schemes to reliably reticulate water to meet user demands.

At scheme, catchment and regional levels, water quantity and quality limits on resource use dictate irrigation practices. While catchment and regional-scale controls may not impact on-farm individual irrigation decisions, they can affect irrigation practice as a whole. With increasing intensity of irrigation the risk of contamination of groundwater or surface water also increases. In some areas of NZ deterioration of water quality is already apparent (Environment Canterbury, 2016a). Therefore nutrient management has also become the domain of national and regional government and regulatory frameworks are currently under development. In Canterbury, the location of this project, water take consents have a number of environmental conditions attached to them. These include (or are about to if not already), improved WUE and farm nutrient management plan requirements and self-audited management of water quality.

At regional and national levels, public perceptions about irrigation and the demands of competing users (including those expanding irrigation), influence irrigation practices. The clean-green image projected by the tourism industry often clashes with agricultural intensification, as the latter is perceived as polluting the clean-green environment. A recent example of such a clash can be found at RNZ (2016).

At the national level, the science knowledge available to make informed decisions, linking cause and effect, becomes limited. For example, at farm scale, lysimeters that measure irrigation-drainage are used to link over-irrigation to the loss of water and nutrients below root zone. However, relating the impact of over-irrigation and the resulting drainage and nutrient loss at one farm, to wider catchment and regional scale water quantity and quality, is challenging. The contestability of science knowledge is very high at these large scales.

In essence, irrigation decisions and investments are made on-farm, but are informed and constrained by the wider system in which they fit. Hence, to be successful, on-farm irrigation solutions must encompass and represent the wider system, along with the constraints and opportunities it presents. Also, the solutions developed and the resulting effect of these solutions on WUE and irrigation practices should be demonstrable to both on-farm and off-farm stakeholders. This highlights the relevance of one of the nine co-innovation principles, "be aware of the wider context".

The knowledge of the wider irrigation landscape has been very useful in including and responding to external stimulants to improve irrigation in NZ, e.g. IrrigationNZ has adopted an 80% beneficial use performance target for irrigation (IrrigationNZ, 2016). Similarly, the Sustainable Dairying Water Accord requires irrigation systems to be designed and operated to minimise the amount of water needed to meet production objectives (DairyNZ, 2016). The regional regulating authority in the pilot region, Environment Canterbury (a member of the stakeholder community), have designed a Matrix of Good Management, a set of recommendations to improve irrigation and nutrient management in the region (Environment Canterbury, 2016b), which is to be implemented in 2017 under the National Policy Statement on Freshwater described in Snelder et al. (2014).

Lesson 2: learn from each other and be flexible and adaptive when implementing co-innovation

Co-learning has been central to the study. All stakeholders - researchers, irrigation scheme managers and pilot study farmers - have been learning from interactions and through reflection on on-farm biophysical data and observations. Biophysical data provide a 'stake-in-the-ground' for discussion at the workshops and enable a means of understanding the decision making on- farm, as well as how the decision making at a scheme or region level has an impact on decisions on-farm.

Researchers co-learning with farmers

The project was originally aimed at assisting farmers in scheduling irrigations based on current irrigation demand and forecast weather. However, researchers have adapted the information provided throughout the project as they have learnt from other perspectives represented. For example, at the start of the project a soil moisture sensor was installed at 20 cm below surface (coinciding midway to 40 cm root zone) so that soil moisture conditions could be measured and irrigations could be scheduled accordingly. However, interactions at Workshop 1 indicated that drainage resulting from over-irrigation (applying more water than the top soils can hold) and poorly-timed irrigations (irrigating before a rainfall event or when soil moisture is high) was important, as the regional authority have been mandating farmers to store as much as 80% of applied irrigation in the soil and allow only 20% of irrigation as drainage. However, farmers were given no specific procedure or tool to measure irrigation-drainage, nor were any practices recommended to prevent drainage. At Workshop 2 the discussion thus focused on drainage estimation to enable stakeholders to understand the process and ways of preventing irrigation "wasted" as drainage. At that workshop, farmers also expressed interest in knowing the monetary value of their drainage, which became the theme of Workshop 3. We chose, for every hectare of irrigated land, an arbitrary monetary value of $1.50 per mm of rainfall-drainage and $2 per mm of irrigation-drainage. At Workshop 3, we presented these numbers to the stakeholders and there was a general agreement that these numbers were reflective of actual numbers. Cumulated at farm scale, the monetary benefits proved substantial. At Workshop 3 researchers and stakeholders sought tools that could allow monitoring and managing irrigation and drainage together in real time. At Workshop 3, researchers introduced the use of a profile soil moisture sensor in place of a single point soil moisture sensor used at 20 cm depth. The profile soil moisture sensor measures soil moisture at eight depths along the soil profile (i.e. every 10 cm interval over the top 80 cm soil profile). This has enabled researchers to provide farmers with information on irrigation demand and drainage at the same time. Farmers could schedule their irrigations using the soil moisture at the top 20 cm and monitor the drainage by reviewing the soil moisture levels at 80 cm depth following the irrigation. Pilot study farmers were given real-time, 24/7 online access to these data and were individually trained in December 2015 and January 2016 to use the new data to schedule irrigation.

Irrigation scheme manager co-learning with farmers

The weather forecast that the farmers receive via daily email update provides 2-, 6- and 15-day weather forecast (rainfall, temperature, humidity and wind speed and direction). Because of the unique weather conditions of NZ, it is generally considered that any forecasts past 48 hours are less reliable and often changeable over a very short period of time (hours). Following the first year of this project, the irrigation scheme took notice of the accuracy of 2-day weather forecasts and reduced their irrigation water request lead time from 48 to 9 hours. This allowed the pilot study farmers to use the best weather forecast available when ordering their irrigation water from the irrigation scheme.

Farmers co-learning with other farmers and researchers

At Workshop 1, when farmers were queried on their use of weather forecasts, the general response was that forecasts were important at the start and end of the irrigation season ("shoulder season") and were less important during the peak season when irrigations are applied regularly and frequently with no regard to weather forecast or demand (a 'just-in-case' irrigation practice). At Workshop 3, after collecting data for over three years and observing farmers' behaviour, the researchers presented biophysical data that showed evidence for substantial irrigation-drainage during the peak season, most of which resulted from untimely irrigations (e.g., irrigation on previously wet soil, irrigation immediately preceding a rainfall event) and the complete absence of irrigation-drainage during the shoulder season. This information provided an opportunity for farmers to reflect on their irrigation decisions and decide whether it was appropriate to change their irrigation management during peak season. In December 2015, during a one-to-one meeting with a pilot study farmer, he indicated that based on the data supplied in the project he had skipped a few irrigations even when his neighbours continued to irrigate. This suggests that reflection on practices in this case actually influenced behaviour to some extent. This also reflects the co-innovation principle regarding flexibility. One of the key drivers of irrigation decisions during peak season is poor reliability of supplies. This has not changed over the course of the project so farmers may not wish to change their irrigation practices, even though they have been shown that irrigation-drainage occurred during the peak season. However, with the new profile soil moisture probe they have an option to reconsider the amount of irrigation applied.

Lesson 3: network development and increased engagement with co-innovation

Over the course of the project a network of farmers and other stakeholders has been built within the irrigation scheme through the provision of the daily emails. At the beginning of the project in December 2012 the daily update was sent to the farm owners/managers of the five pilot study farms. The daily update is now being sent to 25 individuals every day and each recipient can see the irrigation practice occurring at every pilot study farm. All the recent additions to the list were made on the request of recipients. As the pilot study farmers share their experience with their neighbours and peers at informal gatherings, the daily updates have gained more recipients.

In addition, over the course of the three workshops more people have been added to the network, contributing knowledge and experience; for example, an exchange in workshop 2 where one pilot study farmer with 20 years of farming experience, shared with another his experience with managing soil drainage, saying "*if you keep growing grass longer, drainage will decrease because increased organic matter leads to increased water retention/storage*". The workshops have helped to develop an understanding of the irrigation management issue and built trust amongst the project participants. The workshops have also been a forum for hearing, sharing and understanding multiple views on water management. The trust that has been built during the process has enabled additional stakeholders to be bought into the project, particularly representatives from the regional council.

Discussion

The co-innovation process has been leading to significant learning and observable irrigation practice changes among the stakeholders. Changes in irrigation scheduling from the start to date, as well as changes in the project focus and description, are evidence of these changes. Widening the stakeholder community to include both on-farm and off-farm stakeholders allowed us to understand the scope and complexity of on-farm irrigation decisions and to identify structures and external stimulants and controls that influence WUE at farm scale. These observations correspond to those reported in van Mierlo et al. (2013) on the application of an innovation system perspective in Dutch poultry subsectors, and reaffirms the importance of acknowledging the multi-level and multidisciplinary character of innovation highlighted by other researchers (e.g. Turner et al., 2016; Geels, 2002; Smits, 2002). The presence of regional council representatives (Environment Canterbury) at Workshops 2 and 3 provided legitimacy to the irrigation practice among the end-users, through recognition of the environmental benefits of their practices and was reinforced through further initiatives by councils to request presentations about the project to other regional water management groups. However, such inclusions had to be done very carefully; being mindful of contrasting and conflicting ideas is considered integral to stakeholder participation (Neef & Neubert, 2011; Cornwall, 2008; Leeuwis, 2004). We did not introduce the regulatory authority as a stakeholder at Workshop 1, because sufficient trust first needed to be established between researchers, the pilot study farmers and the wider irrigation scheme. Our experiences correspond to those reported by Schut et al. (2014) who emphasised the need for context-sensitive research strategies in competing claims situations. Hence, much attention was paid to decide on the right moment and time of involvement and potential side effects of research actions.

