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JUST-IN-CASE TO JUSTIFIED IRRIGATION: IMPROVING WATER USE EFFICIENCY IN IRRIGATED DAIRY FARMS

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Abstract

NIWA is undertaking a field study in the Waimakariri Irrigation Scheme to test the usefulness of weather forecasting for enhancing irrigation scheduling and improving water use efficiency. As part of the study, a selection of farmers in the irrigation scheme are being provided with farm-specific observed data on current rainfall, soil moisture, soil temperature and drainage, estimated evapotranspiration, and region-specific 2, 6 and 15 day rainfall forecasts. Based on these data, farmers may make informed irrigation and nutrient application decisions. Our observations thus-far highlight that changes to irrigation practices are not only about changing the technology for irrigation scheduling but also about changing the mindset and behaviour of farmers towards irrigation practices. In addition to biophysical data that provides evidence about the gains from enhancing irrigation practices, continued education and training, are identified as being critical to ensuring behavioural change. Encouraging trust between stakeholders and end-users, educating the end users of the benefits (economic and environmental) derived from alternative practices, and providing a guided pathway to change are key enablers to behaviour and practice changes. We explore the co-innovation approach used in our study as well as emerging challenges to furthering this approach.

Introduction

Irrigation is a critical input to agricultural production. Irrigation provides an insurance against climatic and weather uncertainties. As much as 70% of water consented for abstraction in New Zealand is consented for irrigation purpose. Irrigation management in New Zealand is rapidly evolving as end-user needs and regulatory policies evolve. Since 2002, the size of irrigated area in New Zealand has almost doubled, and currently stands at 720,000 ha (IrrigationNZ, 2017). This growth in irrigated agriculture is reflected in its estimated contribution to GDP, which has risen from $0.92 billion to $2.17 billion during this period (Ministry of Agriculture and Forestry, 2004; Ministry for Primary Industries, 2014).

Irrigation in New Zealand

Over recent years, irrigation practices have been increasingly coming under scrutiny as water quantity and quality issues come to the fore. In response to this, efforts are being undertaken at multiple levels, such as changing application modes (e.g., flood to spray irrigation), changing the modes of delivery to reduce transit losses (e.g., open channel water races to pipes), quantifying and understanding the performance of irrigators (e.g., measurement of distribution efficiency of spray irrigators), and scheduling irrigations to match demands. According to IrrigationNZ (2017), nationally spray irrigation has increased by 21% (increase to 122,800 ha) and flood irrigation has dropped by 17% (a drop by 16, 400 ha). Regional councils, such as the Environment Canterbury and Environment Southland, have dedicated programmes providing tools and tips for improving irrigation practices (Environment

Canterbury, 2017; Environment Southland, 2017). With the many advances in hydrological and weather forecast sciences, irrigation management can be made more modern and efficient by taking into account of water supply and demand as controlled by short-term weather conditions (Srinivasan et al. 2015).

Irrigation practices

Of the potential changes that could improve on-farm irrigation efficiency, irrigation scheduling has generally been acknowledged as the most effective, but least practiced, as it demands a continuous user input and an understanding of soil and crop demands. At farm-scale, irrigation practices are frequently influenced by the *availability* of water for irrigation, while considering the consented volume and environmental restrictions such as minimum flows.

In general irrigators tend to use a **"just-in-case"** approach, irrigating whenever water is available, even when demand is low. The alternative best practice is "deficit irrigation". This is a **"just-in-time"** approach, where irrigation is scheduled based on the knowledge of current soil and/or crop demands, rather than water availability. Deficit irrigation uses soil moisture data and water balance models to estimate the demand, but it does not account for short-term variations in future (2 to 6 day) water supplies, such as impending rainfall or changes to restrictions as a result of changing river flows.

Uptake of irrigation management tools

Agricultural Innovation Systems (AIS) are designed to address complex ("wicked") problems such as water management. Co-innovation is one approach widely applied to address these complex problems. For the Waimak project we used a co-innovation approach to bring together diverse perspectives within a wider system to co-develop a *shared vision* for efficient on-farm irrigation management. While AIS are predominantly applied at farm scale, the solutions and ideas that emerge at these scales tend to permeate and spread across scales as well as disciplines.

