Balancing the push and pull factors of land-use change: a New Zealand case study

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Abstract

New Zealand is increasingly facing environmental and social challenges associated with its current land-use choices. There is therefore a drive to find ways to continue to add value to its primary sectors, which are of significant economic value to the country whilst at the same time mitigating the externalities associated with the use of land in primary production. Next-generation systems (NGS) are identified as potentially being able to address these challenges. Through the application of a multi-criteria decision making tool, this paper identifies the factors that are important to individual land managers in terms of choice of land-use and how these factors may act as barriers or facilitators of change. By examining land-use change as a combination of push and pull factors between alternative systems, this paper highlights the complex and context specific nature of decision-making at the individual land-manager level and the importance of risk perceptions. It argues that simply pushing land managers away from land-uses that have “undesirable” characteristics through regulation is unlikely to lead to a sustainable transition without the existence of viable alternatives. There is a need to balance increasing the risk of current land-uses whilst at the same time reducing the risk of transitioning to next-generation systems.

Keyword Land-use change · Multi-criteria decision-making · Risk · New Zealand

Background and introduction

The challenges associated with current land-uses in New Zealand have been well documented (OECD 2017, Bibbee 2011; Davies et al. 2018; Journeaux et al. 2017). They have arisen, in part due to a rapid growth in dairy production over the last 20 or so years with consequent shifts in land-use away from less intensive beef and sheep livestock production in particular. In addition to these changes at the extensive margin, existing dairy farms have generally increased their intensity of production. Due to the low level of government intervention in NZ agriculture, these changes have been driven by market factors and have contributed to significant economic growth for New Zealand’s primary sector. However, there have been external costs associated with these changes to the nature of NZ agriculture. According to the OECD (2017), New Zealand is experiencing unprecedented levels of water scarcity and water quality issues, very high per capita greenhouse gas (GHG) emissions, threats to biodiversity and significant erosion of vulnerable hill country. Whilst the nature of these environmental concerns is similar to other developed countries, some are particularly acute for New Zealand. For example, it stands out amongst developed

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economies due to the fact that GHG emissions from agriculture account for 48 per cent of total emissions (MfE, 2019). Beyond the direct impacts, a decline in environmental quality threatens the ability of New Zealand to uphold its marketed “clean green” image (MfE 2001). This has led to a push to find ways that NZ can continue to add value to its primary sectors whilst at the same time mitigating the externalities associated with land-use in primary production, particularly around emissions to air and water.

Novel, alternative land-use systems, referred to hereafter as next-generation systems (NGS), exist that could help address these challenges (Renwick et al. 2017; Davies et al. 2018; Brown et al. 2019). 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. A number of studies have investigated the potential viability of new agricultural land-uses within New Zealand (CDC 2015; Coriolis 2012; Boyd 2017; Bryan 2015). These studies have identified, amongst others, dairy sheep, dairy goats, hazelnuts, forestry with multicropping and manuka honey as systems with the potential for significant expansion and which may have lighter environmental footprints than the predominant systems in New Zealand. However, whilst extensive work has been undertaken identifying potential new opportunities, there has not been a large scale move towards more benign land-use and agricultural systems with lower environmental impact (Fairweather & Campbell 2003; McDonald et al. 2016). In fact, more of a transition to intensification and increased production within existing systems has been witnessed (Brown et al. 2019; Hunt 2015). The response of government both at a national and regional level to these pressures has largely involved placing increasing restrictions on current land-uses (Journeaux et al. 2017) which may be viewed as pushing land managers away from certain enterprises. Industry responses have generally been high level rather than specific, focused on conferences, working groups and strategies.¹

However, without viable alternatives for land managers, such push factors risk harming the economic viability of an important sector of the New Zealand economy, particularly in the context of the impact of Covid-19 on other

sectors, notably tourism. There is therefore a need to better understand the factors that may push or pull land managers towards alternative land-use systems so that possible interventions can be identified that will aid the NGS land-use transition process in New Zealand (Renwick et al. 2017; Journeaux et al. 2017).

This paper adopts a novel approach to understanding the barriers and facilitators of system change. It considers the perspectives of land managers and what they are seeking from a new system and in the process identifies the factors that are pushing (or pulling) them away from their current system and towards a new one. This paper is based on the premise that there is a need to understand the motivations and perceptions of land managers regarding land-use change in order to support a transition to options that lower environmental impacts and meet emerging social requirements within both rural and urban parts of New Zealand (Hunt 2015; Fairweather & Campbell 2003; McClintock et al. 2002; Brown et al. 2019; McDonald et al. 2016). We argue that if particular factors are key to the decision-making process in terms of changing land-use, then it is within these factors that barriers to or facilitators of change can be found. These insights can enable more informed policies to be developed that can de-risk and accelerate the transition process.