The co-innovation process also saw changes, mainly resulting from reflexivity, to the roles of the researchers and other stakeholders. Stakeholders continually reflected on the process and pathways towards system change, and this led to changes in roles. Researchers moved between being a fully independent science knowledge holder and supplier in a technology transfer approach to, with co-innovation, donning the roles of broker and facilitator. The relationship between researchers and other stakeholders moved beyond informative to co-learning and capacity building. Such transitions have been described by Schut et al. (2014) as changes in dynamics of boundary arrangements at the researcher-stakeholder interface. This mandated a reconceptualisation of researcher roles towards knowledge co-creation, network building, brokerage and entrepreneurial activities, roles that have been observed in other similar studies (Hermans et al., 2013; Klerkx et al., 2012; Wieczorek & Hekkert, 2012; Leeuwis & Aarts, 2011). Similarly the pilot farmers, by having conversations with other farmers in the scheme, enhanced the dissemination of the WUE message.

Use of co-innovation meant that the stakeholders needed to remain flexible in their practices as well as perception of problem and process. Project objectives were continuously revised in response to ongoing monitoring, evaluation and reflection on the processes in the workshops. This captures elements of reflexive monitoring, as outlined in van Mierlo et al. (2010). During the course of the project the definition of WUE expanded from water quantity management (irrigating the right amount at the right time) to water quantity and quality management (irrigating the right amount at the right time and minimising drainage and associated nutrient loss from root zone). This broadened the scope and focus of the project. Our findings support previous work from Leeuwis & Aarts (2011) and van Mierlo et al. (2010) who argued that project flexibility can foster collective identification and utilisation of “perceived windows of opportunity”, which increases the potential to reach what Röling (2009) refers to as “science-for-impact”.

As a part of the pilot study the recipients of daily email updates are allowed access to biophysical data from the participating farms. Discussions during the workshops indicated that farmers, in addition to the data from their own farm, frequently took notice and interest in irrigation activities occurring at other farms, which helped with co-learning among farmers. However, as we scale up from pilot farms to wider irrigation schemes and beyond, such a ‘shared-data’ approach may become less practical, potentially hampering the learning among the stakeholders. It would be interesting to explore how this potential co-learning and self-organisation can be sustained within the increased complexity associated with scaling up and out, as has been identified by Hermans et al. (2013) and others.

Conclusions

The co-innovation process reinforces that decisions, controls and drivers for on-farm water use and management intersects with the values and perspectives of off-farm stakeholders, particularly those linked to environment, economy and regulations. The co-innovation process has helped researchers to develop a wider view of the complex problem of WUE, which is a significant shift from the technology transfer approach. This wider view of the system has allowed researchers to effectively respond to the impacts of external stimulants that influence water use on farms. Because of the on-going learning that occurs during the co-innovation process, stakeholders have to be flexible enough to adapt to the information provided and respond accordingly. Within the irrigation scheme, farmers and the scheme managers are responding to the daily updates provided by changing their irrigation behaviour and practice, both on-farm and at the scheme levels. Stakeholders involved in the project recognised the need to manage water better and are engaged in learning about WUE. Some of the learnings could not be immediately put into practice however owing to external factors (e.g. farmers inability to reduce irrigation frequency and the resulting irrigation drainage during peak irrigation season owing to poor supply reliability). Such learning highlights the importance of capacity building as part of innovation and the innovation process.

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Triggering system innovation in agricultural innovation systems: initial insights from a Community for Change in New Zealand

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Abstract: The ability of actors to co-innovate is influenced by how Agricultural Innovation Systems (AIS) are structured, with systemic problems related to the absence or weakness of structural elements. To create structural change, the causes of interconnected systemic problems need to be dealt with by addressing underpinning institutional logics; so called system innovation. This requires active engagement with potential change agents, with potentially conflicting perspectives about the underpinning institutional logics. This paper describes a process for stimulating this engagement to develop a shared understanding of systemic problems, challenge prevalent institutional logics and identify individual and collective actions that change agents might undertake to stimulate system innovation. To achieve this the process included (i) multiple actors from the AIS, (ii) steps to prompt reflexivity to challenge underlying institutional logics, (iii) an iterative process of practical experimentation to challenge current practices, and (iv) actions to encourage generative collaboration. Problem structuring was used to support potential change agents to develop a shared understanding of three systemic problems and understand the role that inter-relationships, perspectives and boundaries play in reinforcing or destabilising current practices and institutional logics. There is early evidence that involving multiple actors from the AIS in challenging underlying institutional logics and encouraging generative collaboration is stimulating project-level actions and recognition of wider AIS barriers and opportunities. This confirms the benefits of collective system analyses for identifying and addressing structural changes and extends this to potential for system innovation of the AIS. A challenge still to be addressed is how to simultaneously resolve innovation project-level actions with AIS-level actions.

Keywords: System innovation, agricultural Innovation systems, problem structuring, reflexivity, soft systems methodology

Introduction

In response to earlier identified shortcomings of a science-driven, linear, technology transfer approach to innovation in New Zealand (Davenport et al., 2003; Leitch & Davenport, 2005; Morriss et al., 2006; Ministry for Primary Industries, 2013; Turner et al., 2014, 2016), there is interest in bringing together relevant actors from the primary sector to increase innovation in a coordinated and interactive fashion through co-innovation (Dogliotti et al., 2014; Hall et al., 2001; Klerkx et al., 2012). However, the ability of actors to co-innovate is influenced by the structural composition of the Agricultural Innovation System (AIS); the presence of actors, their interactions, the institutions that influence their behaviour, and supportive physical, financial and knowledge infrastructure and incentives (Klein-Woolthuis et al., 2005; Nettle et al., 2013; Wieczorek & Hekkert, 2012).

Often systemic problems are related to the absence or weakness of these structures (Wieczorek & Hekkert, 2012). To address this, policies that pro-actively stimulate and support co-innovation at the systems level are needed (Wieczorek & Hekkert, 2012). Many countries, including New Zealand, have yet to fully embed such policies (Friederichsen et al., 2013; Minh et al., 2014; Nettle et al., 2013; Schut et al., 2015; Turner et al., 2016) by addressing the institutional logics underpinning systemic problems (Kivimaa & Kern, 2016; Fuenfschilling & Truffer, 2013; Turner et al., 2016). Institutional logics are "the socially constructed, historical patterns of material practices, assumptions, values, beliefs and rules by which individuals produce and reproduce their material subsistence, organise time and space and provide meaning to their social reality" (Thornton & Ocasio, 1999: p. 804). For example, in the New Zealand AIS science-centred innovation focused on revenue generation from science-driven knowledge development is a prevalent blending of science and commercial institutional logics. This is attributed to public sector reforms in the 1990s when the Government invested in science to support policies pursuing economic goals to increase the relevance of knowledge development for innovation (Turner et al., 2016).

Some authors (e.g. Borrás, 2011; Leitch et al., 2014) argue that innovation policy learning therefore needs to make visible these underpinning institutional logics in order to generate new analyses and potential solutions for systemic problems that have proven difficult to resolve. Research on system innovation (e.g. Fischer et al., 2012) has shown this requires active engagement with potential change agents, such as policy makers, researchers and industry leaders, who may hold different and potentially conflicting perspectives about broader systemic problems and underpinning institutional logics (Beers et al., 2015; Turner et al., 2016). This engagement would seek to develop a shared understanding of systemic problems, challenge prevalent institutional logics, and identify actions that potential change agents might individually and collectively undertake to bring about system innovation in the AIS.

The aim of this paper is to describe a process for achieving this using key systemic problems and their underlying institutional logics to stimulate dialogue, formation and ongoing interaction among actors, in what we refer to as Communities for Change. The activity described in this paper is part of a large Government-funded programme, Primary Innovation, that seeks to facilitate change in the New Zealand AIS to effectively support co-innovation in the primary sector (Botha et al., 2014). Our contribution to the literature on AIS is addressing a challenge identified by Turner et al. (2016) – that of developing interventions in the AIS in order to institutionalise policies to stimulate co-innovation (Howells & Edler, 2011).

The paper is organised as follows: the next section provides a description of the methods used to implement system innovation of the New Zealand AIS; the following section presents results so far from the initial stages of the formation and ongoing interaction among Communities for Change around key systemic problems, and we conclude the paper with a discussion of the main insights on potential for triggering system innovation in AIS.

