Innovative and targeted mechanisms for supporting adaptation in the primary sector

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Final Report

DRAFT

April 2015

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REPORT INFORMATION SHEET

Report Title	Innovative and targeted mechanisms for supporting adaptation in the primary sector
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Client	MPI
Client Contract No:	FRI 131412
Sidney output number	
Date	April 2015
Confidentiality Requirement	Publically Available
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EXECUTIVE SUMMARY

There is considerable evidence to suggest that the impacts of climate change will affect primary producers, disproportionately, in relation to other economic activities. Forestry, horticulture, and dairy depend not only on day-to-day climatic conditions, but have built their businesses around experience and understanding of a long-term mean. Delayed, insufficient, or even a failure to adapt will have significant costs and attendant effects on business survival. To support adaptation in the primary sector targeted mechanisms for information delivery, innovation, practice-change and knowledge transfer need to be enhanced. Therefore, the ***aim of this research was to identify novel methods of technology transfer and communication in order to support adaptation planning in the primary sector***.

The hypothesis was that overcoming barriers to adaptive action, in order to lead to enduring practice change, requires provision of appropriately tailored communication and information, at a specified target audience, using appropriate communications mechanisms and participatory and learning-based approaches which all need to address the decision maker's information requirements. The focus of the report is to provide research findings and recommendations against the following objectives and questions:

Objective 1: To review and evaluate the existing methods, tools and mechanisms used in New Zealand climate change adaptation communication and research.

1. *RQ1: What are the current mechanisms used for knowledge transfer and climate change adaptation communication in New Zealand? What are their strengths and weaknesses?*

Objective 2: To identify the motivating levers of decisive action and decision makers' information requirements at different scales across primary sector activities.

2. *RQ2: How are decisions regarding climate change adaptation currently made in different primary sectors?*
3. *RQ3: What are the critical decision points that might potentially be targeted for information provision to support learning for adaptation?*

Objective 3: To identify communication mechanisms that might facilitate and support practice change in the primary sector, through knowledge co-development for adaptive action.

4. *RQ4: What are new mechanisms that might encourage and support practice change in the primary sector to develop greater resilience in the face of climate change impacts and implications?*

The review of existing methods, tools and mechanisms showed that the in New Zealand, the majority of research projects address the potential impacts of climate change with only limited stakeholder interactions, and emphasised the communication of facts, concepts and general ideas rather than how best to operationalise climate information for adaptation decisions. Examples of successful communications strategies that engaged with stakeholders to explore complexity and co-create potential pathways to adaptive solutions were identified, and highlight the need to better understand an actor's ability, willingness or capacity to act and its relationship to framing climate change messaging. Many climate change projects in New Zealand address the potential impacts of climate change with limited interaction with stakeholders meaning change in the primary sector will likely face substantial resistance because the social and economic contexts of the issues have not been adequately accounted for.

The review of critical decision points and levers of action through systems analysis, revealed six potential key leverage points to influence adaptation behaviour. It should be noted however, that the capacity to influence leverage points are likely to lie across the primary sectors, government organisations and institutions; and other entities, and will therefore require greater coordination, cooperation and communication across governance regimes.

Lastly, the research identified a range of alternative mechanisms that will afford better learning by decision makers in the primary sectors. Given that information needs will increase exponentially, given the scale and extent of changes that will be required (Kirchoff et al., 2013), mechanisms will need to address and take advantage of opportunities associated with diversification and any increase in biological productivity, as well as overcome barriers such as the ability to act or access and use of capital.

Based on these findings, we recommend:

- Future SLMACC, CCTTP and other funded programmes seriously consider how the result of the research will address end-user drivers.
- That MPI consider funding implementation of tools such as risk frameworks based on New Zealand climate data and climate change scenarios.
- That consideration is given to the establishment of a national review of climate change adaptation.
- Consider working with industry stakeholders to identify innovative and influential farmer-grower practitioners, to develop demonstration projects or implement adaptation practices on focus farms and forests, and
- That MPI consider initiating the establishment of a pan-sector roundtable on adaptation, to facilitate greater discussion about the pathways to greater resilience in the primary sector.

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1 INTRODUCTION

1.1 Climate change, adaptation and New Zealand's primary sector

The weight of scientific evidence is clear, anthropogenic emissions of greenhouse gases (GHG) are having a significant impact on global climate and will continue to do so for the foreseeable future, regardless of any reductions in emissions (BoM & CSIRO 2014; IPCC 2014; New Zealand Government 2015). Emissions are tracking near the upper envelope of projections and significant adaptation will be required (Rahmstorf 2007 et al.; Gluckman 2013; Horton et al. 2013).

Table 1: Summary of the projected impacts for New Zealand (IPCC 2014)

The regional climate is changing
Long-term trends are towards higher surface air and sea-surface temperatures, more hot extremes and fewer cold extremes, and changed rainfall patterns.
Warming is projected to continue through the 21st century
Warming is expected to be associated with rising snow lines, more frequent hot extremes, less frequent cold extremes, and increasing extreme rainfall related to flood risk in many locations. Annual average rainfall is expected to decrease in the north-east South Island, northern and eastern North Island, and to increase in other parts of New Zealand. Fire risk is projected to increase in many parts of New Zealand. Regional sea level rise will very likely exceed the historical rate (1971-2010).
Uncertainty in projected rainfall changes remains large for New Zealand
Precipitation changes are projected to lead to increased runoff in the west and south of the South Island and reduced runoff in the north-east of the South Island, and the east and north of the North Island. Annual flows of eastward flowing rivers with headwaters in the Southern Alps (Clutha, Waimakariri, Rakaia, and Rangitata) are projected to increase by 5-10 % in response to higher alpine precipitation. Most of the increases occur in winter and spring, as more precipitation falls as rain and snow melts earlier.
Recent extreme climatic events show significant vulnerability of some ecosystems and agriculture to current climate variability
The frequency and/or intensity of such events are projected to increase in many locations. Recent floods caused severe damage to infrastructure, farms and houses. Widespread drought in many parts of New Zealand (2007-2009; 2012-13) resulted in substantial economic losses of NZ$3.6b in direct and off-farm output in 2007-09.
Without adaptation, further changes in climate, atmospheric CO2 and ocean acidity are projected to have substantial impacts on water resources, coastal ecosystems, infrastructure, health, agriculture and biodiversity. Freshwater resources are projected to decline for rivers originating in the north-east of the South Island and east and north of the North Island. Rising sea levels and increasing heavy rainfall are projected to increase erosion, with consequent damages to many low-lying ecosystems, infrastructure and housing; increasing heat waves will increase risks to human health; rainfall changes and rising temperatures will shift agricultural production zones; and many native species will suffer from range contractions and some may face local or even global extinction.
Some sectors in some locations have the potential to benefit from projected changes in climate and increasing atmospheric CO_2.
Examples include reduced energy demand for winter heating and forest growth in cooler regions except where soil nutrients or rainfall are limiting. Spring pasture growth in cooler regions would also increase and be beneficial for animal production.

