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IRRIGATION INSIGHT – A MBIE PROGRAMME THAT BLENDS CLIMATE, HYDROLOGY, ECONOMICS AND SOCIAL SCIENCE FOR IMPROVED WATER USE EFFICIENCY

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Abstract

Irrigation Insight is a MBIE-funded co-innovation programme focussed on understanding how the development of novel knowledge and tools affords dairy farmers the confidence to change established irrigation management practices, to more precisely apply the water needed by crops—where, when and how much. The research examines the application and effectiveness of combining improved weather forecasts, drainage estimations, and understanding of economic implications to inform on-farm water management on irrigated dairy farms. The programme aims to support dairy farmers in moving away from a 'just in case' or 'just in time' scheduling towards a justified irrigation approach that accounts for both current and future demand and supply. Five pillars make up the work programme: weather forecasting, soil hydrology, social science, economics and knowledge exchange. The programme is currently implemented on 11 dairy farms across the Canterbury Plains. The pilot farms are equipped with soil moisture sensors and provided site-specific short-term weather forecasts (1-6 days) to assist farmers with irrigation decision-making. In addition, the economic component of the programme assists farmers in understanding the financial gains and losses resulting from their irrigation management choices. Weather forecasting, soil moisture conditions and economic implications will combine to assist decision making and improve financial and environmental outcomes for case study farms, and the lessons learned will be scaled-up to support wider behaviour change. The programme partners are DairyNZ, AgResearch, Fonterra and IrrigationNZ. LIC is a research partner.

Introduction & Background

Irrigation management in New Zealand is influenced by hydrological, climatic, environmental, economic, regulatory and cultural factors that impact the farmers' ability and desire to rationalise their irrigation practice. Despite advances in biophysical sciences and on-farm technologies, many current irrigation management practices are not considered to be efficient, economic, or well informed by science. For instance, IrrigationNZ (2016) indicates that irrigation efficiency can be improved by as much as 20% through improved scheduling practices.

Irrigation Insight (II) is a MBIE-funded Endeavour programme that uses the concept of "justified irrigation" (JI), where each irrigation decision considers current and future soil/crop water demand as well as forecast water supply. The II programme is designed to improve irrigation practices and help farmers achieve these targets through proactive management and use of high resolution (1.5 km) weather forecasting. The programme focus is consistent with an industry-led initiative, the Sustainable Dairying Water Accord which requires irrigation systems to be designed and operated to minimize the water needed to meet production objectives.

Today's irrigation practices consider only current water supply and/or demand and are not often based on short term forecast (2-6 day) variations (e.g. impending rainfall or changing river flow). Farmers tend to irrigate by schedule or whenever supply of water is available, irrespective of demand ("just-in-case"). An alternative practice, deficit irrigation ("just-in-time"), bases irrigation on water demand, rather than supply. Both sets of practices can lead to economic losses (nutrient loss from root zone, stunted pasture growth from soils being too dry or wet) and environmental costs (contamination of receiving water from nutrients lost from root zone, reduced stream flow). The II programme is looking to advance the just-in-time irrigation into a justified irrigation by incorporating short term weather forecast.

The II programme researches the economic benefits of incorporating high resolution (spatial and temporal) weather data into irrigation decision making, including the risks arising from uncertain forecasts. We hypothesize that II would allow farmers to utilise forecast rainfall and existing soil moisture information better, reducing irrigation applications relative to other scheduling practices (e.g. deficit irrigation). As irrigation frequency decreases, water storage requirements and the associated loss of land to water storage will reduce. We test our hypothesis with data from surveys of current irrigation practices, on-farm measurement of irrigation demand and modelling of forecast demand and supply. NIWA's environmental monitoring network and supercomputing capabilities provide a platform for the work. The economic benefits from JI practices could range from financial savings and effects on productivity, to opportunities arising from saved water. At a farm level the extent of economic benefit will depend on the farmer's ability to adopt JI (e.g., infrastructure to schedule irrigation as and when desired). We analyse farmers' performance to evaluate their ability to adopt JI practices, which in turn will support further learning and upskilling.

Co-innovation principles underpin the programme and enable kaitiakitanga – sustainable management of land and water for future generations. Co-innovation enables stakeholders to jointly explore issues, develop knowledge and design solutions in response to complex problems, with a shared commitment to learning from the process. Currently the programme provides an online farm-scale tool that combines and visualizes current water demands and predicted future supplies in real time to enable JI decisions. We enhance the uptake of JI tools and practices through on-farm demonstrations, workshops and training programmes developed in conjunction with industry partners.