Methodology

The aim of the process described here was to actively engage a diverse and distributed Community for Change in reflexive policy learning to collectively challenge and address institutional logics underpinning AIS-level systemic problems. To achieve this, a collaborative process was designed with four elements (Table 1).

Table 1. Elements guiding the design of the process for triggering system innovation derived from AIS and system innovation literature

Element	Rationale for the element	References
Include multiple actors from the AIS	To engage and motivate multiple actors in maintaining a strategic focus on systemic problems relevant to them and wider structural change in the AIS. This encouraged the inclusion of a heterogeneous group of actors from multiple sectors: Government, research organisations, industry, farmers and growers	Amankwah et al., 2012; Gildemacher et al., 2009; Hermans et al., 2015; Totin et al., 2012
Support reflexivity to challenge underlying institutional logics	To support reflexivity by actors on underlying institutional logics regarding systemic problems and potential solutions	Arkesteijn et al., 2015; van Mierlo et al., 2010; Kivimaa & Kern, 2016
Encourage an iterative process of practical experimentation that challenges current practices and supports systemic changes	To encourage an iterative process of practical experimentation that challenges current practices and supports systemic changes, by encouraging innovative actions that may prove useful in bringing about systemic change. This enables: (i) a process that is flexible enough to respond to new understanding of the systemic problem and potential systemic instruments; (ii) the seizing of new opportunities as they emerge; and (iii) the development of solutions that are better tailored to the systemic problems	Smart et al., 2007; Douthwaite et al., 2002; Hueske et al., 2014; Klerkx et al., 2010; Beers et al., 2014
Encourage generative collaboration	To encourage actors to collaborate in ways that are generative so that the outcomes of the whole are greater than could be expected from the sum of actions of the individual actors involved.	Beers et al., 2006; Franco, 2013; Midgley et al., 2013

These elements were used to guide the design of the process described in the following sections. Additionally from a practical standpoint the process also needed to utilise fit-for-purpose, low-cost processes and infrastructure to work with a Community for Change distributed throughout New Zealand and with limited time to contribute. These considerations limited the opportunities for face-to-face meetings.

Identifying key systemic problems in the AIS
To engage and motivate multiple actors to maintain a strategic focus on systemic problems relevant to them and wider structural change in the AIS, 30 actors in the AIS were interviewed using a systemic policy analysis framework (Wieczorek & Hekkert, 2012) to take a holistic innovation systems view (see Turner et al., 2014, 2016 for details). The individuals interviewed were assumed to play a key and catalysing role in shaping the direction and speed of innovation (Turner et al., 2016). The semi-structured interviews probed the actors' roles in the New Zealand AIS and the perceived systemic problems (or barriers) to innovation. The interviews were also used to identify different needs from enhanced innovation. This information was used to link potential solutions to actor needs. Interviewees were then brought together in a workshop to collectively validate, reflect on and explore the key systemic problems.

The interviews, workshop and subsequent data analysis identified underlying causes of systemic problems that hinder effective functioning of the New Zealand AIS, which were then clustered into three themes (Turner et al., 2016). Table 2 describes these themes, the systemic problems they relate to and the underlying institutional logics.

Table 2. Underlying systemic problems in the New Zealand AIS, explanatory institutional logics and associated themes *(Source: Turner et al., 2016)*

Systemic problems	Institutional logics	Themes
Competition for resources for individual innovation agendas and activities	Competitive science in silos	Coordination of innovation agendas and activities
Insufficient capacity in small to Medium-Sized Enterprises to undertake market formation, entrepreneurial activities and knowledge development	Laissez-faire innovation	Build entrepreneurial activity to support implementation and commercialisation
A focus of science organisations on science-driven knowledge development to generate revenue	Science-centred innovation	Embed other forms of knowledge in research projects

We used Value Add Documents (VADs) (Beers et al., 2015) to describe the three themes (Table 2) in order to support actors' reflexivity on institutional logics, underlying systemic problems and potential solutions. Each VAD was structured to include (Beers et al., 2013; 2015): (i) a description of Primary Innovation research activities; (ii) identification of a systemic problem in the New Zealand AIS, from the multiple perspectives of different actors in the AIS; (iii) relevant research results; and (iv) multiple potential activities that different actors might carry out to deal with the problem. The three systemic problems have distinct foci that overlap. The VADs were not intended to provide change agents with a definitive diagnosis and prescription for change, but served to stimulate discussion among them about what actions might be possible and/or desirable by different actors in the AIS.

Stimulating reflexivity and coordinated action in the AIS

The purpose of establishing Communities for Change was to engage AIS actors with innovation system level change in a way that would stimulate reflexivity and lead to coordinated action in the AIS. To encourage actors to collaborate around each of the three systemic problems (Table 2) in ways that are generative, problem structuring methodologies (see below) were used to support change agents to develop not only a shared understanding of these problems, but also to understand the role that inter-relationships, perspectives and boundaries play in defining issues and potential solutions (Midgley et al., 2013). This explicitly systemic approach opens up new framings, strategies and actions (Franco, 2013).

Community for Change Workshops

To date there have been two workshops aimed at establishing the Communities for Change drawing on invitees from across industry, Government, and research organisations in the New Zealand AIS. The first, with seven participants, had the explicit purposes of: (i) creating a shared ambition for change; (ii) beginning collaborative problem structuring to understand and plan for relevant change; and (iii) forming Communities for Change around each systemic problem. The second workshop, with 20 participants, had a similar purpose.

Each of the workshops used the VADs as 'catalysts' for problem structuring and as triggers for action. As such they can be considered boundary objects (Klerkx et al., 2012); an entity that has sufficient shared meaning between diverse actors to enable collaboration but sufficient plasticity of meaning to enable each actor to use the object in their own situation (Star & Griesemer, 1989). The workshops followed the four design elements (Table 1):

1. multiple participants from a range of expertise were gathered;
2. systems thinking tools were used to support critical reflection on what constitutes the problem area and prompt new problem framings leading to alternative institutional logics that might contribute to systemic change (‘problem structuring’ – Mingers & Rosenhead, 2004);
3. possible change initiatives that were co-created in an interactive and iterative manner;
4. the process brokered the bringing together of solution elements to promote outcomes greater than participants could devise separately.

The core of the workshops was the second element; make visible how different institutional logics shaped how problems were understood to structure dialogue among participants with differing viewpoints and generate fresh perspectives on ‘the problem’ and action planning. Soft Systems Methodology (Checkland, 1999) helped participants from diverse perspectives consider how to express the desired system transformation, who that transformation may affect, who may be needed to make it happen, what underlying assumptions may shape the transformation, who functions as the effective ‘owner’ of the system and what factors are givens in the environment around the system that may influence outcomes. Activity Theory (AT) (Engeström, 2001) teased out potential components operating together in key activities. This enables groups with diverse viewpoints to consider what formal or informal procedures, enabling technologies, divisions of labour and collaborations make up a given activity, and what might be worth introducing in an improved activity.

Online Network Hub
An online network Hub was used to encourage an iterative process of practical experimentation that challenges current practices and supports systemic changes, while also addressing a key challenge of maintaining dialogue among a distributed community of time poor participants. The Hub is a purpose-built social networking site to support sharing resources, hosting discussion and reporting actions by change agents working on each of the three systemic problems (Table 2).

Experience shows that realising the collaborative potential of the Hub is neither automatic nor simple (Ellison et al., 2015). There is currently limited understanding of how social networking sites may function for knowledge management and collaboration (Razmerita et al., 2014). Social networking sites have been classified into: (i) information dissemination and sharing; (ii) communication, collaboration and innovation; (iii) knowledge management; (iv) training and learning; (v) management activities; and (vi) problem solving (Razmerita et al., 2014). The Hub attempts to facilitate all six. Peters and Manz (2007) argue that three interdependent antecedents are necessary for virtual collaboration: trust, shared understanding and depth of relationships. These typically need to be established and nurtured through face-to-face interaction. For this reason the online Hub communities will be invited to further face-to-face workshops. In addition the Hub will be actively facilitated by members of the research team, and contributions to the Hub discussions and resources will be made from people generally trusted.

Evaluation of the process for triggering system innovation
In the two Community for Change workshops, feedback sheets were used to: (i) evaluate the extent to which participants experienced the process design elements (Table 1); (ii) evaluate the extent to which participants identified with the description of the systemic problems (Table 2); and (iii) gather intended actions for systemic change. Workshop participants scored statements from 1 - strongly disagree to 10 - strongly agree. The data from feedback sheets were supplemented with outputs from the workshops.

Follow-up interviews, three months after the last workshop, were undertaken with 14 of the workshop participants. The interviews, conducted by three programme team members, explored four themes through semi-structured questions: (i) the extent to which participants experienced the process design elements in the workshop; (ii) to what extent participation in the workshops is supporting their understanding of co-innovation and encouraging them to take relevant actions in New Zealand's AIS; (iii) actions taken and intent to take further actions at the system level; and (iv) what participants need in order to effectively work as a group to improve primary sector innovation, including participating in the online Hub.