Many studies have been conducted on the potential impacts of climate change and the required adaptation pathways needed (Fazey et al. 2015; IPCC 2014; Wise et al. 2014). New Zealand has a diverse range of climo-edaphic environments, providing an opportunity to utilise the country as a microcosm to monitor and project current and future climate change impacts by studying the various changes and conditions (assumptions of projected impacts on New Zealand is given in Table 1). Particular attention has been paid on the adaptation of urban areas (e.g. Hunt and

Watkiss 2011), including New Zealand cities (Jollands et al. 2005). This body of research has focussed on medium to long-term effects of climate change on city-scale factors such as infrastructure, health, land use, biodiversity and socio-economic issues (e.g. Brown et al. 2015; Hajat et al. 2014; McCarthy et al. 2010; Puppim de Oliveira et al. 2014). From a New Zealand perspective, some of the key impacts on major cities has already been identified through studies in Hamilton (Ruth et al. 2007) and Wellington (Jollands et al. 2005), which found socio-economic pressures, arising from factors such as population growth, economic development and health (also see Bambrick et al. 2008; McMichael et al. 2003), are likely to be the most dominant elements effected as a result of climate change.

Effects on the semi-rural and rural areas are also just as important to highlight. As demonstrated in the most recent assessment from the Intergovernmental Panel on Climate Change (IPCC), climate change is expected to have deleterious effects across diverse ecosystems from coastal and estuarine environments (IPCC 2014), with flow-on effects for conservation and biodiversity, in particular to productive lowland systems, where increases in pests and weeds, climate variability and extremes, and changes in the frequency of damaging events are likely to have significant consequences for gross domestic product (GDP) (Table 2). As climate change is expected to have a profound impact on natural resources, and thus on the primary sector (agriculture, forestry and fisheries), it is imperative to understand the projected areas at risk and how to be informed on the appropriate adaptation responses (Anwar et al. 2013; Fleming et al. 2014; Olmstead 2014; Park et al. 2012; Rickards & Howden 2012). The sustainability of the primary sector, which contributes to fundamental issues such as food security, social benefits and economic growth, is highly vulnerable to future climate changes and variability due to expected impacts such as increases in extreme weather events, temperature changes, and decreases in rain fall, crop viability and yields (IPCC 2014; Marshall et al. 2014).

The New Zealand primary sector contributes 6.0% to GDP, and over half of our export earnings. Agriculture, fishing and forestry dominate the primary sector, accounting for 5.0% of the GDP. Approximately half of our land is in productive pasture and arable cropping, including 1.8 million hectares of productive forest plantation. Dairy farming is fundamental to the rural economy, and accounts for almost half (47.6%) of agricultural earnings. Forestry contributes 1.1% of GDP, and contributes 9.7% of export earnings. New Zealand has a temperate and mild climate, and the soils are now well suited to agricultural production, including forestry. New Zealand's marine coastal environment and climate is also well suited to aquaculture, though 83% of capture is from wild fisheries. Horticulture is growing in importance, predominantly due to niche production of high value wine and kiwifruit (NZ Treasury 2014).

Climate change is likely to have significant impacts for a wide-range of primary sector stakeholders. Climate variability and extremes currently have a marked effect on pastoral farming systems. Flow on economic effects for horticulture, forestry and viticulture are likely. For the primary sector, climate change will require significant levels of practice change, in order to manage increased climate variability and extremes.

Impacts on the rural and semi-rural environments, and the adaptation of enterprises to a changing climate is therefore of fundamental importance in supporting a sustainable primary sector, and maintaining a strong economic future for New Zealand. While there is support at Government level for effective adaptation planning and rural decision making, practice change is slow.

More importantly however, climate change is likely to make organisations and institutions more vulnerable and less resilient to external shocks, which can affect business operations (Dany et al. 2014; Mandryk et al. 2015). Climate change induced shocks include anticipated changes in the frequency of extreme events, as well as the incremental impacts arising from changes in climate, such as fire, drought, disease, and biological productivity. Despite the considerable work already done, significant knowledge gaps remain in our understanding of potential impacts and implications for New Zealand, in particular for the country's primary sector (IPCC 2014, Reisinger et al. 2014, Hennessy 2007, Kenny 2010, Burton & Peoples 2015).

Comprehensive monitoring of changes is needed in order to improve estimates of potential future change and knowledge gaps relating to first and second order effects across all sectors. Within New Zealand, the primary sector is yet to implement substantial practice change in response to current and future climate change needs, possibly due to the limited amount of adaptation planning occurring on the ground (Evans et al. 2014; Britton et al. 2011; Manning et al. 2015). Therefore, one approach to overcoming the barriers to decision making and planning for adaptation is through the design and delivery of tailored communications (Lyle 2015; Nursey-Bray et al. 2012), which is the focus of this research. Sustainable behaviour change strategies require design and effective action-oriented messaging that addresses a key barrier to practice change occurring (McKenzie-Mohr 1999). Such targeted communications, that focus on precise and defined sub populations, and address their particular requirements and issues, are more likely to affect changed behaviour than information alone, even when information is congruent with one's values, as there is no direct link between values and action (Futerra 2010). Many communications strategies are targeted towards changing attitudes, rather than behaviour, but it is behavioural practice change that will bring about sector-level adaptation.

Table 2: Summary of climate change for eastern New Zealand (Clark et al. 2012)

Climate variable	Direction of change (confidence)	Magnitude of change
Mean temperature	Increase (****)	>0.9 by 2040 >2.1 by 2090
Mean rainfall	Annual decrease (**)	<5% by 2040 <6% by 2090
Extreme rainfall	Heavier and/or more frequent rainfalls (**)	High intensity rainfall with probability of 50-yr return >10% by 2040 >18% to 34% by 2090
Major drought	Increase in all areas that are currently prone to drought (***)	Major drought events with probability of 20-yr return >10% additional time spent in drought
Wind (average)	Increase in the annual mean component of wind flow across NZ (**)	Appx 10% increase in mean annual westerly flow
Strong winds	Increase in severe wind risk (**)	Up to 10% increase in strong winds (>10m/s) by 2090
Storms	More storminess possible (*)	-
Sea level	Increase (****)	At least 18-59 cm (1990-2100)
Storm surge	Assume tide elevation rises with MSL (**)	-

1.2 Research aim, model and objectives

The aim of this research was to identify novel methods of technology transfer and communication in order to support adaptation planning in the primary sector. This research hypothesises that overcoming barriers to adaptive action, in order to lead to enduring practice change, requires provision of appropriately tailored communication and information, at a specified target audience, using appropriate communications mechanisms and participatory and learning-based approaches which all need to address the decision maker's information requirements (see Figure 1).