This paper proceeds in two steps:

1. A multi-criteria decision-making framework is applied with a range of New Zealand land managers to enable a greater understanding of the criteria used in the land-use decision-making process.
2. Discussion with land managers identifies key factors that are preventing or facilitating land-use change. These factors are viewed in terms of whether they exert a push away from or a pull towards different land-use systems.

Context

There is an extensive international literature that considers how movement occurs away from one form of land-use to another and why such movement may not occur as quickly as expected (Schmidt & Marschinski 2009; Pannicke et al. 2015; Clifton-Brown et al. 2017; Hagemann et al. 2016; Huber et al. 2017). Significant factors influencing the extent and speed of change include socio-economic, policy-institutional and agro-ecological systems, elements or interactions. These are often identified as factors that influence, drive or moderate change. Studies in other areas of adoption of novel systems, both in the context of the bioeconomy and elsewhere, have shown that multiple factors are likely to contribute to low levels of innovation adoption (McDonald et al. 2016). It has been found that resistance to emerging

¹ For example, Te Hono was convened in 2012 as an industry initiative bringing together 260 chief executives and leaders representing 80% of New Zealand's primary sector to pursue innovation and transformational change in their industries (Te Hono online, n.d.). Also, Beef+Lamb NZ, as the largest industry body representing pastoralists in New Zealand, has adopted their own industry sustainability strategy, with a goal of carbon neutrality by 2050 (Beef+Lamb NZ Ltd online, n.d.).

technologies or land-use options remains significant (Henry and Trigo, 2010; Bilali 2018; Brudermann & Sangkakool 2017; Wirth et al. 2018). Research addressing such factors has often identified barriers to adoption as an important element of understanding how to progress the bioeconomy, in such industries as biotechnology, energy or built infrastructure. There is also the need to consider these issues as they apply to the agricultural sector and agri-food systems (Bilali 2018; Huber et al. 2017; McDonald et al. 2016).

The presence of multiple interacting factors has been demonstrated and documented in a number of case studies of land-use changes (Bryan 2013). For example, Clifton-Brown et al. (2017) found that *Miscanthus* plantings were lower than expected in the UK despite significant technological and geographical barriers having been overcome through research programmes and there being identifiable on-farm benefits. They identified agronomy, capital costs, logistics, social acceptability of land-use change and market confidence and maturity regarding final products as being barriers. Similarly, Bennich et al. (2018) investigated the Swedish forestry industry and identified particular social and ecological factors as barriers in addition to the often cited technological factors. In the context of uptake of conservation agriculture (CA), Baudron et al. (2015) emphasised that it is important to understand both the barriers to adoption and the drivers experienced by land owners and land-users who may adopt CA and their own factors of demand across these areas such as water, nitrogen, erosion control and energy use.²

A number of authors have argued that to increase our understanding of barriers requires an approach that considers multiple perspectives, addressing both micro-level factors (at the farm, enterprise and rural landowner level) and macro or higher level factors (institutions, markets and policy) (Nankya et al. 2017; Henry and Trigo 2010; Journeaux et al. 2017; Brown et al. 2018). For example, within New Zealand, Journeaux et al. (2017) state that “The literature suggests that economics, natural resources of soil type, slope and climate, as well as social preferences and the interaction of these is what will drive land-use change. Factors that influence these, such as the impact of regulations on economic returns of a particular land-use, will therefore contribute to land-use change” (p. 20). McDonald et al. (2016)

and Brown et al. (2019) discuss findings that identify a number of important factors when explaining why land-use change was not undertaken by New Zealand landowners and land managers. These included social, economic and environmental areas of concern, with particular emphasis given to preference-based or personal life-style choices. This can explain the fact that despite a number of studies and tools being developed/used in NZ to identify the biophysical suitability of land-use options, this has not led to widespread uptake of NGS.

Risk has been repeatedly shown as key to understanding the process of innovation adoption in many contexts, including the uptake of novel land-uses (e.g. Sangkakool et al. 2018; Kim et al. 2015; Just and Zilberman 1983; Abadi Ghadim et al. 2005; Hand & Tyndall 2018; Journeaux et al. 2017; Brown et al. 2019, Chavas & Nauges 2020). Within agriculture, adoption of new systems/technologies generally involves some risks to the business. For example, they may be unproven in the farm situation; require capital investment (therefore increasing debt levels); require changes in management practices or to the farm system as a whole; and/or require the development of new skills. However, they also have the potential to be part of a risk management strategy for a business. This could be through selection of less risky systems/technologies, improvements in profitability, a reduction in the variability of product quality or enabling regulatory compliance.