Results
Here we present evidence to date of progress toward triggering system innovation, organised by the extent to which the participants experienced the guiding elements for the design of the process (Table 1), identified systemic problems and motivated actions.

Evidence of process design elements
Feedback sheets and follow-up interviews provided evidence that participants perceived the design elements (Table 1) as present, especially in the face-to-face workshops. In particular, there was a sense that the process was accommodating multiple perspectives and providing a systems view of innovation.

Including multiple actors from the AIS
Interviewees agreed that a range of perspectives were present, and this enabled consideration of the wider context of innovation and an understanding of others' points of view, including recognition of shared issues. A challenge is that the breadth of perspectives made it difficult to identify a focus (goal or vision) for action. A few interviewees identified the need for more industry representation in the Community for Change, including farm advisors, especially as these actors were seen as key to implementing co-innovation.

Reflexivity to challenge institutional logics
There was limited evidence that reflexivity to challenge underlying institutional logics was achieved, however, one interviewee observed: "*By having industry present at the workshop and enabling them to voice their concerns you opened up the dialogue and enable that to challenge of the current regime.*" Interviewees from research organisations did, however, identify tensions in the current AIS: (i) an emphasis on science outputs that encouraged scientists to share ideas only once they were well formed; and (ii) an emphasis on generating revenue for research organisations that did not encourage time to understand multiple innovation agendas and actor expectations. This suggests that these members of the Community for Change are beginning to question embedded institutional logics.

Process of practical experimentation
Interviewees identified a number of existing and planned actions that challenge current practices. These tended to be at the project-level, e.g. by providing practical, readily accessible tools such as monitoring and evaluation, AIS diagnostic questions and experts to support the implementation of co-innovation. More broadly there was reference to investigating different models of science-industry interaction. These models and associated practices were identified as more tangible for actors to work on as a group and have "*better scope for change and influence*." The need for focus within the Community for Change around a practical area (or project) in which to collectively test systemic actions (perhaps through identifying and experimenting first at a project level) was called for. There were fewer examples of practical experimentation with systemic changes, although one interviewee highlighted the need for Government agencies to resource the collection of statistics that evidence the impact of co-innovation.

Generative collaboration
Interviewees suggested that the beginnings of generative collaboration were present, referring to trust, a common language and hence the opportunity to share perspectives, which stimulated a recognition of new perspectives. One interviewee highlighted intermittent face-to-face interactions as a challenge. However, examples of the need for generative collaboration were identified, such as the desire from a research organisation member for research funders to stimulate demand for co-innovation. The need for generative collaboration was also recognised in terms of the inter-relationships among the systemic problems (Table 2).

Evidence of being motivated and able to take action

Identifying with systemic problems
Feedback sheets from the workshops provided evidence that participants did identify with the systemic problems and they themselves experienced them in their day-to-day activities. Participants at the second workshop agreed that the systemic problems identified (Table 2) were ones they recognised (Average score = 7.9 out of 10, with a range of 4 to 10, from 14

responses) and that they were also dealing with (8.0, range 5 to 10). However, there was less agreement with the solutions identified prior to the workshop (6.4, range 3 to 10) or confirmation that they might be able to contribute to the solutions (7.0, range 3 to 10). The aim of the second workshop was to increase the intent of participants to embark upon solutions by involving them in identifying solutions that they could contribute to. To this end, participants at the second workshop were more positive about where possible changes could be made (7.4, range 3 to 9) and felt challenged to take action (7.5, range 6 to 10).

The follow-up interviews suggest that members of the Community for Change identified with the desire to implement co-innovation in projects. This included to better understand what co-innovation means in practice for different Government, industry and research actors; use a co-innovation project as a focus of action for the Community for Change; and work together to create tangible success. There was a view that the terms co-innovation and co-development were being more widely used in the AIS, but that these concepts had different meanings to different actors.

Planned actions by the Community for Change

We found limited evidence of actors beginning to develop systemic instruments. Actions are being taken, however these tend to be at the project-level, e.g. implementing co-innovation in existing projects, tools to support co-innovation and ways to extend the use of co-innovation into other projects. Another example was the plan to run a co-innovation showcase at Fieldays, New Zealand's largest agricultural event, to encourage agribusiness companies that traditionally compete to co-innovate instead.

Other actions described linking with other participants to share knowledge or to take coordinated action by linking separate activities in their organisations. Examples included: (i) learning how another research organisation had developed Key Performance Indicators for encouraging co-innovation; (ii) utilising knowledge from Primary Innovation in other innovation projects and organisational changes; and (iii) developing university courses to build capabilities for co-innovation, innovation brokerage and entrepreneurship by science students.

Evidence of the beginnings of a distributed Community for Change

Twenty people attended the second one-day workshop and 32 individuals signed up for the Hub in response to an email invitation and, for some, a follow-up conversation. This action by Community for Change members suggests a first step toward distributed online collaboration. At the time of writing, seven of the 32 signed up have elected to join a specific theme group. However, activity on the Hub is low and the team is trialling strategies for stimulating and supporting collaboration using the Hub.

Interviewee feedback on using the Hub was mixed, with some indicating they would be unlikely to use the Hub due to a lack of time or a preference for face-to-face interaction. Community for Change members that did indicate an interest in using the Hub, emphasised the need for new information to be regularly added and for reminders to contribute to the Hub.

Discussion

There is evidence of the beginnings of a Community for Change through multiple actors developing wider perspectives of innovation and the AIS, and identifying opportunities to challenge underlying institutional logics. Such collective system-level learning towards transformative structural changes has previously been observed in the Dutch poultry (van

Mierlo et al., 2013) and agricultural (van Mierlo et al., 2010) sectors. This system-level learning has already increased networking and coordination of activities among the Community for Change to support co-innovation, however actions planned tend to be at the innovation project-level, rather than the AIS-level. This may be due to participants in the NZ context: (i) still developing their understanding of co-innovation as a practice within their own realms of experience and influence before committing to actions that might embed it across the AIS; and (ii) feeling limited in their capacity to enact change at the AIS-level.

Moving from project- to system-level changes

Our findings suggest that moving from project to AIS-level change remains a challenge. Members expressed a desire to investigate different models of science-industry interaction, such as co-innovation. These were identified as more tangible to work on as a group and have "*better scope for change and influence*." Simultaneously there were calls for top-down commitment to co-innovation, e.g. in Requests for Proposals, so that the co-innovation practices are first mandated and then become business as usual.

Simultaneous AIS and project-level change suggests a need for better linking of project-level implementation of co-innovation with barriers and opportunities in the New Zealand AIS. This is similar to niche and regime relationships in the multi-level perspective (Geels, 2004; 2010) where transitions in the making feature important boundary-crossing processes between initiatives and their environment (Beers et al., 2015). The Community for Change included tactics to support these boundary-crossing processes through: (i) the inclusion of project-level actors with system-level actors in the Community for Change; and (ii) the Value Add Documents' translation of innovation project insights into potential strategic-level actions (Beers et al., 2015). A future step could be organising the Community for Change around a specific innovation project to identify actions they can simultaneously take at these different levels in order to further stimulate co-innovation in the project.

Agency at the system-level

A need for leadership to stimulate AIS-level change was identified and expressed as a sense that large changes are needed at the organisational and AIS-level, which are beyond their individual influence. The concept of institutional entrepreneurship may help to resolve this tension between system-level institutional change and limited actor agency to enact this change (Battilana et al., 2009; Bremmer et al., 2014), by identifying actors that are able to strategically transform existing or create new institutions (DiMaggio, 1988). Tactics that these institutional entrepreneurs may apply to implement change projects (Pacheco et al., 2010; Battilana et al., 2009) include: (i) framing and re-framing by developing a vision that can convince others; (ii) coalition building by mobilising others to support change; and (iii) motivating others to achieve and sustain the vision.

There is evidence of some members of the Community for Change implementing the first tactic. For example, the inclusion of the Ministry for Primary Industries' extension framework, which includes co-innovation as an approach, in Over the Fence (Casey et al., 2015) and in the Ministry's Science Strategy (Ministry for Primary Industries, 2015). This high-level endorsement of co-innovation as a desirable practice is shaping expectations of innovation project funders and influencing project planning and management across primary sectors. This example and other institutional entrepreneurship tactics could be concrete actions encouraged and supported in the Community for Change.

Conclusion

Our findings provide early evidence that involving multiple actors from the AIS in challenging underlying institutional logics and encouraging generative collaboration is stimulating project-level actions to enable co-innovation and recognition of AIS-level barriers and opportunities. This confirms the benefits of collective system analyses using an innovation systems perspective to identify and address structural changes in the AIS (Bremmer et al., 2014; van Mierlo et al., 2010; 2013). It also suggests that such collective system analyses can enable identification of actions that may address underpinning institutional logics with the intention of enhancing the performance of the AIS. A challenge still to be addressed is how to simultaneously resolve innovation project-level actions with AIS-level actions, reflecting niche and regime relationships in the multi-level perspective.