Programme structure

The II programme consists of four major components that are linked by a fifth component (see Figure 1). All five components inform and enhance each other, and are spread across the entire programme (see Figure 2).

Programme components

The programme is based on 4 guiding principles:

1. Provide reliable, accessible, easy-to-understand and actionable real-time information
2. Identify and account for uncertainty associated with information provided
3. Account for economic risks and benefits associated with use of JI practice
4. Facilitate and enhance stakeholder development and uptake of JI practice.

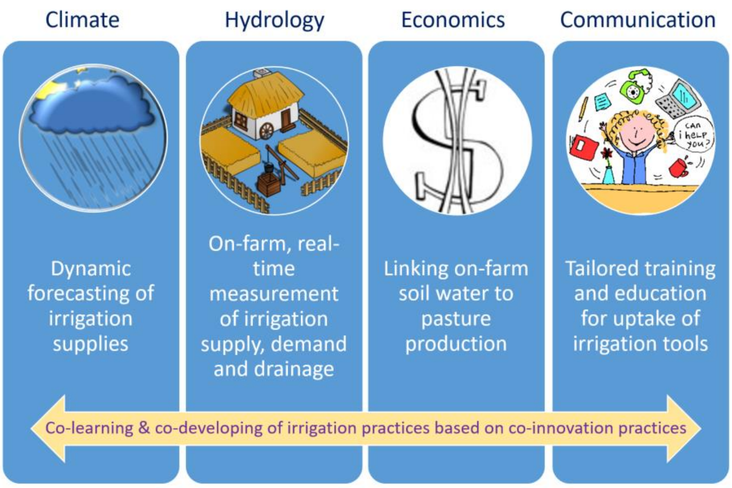

Figure 1. Irrigation Insight MBIE Endeavour programme – Programme structure.

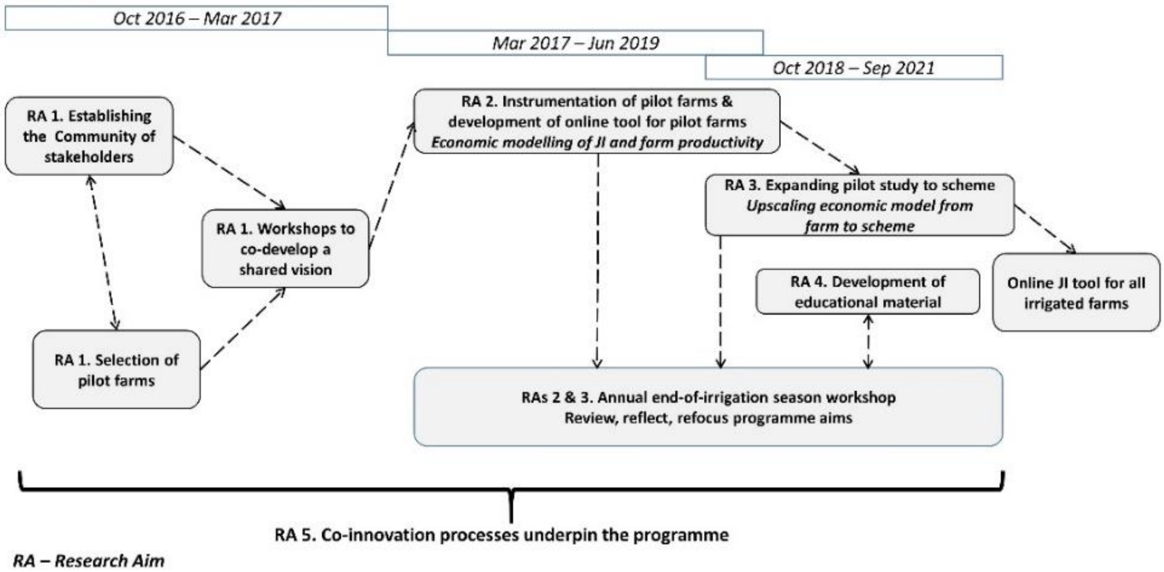

Figure 2. Timeline of irrigation insight MBIE Endeavour programme components.

Climate: The proposed research is conducted on 11 irrigated farms (see Figure 3) with varying biophysical demands on irrigation. On each farm, a profile soil moisture sensor and rain gauge have been installed to collect high frequency (10-minute) data on soil water conditions (proxy for current water demand), and rainfall plus irrigation (proxy for current water supply), respectively. The soil moisture sensor measures changes in soil water conditions at eight depths at 10 cm intervals.