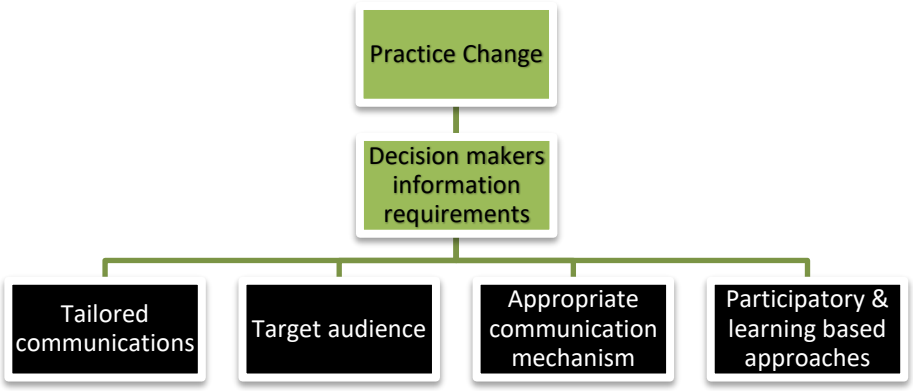

Figure 1: Research hypothesis

The research posits a generic model of tailored communication that aims to ensure receptiveness of, and interaction between the message, communication mechanism and target audience (Figure 2. The *audience* consists of primary sector land managers, the *message* is the information and knowledge required for adaptation in primary sector businesses. The communication *mechanisms* are those that are develop learning, i.e., participatory and to overcome adaptation inertia and other barriers to action. The research acknowledges from the outset that climate change adaptation is a partnership between science and business and that science information must address the knowledge requirements of business as the foci of adaptation action.

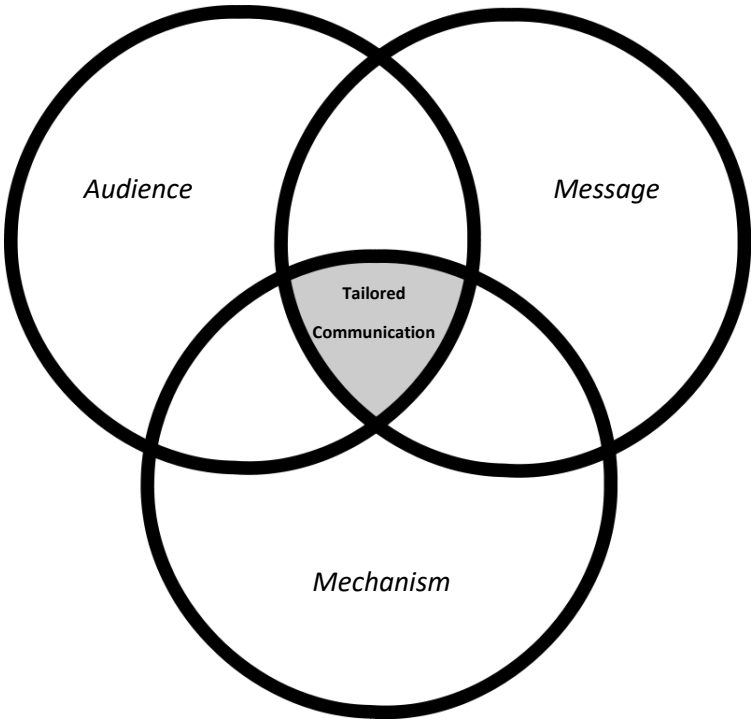

Figure 2: Generic model of tailored communication

The research had three objectives:

1. To review and evaluate the existing methods, tools and mechanisms used in New Zealand climate change adaptation communication and research;

2. To identify the motivating levers of decisive action and decision makers' information requirements at different scales across primary sector activities; and
3. To identify communication mechanisms that might facilitate and support practice change in the primary sector, through knowledge co-development for adaptive action.

1.3 Research questions

Taking into consideration the aim and objectives of the research, the following guiding questions were posed:

1. What are the current mechanisms used for knowledge transfer and climate change adaptation communication in New Zealand? What are their strengths and weaknesses? (Objective 1)
2. How are decisions regarding climate change adaptation currently made in different primary sectors? (Objective 2)
3. What are the critical decision points that might potentially be targeted for information provision to support learning for adaptation? (Objective 2)
4. What are new mechanisms that might encourage and support practice change in the primary sector to develop greater resilience in the face of climate change impacts and implications? (Objective 3)

1.4 Research design and method

The research seeks to answer these questions though an interdisciplinary and mixed methods approach, drawing insights from diverse fields, including education and learning, systems thinking and climate change adaptation. The research is also informed by the research team's experience and interests in participatory and collaborative approaches to the co-production of knowledge in which engaging with primary producers was central to identifying critical decision-points.

The research used a qualitative approach, using tools to review and evaluate existing mechanisms for information and knowledge transfer, and drawing extensively on systems thinking to provide insight into novel or more productive approaches that might broker knowledge translation in ways that address decision makers' specific learning needs. Empirical evidence was also obtained using semi-structured interviews and focus groups with stakeholders involved in a range of primary activities including decision makers.

1.5 Report structure

The report is organized as follows:

Section 2 presents the conceptual and theoretical frameworks used to guide the research. The frameworks draw upon affordance and learning taxonomies to evaluate and determine communication mechanisms, and to clearly identify critical decision steps in order to broker climate change adaptation knowledge and information.

Section 3 outlines the research methodology, including the plan to address all the research objectives, use of mixed methods and the application of systems thinking.

Section 4 critically analyses the current mechanisms for information and knowledge transfer of climate change within the primary sector in New Zealand.

Section 5 presents the results of empirical work with stakeholders from the kiwifruit, dairy, dry stock, cropping, horticulture and forestry sectors that sought to obtain insight into decision making processes, focusing on managing risks associated with climate change. The analysis draws upon systems thinking to clearly identify critical decision steps and mechanisms for brokering climate change adaptation knowledge and information.

Section 6 presents the main research findings and implications for technology transfer based on additional reviews of academic literature and other sources such as Government and international institutions, non-government organisations (NGOs), to collate potential communication frameworks and mechanisms that might facilitate and support practice change through knowledge co-development for adaptive action.

Section 7 concludes the report with a series of recommendations.

2 ISSUES OF CLIMATE CHANGE COMMUNICATION FOR ADAPTATION

2.1 The adaptation imperative

There is an increasing sense of urgency among researchers, policy makers, and civil society engaged "in a race against time to understand how adaptation can be facilitated, supported, and ultimately sustained, in societies at risk from climate change impacts" (Coulthard 2008, p.479). The demand for research to inform adaptation has arisen from a growing awareness of the potential threat posed by a changing climate (IPCC 2007). This is evident in two significant transformations in the international research and policy environment (Nelson et al. 2010).

First, there is a growing debate on how best to respond to the challenges of climate change, between the current priority and attention given to the reduction of GHG emissions towards greater consideration of adaptation: the modification of behaviour believed to either alleviate adverse impacts or to realise new opportunities in response to observed or expected changes in climate and associated extreme weather events (Smit & Pilifosova 2003; Adger et al. 2009).

Some degree of climatic change is inevitable and adaptation unavoidable (Howden et al. 2007; Burton 2011; Smith et al. 2009). However, even with dramatic and immediate reductions, historical GHG emissions will continue to influence temperature for several centuries (Schneider 2009; Solomon et al. 2009; Matthews et al. 2009). Evidence from biotic systems show there is a high probability that climate change is already occurring (IPCC 2014, Cai et al. 2015). Adaptation has become a necessary part of climate change discourse and a fundamental response to the threat posed by climatic changes that will occur, or are already occurring as a result of anthropogenic GHG emissions (Ford 2007).