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Navigating the unknown - practice-led collaborative research for the improvement of animal welfare

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Abstract: There is a growing policy interest in agricultural innovation generated through practice-led collaborative learning processes. While there is a considerable body of work on how local innovation is generated and facilitated in the field of natural resource management, far less has been done in the area of farm animal welfare. Using the egg-laying-hen sector as a case study, the EU-funded Hennovation project is testing mechanisms to facilitate practice-led innovation in sustainable animal welfare through development of 'innovation networks'. Up to 12 innovation networks, involving producers and laying-hen processors, have been mobilised at local, national and European level. These are supported by a variety of actors and moderated by external facilitators. This paper presents a framework for the management and facilitation of practice-led collaborative innovation processes in sustainable animal welfare. This framework has been developed and is tested through action research and a Delphi- style consultation process and includes key steps and guiding questions allowing the facilitators to assess and monitor their intervention in innovation processes. Practice-led innovation processes are network specific and evolve as the actors within the network come together to share common problems, experiment with possible solutions and learn. The end-results of these processes, in terms of outputs, are often unclear at the outset and thus planning for them raises specific methodological challenges. In focusing on collaborative approaches to innovation, this project contributes to the integration of science and practice leading to solutions designed to deliver lasting change in animal welfare practices.

Keywords: Practice-led, innovation, collaborative learning, innovation networks, facilitation, animal welfare

Introduction

There is a growing policy interest in on-farm agricultural innovation generated through practice-led collaborative learning processes. The EU H2020 research strategy, for example, is currently promoting a multi-actor approach to innovation that includes a high level of farmer engagement (SCAR, 2013). The interest in practice-led innovation stems from the realisation that, despite large investment, there remains a significant gap between scientific research and the adoption of applied science into farm practice (Akrich et al., 2002). Practice-led innovation responds to the demand for innovation in practice to solve problems using practical knowledge and creativity at the local farm level.

While there is a considerable body of work on how local innovation is generated and facilitated in the field of natural resource management, far less has been done in the area of farm animal welfare. Using the egg-laying-hen sector as a case study, the EU-funded Hennovation project is exploring and testing mechanisms to stimulate and facilitate practice-led innovation in sustainable animal welfare through development of 'innovation networks'. In short, the project's mission is to promote practice-led innovation, instigate innovation networks, develop the skills of participants and facilitate the interaction and learning of individuals within the network.

Formation of Innovation networks

Innovation networks, involving producers and laying-hen processors, are mobilised at local, national and European level. These are supported by a variety of actors such as veterinary surgeons, researchers and industry and are moderated by external facilitators (Figure 1).

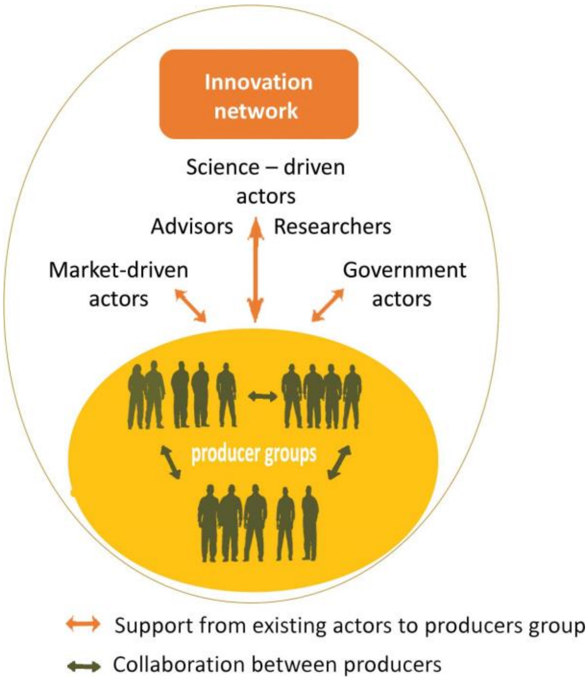

Figure 1. Schematic overview of the Hennovation innovation networks

Currently there are in 12 innovation networks established and running in the United Kingdom, The Netherlands, Sweden, Czech Republic and Spain. Network size varies from five to eight producers with a variety of support actors e.g. veterinarian, feed company, scientist and pullet rearer, based on the specific topic addressed by the network. The laying-hen production system varies between groups, e.g. organic, free range and more conventional cage systems. One of the networks includes producers of several production systems. The networks are exploring a variety of topics based on their need and ideas such as: the effect of light on feather peaking, nutrition to prevent feather peaking, methods of feather scoring, increased communication between pullet rearers and producers, hen predation in relation to feather peaking and new ideas for marketing eggs of non-beak-trimmed birds. Several networks in different countries have identified a similar topic to work on, and this provides opportunities for trans-national collaboration.

Most networks are formed from larger pre-existing groups connected to a specific egg packing company or veterinary practices. After an initial three months of implementation, reflection on network mobilisation and facilitation by the facilitators, revealed that the use of such intermediates is pivotal in enabling network mobilisation. It was also noticed that there is a great diversity within as well as between countries on what motivates producers to participate in a network. In some countries for example mentioning the upcoming EU ban on beak trimming in laying-hens is a motivational factors whilst in other countries it was too controversial to mention this. During the initial reflection, discussion also revolved around the challenge of overcoming a culture of receiving rather than collectively creating or producing knowledge. Thus some producers were expecting or were more motivated to learn from "experts".

The role of the network facilitator

The role of the network facilitator in the project is to mobilise the networks, guide the network through the innovation process, promote social learning and encourage engagement with support actors (Klerkx et al., 2012). The facilitators stimulate the co-creation of knowledge (Wielinga & Herens, 2013) which is different from more traditional advisory roles of knowledge dissemination (Roling, 1990). Practice-led innovation processes evolve as the actors within the network come together to share common problems, experiment with possible solutions and learn. The end-results of these processes, in terms of outputs, are often unclear at the outset and planning for them raises specific methodological challenges (Wielinga & Vrolijk, 2009). Thus the question arises how do you facilitate a messy process of which you do not know the end-result. Klerkx and Gildemacher (2012) indicate that facilitators can use existing methods and tools, however facilitating the innovation process is learning by doing. The function and role of facilitators in the innovation process has been widely described in literature (Howells, 2006; Klerkx & Jansen, 2010) however much less is written on how to actually support the facilitator to perform this role. A framework for the facilitation and management of practice-led collaborative innovation processes was developed and is currently being tested by the network facilitators to provide more structure to the facilitation of the innovation process.

Development and testing of the framework for the facilitation and management of practice-led collaborative innovation processes.

Development of the framework

The initial framework was developed by ten facilitators from five different countries in Europe (the United Kingdom, The Netherlands, Sweden, Czech Republic and Spain) during the first workshop for network facilitators in September 2015. The framework was developed to guide the facilitation of the innovation process and to stimulate learning by the facilitator on how to manage this process. The challenge in the development of the framework was that on the one hand it needed to provide enough structure to be useful for the facilitator whilst on the other the framework needed to be generic and flexible enough to accommodate the diversity and unpredictability of the process (Klerkx & Gildemacher, 2012). The framework was built on the experience of the facilitators and they identified six key process steps:

1. Problem identification;
2. Generation of ideas;
3. Action planning and resource mobilization;
4. Practical trialling and development;
5. Implementation and upscaling on-farm;
6. Wider dissemination of the innovation.

During the workshop the facilitators identified key activities for each step. These were captured in the framework as guiding questions to encourage facilitators to think through and reflect on the progress in each step of the process. Questions developed relate to the network functioning and capacity, interaction with relevant support actors, use of a diversity of knowledge and uptake and dissemination of the innovation.

Testing of the framework

The framework is currently being tested and refined through action research by the facilitators and a Delphi style consultation process in three rounds. Tools such as the learning history (Kleiner & Roth, 1996) are used to reflect upon learning. Over a period of 18 months data on progress and reflection is systematically documented by each facilitator in a wiki to stimulate reflection and peer learning amongst the facilitators. Although the framework is presented stepwise the innovation process is not linear. The time allocated for each step cannot be predicted (Klerkx & Gildemacher, 2012) and depends amongst others things on a variety of factors such as network capacity and the specific idea trialled by each network.

Conclusion

Overall there is a large diversity in capacity and functioning of the innovation networks, both within and between countries. This provides a great opportunity as well as a great challenge for the facilitators learning to manage the innovation process. The framework developed supports the facilitators to navigate through the unknown territories of the innovation process. Further testing of the framework as part of the Hennovation project and in other livestock sectors will lead to further refinement and validation of the framework.

In focusing on collaborative approaches to innovation, this project contributes to the integration of science and practice leading to solutions designed to deliver lasting change in animal welfare practices.