Rainfall forecasts are based on global and regional NWP (Numerical Weather Prediction) models. NWP models with a global coverage provide forecasts 6 days into the future, and improved accuracy over the first 3 days is obtained using two local implementations of the UK Met Office Unified Model. NZLAM (New Zealand Limited Area Model) provides forecasts 3 days into the future at 12 km resolution, and NZCSM (New Zealand Convective Scale Model) provides forecasts 48 hours ahead at 1.5 km resolution. Both models are run every 6 hours, using results from previous runs to provide initial conditions, and provide forecasts at hourly time steps. In addition to estimating rainfall amounts over next 2-6 days, to account for uncertainty, we provide the probability of rainfall exceedance of pre-chosen thresholds, such as probability of exceedance of 10 mm of rainfall over next 24 hours. We also provide the most likely 6-day cumulative rain in daily time steps along with the range of possible amounts for each day. This approach will quantify the risks associated with forecasts, which farmers can use to inform their decisions. Combining the forecast information from a range of input NWP models in a sensible and accessible way will enable more strategic short- and medium-term planning, and hopefully reduce the need for farmers to triangulate their information from various disparate weather information sources.

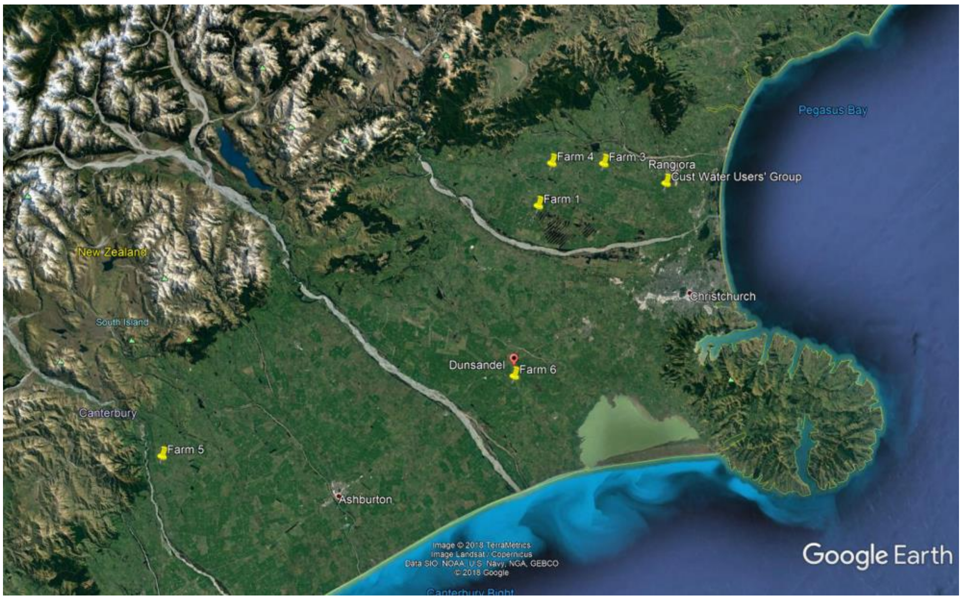

Figure 3. Irrigation Insight MBIE Endeavour programme – pilot farm locations.

Hydrology: Using a water balance model, data on current soil conditions and forecast rainfall (2-6 day) conditions are combined to produce current demand and forecast supply. The water balance model accounts for farm-specific irrigation demand, evaporation (current and forecast) and supply (current and forecast) conditions. Participant farmers are currently trained in using the online tool (termed as web-portal tool hereafter) at one-to-one meetings and hands-on workshops. At the end of each irrigation season, participants and pilot farmers are gathered for a workshop to review the information provided and the irrigation decisions made. Feedback will be used to refine the tool, data collection and presentation, and plan additional training as needed.

The web-portal tool provides summaries of farm-specific rainfall, irrigation, soil moisture and drainage data for user-defined periods, allowing farmers to track their irrigation practices. As JI practice becomes common, these summaries will become a part of audited self-management practice, providing regulators with objective evidence regarding environmental compliance.

In addition to the web-portal tool that assists farmers with day-to-day operational irrigation decisions, the programme is currently developing an irrigation strategy tool. The irrigation strategy tool is designed to help farmers assess macro irrigation scheduling options, such as adopting justified irrigation relative to deficit irrigation, while the web-portal tool deals with marginal decisions on each farm. In addition, risk is considered in the web-portal tool, given the inherent uncertainty in weather forecasts and using these to inform decision-making. Comparatively, the irrigation strategy tool focuses on average results across long term seasonal data and considers all critical information such as irrigation supply and demand, infrastructure limitations and weather forecast uncertainty, needed to make optimal irrigation decisions.

