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NEXT GENERATION SYSTEMS; A FRAMEWORK FOR PRIORITISING INNOVATION

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Introduction

Primary production industries are constantly changing in response to external factors such as new market opportunities, consumer demands, changing community expectations of the social and environmental outcomes associated with the primary sector, and technological innovation (Gerber et al., 2010). These external forces for change will likely intensify over the next 10 years (MfE, 2016; DairyNZ, 2016; NZHEA, 2016).

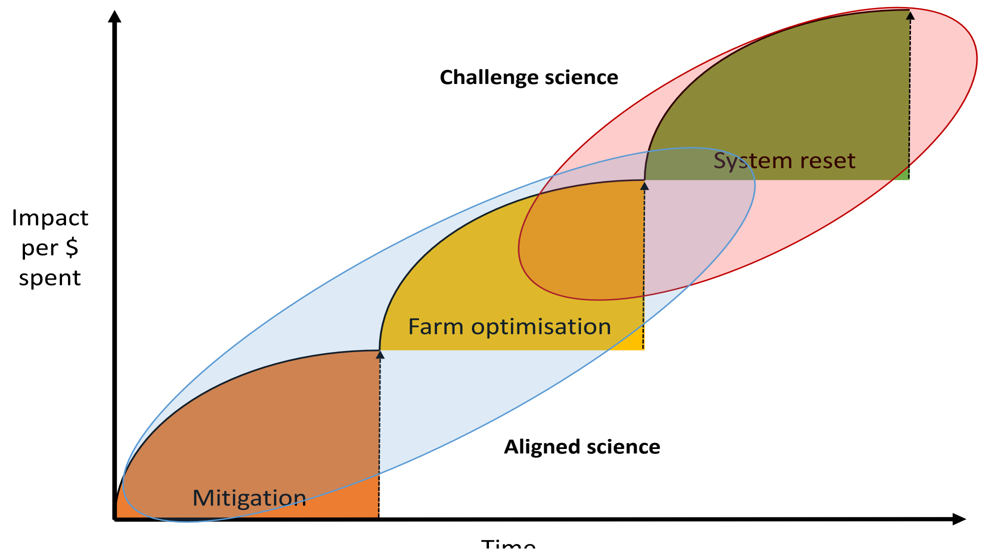
To enable primary producers to meet government targets such as doubling the value of New Zealand export returns while improving environmental performance, next generation land-based primary production systems (NGS) will be required. Next-generation systems may include redevelopment or redesign of existing enterprises and production systems, wholly new or novel enterprises, and new technologies that add options across temporal and spatial scales. The systems may cover a broad range of pastoral, arable, horticultural and forestry industries.

To move beyond business-as-usual, there is widespread agreement that greater innovation is required from all primary production industries, especially agricultural, horticultural and forestry sectors. CSIRO and CGIR propose that greater innovation requires greater coupling of research and technology with markets and also that policy changes will be required for solutions to emerge that will have an impact (Hall et al., 2016). Whilst incremental change will be valuable, solutions to the complex challenges facing the land-based sectors must provide opportunities beyond systems optimisation to transformational change.

The Our Land and Water National Science Challenge, under which this project sits, recognises that such a transformational change in systems requires transformational science (OLW, 2015). This may be defined as science that will deliver a generational leap in impact, but at today’s cost. Within the challenge this can, for example, be thought of as going beyond mitigations designed to retrofit existing farming operations within a catchment contaminant limit. The transformations needed may involve optimising the placement of farms within a catchment or even a complete system reset and redesign to create profit and environmental headroom. It is the role of the challenge to provide leadership in this area and to align additional science that fits this strategy, but also connects to near to short-term science needs (Figure 1).

Within the broader context of the OLW Challenge, this project is concerned with identifying NGS and engaging with land-use managers to support the process of transformation. This paper reports on the initial stage of the project that aimed to develop a general framework by which potential NGS could be identified, particularly relating to land-use systems.

Figure 1. Conceptual diagram showing the focus and leadership role of challenge science



Source: (R. McDowell, pers. comm.)