Second, while there is a high degree of confidence in the fact that the climate will continue to change in significant ways, the exact nature and consequences of these changes remain highly uncertain, owing to the complex feedback mechanisms between the differing components of the climate system (IPCC 2007). This uncertainty, with respect to climate change, is precipitating a rethink of traditional approaches to risk management. Historically, climate-related science and policy have emphasised the analysis of scientific systems for the purpose of predicting extreme events such as storms, floods and droughts, and modelling estimates of their likely impacts (Dale et al. 2001; Keenan et al. 2011). Beginning with a changed climate, models are used to describe the impacts on agricultural production and determine what the characteristics of regional climate patterns might be in the future in a linear fashion (Parry et al. 2005; Schubert et al. 2008).

Given that the extent to which the management of climate variability is intrinsic to the primary sector however, this has the potential to provide a foundation from which adaptation to climate change can occur (Howden et al. 2007). This advantage has proven difficult to realize, as adaptation to climate variability and change has often been conceptualized as a linear sequence of technical responses to clearly identified, measurable and predictable sources of risk (O'Brien et al. 2007; Nelson et al. 2010). A narrow focus on forms of risk that can be quantified and predicted can have the unintended consequence of under-emphasising the longer-term and more holistic opportunities to build adaptive capacity. It also overlooks fundamental difficulty in predicting future changes in the climate system (Barnston et al. 2005), and tends to focus on the drivers of climate variability and change which cannot be influenced by decision makers (Nelson et al. 2007; Meinke et al. 2009).

In light of these considerations, there have been calls for empirically-based studies that explore actual rather than predicted impacts and adaptive behaviour in particular places over particular periods of time (Kelly & Adger 2000; Meinke et al. 2009; Wilbanks & Kates 2010; Liverman 2010). Despite advances in understanding the potential impacts and implications of climate change for the primary sector, knowing what, when and how specific adaptation practices need to change is another matter (Clark et al. 2011). For example, to-date there is little evidence of actual adaptation practice change in New Zealand.

2.2 Critical barriers that impact on communication for adaptation

This section briefly summaries the international research that identifies a range of barriers to adaptation planning and implementation.

2.3 Barriers to climate change adaptation

Moser and Ekstrom (2010) define barriers as obstacles or impediments that stop, delay, or divert adaptation planning and implementation. They are malleable, hence with effort they can be overcome resulting in creative management, change of thinking, resource prioritization, as well as re-thinking and reengineering land uses, institutions and business processes. Barriers make adaptation less efficient and effective, which in turn increase cost and reduce the advantages of opportunities. Considerable barriers exist and can emerge in developing and implementing climate change adaptation strategies. Understanding the nature of those barriers to adaptation is important in order to find strategic ways of dealing with them. Not addressing the barriers to adaptation "may itself be an obstacle to progressing in the adaptation process" (Moser & Ekstrom 2010, p. 22027).

Biesbroek et al. (2013) found that an impressive number of barriers to adaptation have been reported and also that there could be endless potential barriers. The barriers found were focused on the wider institutional and social contexts of adaptation activities namely from the actors, the governance system, and the context of where adaptation takes place confirming the structural elements of Moser and Ekstrom (2010), (Figure 3**Error! Reference source not found.**). Therefore, shifting the focus to asking 'how' and 'why' barriers emerge is recommended.

Moser and Ekstrom (2010) suggest that adaptation occurs in a rational decision making process such as going from problem definition to planning adaptation and implementation management. Their structural elements of adaptation framework reflect the foci of actor networks that evolve over time, the wider context and the actual system of interest. The greater context encompasses the actors and the system of interest; it is defined or bounded by its ability to enable or not conditions that shape actions (Figure 3). Hence, each structural element is a source of potential

barriers, as is each component of any decision making process.

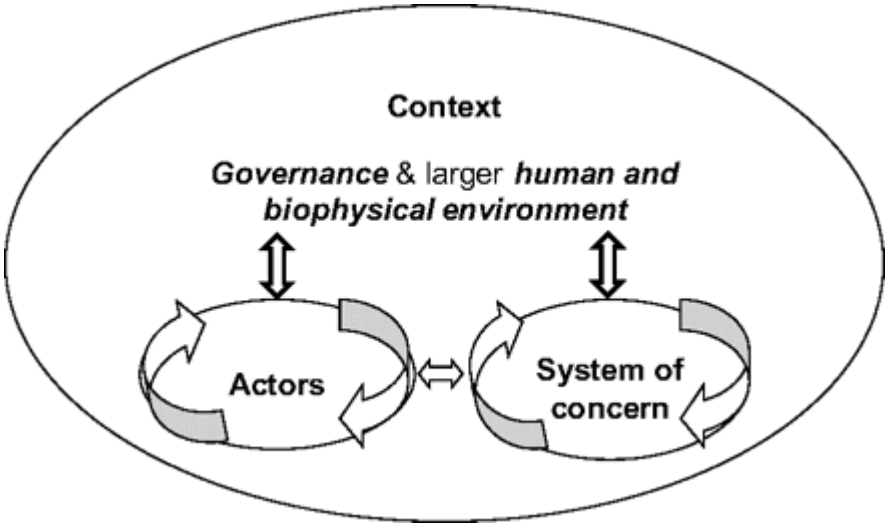

Figure 3: The structural elements of the diagnostic framework: interacting actors, the governance and larger socio-economic context, and the system of concern.

Source: Moser & Ekstrom 2010.

From the structural elements framework, barriers to adaptation in business can be generated from the:

- personal characteristics of decision makers where decision makers are influenced from individual beliefs, attitudes, values and goals which drive perceptions of risk and risk tolerance, and ability and willingness to enact change and implementing adaptation action (Moser & Ekstrom 2010, Adger et al. 2009; Grothmann & Patt 2005; Dilling & Moser, 2007; Centre for Research on Environmental Decisions 2009);
- wider business operating environment, made up from the economic, legal, and social institutions as well as societal perceptions, values, and norms (Adger et al., 2009) and the social networks that are defined by interactions between the decision maker and other who influence decisions as the social environment can affect the perceptions of the feasibility or credibility of different adaptive actions (Dowd et al. 2014); and
- business system in which the decision maker works which defines the ability to produce, and access resources (Moser & Ekstrom, 2010).

The following sections briefly discuss some of theoretical constructs that are used to frame some of the barriers that impede adaptation action in the New Zealand primary sector. We use the interaction framework Figure 2 for identifying barriers (i.e., barriers that arise from the mechanisms, messages, audience).