In the field of agricultural economics, notably in adoption studies, risky decisions have traditionally been analysed in the light of von Neumann and Morgenstern’s (1947) expected utility theory (EUT) (Bocquého et al. 2014). Classical expected utility theory (EUT) argued that decision-makers evaluated the possible losses or gains available from a new alternative (i.e. a technological innovation or land-use) together with the likelihood of their occurrence to help make their decision (Bocquého et al. 2014, 2015; Chavas & Nauges 2020). However, empirical studies of decision-making often supported a more behavioural model such as prospect theory (PT). PT accounts for more subjective or behavioural elements to individuals’ risk perception in decision-making, including comparison with a status quo or reference point making risk a relative, rather than absolute, measure. PT also predicts that as predicted outcomes move further away from this status quo, attitudes to risk also change and differ above or below the status quo, and especially in relation to unlikely extreme events (Bocquého et al. 2014, 2015; Chavas & Nauges 2020; Gonzalez-Ramirez et al. 2018).

Understanding more accurately, the relationship between risk and farmer decision-making may enable better design of more effective and targeted policy interventions (Bocquého et al. 2014, 2015). For example, a number of studies have examined risk perception as a way of understanding barriers

² For example, they state ‘The success or failure of CA interventions should not be measured by the intensity of tillage or by the quantity of surface mulch in the target area, but by the impact of the intervention on e.g., cost of production, erosion control and water productivity. This implies that attention should be placed on understanding who the target groups (“clients” of the innovation) are, and what their demand is (e.g., performance, cost, labor demand), similarly to the design-specification process used in the industrial and commercial sectors [6]’. p. 349.

to adoption (Kim et al. 2015; Pannicke et al. 2015; Baudron et al. 2015; Hand & Tyndall 2018). A key component of this has involved classifying land managers according to their tolerance for risk (e.g. whether they are risk averse, neutral or seeking) and whether or not this affects the likelihood of adoption.

Understanding the risks faced and the tolerance for risk of land managers can provide insights into how adoption of more sustainable systems can be encouraged. For example, modern portfolio theory (MPT) highlights how risk can be managed through (in this case land-use) diversification (Radulescu et al. 2014; Werners et al. 2011; Paut et al. 2019). For example, Radulescu et al. (2014) used MPT to examine risks across weather, markets and the environment. When the levels of risk across these areas were adjusted, the preferred diversification portfolios also changed. This suggests that not only is diversification (for example, through the addition of an NGS to the farm system) a strategy that may reduce risk, but also that the nature of the diversification will vary depending on the land manager's tolerance for risk (Radulescu et al. 2014; Paut et al. 2019).

In line with this, Hand and Tyndall (2018) found that land managers make decisions around new land-use options according to their perceptions of financial and market risk and that lowering risk and uncertainty was important in supporting land-use decision-making. Pannicke et al. (2015) argue that risk arises when considering transitions away from traditional resource use because of competing claims on limited resources. They argue that the stronger the competition between land-use alternatives, the greater the risk that is present in the transition from one to another. They also noted sources of risk from potential product conflicts such as where existing products are well tested and proven and so are more readily accepted by consumers as compared to products from NGS.

In NZ, risk perception was recently captured as part of the biennial Survey of Rural Decision Makers (Manaaki Whenua Landcare Research, 2019). Land managers were asked to report on their values towards subjects including taking risks, experimenting and trying something new in different industries across the primary production sector. On a scale of 1 to 10, arable farmers on average scored their preparedness to take risks as 6.4. In comparison, dairy farmers returned a score of 4.9, Grazing farmers a score of 4.7 and other stock farmers returned a score of 5.3.

Of particular relevance to this study, Baudron et al. (2015) identify trade-offs made at the individual land-user level as an important factor when understanding the adoption of new agricultural systems. This supports an approach that attempts to understand decision-making from a multi-criteria perspective as it can highlight current gaps in decision-making support.

Methodology

Multi-criteria decision-making framework

This study adopts an approach based on Multi-criteria decision-making (MCDM) to understand the importance that individual land managers or groups place on particular factors within the decision-making process. MCDM methods are being increasingly applied to a wide range of issues across a number of scientific disciplines (Diaz-Balteiroa et al. 2017; Zavadskas et al. 2017; Marttunen et al. 2017). In this context, it has become increasingly utilised where technical information and expert judgement is involved (Ananda and Herath 2009, Huang et al. 2011) and has been widely applied in investigating sustainability both generally and in relation to land-use (e.g. Alrøe et al. 2016; Bausch et al. 2014; Allan Planning and Research Ltd 2013; Cinelli et al. 2014; Mardani et al. 2015; Zavadskas et al. 2017).

The analytical hierarchy process (AHP) is one of the most widely used methods for undertaking MCDM (Saaty 2008; Huang et al. 2011; Mardani, et al. 2015; Diaz-Balteiroa, et al. 2017; Marttunen et al. 2017). AHP assists decision-makers to construct their preferences via criteria weighting and scoring. (Diaz-Balteiroa et al. 2017; Marttunen et al. 2017; Ishizaka and Siraj 2018) and has been used in broadly similar contexts (see, for example, Lai et al. 2012; Fontana et al. 2013).