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Addressing complex challenges using a co-innovation approach: lessons from five case studies in the New Zealand primary sector

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Abstract: Co-innovation can be effective for complex challenges – involving complex interactions among multiple stakeholders, viewpoints, perceptions, practices and interests across programmes, sectors and national systems. However, there is limited systematic research on how co-innovation works in different projects. Approaches to challenges in the primary sector have tended to be linear, where tools and outputs are developed by a few, mostly scientists/researchers, and then extended to stakeholders. A co-innovation approach first deciphers and delineates the biophysical, societal, regulatory, policy, economic and environmental drivers, constraints and controls influencing these challenges at multiple levels. Secondly, stakeholder interactions and perspectives can inform and change the focus, as well as help in co-developing solutions to deliver agreed outcomes. Here we analyse the results of applying a co-innovation approach to five research projects in the New Zealand primary sector. The projects varied in depth and breadth of stakeholder engagement, availability of ready-made solutions, and prevalence of interests and conflicts. The projects show how and why co-innovation approaches in some cases contributed to a shared understanding of complex problems. Our results confirm the context-specificity of co-innovation practices.

Keywords: Co-innovation, innovation projects, co-innovation principles, New Zealand, agriculture, horticulture, pastoral, forestry, Agricultural Innovation Systems

Introduction

Understanding how innovation happens and ways in which research projects can be optimised to increase their innovation potential may enhance rates of adaptation (Hermans et al., 2013) and adoption of technologies from research, science and technology investments. To address shortcomings in technology diffusion and uptake approaches there is increased focus on bringing together relevant agricultural sector actors in a coordinated, interactive fashion through co-innovation (Dogliotti et al., 2014; Hall et al., 2001; Klerkx et al., 2012). Literature on agricultural innovation processes (e.g. Klerkx et al., 2012; The World Bank, 2006) indicates an evolution and broadening of theoretical perspectives. Agricultural systems innovation processes differ from linear, technology-transfer-oriented approaches, being more evolutionary, multidisciplinary and multi-stakeholder approaches, which consider social, economic and institutional as well as technical changes (Klerkx et al., 2012).

Co-innovation is an iterative process that brings together knowledge from many stakeholders, along with changes in technology, markets, regulations and other practices that support the commercialisation and implementation of the knowledge to improve production, exports, profits and/or the environment (Garb & Friedlander, 2014; Klerkx et al., 2012; Leeuwis, 2004; Röling, 2009). This process requires negotiation amongst previously unconnected stakeholders with competing values, worldviews, interests, planning horizons, incentives and accountability (Botha et al., 2014; Johnson & Gregersen, 1995; Schut et al., 2014). Co-innovation practice is context-specific and adaptive: how and when co-innovation is implemented must be tailored to the particular situation and may change over time (Hall, 2005; Klerkx et al., 2010; Neef & Neubert, 2011; Schut et al., 2015). "Explicit or implicit choices are usually made as to who might take part" and "the question of who participates – as well as who is excluded and who exclude themselves – is a crucial one" (Cornwall, 2008, p.275), especially when the transaction costs associated with increased interactions among stakeholders outweigh perceived benefits (Ortiz et al., 2013). While this is increasingly acknowledged, there is relatively limited comparative research unravelling how, under a given overarching programme, different co-innovation projects may work differently (except, e.g. Seuneke et al. (2015)), although this is highly important to stimulate learning within a programme context (Thiele et al., 2007).

These implementation differences are assessed in a large New Zealand (NZ) Government-funded research programme, Primary Innovation (PI), was initiated in 2012 with two aims: i) implement and evaluate the effectiveness of co-innovation approaches in the primary sector (Botha et al., 2014); and ii) identify barriers and enablers to co-innovation in the NZ primary sector (Turner et al., 2016; Turner et al., 2013). To achieve the first aim, the PI programme became involved in five NZ primary-sector research projects where attempts have been made to apply a co-innovation approach. Each of the projects applied nine principles of co-innovation that underpin and inform activity. These principles were adapted from Nederlof et al. (2011) and are presented at this conference by Coutts et al. (2016).

We focus on two co-innovation principles that were applied in practice across all innovation projects: i) take time to understand the problem from many different views; ii) be inclusive in terms of diversity of stakeholders. These principles were seen as those that could most affect a project's focus and direction. We use interpretations of what constitutes innovation, following stylized innovation models articulated in Klerkx et al. (2012) to indicate the position of each project in the range from technology transfer to co-innovation in the Agricultural Innovation System (AIS). We also use Pretty's (1995) typology of stakeholder participation to identify different types and degrees of participation reflecting the diversification of the projects' goals and structures: i) manipulative participation; ii) passive participation; iii) participation by consultation; iv) participation for material incentives; v) functional participation; vi) interactive participation; and vii) self-mobilisation (Pretty, 1995). This typology has its constraints (Leeuwis, 2004; Neef & Neubert, 2011), but highlights the importance of genuine and meaningful participation. We argue that Pretty's typology remains useful for analysis of the projects over time and across projects.

Three research questions primarily focusing on stakeholder involvement in problem definition in the research projects thus guided our analysis: i) did the co-innovation process result in a change of problem definition? ii) if the definition had changed, to what extent can it be attributed to stakeholder involvement? iii) what were the barriers and opportunities to stakeholder participation shaping problem definition?

Innovation project descriptions

Three projects (Water Use Efficiency (WUE), Tomato Potato Psyllid (TPP) and Timber Segregation) are led by research organisations; the other two (Heifer Rearing and Nutrient Management) are led by industry organisations. The projects started independently at different times, some before the PI programme started in October 2012, and some after. Each has progressed at a different rate because of various degrees of stakeholder involvement, a key part of co-innovation, and varying divergence of worldviews, interests, norms and values, planning horizons, incentives and accountability mechanisms of those involved (Botha et al., 2014; Klerkx et al., 2012).

We introduce the projects individually to provide context for the interactions taking place. The projects serve as case studies deliberately chosen to cover two interdependent characteristics of problems in NZ primary industries that influence the effectiveness of co-innovation: (i) knowledge contestability (Andresen et al., 2000); and (ii) a choice of mechanism for change - regulation (e.g. targets), market signals (e.g. pricing) and voluntary approaches (e.g. information distribution, extension, education) (Röling, 2009). None of the mechanisms for change function in isolation, but some have more influence in certain circumstances than others. The five projects investigate problems ranging from where knowledge is uncontested to highly contested. Where knowledge is uncontested, the scope of the problem is well agreed, while with highly contested knowledge, different stakeholders view the problem scope differently. Knowledge becomes more contested at larger scales as the number of stakeholders increases and therefore competing values and perspectives and potential solutions also increase (Andresen et al., 2000).

Water use efficiency

The aim of the WUE project is to improve on-farm irrigation decisions using better characterisation of current irrigation demands and accurate, accessible short-term weather forecasting. This project is being piloted on five NZ South Island farms within an irrigation scheme. The research and PI projects started in October 2012. The farmers are provided with farm-specific observed data on current rainfall, soil moisture, soil temperature, drainage and evapotranspiration, and region-specific 2-, 6- and 15-day rainfall forecasts (Srinivasan et al., 2015). The data are shared with farmers in real-time via a dedicated website and as a daily email. Based on these data, farmers make informed irrigation application decisions. Annually, the farmers, irrigation scheme managers, researchers and other relevant stakeholders (e.g. members of a local catchment committee, personnel from neighbouring irrigation schemes and regulatory and government agencies) meet to review the irrigation decisions made during the season. These meetings are a forum for sharing and discussing ideas, as well as reviewing and refining information provided. These workshops and other formal and informal meetings also refine and reshape the problem being addressed as well as the solutions achievable (Srinivasan et al., 2016).

Tomato potato psyllid

TPP is a vector of the bacterium *Candidatus Liberibacter solanacearum* (CLso). This complex became a major problem in NZ potato crops in 2008. The aim of the TPP project is to assist the NZ potato industry to realise export growth by addressing the industry's pressing need for economically and environmentally sustainable control solutions for the TPP/CLso complex. The research project commenced in October 2013, with the PI programme becoming involved in June 2014. The research project entails fundamental research in three, mainly laboratory-based objectives: (i) sensory cues; ii) population genetic variability, and iii) host plant response), while the fourth objective is 'knowledge transfer to stakeholders'. The science objectives each have an objective leader, while the fourth objective does not. Knowledge transfer was not planned until complete tools or knowledge were available (at project completion). Unlike in the other case studies, the innovation project leader is not the TPP research project leader.

Heifer rearing

The Heifer Rearing project is a DairyNZ-led initiative focusing on the improvement of dairy herd reproductive performance by lifting the proportion of heifers entering the national herd at target live weight. Industry data indicated that 73% of such heifers are 5% or more below target (McNaughton & Lopdell, 2012). This represents a national loss of $120M per annum in dairy farm profit industry-wide (Brazendale & Dirks, 2014). The research project and PI commenced together in September 2013. The project initially formed a stakeholder industry advisory group which completed a causal analysis for understanding the influences on under-grown heifers in October 2013. Drivers and obstacles for improvement were identified; however, the number of farmer participants was proportionally low.