2.4 Mechanisms and their affordances

Mechanisms refer to the different ways in which information about climate change and adaptation is communicated to end-users. This can include one-way and static forms of communicating information (e.g. written reports, videos, and conference presentations) to more interactive or participatory channels (e.g. online decision-support tools, or workshops (Moser, 2010). Mechanisms have certain affordances. Affordances refer to the attributes of a 'thing' (i.e., computer) or a setting (workshop) that provides the potential for action (Kennewell 2001). Gibson's (1979) classic example is that of a door handle. A door handle has certain attributes,

location, structure, feel, and size which enable certain activities or actions to occur such as facilitating the opening of a door. Affordances are dependent on the object (or setting) and the needs and perceptions of the user (context). In this context, we are interested in the affordances of different communication mechanisms used for informing decision makers about climate adaptation. Each of the different mechanism used for transferring knowledge has unique properties that affects its effective role in learning[1] and hence in its ability to 'transfer' technology (or technological understanding, or potential strategies and process for climate change adaptation).

For the purposes of this discussion, we define the aim of technology transfer as a learning mechanism that results in some form of action by the receiver, which can include a decision so that no action needs to be taken or a decision can be deferred. For example, we do not consider awareness rising as technology transfer in this context, but recognise that it is valid in other contexts. An example of technology transfer under our definition would therefore include extension activities whereby the interaction results not only in increased end user understanding of the problem, but by which the end user is enabled and empowered through learning mechanisms to reach a decision to behave in a way that changes his/her current practice.

While some of the affordances of mechanisms are absolute, e.g., printed material affording only one-way communication, perceived affordances are also relative to the needs of learners (Lockee, Moore, & Burton, 2001). So, the affordance of a mechanism refers to a much larger part of the learning environment than just that of the mechanism. In other words, the effectiveness of a mechanism in learning is also dependant on the large number of contextual variables, and any use of a particular mechanism does not act independently of the context. Therefore, it becomes impossible to identify the most suitable mechanism to meet particular learning objectives without detailed reference to the context (Kennewell, 2001).

2.4.1 *Bloom's Taxonomy*

Bloom's revised taxonomy of learning domains identifies six categories of cognitive learning that involves knowledge and the development of intellectual skills (Anderson et al. 2001; Heer 2012). This firstly includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. The second dimension of the taxonomy is the classification of the types of knowledge, from factual (basic understandings that people must have) to metacognitive (abstract knowledge) (Anderson et al. 2001). The third dimension represents a continuum of increasing cognitive complexity, from lower order thinking skills to higher order thinking skills (Table 3). (Anderson et al. (2001) identify nineteen specific cognitive processes that further clarify the scope of the six categories (Table 4).

The knowledge dimension classifies four types of knowledge that learners may be expected to acquire or construct, ranging from concrete to abstract (Krathwohl 2002)

[1] Technology transfer is conceptualised as a learning process, i.e., the receiver has to take information, understand and comprehend it, and then be able to apply it to their situation

Table 3: Lower order to higher order thinking skills (Anderson et al. 2001)

Lower order thinking skills ⟷ Higher order thinking skills					
Remember	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Recognising Identifying Recalling Retrieving	Interpreting Clarifying Paraphrasing Representing Translating Exemplifying Illustrating Instantiating Classifying Categorizing Subsuming Summarising Abstracting Generalizing Inferring Concluding Extrapolating Interpolating Predicting Comparing Contrasting Mapping Matching Explaining Constructing Models	Executing Carrying out Implementing Using	Differentiating Discriminating Distinguishing Focusing Selecting Organising Finding Coherence Integrating Outlining Parsing Structuring Attributing Deconstructing	Checking Coordinating Detecting Monitoring Testing Critiquing Judging	Generating Hypothesizing Planning Designing Producing Constructing

Table 4: Four types of knowledge: Ranging from concrete to abstract.

Concrete knowledge ⟷ Abstract knowledge			
Factual	**Conceptual**	**Procedural**	**Metacognitive**
Knowledge of terminology	Knowledge of classifications and categories	Knowledge of subject-specific skills and algorithms	Strategic knowledge
Knowledge of specific details and elements	Knowledge of principles and generalisations	Knowledge of subject-specific techniques and methods	Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
	Knowledge of theories, models, and structures	Knowledge of criteria for determining when to use appropriate procedures	Self-knowledge

Each of these dimensions are roughly hierarchical (Anderson et al. 2001, Heer 2012), meaning that an individual must be able to recall basic knowledge and facts before being able to move through the other steps and eventually be able to critically evaluate knowledge and apply it to their particular setting. In order to acquire knowledge and adapt to a changing climate on their own properties, landowners or organisations must be operating at the top end of both the cognitive learning and knowledge dimensions. Consequently it is important to use mechanisms that assist with this learning process and have the appropriate affordances to promote the required learning.

2.5 New ways of communicating for climate change adaptation

New ways of communicating climate change information are required in order to realise opportunities and support decision making for more adaptive futures (Moser 2010). Despite advances in adaptation research and greater understanding of the nature of primary sector vulnerability, there remains little evidence of long-term changes that might reduce future climate-related losses and improve resilience. Despite the growing awareness of the need for greater adaptation in the primary sector, there remains an adaptation deficit in New Zealand (Burton 2011, Fitzharris 2007, Hennessy et al. 2007, Reisinger et al. 2014). The lack of work on adaptation is further compounded by the emphasis in New Zealand – on GHG mitigation instead of adaptation (Greenaway & Carswell 2009, Burton 2011, Ford & Berrang-Ford 2011). Communications mechanisms, such as the Assessment Reports from the Intergovernmental Panel on Climate Change (IPCC 2007, 2104), the Stern Review on the Economics of Climate Change (Stern 2006) or the recent report from the Prime Minister's Chief Science Advisor on the outlook for New Zealand under climate change (Gluckman 2013), receive a great deal of attention in the media and in science and policy communities, however may have little practical influence in on-the-ground adaptation planning or behaviour change (Moser 2010, Prokopy et al. 2015). Therefore, there needs to be more research conducted on the information requirements of decision makers and how meetings those deficits which lead to greater practice change and the required climate change adaptation actions.

2.6 Decision makers and their information needs

Decision making is complex, involves a range of individuals both internal and external to an organisation, who may evaluate risk and impact using different decision making criteria (Bouchart et al. 2002). Garforth (2006, p.) states that "*it is widely recognised that farmers' business and land management decisions are influenced by factors other than profit, including perception of risk, attitudes, issues of family life cycles and succession, and the opinions of other farmers and the professionals with whom they interact*". Understanding who participates in decision making in a specific domain and how these participants interact can, therefore, be a key component of generating useable scientific information (Morss et al. 2005). These complexities include:

- The real world context of climate change including: multiple stressors and the capacity of businesses, and local and government institutions to respond by assessing the vulnerability and risks imposed by a changing climate (Fleming et al. 2014; O'Brien & Leichenko 2000);
- Expanding the scope to include other factors which affect adaptive capacity. For instance, the competition for resources within regions where there is universal impact of climate change, (e.g. competing for access to fire fighters, water or feed; Adger et al. 2009), or having to change to in-house management of the effects of more intense and more frequent extreme events rather than using of external resources;
- The intersection between enterprise resilience and regional resilience (Morss et al. 2005);
- Information and adaptive actions are required to manage implications from large scale events (geographic, frequency, and intensity) (Morss et al. 2005);
- Localised understandings of vulnerability (e.g. Luers et al. 2003; Polsky et al. 2007; Schroter et al. 2005; Turner et al. 2003);
- Other factors of vulnerability analysis: cultural, institutional and social and how they affect vulnerability, including sensitivity and response capacity (Morss et al. 2005); and

- Barriers to adaptation (Arnell & Charlton 2009).