A crucial component of applying MCDM and the AHP is identification of the criteria to be used to evaluate alternative systems (Fontana et al. 2013; Talukder 2016). Within this research, the criteria were identified (and refined) through a process involving review of the literature, scientific opinion and verification with those involved in land management (van Asselt et al. 2014; Jozi and Ebadzadeh 2014; Fontana et al. 2013). From the process, a number of criteria emerged which were classified into six key domains: financial, market, environment, social well-being, regulation and knowledge base (Fig. 1).

As explained in Renwick et al. (2019), the AHP analysis is conducted in three stages. First, the AHP is applied with participants at the domain level and weights generated as to the overall importance of each of the six domains. Second, it is then applied within each of the domains across the subdomain criteria generating weights for each of the criteria. Finally, the weights for each of the criteria at the subdomain level are multiplied by those generated for the overall domain to arrive at an overall value for individual criteria. For example, if the weight for the financial domain overall was 0.5 and that for return on investment within that domain was also 0.5, this would mean that the overall weight for return on investment in the final decision-making process would be 0.25 (0.5×0.5). Weights for individual criteria can

Fig. 1 MCDM framework domains and subdomains

therefore theoretically range from zero, if that criterion has no influence on decision-making through to one if it is the sole determinant.

As part of a wider 5-year project on NGS, interviews were held with rural land-use decision-makers in the commercial owner-operator agricultural sector of New Zealand. Through the application of an MCDM framework, the interview-focused methodology sought to allow participants to describe factors within the domains that may be pushing them away from or pulling them towards land-use options (both existing and NGS). Table 1 provides a brief summary of the characteristics of the land managers, who differed in their context in terms of drivers of land-use change, their geographic location and business type. They were not chosen to be representative of the farming community as a whole, but because they were actively considering land-use change (or had recently changed land-use). An advantage of comparing such potentially different land managers is that this captures the differences in importance land managers place upon the elements of decision-making. In total, 25 land managers were interviewed over a 2-year period from January 2017 to July 2019.

Results

Initially the findings are presented in terms of the importance given to the various factors that may influence land-use change (the domains and subdomains within our study). The second stage highlights the extent that these act as

barriers to change and presents the findings as to how push and pull factors interact to influence the decision-making of land managers.

Domain level

Figure 2A and B present the average and individual weights, respectively, for the land managers. On average, at the domain level, the most important factors influencing decision-making were within the environmental and financial domains (Fig. 2A). Social well-being factors were next in terms of importance with market and regulation below these. On average, the lowest weight is found for knowledge factors. However, it must be noted that these findings are not easily generalisable beyond the sample due to the nature of participant selection. The individual weights highlighted the diversity across the sample in terms of the importance placed on the different criteria (Fig. 2B). In terms of understanding barriers and facilitators of land-use change, this diversity suggests that the factors that influence change will vary considerably across land-users. In addition, land managers often saw linkages across factors and suggested that multiple domains or factors are likely to be exerting influence on decision-making concurrently.

Sub-domain level

Drilling down to the subdomains within the framework, the results show variation in weightings of the subdomains in two ways: there is notable variation in the degree to which

Table 1 Summary of Interview Participants

Interviewee ID	Location	Land mgmt. descriptor	Driver for change	NGS or non-NGS considered
INT001- INT010	SI	Family farmers	New Irrigation Scheme supporting a shift from dryland, to irrigated systems with increased diversification opportunities	Range of annual crop systems
INT011	NI	Family farmer	Succession planning important. Return from current arable system seen as too low	Switch to horticulture (apples, kiwifruit)
INT012	SI	Hill Country	Looking to generate profit from traditional sheep and beef land	Range of diversified land uses
INT013, INT014, INT015, INT016	SI	Maori Corporate MC	Looking for returns from land coming out of forestry and diversification from dairy investment	Sheep dairy, horticulture
INT017-INT020	NI	Maori Trustees MT	Harvested forestry land and now looking for alternatives	Hazelnuts, mixed tree crops, tourism, horticulture
INT021	NI	Regenerative farmer*	Looking for sustainable land uses at scale	Hazelnuts
INT022	NI	Smallholding*	Needs high value added, concerned about regulatory impact	Multiple cropping linked with forestry (nuts etc.)
INT023	SI	Small family farmer	Generate income from relatively small area	Sheep dairy
INT024	NI	Small family farmer	Needs value added from area constrained by strong regulatory control in terms of nitrate limits	Value added beef
INT025	SI	Family farmer	Regulation from water placing pressure on dairy production	Sustainable land uses

an individual subdomain influences decision-making and subdomain weightings vary between individuals. Table A1 and Fig. A1 in the Appendix present the full results, whilst Fig. 3 provides an example of this variation using the financial domain as an example.

Figure 3 also shows that participants who gave a similar weight to the financial domain, varied considerably when it came to the weights for the sub-criteria within that domain. This pattern was replicated across the other domains. This highlights that the considerable variation we find in the weights given across our respondents is not simply a result of some land managers being more focused on one domain (financial, environmental etc.) than the others, but is also due to variation within the domains. This is shown more clearly when land managers are grouped according to which of the domains they gave their highest weight to (Figs. 4a, b and c).