In this context a number of studies have already investigated the potential viability of new land-use systems within New Zealand (for example see CDC, 2015; Coriolis, 2012; Boyd, 2016; Bryan, 2015). These studies have identified, for example, dairy sheep, dairy goats, hazelnuts and Manuka honey as systems with the potential for significant expansion. However, in addition to identifying potential NGS there is the need to take into account the context in which any system is likely to be implemented. For example, land-owners' goals and objectives clearly vary (Pannell et al., 2012) and this directly influences whether or not new systems are adopted. In addition, there is spatial variation in such factors as climate, topography, regulatory pressures (for example from nutrient emission limits) and production opportunities (for example from new irrigation schemes). The requirements from novel systems and their likelihood of being adopted will, therefore, vary considerably across New Zealand. This means that any framework to identify potential NGS needs to take into account the situation of the individual land-manager. In the following sections we describe the development of such a framework and test its usefulness using a simple example involving two land managers and one possible NGS – dairy sheep.

Developing the Framework

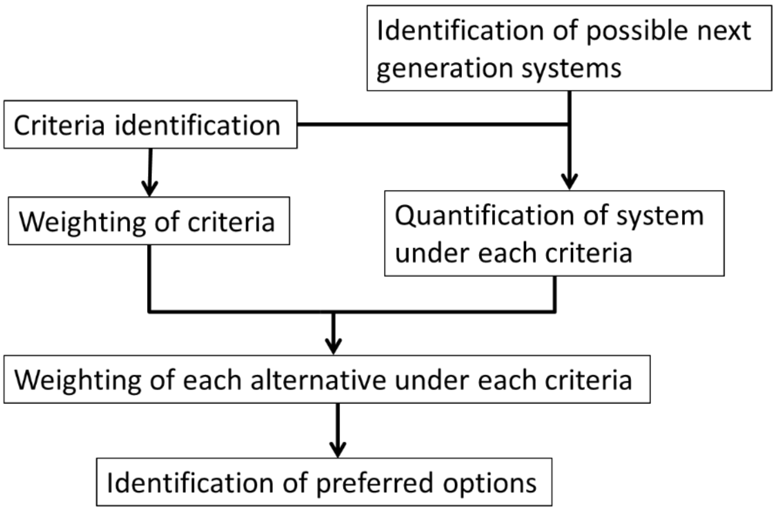
The framework for identifying and selecting NGS is based upon the concept of multi-criteria decision making (MCDM). MCDM is well suited because it provides the ability to simultaneously consider multiple domains (for example, financial, social and environmental) where selection of best alternatives is highly complex. The approach here recognises that for land owners and managers, this assessment is primarily a business decision but is, of course, influenced by other factors. A key advantage of an MCDM approach is that it allows the selected criteria to be weighted depending upon the individual's situation. In addition, instead of transforming all interests and goals into monetary units and performing a cost benefit or cost effectiveness analysis, MCDM acknowledges that not all factors can be expressed in money terms (for example, individual preferences for livestock farming).

MCDM has been widely used in investigating sustainability both generally and in relation to land use (e.g. Alrøe et al., 2016; Bausch et al., 2014; Allan, 2013; Cinelli et al., 2014). Although less common, it has also been used within the context of managerial decision making. For example, Beim and Le´Vesque (2008) used the approach to investigate the business decision as to whether or not to enter a new international market.

There are a range of methodologies that have been developed for undertaking MCDM analysis. Evaluation of the different approaches highlights that each has particular strengths and weaknesses and no one approach can be seen as definitively better than others (Cinelli et al., 2014). As outlined by Saaty (2008), the Analytical Hierarchy Process (AHP) is appropriate for the requirements of this study. Using this method the framework outlined in Figure 2 has been developed based on published literature and refined following feedback from industry representatives, consultants and rural entrepreneurs.

Effectively the process involves first identifying possible NGS that could be relevant to the New Zealand situation. The next stage requires identification of the criteria against which the systems can be evaluated. The performance of the selected system is then quantified against these criteria (this can be undertaken using objective data but can also be more subjective – for example through expert opinion). In addition, the importance (weights) of the criteria to the decision making process are determined using AHP through engagement with the relevant decision maker (s). The final stage of analysis involves weighting each alternative system under each of the criteria allowing identification of preferred options.