2.6.1 *Information deficit and information provision*

A reoccurring theme appearing across the literature is that decision makers require more information in order to make decisions about adaptation (i.e. the information deficit model). The information deficit model assumes there is a universal appreciation of the value of science (Sturgis & Allum 2004). It describes a one-way model of communication, from science sufficiency to public deficiency (Gross 1994). More recently, the model has been described as the "loading dock" approach to knowledge transfer, produce the information and they will come, therefore taking for granted an implicit assumption that there is a universal public trust in science. In recent years, the information deficit model has been criticised as overlooking the social context of science, in which individual/public ethics, values and politics are of equal importance in public acceptance of science communications (Nerlich et al. 2010; Sturgius & Allum 2004). Information deficit is widely used in much of the climate change communication and extension literature.

Most existing knowledge-sharing mechanisms rely on traditional, one-way communication methods that place an emphasis on information provision. Such approaches often result in missed opportunities for policy-makers and stakeholders to contribute to discussions with researchers; for knowledge brokers to gain a deeper understanding of policy-makers' needs; and for all parties together to work out the details of a policy problem, identify missing but needed information, and consider possible responses. Compounding the problem, many current knowledge-sharing mechanisms are designed to convey a generic message to a generic context (e.g., climate change presentations with an 'impacts and implications' slide). Few are designed to encourage researchers, policy-makers and stakeholders to work through what the information means for their local context (Whitmarsh et al. 2011). The net result of ignoring affective aspects is to isolate the science from the public context that makes the issue important. The Information deficit model does not depreciate the critical role data and information has for informing and evidenced-based decision making, but suggests that an approach that relies solely on information, even high quality information, will have limited ability to affect change.

In order to overcome these and other considerations that stand in the way of adaptation, climate change communication must continue to shift away from the information deficit model, and direct greater attention to the affective barriers to practice change. Any effort that seeks to use communication in support of individual and collective behaviour change must have a clear understanding of the habits, barriers, identities and pragmatic support needs, as well as institutions, laws, and social norms that facilitate or constrain adaptation behaviours (Moser & Dilling 2006). Importantly, scientists and other communicators must avoid (or abandon) the assumption that better information and understanding alone will lead to more environmentally-friendly behaviour or policy support (Gardner & Stern 2002; McKenzie-Mohr & Smith 1999; National Research Council 2002). Therefore, a more collaborative, co-development and co-learning approach is recommended.

2.6.2 *Participatory and co-learning mechanisms*

Communications mechanisms can be interpreted as a continuum, ranging from one-way information transfer, to those methods where knowledge is developed within participatory and social learning processes, typically involving many people in a social learning environment. Information provision, at one end of the continuum is based on the information deficit model,

while at the other end the emphasis is on participatory co-learning (Figure 4***Error! Reference source not found.***).

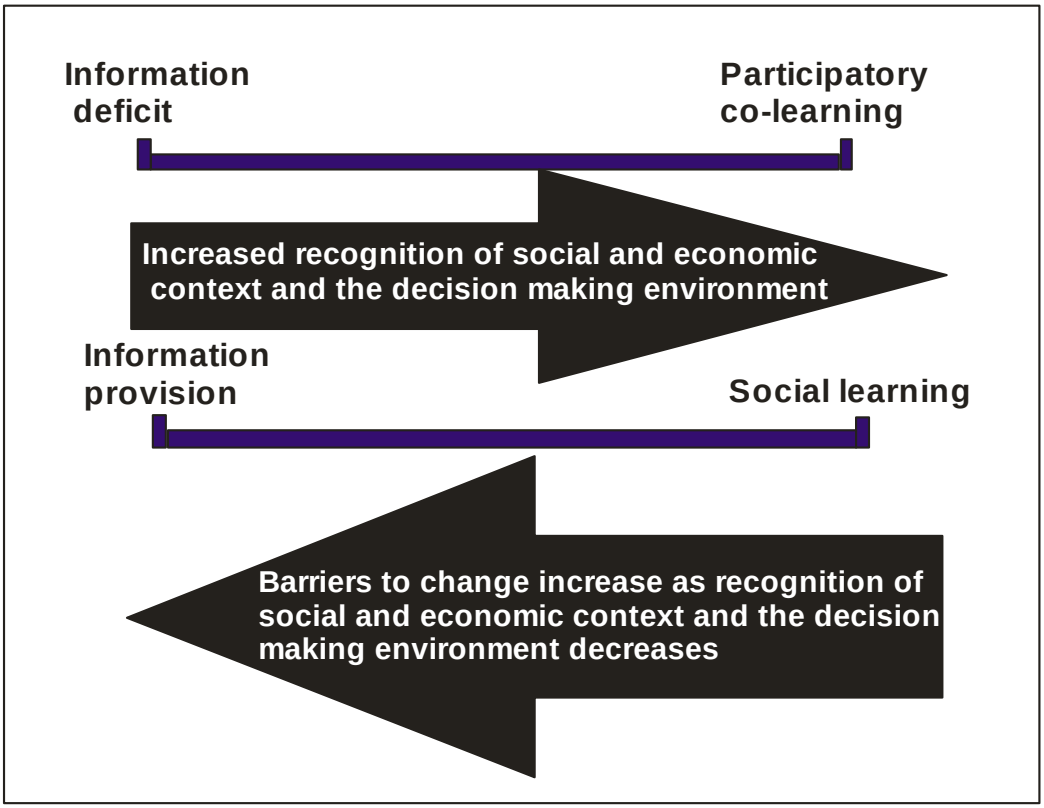

Figure 4: Communication mechanisms

In contrast to the information deficit approach, participatory and social learning environments address people developing knowledge together. In other words, enabling social learning and includes mechanisms such as (e-)workshops, communities of practice and learning packages (in learning management systems). These methods are orientated strongly to specific learning outcomes for the end user that does consider their contexts and values (Moser 2010; Shaw et al. 2009).

Participatory methods provide feedback between science, policy and end-user so that:

- The messages (data) suit the audiences (i.e., is fit for purpose) and
- The mechanisms engage effectively with the audience- learning styles; and

The mechanisms support environments for social learning (including values discovery and identify boundary issues). There is a substantial literature on adaptive assessment and management and on all manner of social learning (e.g., Aldunce et al, 2015; Collins & Ison 2009; Lorenz 2013; Ison et al., 2011), with some of the literature identifies hurdles in practice (e.g. van der Brugge & van Raak 2007). Social learning helps address the incentives and disincentives for individual learning, knowledge networks, and the impediments to knowledge flows; the importance of leaders and processes of diffusion of adaptation innovations (technologies and practices). This programme will critically evaluate current climate change communication mechanisms at three scales, and, through participatory engagement, determine which methods are more responsive to both the knowledge and behavioural needs of decision makers. The approach undertaken in this work addresses a current gap in organisations' ability to assess risk and plan for the impacts of climate change. We will take a different approach by using what the organisation wants and/or needs to

drive the information requirements and consequently define the appropriate mechanisms. Essentially, we will close the information loop using participatory approaches.