These findings at the subdomain level highlight that it is not possible to classify land managers as simply being driven, for example, by environmental or financial factors, because within these broad areas, they place markedly different levels of importance on the sub-criteria. Overall, the MCDM process gives a clear indication of the importance that land managers are placing on the various components of the decision-making process.

Domains as indicating barriers to land-use transformation

Whilst discussing the underlying processes that led to the derivation of the weights, the land managers often referred to the characteristics of these factors that would push or pull them between different land-uses and how they would facilitate or act as a barrier against land-use transition.

Financial and market barriers

In general, as would be expected, profitability was a key consideration for the land managers. For some, profitability (or lack of it) was a push to change the system. For example, INT008 stated: “We very much look at how much profit per hectare... and the variability has been huge over the years ... for me to reduce variability in profit is a big thing. We’re not too concerned about payback period.... there’s capital available so that’s OK.” INT011 stated that his key to expanding in vegetable growing has been identifying crops with viable rates of return, feeling these are not currently available (i.e. returns offered are too low): “[we have] tried everything we can to make it more profitable but the pricing is not going to change therefore we need to change course”. For others, however, a lack of profitability of alternative systems, when estimating returns on currently available information, was seen as a barrier to change.

Fig. 2 **a** Average domain weights across all participants (each domain weight represents a calculation of the average of interviewees' responses). **b** Box and Whiskers plot of participants domain weightings.

Profitability was not the only financial consideration for land managers. When describing the main pull factors towards a particular land-use, INT009 describes the desire to diversify income as well as the need to generate a good profit per hectare as key factors: ‘We’re always looking at something, to diversify. ...To consider a new crop it would have to present income diversification but also return a higher profit’. INT025 described the weighing up of the various components within the financial domain: “We can handle a longer payback period, as long as we have a good return on our capital invested...We’re willing to accept a longer

payback period, but not lots of variability...We’re willing to invest capital as long as it is returning and delivering a good profit per hectare... not to concerned about the pay-back period ... sums us up”. INT012 describes the relative importance of the range of criteria within the financial domain: “Capital Investment is very important...I’m not a risk taker, so this makes diversification important...Return on Investment is much more important—profit per hectare means nothing. Because it’s more about how much you pay for the land”.

Fig. 3 Illustration of variation in subdomain weightings for all participants using the financial domain as an example

Within the market domain, land managers frequently discussed scale (or lack of it) and the ability (inability) to capture value added from their enterprises as a strong motivation (or barrier) to change. For example, INT003 described significant barriers to high-value seed growing: “To get the most value out of these [possible alternatives] you need the value-add, but then you’ve got to have scale to get into it... You have to have good market factors to be profitable”. INT003 was considering alternative grains, however, and was aware that should they become more attractive to other growers, the small size of the market would quickly increase grower competition and lower prices and hence result in lower financial viability: “All scrapping over the same scraps... it’s hard because I wanna do [a NGS] on my own ‘cause I don’t think the market is big enough for more [people]”.

INT022 also considered value added to be very important and a determining factor in selecting hazelnuts over blueberries. After that, they considered that the scale of the market was equally important as the infrastructure/supply chain. For INT025, to capture value added was the most important factor: “Scale is not as important as the ability to capture the value ...” This was supported by INT024: “Market factors will dominate in the end...I want to move towards growing more value”.

Possible variability in supply was seen as an issue particularly for INT025: “... that’s the issue with the cherries, isn’t it? Not having enough cherries... You’ve got to invest to reduce the volatility. That’s what we’ve done here with water and soils. We’ve upgraded our irrigation schemes because we’re taking the volatility out of it ... the variability of supply, we’d want to sure that up”. INT003 was also concerned with variability of supply in high value seed production.

INT003 indicates consideration of risk in their requirement for security of income and dislike of variability. Variability is a part of crop farming they dislike as it changes from year to year. When asked if this is why they mix cropping with livestock, they confirm with a statement: “You can harvest a grazing animal any day of the week” and that they chose to have several different enterprises to manage the risk of variability and increase diversity. When specialised diversification (allowing someone else to farm their speciality crop on your land and/or you go and farm your speciality enterprise on a portion of someone else’s land) was mentioned, they felt that they could spread their risk through a specialised diversification approach if it was available.

Fig. 4 **a** Weightings of subdomains, by participants who gave the financial or market domains their highest weight ranking. **b** Weightings of subdomains, by participants who gave the environmental or regulation domains their highest weight ranking. **c** Weightings of subdomains, by participants who gave the knowledge or social domains their highest weight ranking.