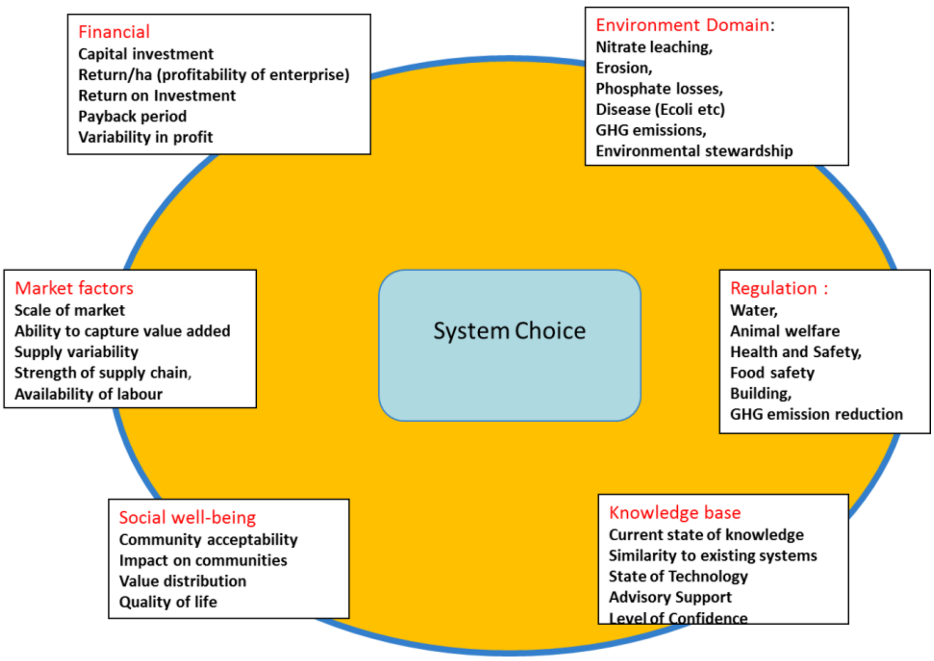
Figure 2. Framework to identify Next Generation Solutions using MCDM Assessment



Criteria Identification

As noted above a crucial component of the AHP is identification of the criteria to be used to evaluate alternative systems. Within this project, the criteria were identified (and refined) through a process involving review of the literature, scientific opinion and verification with those involved in land management. From this process a number of criteria emerged which were classified into six key domains: financial; market; environment; social well-being; regulation and; knowledge base (Figure 3).

Figure 3. Domains and examples of Sub-Criteria of the Assessment Framework.