2.6.3 *A targeted approach*

This research is focusing on the mechanisms of communication and technology transfer that are pre-disposed to an action response in end-users (i.e. the research has an ambition for change and concerted action in end-users, not just simply awareness building). The research is end-user centric, where we are interested in mechanisms and knowledge that is appropriate to how end-users operate (i.e., is responsive to *their* decision making ethics, values, processes and environment). It critically evaluates current climate change communication mechanisms and, through participatory engagement, determines which methods are more responsive to both the knowledge and behavioural needs of decision makers.

3 RESEARCH METHODS

The assessment, which forms the basis of the study, had two main stages of analysis: (1) assessing current mechanisms and decision making processes, and (2) identifying new mechanisms to support decision making for adaptation. The research employed uses a combination of qualitative techniques in order to document and empirically ground the context in which mechanisms impact on decision making regarding adaptive behaviours.

Three main methods were used to collect data. Methods included: (1) document review and critical evaluation of primary sources such as project reports; (2) workshops and interviews with primary sector practitioners; and (3) the application of systems thinking tools, including causal loop analysis to identify critical decision points. The selection of methods is consistent with studies on social learning in climate change adaptation, which emphasise the need for empirically grounded, place and/or sector-specific analysis with the participation of affected stakeholders (Tschakert et al. 2010). The research strategy and methods used to address these, and the overall objectives of the research, are summarised in Table 5.

Table 5: Research methods as they relate to the research objectives

Objective	Methods
1. To review and evaluate the existing methods, tools and mechanisms used in New Zealand climate change adaptation communication and research	• Analysis of relevant literature to develop conceptual framework for study; • Identify relevant projects on climate change adaptation in New Zealand; • Develop evaluation framework to assess communications, knowledge transfer and decision-support in previous work on adaptation in the primary sector; • Develop semi-structured interview to be administered across range of primary sector stakeholders.
2. To identify the motivating levers of decisive action and decision makers' information requirements at different scales across primary sector activities	• Semi-structured interviews with forest sector producers to determine current exposure-sensitivities (climatic and non-climatic risks) and adaptive capacity; • Workshops with primary producers (agricultural and horticultural) in Bay of Plenty and Canterbury to determine climatic risks, decision making influences, timeframes, and barriers to adaptation; • Application of systems thinking tools and concepts to identify critical nodes and drivers impacting on decision making.
3. To identify communication mechanisms that might facilitate and support practice change in the primary sector, through knowledge co-development for adaptive action	• Drawing on the findings of the above two objectives, identifying leverage points in decision making to enact practice change; • Present alternative communication mechanisms that could be used to address the needs.

3.1.1 *Objective 1: Review and evaluation of existing mechanisms in use in the New Zealand primary sector*

3.1.1.1 Review process

In order to evaluate current mechanisms for climate change communication and adaption in New Zealand, a short review was undertaken in the first three months of the project (for the detailed analysis and findings see Section 4). This consisted of a) contacting key informants to identify relevant projects; and b) undertaking a review of documents relating to relevant projects; in an iterative manner.

Document Review

Relevant projects and related documents were identified by the research team, and through consultation with other researchers involved in climate change research in New Zealand. Projects were selected for analysis on the basis of the following criteria: (1) did the project advocate action for adapting to the impacts of climate change, or (2) did the project trial new adaptation techniques. A total of 30 projects were included in the analysis, including SLMACC, SFF and other projects funded by central and local government (a summary of projects reviewed is provided in Appendix A). Project reports, work plans, published papers and presentations relating to these 30 projects were collected from project leads or sponsors (i.e. principal investigators or the funding agencies). Where possible, key informants (such as the principal investigator) affiliated with each of the selected projects were also contacted to discuss the project and share any documents they had with the project team.

Informal interviews

An informal interview template sheet was developed by the research team in May 2014, based on the research team's knowledge of the technology transfer process. Key informants were asked to identify any adaptation projects they were aware of or engaged in, and to describe the technology transfer process and provide any evidence of effectiveness (i.e., evidence of practice change or adoption of key ideas in the sector as a result of the project). The aim was to solicit information from researchers and other actors engaged in different forms of technology transfer, to ensure that as many different mechanisms as possible were identified. The researchers were also able to uncover documents and reports that were not widely available, as a result of their position within a Crown Research Institute. These documents provided additional information on transfer mechanisms previously and currently in use (Heckathorn 2011).

Interviews were neither recorded nor transcribed, as the format was an informal discussion about the nature of the project and the transfer mechanisms employed. Instead, a consistent template was developed to manually record from the data available for each identified project (i. e. documents and the informal interview):

- The project purpose, duration and funding mechanism;
- Research methodology, and any extension/knowledge transfer/communications mechanisms used;
- The research outcomes, and how effectively these were communicated to end-users;
- Whether or not the interviewee was aware of other projects or tools development relevant to their sector, in order to ensure the breadth and depth of the review of existing mechanisms; and

- Who was involved in the project as well as any additional key decision makers that the project team might not have considered, and which could potentially be contacted.

These templates formed the basis for evaluation.

Mechanisms were evaluated on the basis of their learning affordance(s). Bloom's taxonomy was then used to code the cognitive affordances of different mechanisms. A second analytical interpretation provided insights into what each project set out to contribute to knowledge and practice and the rationale behind how they sought to do this. Each project was categorised based on two key factors:

1. To what extent did the research interact with intended end-users along a continuum from dyadic information exchange through to co-operative learning?
2. What was the focus of the project along a continuum from information provision regarding the impacts of climate change through to advocating and developing climate change adaptation practice?

3.1.2 *Objective 2: Decision makers' information requirements at different scales*

The research also documented existing decision making processes and practices among stakeholders from the primary sector. Semi-structured interviews and workshops were used as the primary methods for the collection of empirical data. Given the researchers' backgrounds, and previous experience, as well as logistical considerations, interviews were conducted with representatives from commercial forestry and workshops were used to gather information from farmers and horticultural producers. Workshops and interviews solicited information on:

- current processes involved in making decisions (strategic or otherwise) – who and/or what (i.e. current mechanisms) does each decision maker rely on to make informed decisions regarding climate change;
- what decision makers do when there does not seem to be enough information to make an informed decision;
- the adequacy of current knowledge mechanisms;
- the preferences for each individual decision maker for engaging with mechanisms and their associated information; and
- the desired state for decision makers and their climate change mechanisms.