Nutrient management

The Nutrient Management project focuses on activities on a network of Canterbury commercial farms in NZ's South Island. This network is part of a large government-funded research programme combining the expertise and resources of three Crown Research Institutes, one University and two industry-good bodies, and targets the twin challenges of reducing nitrate leaching and increasing profitability of arable, sheep and beef, and dairy farms. Experiments are conducted on pasture mixtures and crop sequences, and modelling of plant/soil and animal components as well as farm systems incorporating the options developed. While the topics are technical (Pinxterhuis et al., 2015), the programme approach is based on co-innovation principles to achieve maximum uptake of these options (Edwards et al., 2015). The farmers' network is involved to co-develop the options with the research and development (R&D) community, test them on-farm and demonstrate to the wider community. The project started with the development of the research proposal from late 2012, incorporating co-innovation principles from the PI programme.

Timber segregation

The Timber Segregation project is part of a larger government and industry co-funded programme. It aims to increase the value realised from existing forests through the development of cost-effective approaches to characterise and deal with variation in wood properties within and between trees (Moore & Cown, 2015). This will give wood processors increased confidence in the properties of the resource, so that more of the harvested resource is processed into added-value products, rather than exported as raw logs. The project started in October 2013, having been identified as a PI case study 12 months earlier. It thus deliberately set out to take a co-innovation approach during the proposal writing stage as well as during the project itself, particularly as a wide spectrum of views on the benefits of segregation was recognised. The specific research aim was developed through a series of workshops and roadshows with stakeholders from the forestry and wood-processing sectors including technical managers, executive managers and staff from government and sector research organisations. Once the project funding was approved, the detail was revised with the industry co-funding partners. In addition to a governance group, an innovation cluster group has been formed whose membership includes researchers, forest growers, wood processors, industry associations and segregation tool manufacturers. This group meets annually to share ideas, discuss the research and develop a deepening understanding of problems and potential solutions.

Methods and analytical framework

To compare the five projects, the innovation project leaders (all biophysical scientists) and/or other project team members and a social science research team conducted a workshop in February 2016. The people most heavily involved in managing the projects and monitoring outcomes brainstormed the project goals, stakeholders and progress from the proposal stages to the present (February 2016; 2–3 years in for all projects). This paper uses data collected from the five individual projects, as well as personal experiences of the project teams and leaders. Each project was considered in relation to their type of stakeholder inclusion (Pretty, 1995) and their position on the AIS continuum from technology transfer to co-innovation, particularly project flexibility over time, on a scale of 1–5 (Klerkx et al., 2012). This enabled comparisons in terms of project goals, structure and stakeholder involvement and their effects on stakeholders' understanding of the problem and project focus to be determined.

How the innovation projects have changed

Innovation projects at proposal-writing stage

In all projects, stakeholders were involved at proposal-writing stage, giving formal and informal input (Table 1) (Pretty, 1995). The projects were also assessed for conceptual, organisational, and institutional features connected with theoretical perspectives on agricultural innovation (Table 2) (Klerkx et al., 2012). Nutrient Management and Timber Segregation, and to a lesser extent Heifer Rearing, used more of an AIS perspective at the proposal-writing stage than the other projects, which resulted in an opportunity to create a shared understanding of the problem and build trust.

Table 1. Status of the innovation projects at proposal writing stage: problem definition, stakeholder participation and engagement methods used.

Innovation project	Problem/project definition or focus	Type of stakeholder	Engagement methods	Stakeholder engagement (Pretty, 1995)[1]
Water use efficiency	Improved irrigation and water use efficiency	Farmers, irrigation scheme, researchers	One-on-one meetings, phone calls	Passive participation
Tomato potato psyllid	Developing economically and environmentally sustainable control solutions for the TPP/CLso complex	Industry, some larger growers	Formal meetings, phone calls	Passive participation

Heifer rearing	Increase dairy farmers' profitability by increasing the number of heifers that meet liveweight targets pre-calving	Dairy farmers and graziers, industry, researchers, private companies	Advisory group meetings, farmer workshops, phone calls	Interactive participation
Nutrient management	Reduced nitrate leaching from arable, sheep & beef, and dairy farm systems	Researchers, industry	Formal meetings, workshops, email, one-on-one meetings, phone calls	Functional participation
Timber segregation	Improve the financial returns to growers and processors through better information on the wood properties of the forest resource	Growers, researchers, private companies	Formal meetings, workshops, roadshows, one-on-one meetings	Self-mobilisation

[1]*Stakeholder engagement types from minimal to maximum inclusion: 'passive participation' (people are informed about what is going to happen); 'participation by consultation' (people can give their own views); 'functional participation' (people participate by creating conditions that are favourable for an external project; 'interactive participation' (people participate in joint analysis and decide on follow-up) and 'self-mobilisation' (people take their own initiatives) (after Leeuwis, 2004).*

Table 2. Analysis of the five innovation projects at proposal-writing stage using six characteristics of AIS (descriptions adapted from Klerkx et al., 2012). Start dates are mentioned in project descriptions. Cell shading indicates the project's position on the AIS continuum from technology transfer (white) to co-innovation (dark grey); the darker the background, the greater the alignment of activities with AIS.

Innovation project	Water use efficiency	Tomato potato psyllid	Heifer rearing	Nutrient management	Timber segregation
Degree of stakeholder involvement	One-way flow of technology or knowledge from developer	One-way flow of technology or knowledge from developer	User and developer jointly define problem, then one-way flow of technology or knowledge from developer to user	User and developer collaborate in research and extension	User and developer collaborate in research and extension
Range of disciplines involved	Single discipline driven (e.g. agronomy)	Multidisciplinary (e.g. plus economics)	Multidisciplinary (e.g. plus economics)	Transdisciplinary (e.g. plus sociology and grower experts, with limited stakeholder involvement)	Transdisciplinary (e.g. plus policy makers, with broad stakeholder involvement)
Scope of the potential impact	Efficiency gains (input-output relationships)	Efficiency gains (input-output relationships)	Efficiency gains (input-output relationships)	Production unit-based livelihoods	Value chain, institutional change
Impact of stakeholder involvement	Technology packages	Modified packages to overcome constraints	Modified packages to overcome constraints	Joint production of knowledge and technologies	Joint production of knowledge and technologies
Driver	Supply-push from research	Supply-push from research	Supply-push from research	Responsiveness to changing contexts, patterns or interactions	Diagnose growers' constraints and needs
Position within the wider system	Aware but not engaged with policy/decision makers	Science not engaged with policy/decision makers	Aware but not engaged with policy/decision makers	Engaged with policy/decision makers	Aware but not engaged with policy/decision makers

Innovation projects now

In February 2016, the application of co-innovation principles in the projects had led to a re-shaping of the problem/project focus, except in the TPP project (Table 3) which is locked into contracted milestones with a Government funding agency and thus scored `inflexible' in terms of capacity to reshape the problem (Table 4). All the projects moved more towards AIS in most categories over the period in which the co-innovation principles were applied (Table 4). The type of stakeholder and the engagement methods increased for all projects, except for TPP, since solutions are still under development through tightly managed research aims (Tables 1 and 3). Two barriers were identified for TPP. Firstly, the research project had already started before the PI team became involved, so co-innovation was introduced to project team members after traditional project development and delivery processes were established. Secondly, the PI team identified through interviews with key people that the intended knowledge exchange with stakeholders was seen as largely linear (Vereijssen et al., 2015) and engagement awaits the production of technical solutions (e.g. resistant/tolerant cultivars). The PI team has offered support to deliver the knowledge transfer objective.

A significant change in stakeholder type and engagement happened in WUE and Heifer Rearing. In WUE, a co-innovation approach was deliberately embedded at the start. Stakeholders were involved in evaluating the use of weather-forecast-based irrigation practices. Stakeholder views were sought through workshops and one-on-one meetings to ensure the processes and the resulting products were viable and practical. In Heifer Rearing, the project leader DairyNZ proposed a series of regional focus groups in November 2013 to address the lack of farmer involvement with advisory groups. The purpose of these was to gain perspective and solutions from those who would implement them. The emphasis for the solution shifted as a result of these focus groups from a technical approach to increasing heifer live weight to emphasising the relationship between contract heifer graziers and stock owners. Focus groups identified key stakeholders as Beef+Lamb New Zealand and the Livestock Improvement Corporation. In response to the feedback, industry advisory group members were integrated into area-of-expertise working groups and a governance group for the project was established with key stakeholders.

Table 3. Status of the innovation projects after applying co-innovation principles: problem definition and stakeholder participation (February 2016).