Regulations and the environment

The increasing influence regulation has on land-use choice came through strongly during the interviews. For example, INT0 stated that: “It’s [regulation] a limiting factor for our [current] business...I make my decisions based on regulation, not market factors...The RMA [regulation] to me, is the biggest stifler of growth and development in this country ... the process of going through any practice change is undesirable”. Whilst INT008 stated: “I feel that [regulations] are becoming more of a problem ... We haven’t really seen the impact of that [carbon and GHG regulations], have we. As we go forward you might not be able to just get some land and grow potatoes. Regulation could have a huge impact”.

In terms of pushes and pulls, INT025 described being driven away from dairy production, due to stringent environmental regulations, which they saw as their obligation to society to respect or even exceed the requirements of INT025 — “Would rather do something that is easier for regulations [Regulation Domain], irrespective of the financial incentives to do so ...[the Regulations Domain causes] too much pain...”. Whilst INT025 also states: “We wouldn’t be even looking at what we’re trying to do down here if we didn’t realise there’s an environmental problem and we have a social obligation to do something that’s right... Regulation... is a reason for doing...The reason we’re thinking about doing it is because of potential regulation, potential environmental impact, and the social.... they’re the pushes”.

INT024 has been required by government regulation to farm under certain regional plan conditions capping the level of nitrogen loss from their system. They described this as a force pushing them towards their transition to high-value, value-added beef: “In our view, we were just responding to a situation and doing what we had to, to stay in business”. They also describe the effect these regulations have had on other land-users in their region: “Faced with imposed nutrient limits that prevented them from intensifying [the live-stock stocking rate of] their business, [other regional] farmers looked for ways to add value to the beef they produced, rather than add quantity to their farm system”.

Environmental issues were often closely linked to regulation in the minds of the land managers. For example, INT025 — “[Environment and Regulations are] kind of the same thing....go hand in hand... both pulling equally. We want to do the right thing by the environment but we’ve also got a regulation to say ‘you need to do something’”. However, they were also seen as important in their own right. For example, INT025 clearly saw the environment as a pulling factor: “Why are we here today? We’re here today because we’ve decided to be proactive about it. We weren’t driven by some amazing financial return, market factors didn’t push us. We wanted to do what was right by the environment”.

Social and knowledge-based domains

For participant INT003, a key barrier related to the social well-being domain: INT003 — “Social Wellbeing...that’s actually quite important [when compared to the Financial Domain]...If it was all financial, I’d be dairy farming. And I don’t want to be dairy farming! ... I don’t fancy getting up at 5am to milk cows, to be honest”. Producers were well aware of the challenges of securing labour, and this was a concern in terms of adopting some potentially high value horticultural crops. For example, INT025 weighted labour as a strong driver of decision-making, stating they value technology for its ability to reduce their exposure to shortages of labour. This means they would look towards a NGS that utilised technology rather than manual labour.

Whilst the knowledge domain and subdomain elements were generally weighted lower than the other domains, for particular land managers, they were important considerations. For example, INT012 stated that in considering NGS, he would be attracted or pulled towards NGS land-uses where there is opportunity to gain knowledge or intellectual property advantage and that in the absence of this pull, their adoption of an NGS would be limited: “If it’s [The Knowledge Base] proven, then is the opportunity gone?... I think that if the tech is really crap then that’s actually an opportunity [Very open to changing his views, based on new or different knowledge]”. INT004 stated that the strongest pull towards their chosen land-use (dairy) came from the advisory support available: “We have huge support [in our chosen industry]. There’s not the same support for someone in cropping. The more we went into the more we realised how well supported we were”.

When discussing the knowledge domain INT022 noted that: “if you’re making a change then it’s OK to go away from what you’re doing”. However, the less similar the systems were, the less knowledge they would expect to be available and so the more risk that would be present, and they would require greater capital to face the risk. At a higher level, INT024 viewed the issues around knowledge being more at the national level: “I feel quite despondent at the lack of knowledge we have as a country... We’ve funded science to grow production, but not to grow production and look after the environment. Our knowledge base in this area is probably the single biggest risk to the nation”.

Issues that cut across domains

As already has been highlighted with the environment and regulation domain, respondents often felt that issues cut across domains and that the domains were strongly interlinked. For example, INT008 found that: “In my business, they’re [Market and Environment Domains] very interlinked. Things like plastic bags. Being organic, these

[market and environmental issues] are key drivers. It's fundamentally changing how we deliver stuff... you've gotta be very aware of your whole process on your packaging". INT024 described the interaction of multiple factors in their experience of NGS decision-making: "I struggle to answer that [weighting of the Social Wellbeing Domain versus the Financial Domain] because my social well being is inextricably linked to my financial performance. ...If I'm trashing the environment I won't have a business so the environment drives the financial performance". Furthermore, INT024 states: "Growing value in a given political context is hugely difficult. There are so many variables in the political context—social, economic, environment, which is why all these factors are important and interlinked".

As well as issues cutting across domains, it is clear that land managers were looking for systems that could produce multiple benefits. For example, INT011 described the considerable thought they had given to apple cultivation. They describe the maturity shown in the sector as an attractive, pulling, factor. Another attraction was their perception of cooperation between growers in this sector, rather than competing to undercut each other. The third pulling factor was that the returns were significantly higher per hectare compared to those experienced by arable producers.