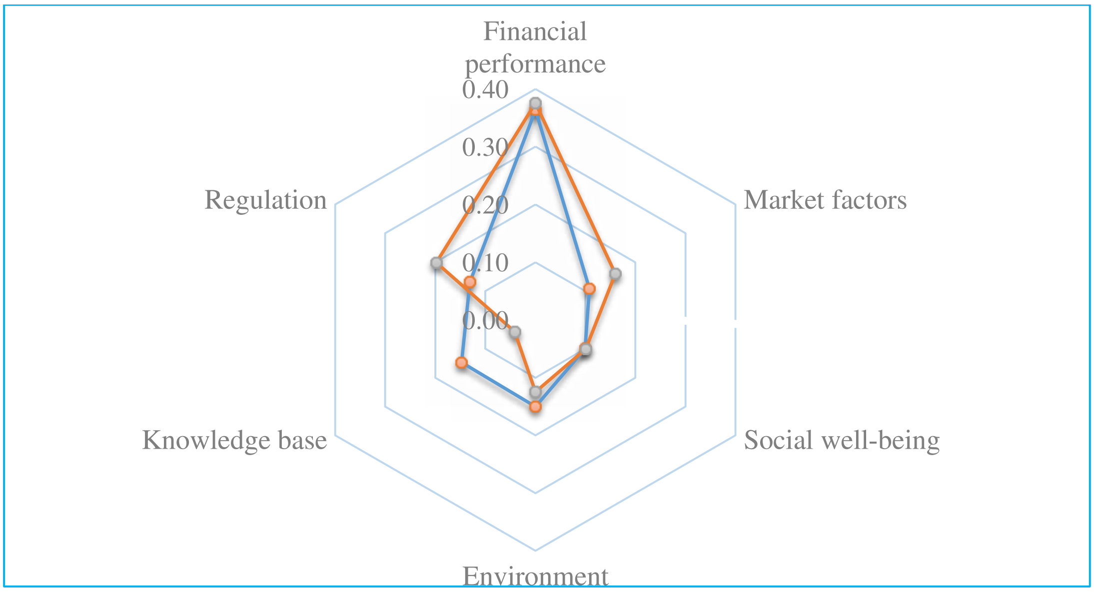
Testing the Framework

Weighting the Criteria

To test the viability of the framework, two land managers were taken through the AHP process at both the domain and sub-domain (individual criteria) levels.[1] Effectively AHP involves undertaking pairwise comparison between the domains to determine the relative importance of one against the other. For example, within the context of this study, this compares financial against environment, financial against market, etc. From these comparisons it is possible to calculate weights for each of the domains. Weights were derived for each of the domains (Figure 4) and for the criteria within each domain (Figure 5) for the two land managers. Financial performance dominated the decision making process with both respondents giving it a weight of nearly 40 per cent out of a total of 100 per cent for all the domains (Figure 4). This means that, even if a NGS performed well across the other five domains, unless it performed well in financial terms it was unlikely to be favoured (adopted) by either of the land managers. Whilst the overall weight given to financial factors was very similar between the two land managers, there was a marked difference in terms of weighting of the criteria within that domain. The length of payback period was the prime concern of the family business whilst the corporate business was concerned mainly with the overall return on investment (Figure 5).

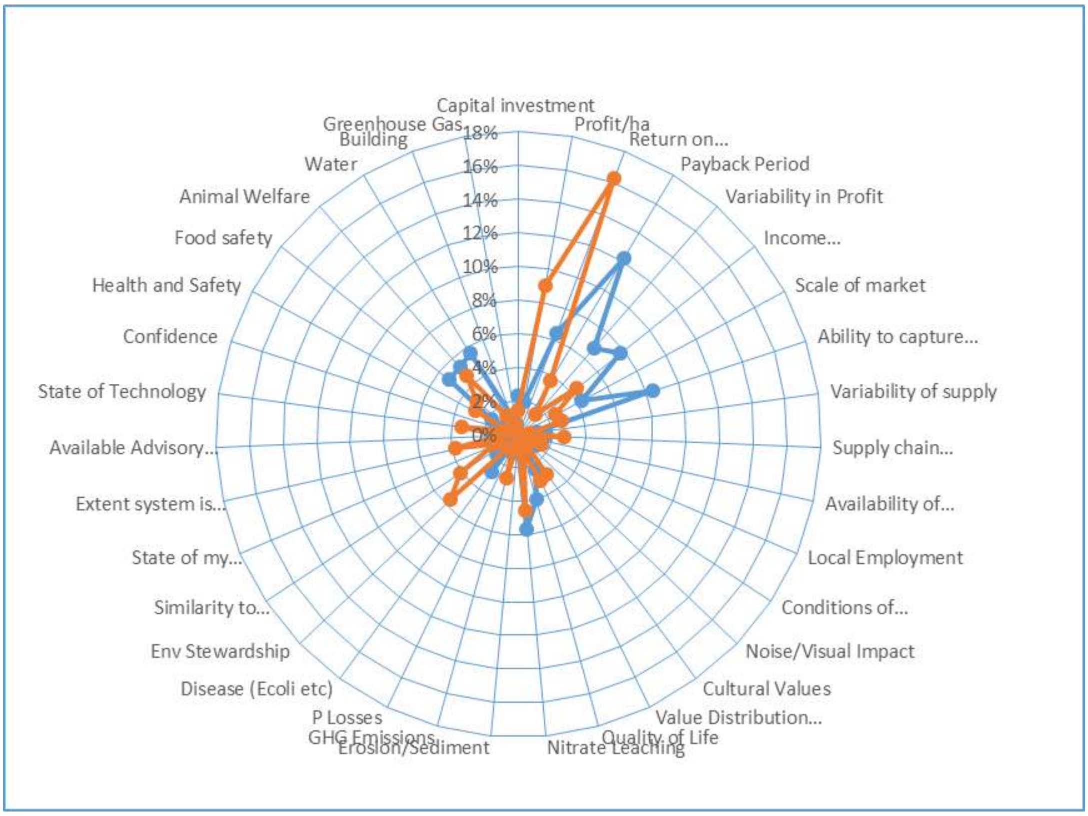
The two interviewees weighted environmental factors very similarly in terms of importance, but they varied in the weights given to the knowledge base and regulation domains. The existing knowledge base was less important to the family business (they felt they could 'learn as they go') but for the corporate (and larger scale investor) it was more important that a solid knowledge base existed. On the other hand, regulatory issues were more important for the smaller business, reflecting perhaps the general understanding that regulatory burden falls more on smaller businesses relative to larger ones.