Innovation project	**Problem/project definition or focus**	**Type of stakeholder**	**Engagement methods**	**Stakeholder engagement** (Pretty, 1995)
Water use efficiency	Improved irrigation, drainage, and water use efficiency	Farmers, irrigation scheme, researchers, regulatory bodies, non-pilot study farmers, farmers from other irrigation schemes, government	One-on-one meetings, phone calls, daily email updates, website, workshops, field days, Q&A sessions	Functional participation
Tomato potato psyllid	Developing economically and environmentally sustainable control solutions for the TPP/CLso complex	Industry	Formal meetings, email	Participation by consultation
Heifer rearing	Improve relationships and farm profitability for both dairy farmers and contract growers through heifers that meet liveweight targets pre-calving	Dairy farmers, graziers, industry, researchers, private companies	Focus groups, advisory groups, advisory panel	Interactive participation
Nutrient management	Reduced nitrate leaching from viable arable, sheep & beef, and dairy farm systems	Farmers, researchers, industry, policy/decision makers	Workshops, focus groups, email, one-on-one conversations, website, media releases, popular articles, conference presentations, journal articles	Self-mobilisation
Timber segregation	Improve the financial returns to growers and processors through better information on the wood properties of the forest resource	Wood processors, segregation tool manufacturers, harvesting managers, log traders	Focus groups, newsletters, workshops	Self-mobilisation

Table 4. Analysis of the five innovation projects in February 2016 using six characteristics of AIS (descriptions adapted from Klerkx et al., 2012). Project start dates are mentioned in project descriptions. Cell shading indicates the innovation project's position on the AIS continuum from technology transfer (white) to co-innovation (dark grey); the darker the background, the greater the alignment of activities with AIS.

Innovation project	**Water use efficiency**	**Tomato potato psyllid**	**Heifer rearing**	**Nutrient management**	**Timber segregation**
Degree of stakeholder involvement	User and developer collaborate in research and extension	One-way flow of technology or knowledge from developer to user	User and developer collaborate in research and extension	User and developer collaborate in research and extension	Co-develop innovation involving multi-actor processes and partnerships
Range of disciplines involved	Transdisciplinary (e.g. plus sociology and grower experts, with limited stakeholder involvement)	Multidisciplinary (e.g. plus economics)	Transdisciplinary (e.g. plus sociology and grower experts, with limited stakeholder involvement)	Transdisciplinary (e.g. plus sociology and grower experts, with limited stakeholder involvement)	Transdisciplinary (e.g. plus policy makers, with broad stakeholder involvement)
Scope of the impact	Efficiency gains (input-output relationships)	Production unit-based livelihoods	Production unit-based livelihoods	Production unit-based livelihoods	Value chain, institutional change
Impact of stakeholder involvement	Modified packages to overcome constraints	Modified packages to overcome constraints	Modified packages to overcome constraints	Joint production of knowledge and technologies	Joint production of knowledge and technologies
Driver	Responsiveness to changing contexts, patterns of interaction	Supply-push from research	Supply-push from research	Responsiveness to changing contexts, patterns or interactions	Diagnose growers' constraints and needs
Position within the wider system	Engaged with policy/decision makers	Science not engaged with policy/decision makers	Aware but not engaged with policy/decision makers	Engaged with policy/decision makers	Aware but not engaged with policy/decision makers
Flexibility in re-shaping problem (1=inflexible; 5=completely flexible)	5	1	5	3	5

Discussion

Changes in the projects described over time (Tables 2 and 4) suggest a shift in the spectrum towards increasing application of co-innovation principles. There can be a perception that using a co-innovation approach in research projects is more advanced because it is a newer development in social science thinking. However, when a problem is less complex and science can provide a simple solution, a technology-transfer method may be the simplest, most economically viable option, as organisational and regional/state/national policy has little influence on improvements or outcomes. So depending on the problem's complexity, different approaches need to be chosen, defined as dynamic research configuration by Schut et al. (2014), or dictated by circumstances. The question for each project is which one(s) of the nine co-innovation principles (Coutts et al., 2016) is/are most important to achieve change and when should they be applied to best effect?

The extent and depth to which co-innovation principles were applied differed between projects. Here we discuss how implementing co-innovation approaches affected the first and second co-innovation principles: i) take time to understand the problem from many different views; and ii) be inclusive.

Did the co-innovation process result in a change of problem definition?

When evaluating the shift toward co-innovation, the projects most quickly able to change and adapt were Timber Segregation, Nutrient Management and Heifer Rearing. In all three, the intent to apply co-innovation came before the establishment of project milestones and at the proposal-writing stage, and in two cases (Timber Segregation and Nutrient Management) before funding confirmation.

Nutrient Management has not seen changes in the problem definition as such, but because of the approach (Edwards et al., 2015) and continued engagement of end-users (industry bodies and farmers in the network), some changes to the approach have been made and new R&D questions have been formulated. These guide the project activities with an emphasis on integrating solutions in farm systems and supporting solution implementation on-farm. Similarly for Timber Segregation, the up-front and ongoing engagement with end-users has resulted in changes in the approach to addressing the problem, rather than the problem definition itself. Within this project, the problem definition and approach are constantly revisited.

WUE has seen the most transformational change, with co-innovation principles becoming embedded in the project over four years rather than just before funding confirmation, as with Timber Segregation, Nutrient Management and Heifer Rearing. WUE integrated flexibility by facilitating stakeholder interactions and bringing in additional stakeholders as necessary. The project expanded the stakeholders' thinking by looking for other opportunities (e.g. economic value of irrigation and drainage management) to enhance their farming, economically and environmentally.

For Heifer Rearing, the application of the defined co-innovation principles did not influence every level of the project because the problem of under-grown heifers is not highly complex nor constrained by organisational/national policy.

TPP has faced the greatest challenge in integrating co-innovation, as PI became involved after project commencement. While the PI team may have a wider view of the activities required to address the TPP problem, milestones were written with a defined view of the science required.

Overall, the integration of co-innovation principles at the inception of a project accelerated uptake of the approach and improved responsiveness and buy-in, leading to better shared understanding of the problem and processes required to address it.

To what extent can the change in problem definition be attributed to stakeholder involvement?

Except for TPP, the type of stakeholders and engagement methods increased when co-innovation principles were adopted. Managing stakeholder participation is a time-consuming and ongoing process mostly led by project leaders. In WUE an external driver forced change in stakeholder behaviour and thinking. During the study, the regulatory authority introduced limits to on-farm water use and capped the amount of irrigation that can be lost as drainage. This provided an external policy stimulant for farmers to look for supporting technologies. The driver to adopt new practices thus changed from a research-based supply push to stakeholder demand to improve the ability to respond to emerging contexts.

In Heifer Rearing, shifts in the problem definition were incremental, with wider stakeholder engagement and problem exploration having two effects: i) widening the base of stakeholders and organisations involved; and ii) redefining the scope and potential impact, from efficiency gains for dairy farmers to production livelihoods of contract graziers. Widening stakeholder engagement did not change the view of the problem, but confirmed its parameters. The apparent failure of earlier attempts to address problems associated with heifer rearing may be from a lack of emphasis on the relationship between stock owners and their contract graziers and mechanisms for optimising the business practices of both.

In Timber Segregation, engagement was organised two-way, with science managers from Scion and industry research brokers involved in formally building support, and a small group of science leaders engaging with a wide range of forestry sector stakeholders to co-develop the scope of the proposed research. Stakeholder engagement had two broad aims: i) to develop an agreed science programme; and ii) to build co-funding support.

What were the barriers and opportunities to stakeholder participation shaping problem definition?

Several project-specific barriers and opportunities were identified that hindered or enhanced the co-innovation process. The ability to respond to stakeholder feedback and insights and therefore the flexibility of the project is driven by individuals within projects (Röling, 2009), more so than the limitations or context of funding mechanisms. Project leaders' comfort with loosely defined milestones or their willingness to re-negotiate milestones with funding bodies has been the greatest influence on adaptability.

In Timber Segregation the industry could "adapt or die", so sector motivation for co-innovation was high; while in WUE the social context shifted providing an opportunity "too good to miss", with researchers and stakeholders "riding the wave" in response (project leader quotes). This leads to the question: "does a co-innovation project have to be the source of innovation (creating new technologies or practices) or, by applying co-innovation, is it possible to adapt existing technologies and practices for application by engaging with the wider context?", resonating with ideas by Douthwaite et al. (2001). Hence, while co-innovation may have a different aim, it is always useful for adapting technologies to users' needs or for creating an enabling environment (see also Garb & Friedlander, 2014).

Overall, flexibility and adaptability, common themes across the projects, were important in achieving positive results from a co-innovation approach. However, the institutional setting and the ability to create the space and buy-in for co-innovation also mattered (see also Neef & Neubert, 2011).

Conclusion

Our experience confirms the context-specificity of co-innovation practices (e.g. Hall, 2005; Klerkx et al., 2010; Schut et al., 2015). By adopting at least the first two co-innovation principles when developing the proposal, or very early in the project, some projects have adapted to new knowledge brought by stakeholders. In some the focus of the project was changed and in others the approach taken to develop solutions changed. The willingness and ability of project leadership to engage with a range of stakeholders, to change project scope or its research approach, was crucial for continued stakeholder engagement. We conclude from our experience as biophysical innovation project leaders that to be successfully implemented co-innovation requires an adaptable mind-set rather than strict adherence to a single method.

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