Co-innovation and tech transfer represent two ends of a spectrum. Figures 1 and 2 present a simple view to these two approaches. Tech transfer approach tends to be dominated by technology and science input while a minority of efforts, usually at the end of a project, are spent in validating the proposed tools and technology. Little time is spent on the problem itself (on why is this problem occurring rather than how the problem can be solved) as well as on implementation pathway. In complex problems such as on-farm water management, an absence of acknowledgement and inclusion of end user input can result in inconsistencies and incompatibilities between science and practice. Co-innovation approach is focussed at addressing these shortcomings of tech transfer approach.

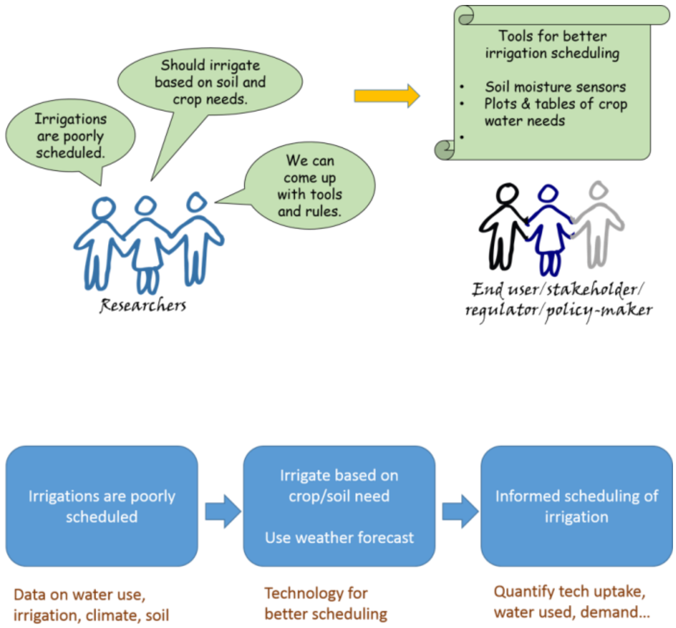

Figure 1. A representation of tech transfer approach to on-farm irrigation management.

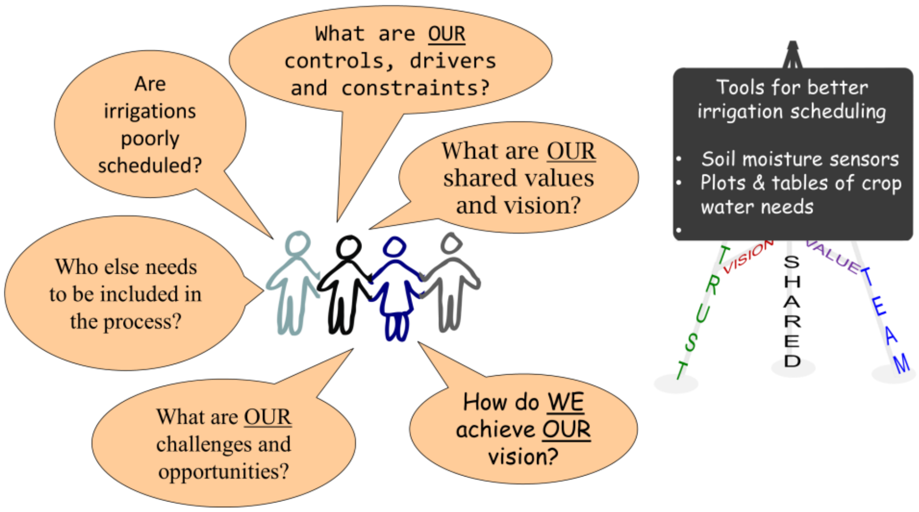

Figure 2. A representation of co-innovation approach to on-farm irrigation management.