Figure 4. Domain weights derived by AHP



[1] The two interviewees represented quite different types of farm businesses. One was a small family farmer whilst the other represented larger corporate style farming.

Figure 5. Individual criteria weights within the domains derived by AHP



Evaluating an emerging system using the criteria

To highlight how the criteria can be used to evaluate emerging systems the weights derived from the two interviewees were used to evaluate one such system - sheep dairy. To quantify the performance of sheep dairy against the selected criteria, expert opinion was sought. For this example, each criteria was rated on a simple one to five Likert scale (with five representing that the system performed strongly under the chosen criteria).[2] Within the financial domain, the dairy sheep system is viewed as performing particularly well in terms of returning a good profit per hectare and a good return on investment (Figure 6). In the environmental domain it was viewed strongly in terms of being associated with relatively low levels of nitrate leaching. On the other hand the system was seen to perform relatively poorly in the market domain in particular in relation to supply chain strength and scale of market. In addition the level of GHG emissions were seen as a weakness of the system within the environmental domain.

[2] For many of the criteria the ratings can be replaced by actual or estimated performance figures (e.g. return per hectare, investment costs, etc) to give a more robust evaluation of system performance rather than relying on the views of a single expert. However, for the purposes of this illustration the scale approach suffices

Figure 6. Performance of Sheep Dairy against Selected Criteria

The final stage of the process was calculate an overall score for the system by multiplying the Likert rating score by the weights derived from the land managers for each of the criteria. The figures came out at 3.69 and 3.79 for the family farmer and the corporate business, respectively. As the Likert scale was used throughout these figures can be taken as representing a score out of five, illustrating that sheep dairy performed well against the weighted criteria for these land managers. Of course, as other systems were not evaluated it is not possible to say how well sheep dairy performs relative to other options. However, the test does show that the framework is able to be applied in practice and both land managers stated that it was able to capture the essence of their decision making process. There is also strength in its ability to calculate an 'overall score' for each system enabling comparative ranking of systems taking into account the factors that are important to each business.

Conclusions

This paper began by highlighting that NGS will be required to enable New Zealand's primary industries to meet the demands placed on them. It also argued that, whilst it is possible to identify a wide range of NGS, evaluation of these systems must be placed in the context of the situation facing individual land managers. To address this a framework with the flexibility to be used at the individual level was developed and tested.

Whilst the paper reports only a simple test of the framework, there appear a number of advantages associated with the approach for the future development of research into next generation systems and their adoption within NZ. First, the interactive approach (using a graphical interface) for selecting the criteria weights allows a detailed discussion with the land-user about the process of system change. Second, through identifying the criteria that are important in influencing adoption of new systems, attention is drawn to areas where objective information is required to support decision making. Thus it can highlight where there are potential gaps in our knowledge that (transformational) science can be used help fill which in turn can reduce the risks to land managers of adopting new systems. The framework can also highlight how well a particular system fits with the land-users' needs and therefore give an indication of the extent of the pressure for change. Finally, it also can help assess the extent that new technologies etc. can shift systems so that they better meet the criteria set by land managers.

The next stage of the project will be to support decision making using the framework through partnerships with innovative businesses undertaking investments in partial or full system transformation. This interaction will be used as a feed-back loop to modify the framework based on gaps identified in collaborative commercial-science evaluations.

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