Economics: This component of the research programme aims to help farmers understand the economic impacts of irrigation choices to enable better, more informed decisions. It uses both modelled and actual data to understand the economic impact of management changes on the pilot farms in response to improved soil moisture and weather forecast information. It has two key aims;

1. to understand the economic and drainage impacts of various irrigation scheduling and management decisions (Irrigation strategy tool), and
2. a tool to help farmers manage risk and make marginal (daily) decisions such as whether to irrigate today, how much, and what is the impact of my decisions, now and in the future (short term, e.g. on the rest of the irrigation rotation) (webportal tool).

Both models are underpinned by similar economic information and relationships which have been described from observing and collecting data from pilot farms, as well as the best available literature**.** These economic impacts are focused on two key areas; direct and indirect costs. Variable direct costs are measured for each mm of water applied (water and pumping costs) or by each day irrigation is used (maintenance and labour). These costs, need to exclude the fixed costs that occur regardless of how often or how much a farmer irrigates. Indirect costs are reflected in changes in the pasture that is available to be offered to cows each season. Changes in pasture growth are calculated based on the relationship of actual evapotranspiration to potential evapotranspiration. Wastage is calculated based on feed offered but not eaten due to soil moisture levels. Pugging is calculated as reduced pasture growth and is based on stocking density and grazing duration.

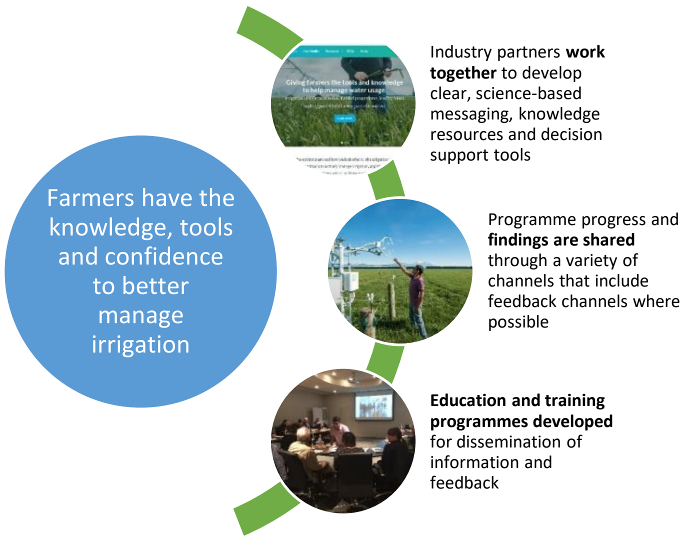

Figure 4. Irrigation insight MBIE Endeavour programme – communication among stakeholders.

Communication: This component forms the core of the programme, and explores various channels of communication between end-users and stakeholders. A public website, http://irrigationinsight.co.nz provides information about the programme to the public.

Co-innovation: Co-innovation provides a framework where methods, data and information from multiple science disciplines can be presented, reviewed and discussed by the Community of Stakeholders (CoS) to develop a shared understanding of the problem. There are several strands within the proposed plan which encapsulate both research and practice elements. These strands will combine to provide a further commentary on, and interrogation of, the practice of "doing" co-innovation in NZ.

To date this research strand has investigated farmers current irrigation practice and begun to identify barriers and enablers of change at multiple scales (i.e. from farm-level to irrigation scheme-level). Changes in practice, knowledge, attitudes and relationships between stakeholders will be tracked. We employ a grounded theory approach, using thematic analysis (Flick, 2009) in which the key themes emerge during the research process. Data is collected via workshops, semi-structured interviews, observations, surveys and feedback sheets (Kitchin and Tate, 2000; Flick, 2009).

The practice strand incorporates reflexive monitoring, facilitation and monitoring and evaluation (M&E). A reflexive monitor is *"an observer, facilitator and sparring partner to encourage participants to reflect on the relationships between project activities, the system context and the ambition for change"* (Arkesteijn et al., 2015). This approach will guide the project team in co-innovation process, creating a space for reflection through reflexive practice (van Mierlo et al., 2010) and ensures that the project operates in accordance with Coutts et al.'s nine principles of co-innovation (2016): 1. take time to understand the problem from different views; 2. be inclusive; 3. engage with and value all sources of knowledge; 4. strive to learn from each other; 5. keep sight of the shared vision; 6. be honest, open and constructive in interactions; 7. be flexible and adaptable; 8. be aware of the wider context of the problem; and 9. stick with the process despite its frustrations. Regular reflection will provide joint check-points on project progress and learning, and identify critical gaps, facilitate the capture of key moments when changes occurred, and ensure the project adapts to changing circumstances (van Mierlo et al., 2010).