INT022 felt that for those looking to make land-use changes, they look towards land-uses that have a supportive industry, supportive R&D and government support. Where these factors are missing, such as in hazelnuts, INT002 predicts lower levels of adoption will occur. In other words, their view is that industry, government and R&D support are important pulls for land-use decision-makers in horticulture. Because they are an owner-operator, they consider the environmental impact and social well-being that result from a land-use to be the most salient drivers in favour of a land-use option; the natural and social environment the land-use creates is what pulls them towards a land-use. Interestingly, INT024 noted they were able to turn a push, regulation, into a pull experienced in terms of market opportunity: "Regulation was a bummer until we turned it into brand value, and now it drives our financial performance".

Discussion

The results have highlighted the key factors (here classed as domains and subdomains) that are being taken into consideration by land managers when considering adoption of a new system or land-use. These generally reflect those found in the literature, for example, the importance given to financial and market factors (Clifton-Brown 2017; Journeaux et al 2017), and the role of non-financial factors such as how systems fitted with personal life-style choices (McDonald et al. 2016; Brown et al. 2019). The MCDM results also highlight

that seldom does one factor dominate the decision-making process, but it is more a case of land managers making an "on-balance" decision after evaluating new systems across a range of (possibly interacting) criteria (Nankya et al. 2017; Henry and Trigo 2010; Journeaux et al. 2017; Brown et al. 2018). This suggests that it is useful to think of existing and new systems as having a range of characteristics (profitability, environmental impact, affect on quality of life, etc.), each of which plays a role in influencing whether a land manager changes their system or not.

The results also confirm the context-specific nature of how land managers make decisions concerning changes to their systems in the face of considerable uncertainty and the importance of preferences and perceptions, particularly concerning risk (Bocquého et al. 2014; Iyer et al. 2020). The findings around risk and risk perception link to the extensive literature on decision-making under uncertainty in agriculture (and more generally land-use) where insights have been drawn based on a range of theoretical underpinnings. As discussed earlier, these include expected utility theory (von Neumann & Morgenstern 1947), prospect theory (Kahneman & Tversky (2018) and game theory (Dillon 1962; Walker et al. 1960). In general, although we did not set out to measure risk preferences, our results do imply a diversity in the appetite for risk across the land managers which is influencing likely adoption of NGS. For example, the focus by some respondents on reducing profit variability rather than overall profitability indicates that a proportion of land managers were relatively risk averse (Bocquého et al. 2014, Chavas and Nauges 2020). In contrast, some land managers exhibited a high tolerance for risk, for example, being attracted to new systems even if the system was unproven on the basis that the rewards may be greater.

For the more risk-averse land managers, efforts to reduce the risks associated with the NGS could lead to greater levels of adoption. Our results indicate that an approach that deconstructs NGS into their individual characteristics allows a systematic understanding of what is pushing and pulling land managers between land-uses and their associated risks. This identification allows decision-makers at different scales to focus on where they can reduce the risks for more desirable systems or land-uses (to increase the pull factors) or increase the risks (increasing the push factors) for less desirable systems or land-uses (Hand & Tyndall 2018). For example, new technologies that reduced the environmental risks associated with NGS (such as the extent of nitrate leaching) or production risks (such as yield variability) could be beneficial. Alternatively, it may involve efforts to reduce market and financial risks associated with novel enterprises.

Often, land-use change is considered as a movement from one system of land-use (e.g. dairy) to another (e.g. horticulture). Our results suggest that it may be more appropriate to think of it within the context of diversification (Radulescu

et al. 2014; Werners et al. 2011; Paut et al. 2019) for example, as a way to reduce risk through diversifying income sources or smoothing production. As discussed earlier, modern portfolio theory (MPT) provides insights as to how risk can be mitigated through diversification and could be used to help land managers attain their objectives given their perception of risks (Radulescu et al. 2014; Werners et al. 2011; Paut et al. 2019).

Beyond the issue of risk, the results also point us to features of potentially less sustainable land-uses that have acted as a pull to land managers, for example, strong governance, sharing of knowledge, and cooperative processing. Replicating these institutional features in alternative land-uses may enhance their attractiveness. Achieving this would necessarily require both public and private cooperation and co-ordination.

The interaction of pushes and pulls around the various financial, regulatory, social and knowledge factors implies that multiple policies may be required to support a transition to more sustainable land-uses. In particular, a mix of policy instruments in what are described as packages (OECD 2020; Hennenke 2004; Givoni et al. 2013), bundles (Milkman et al. 2012) or portfolios (Howlett et al. 2015; Bali et al. 2021) are needed to effectively influence change. Such packages may include the use of incentives (e.g. subsidies) combined with regulatory mechanisms to price in externalities as well as provision of information and other voluntary approaches (Hurlbert et al. 2019; Journeaux et al. 2017). The OECD have also identified opportunities to “stack” policy incentives to allow for multiple incentives to occur together for more effective land-use change (OECD 2020).