In a co-innovation approach, all knowledge – scientific, anecdotal and experiential- and perspectives are considered. Unlike a tech transfer approach, the co-innovation approach tends to be multi-directional, non-linear, and multi-layered with no pre-defined end point. The stakeholders inform and drive the process. A robust co-innovation process encompasses a dynamic monitoring and evaluation process in defining the problem, identifying a solution and describing an implementation pathways towards the identified solution. Thus, co-innovation process tend to be long and time consuming, hence resource intensive. Inclusivity and flexibility are essential ingredients of a co-innovation process. We applied a co-innovation process to our irrigation management study. Firstly we discuss the wider irrigation landscape developed following a co-innovation process. Then we present a few key learnings and reflections based on a case study.

Controls on irrigation as identified through a co-innovation process

Although decisions about when to irrigate are made on-farm, the constraints and drivers to on-farm water management decisions often lie outside the farm gate (Figure 3). The design, development and dissemination of biophysical tools and solutions for improved water management need to consider the interactions between stakeholders, and thus need to apply approaches, such as co-innovation and co-learning, that will assist in developing an understanding and approach to solving the problem.

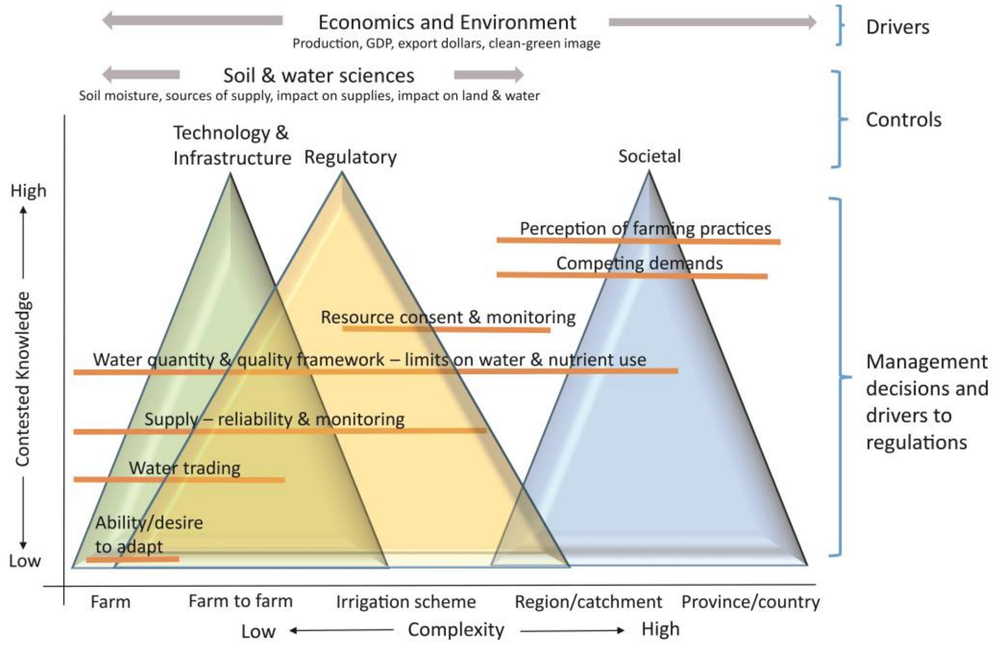

Figure 3. Irrigation management landscape of New Zealand (adopted from Srinivasan et al. 2017).

While irrigation may appear to be a stand-alone on-farm activity, the ability of farmers to practice it efficiently relies on several factors, many of which are beyond the farm. 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 consenting rules may influence irrigation decisions. At irrigation scheme level, the efficiency of on-farm irrigations can be influenced by environmental limits placed on nutrient and water use, and the ability of schemes to reliably reticulate water to meet demands.

At catchment and regional scales, planned water quantity and quality limits on resource use dictate irrigation practices. While catchment and regional-scale controls may not impact individual on-farm irrigation decisions, they can affect irrigation practice as a whole. At these scales, gradients in climate, specifically of rainfall, and soils hydraulic properties (Srinivasan and Duncan, 2011) and long term climate influences such as climate change (Srinivasan et al., 2012) can significantly impact on-farm irrigation practices.