The facilitation role ensures the meetings and workshops use effective techniques (Dick,1991; Chevalier & Buckles, 2011), and that the nine principles are embedded in project activities. M&E will further support the process of reflection and data capture through the construction of a logframe, which is a systematic, visual approach to designing, executing and assessing projects (Owen, 2006). Logframes articulate short, medium and long term goals that will be monitored and evaluated, and highlight how change can be achieved over the lifetime of the project and beyond (Better Evaluation, 2015).

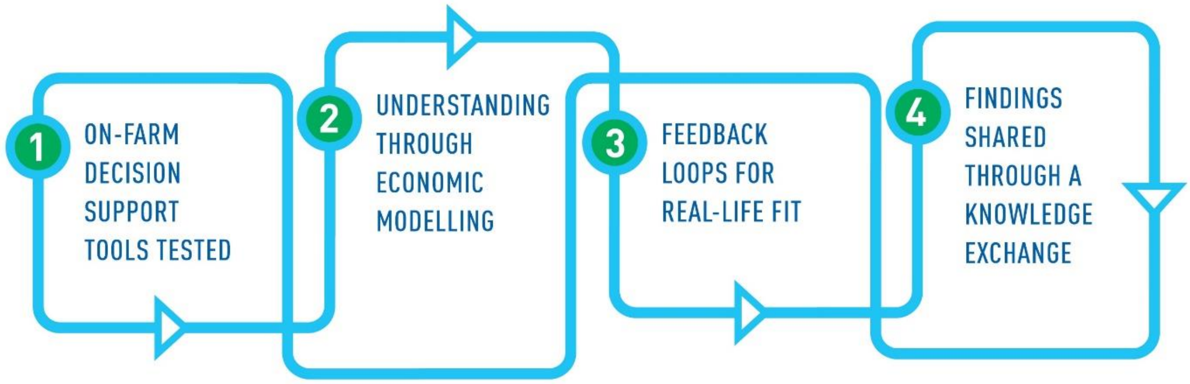

Figure 5. Irrigation insight MBIE Endeavour programme – inclusion of co-innovation principles.

Scaling processes are multi-faceted to include interactions "between biophysical, social, economic and institutional factors" (Wigboldus et al., 2016). In scaling the project from individual pilot farm to multiple farmers at the irrigation scheme level, practical steps will be taken to maintain the integrity of physical data collection. For example, we will use high resolution cloud-resolving NWP models to describe the spatial homogeneity of rainfall in order to optimise the placement of monitoring instrumentation and avoid measurement redundancy; and we will use a cluster-farm approach, where biophysical data will be collected from one farm and shared between multiple farms with similar climate, hydrology, soils and land use. We will monitor for evidence that a collective approach to data collection and sharing encourages change to existing practice, for example a more collective approach to irrigation management decisions.

Scaling processes are interactive and in introducing a novel technology steps will be taken to develop trust between users and suppliers. Quantitative measures will include timeliness of data delivery, data reliability and accuracy, but also qualitative insights into the perceived benefits of data provided and the consequences of any shortfall in delivery. Steps will also be taken to facilitate what has been described as an "enabling environment of change" (Douthwaite et al, 2003, page 247) to include seeking the support of the irrigation scheme, local opinion leaders as well as in-principle support and endorsement from regulators. At farm level, overcoming inertia around established habits and behaviours may require development of a new mindset regarding the institutions (rules & routines) characterising each producer's irrigation practices. Throughout, the scaling process will draw on the CoS for guidance

Conclusions

While the II programme focuses on irrigation decision-making, it also co-benefits water quality management. We envisage the II programme will provide a platform for integrated water quantity/quality management and future research. JI will enable farmers to optimise economic and environmental (farm footprint) outcomes and provide evidence of efficient water use to domestic and overseas markets. Among the significant benefits arising from JI for farmers are:

- Fewer irrigation events (saving money and water, and increasing supply reliability to other users);
- Co-benefits for nutrient management by reducing drainage, leaching and runoff, assisting farmers to operate within environmental limits;
- Introduction of the use of weather-based irrigation technologies that may become essential when climate change impacts intensify, and fosters resiliency to climate variability and droughts; and
- Peace of mind in the face of increasing regulation through a structured and transparent decision-making process.

In a radio interview in 2016, an entrepreneur described a desirable future state: "imagine if we could measure the soil moisture at any given time, integrate that with the forecasted weather and then use an intelligent model to tell the farmer precisely how much water he (or she) needs to give to his (or her) farm" (RNZ, 2016). That is exactly what the II programme is designed to deliver.

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