Recent government-level reports have highlighted the types of policy options that could be used to a greater extent in New Zealand to encourage protection of environmental quality (Tax Working Group 2019; OECD 2017, 2020). In particular, environmental taxes could be designed to increase “push” factors away from current land-uses by creating increased risk associated with factors within the regulation and financial domains. However, in line with the need for packages/portfolios of policies, the OECD also recognises that environmental taxes often “lack the contextual specificity to deliver on multiple fronts” (OECD 2020), such that NGS seek to achieve.

Another available policy instrument relevant to incentives for land-use change in the New Zealand context is the New Zealand Emissions Trading Scheme (NZETS) (Tax Working Group 2019). In the context of this study, an ETS policy could be used to create “pull” factors towards NGS whereby those land-uses were eligible to earn ETS credits improving their attractiveness. The OECD in reviewing the ETS noted that it had strong potential but required significant changes from its current form to deliver emissions-based outcomes from New Zealand (OECD 2017). In the context

of this paper, a key factor is that, for a number of reasons, agriculture was omitted from the ETS as originally constituted. More recently, the scheme has been overhauled and discussions concerning how and when to bring agricultural emissions into the scheme are ongoing (Hurlbert et al. 2019, p703).

The use of financial incentives or subsidies to encourage adoption of new systems or land-uses is an interesting issue within New Zealand when compared to other developed countries. As noted by the OECD, unlike many developed countries, New Zealand does not currently make use of subsidies or other pricing interventions in agricultural industries (Melyukhina 2011; Tax Working Group 2019). In fact, the OECD emphasises that in NZ price incentives are generally seen as misaligned with the overall economic strategy of primacy of world market signals and “limits on government interventions in the agricultural system” (Melyukhina 2011). This said, there are a small number of direct support mechanisms available to farmers, but these too are focused on input and output support (OECD 2019), which contrasts with the wide range of decision-making domains identified as important in the research presented here. This primacy of world market signals also reduces the possibility of using border interventions (such as raising or lowering tariffs or subsidising exports) to influence production decisions.

However, our results imply that other seemingly less direct approaches have the possibility to engender change. For example, given the small domestic market in NZ and the focus on exports, the opening up of export markets for products from NGS (for example, through addressing biosecurity concerns or signing trade agreements) could significantly enhance their attractiveness to land managers. In addition, the fact that respondents highlighted the attraction of sectors where there was alignment across the industry, research and development and certainty relating to government policy suggests that efforts in the public–private space along these lines could be fruitful.

Conclusion

This paper began by highlighting that the increasing environmental challenges associated with current land-uses in New Zealand were increasing the pressure to adopt systems with potentially lower environmental footprints. Despite these pressures, it was also highlighted that there had not been widespread adoption of alternative systems. Within this context, a novel MCDM framework was utilised to provide further insights into the factors (broadly grouped into six domains) that were influencing land-use choices. The results supported the available literature as to the importance of particular factors (domains and subdomains), but also highlighted considerable variation in the weight given

to individual factors across the sample of land managers. Discussion with land managers also made it clear that these factors were operating not in isolation, but as a series of pushes and pulls across multiple land-use choices. Risk was highlighted both explicitly and implicitly as a key issue. The strength of the pushes and pulls land managers experienced between alternative land-use systems were intertwined with their perceptions of risk. The MCDM process, by breaking down decision-making into its individual components, allowed consideration of the individual characteristics of existing and new systems and how the risks associated with these characteristics may influence the choices made by land managers.

The results highlighted that simply pushing farms away from those systems deemed unsustainable will not result in a sustainable transition. The viability of NGS as alternative land-uses is entwined with the motivations of the individual land manager which inherently vary case-by-case, as captured by the MCDM framework. There is a need, through research and development for example, to increase the availability of alternative systems for farms to switch to. Failure to recognise the complexity of decision making and the need for viable alternatives may mean that excessive use of regulation will simply push farmers over an economic cliff-edge.

Policy design that recognises both push and pull factors may be more effective, as it can aim to decrease the risks associated with NGS (to increase pull factors) alongside increasing the risks associated with current less desirable uses (thereby increasing push factors) according to the land-use change outcomes desired. Carefully crafted policy portfolios or packages are required to effectively engender change through balancing incentives with regulations. This raises questions for New Zealand as to whether or not financial incentives or subsidies are in fact an appropriate tool to encourage land-use transition.

In the absence of approaches that are able to address both the pull and push factors of land-use change, a transition to next-generation systems will continue to face delays as farmers may view the risks as too high. More generally, the implied importance of risk and uncertainty in the decision-making of land managers highlights that further work is needed to understand the exact risks faced and the risk appetite of those considering change as they can significantly influence the adoption of next-generation systems.

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