At regional and national scales, public perception towards irrigation, and the demands from competing users, including from those expanding irrigation, influence irrigation practices. At national scale, the science knowledge available to make informed decisions and the ability to link cause and effect becomes limited. For example, using lysimeters, over-irrigation can be shown to result in drainage at farm scale (Duncan et al., 2016). However, relating the impact of over-irrigation and the resulting drainage at one farm, to wider catchment and regional scale water quantity and quality, is challenging.

Going from farm to national scale, the prevalence of differing viewpoints increases as the number of stakeholders increase. 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 the wider system along with the constraints and opportunities it presents.

Case study: lessons, observations and reflections

A pilot study is underway in the Waimakariri Irrigation Scheme (WIS) to investigate the use of weather forecast for better irrigation scheduling. We employed a co-innovation approach to enable a better definition and uptake of irrigation management tools. In 2012, five farms within the scheme were instrumented to measure irrigation, rainfall, and root zone soil moisture and soil temperature. These farm-scale data were combined with locally-corrected weather forecast and supplied to the pilot study farmers as daily email updates. Farmers were trained in reading these updates and schedule their irrigation according to soil/crop water demand and forecast supply (2 to 6 day rainfall forecast). The focus here was to reduce, if possible eliminate, drainage, and thus leaching, resulting from poorly-timed irrigations. Irrigation-drainage may occur from irrigations that occur either before or after significant rainfall events. In WIS, where irrigation requests are irrevocable and have to be made at least 48 hours ahead of planned application, ordered water has to be applied on land if no on-farm storage is available. In such instance, irrigations may occur immediately after significant rainfall events, resulting in drainage.

As a part of the pilot study, end-of-irrigation-season workshops are organised where pilot study farmers, researchers, and representatives from industry, regional councils and neighbouring irrigation schemes gather to go over the irrigation decisions made over the season and the reasons for those decisions. These open forums facilitate stakeholders to share their experiences and perceptions in a friendly environment. Stakeholders learn from others' experiences. Some of the co-learning happened at these meetings include acknowledgement of complexities to on-farm water management, quantification of climate and hydrologic gradients versus water management across the scheme area, challenges to using weather forecasts for irrigation, and the ability to control irrigation to control drainage and leaching, without losing on productivity.

The workshops also highlighted the need for education and training of end users in using irrigation scheduling tools. An understanding of soil properties such as root zone storage and the rate of water loss from root zone to drainage, transpiration and evaporation are key to irrigation management. However, such information are either unavailable to end users or available in a form that needs further interpretation for decision making. This impedes the effective use of soil moisture monitoring technologies and weather forecast as their use is closely linked to soil properties.

Lastly, this pilot study was limited to five farms in a scheme with more than 225 share-holding irrigators. When this study is scaled out to other farms in the scheme and further beyond, there could be additional challenges that have not been either envisaged or solved yet. These challenges could ranges from technical, social and educational. The known challenges range from the need to have a dense array of instrumentation and data integration (combining data from demand and supply ends in time to make an irrigation decision; this includes data accuracy and uncertainty) to education and training of end-users to make best use of available resources. This needs upscaling at many levels – irrigation schemes, research agencies, on-farm soil moisture monitoring services, and policy and regulatory authorities. This upscaling includes education, training and upskilling of stakeholders at multiple levels as well as developing infrastructure and multi- and trans-disciplinary skills.

Conclusions

Co-innovation offers an implementation pathway to accommodate multiple stakeholder views and needs. The application of co-innovation approach to on-farm irrigation management revealed the linkages of on-farm practice to a wider system. While learnings, observations and reflections within the pilot farms show a potential for efficient water use, to realize these efficiencies at larger scales – scheme, region and beyond – an integration of resources, data, stakeholders and capabilities is necessary. Such integration when placed within a co-innovation setting could be slow to evolve but will certainly be more effective and long lasting than when implemented through a tech transfer approach.

Acknowledgements

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