3.1.2.1 Forestry semi-structured interviews

The identification of which actors to interview was determined by using a key informant approach and snowball sampling. The forest sector is characterised by around 100 larger forest owning companies, who manage forestry blocks in excess of 1000 ha, around 1740 owners of between 40-1000 ha, and a myriad of farm foresters (<40 ha) some of which are predominantly running farming units (Wakelin et al. 2014). However, forest management engagement and ownership structure is complex, as some owners manage their lands, other are owner investors, employing forest management companies to manage and produce returns to owners, and other forest companies are simply investment companies. For forestry, semi-structured interviews (n=12) were undertaken with forestry representatives at both enterprise and local scales (i.e. farm foresters (n=5) and commercial enterprises (n=7), across a range of job titles. While the number was low, the people and companies selected are representative of the wider sector. Interview

questions are provided in Appendix 10. Interviews were audio recorded and transcribed, and coded according to our conceptual framework.

While the numbers are not statistically representative of the forest industry as a whole, they represent both investment or family corporate farm forestry schemes, as well as larger commercial enterprises. Results are therefore indicative of the decision making influence of the wider sector.

3.1.2.2 Workshops: Kiwifruit, drystock, cropping and dairy farmers

Unlike forestry, which is relatively limited in terms of the number of commercial stakeholder-actors, there is a much greater number of farming units within New Zealand (approximately 40,000) in the major primary sector categories of animal farming, cropping, and horticulture. Interviewing a handful of these would neither be representative of the larger sector nor conducive to establishing decision practices at local scale. In lieu of interviews, two workshops were held, the first was held in in the Bay of Plenty in November 2014, where forty invitations were sent to farming, cropping and horticultural producers, and only kiwifruit growers responded to the invitation (n=3), and the second was held in North Canterbury, with a mix of drystock, cropping and dairy farmers (n=16) in February 2015. The participants, farmers and horticulturalists were invited to attend a four –hour workshop in which they would be solicited for information in order to empirically document the range of exposure-sensitivities and adaptive capacities employed in regional farming systems, as well as their decision making processes, and influences on adaptation practice, and preferred mechanisms of knowledge transfer (see Appendix 11).

The workshop held in the Bay of Plenty was with participants invitations were sent through to members of the New Zealand Landcare Trust. For the North Canterbury workshop, local farmers were sourced through the local Oxford Primary School Parent Teacher Association as a school fund raiser. Both workshops ran predominantly as a facilitated group session, and the workshop discussion was audio recorded and later transcribed for coding.

Audio recordings from interviews and workshops were transcribed verbatim. Interviews were formatted and loaded into a qualitative data analysis software package (NVivo 10) for analysis. Data was coded and analysed according to the relevant themes as per the conceptual framework.

Analysis

Triangulation

An important criterion for determining the rigour of qualitative research is triangulation (Baxter & Eyles 1997) (see Figure 5). Based on convergence, triangulation suggests that when multiple sources provide similar findings their credibility is considerably strengthened (Knafl & Breitmeyer 1989; Krefting 1990). The transcripts from interviews and both of the farmer workshops were analysed and compared, and there was a high-level of synergies between the findings with respect to major risks, barriers and preferred mechanisms, despite being conducted with different sectors, in different modes, and in different locations. The semi-structured interview format, in combination with the facilitated workshop mode, did achieve the goals associated with data collection as it relates to the research objectives and questions, and can therefore be considered methodologically appropriate (Elliott 1999).

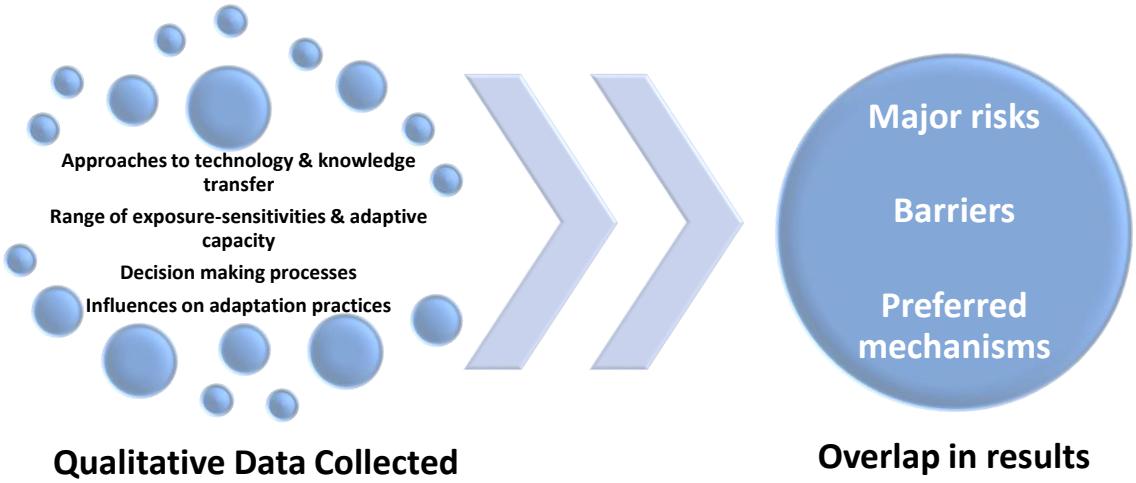

Figure 5 Triangulation of results

The triangulation process provided the basis for identifying key factors as variables of influence in the decision making process. The coded statements were clustered around a theme, and displayed as a mind map.

Systems thinking

In addition to triangulating the data in order to analyse the overlap in the findings, the research also adopted a systems thinking approach. Systems thinking is used here to describe a suite of concepts, tools, and methods relating to the examination of relationships between different components of elements contained within the boundaries of the unit of analysis. It is often used as an approach to problem solving, and is not one thing, but a set of practices within a framework that is based on the belief that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation (Ison 2010). Systems thinking involves understanding a system by examining the linkages and interactions between the elements that compose its entirety.

Systems thinking is championed on the premise that there are emergent properties of systems that do not exist when systems are decoupled into smaller parts (Rubenstein-Montano et al. 2001). Problem-solving in this way involves pattern finding to enhance understanding of, and responsiveness to, the problem. This involves developing common understanding of the problem space at different scales. Empirical data was interpreted using systems thinking methods and frameworks (Williams & HummelBrunner, 2015). The aim was to determine critical decision processes that address risk, vulnerability, adaptation and adaptive capacity relative to climate change. The coded transcripts from the workshops and interviews were used to develop a mind map (Appendix E) as an input to causal loop modelling. The Causal Loop Diagram allowed us to identify nodes of influence and potential leverage points. Additionally, a series of decision maps which characterised decision making processes within organisations and sectors, as well as the actors involved, their motivations and values, and how they may (or how they may not) utilise adaptation mechanisms were developed (Appendix D).

An overview of the steps used in the investigation of decision making processes and information needs is shown in Table 6.

Table 6: Steps undertaken and data sources used to develop CLDs

Steps	Purpose	Data source
Identify key variables	Factors, conditions, decisions that affect or are affected by the system. Understanding an actor's ability, willingness or capacity to act is fundamental to framing messages and mechanisms.	Interview and workshop transcripts were converted to a 'mind map'. The mind map was explored by the research team to describe and identify key variables.
Develop Causal Loop Diagrams (CLD)	CLDs are a visual representation of the relationships between key variables. They are often developed in a workshop setting as a group exercise which can facilitate learning.	The research team, through a group exercise, mapped the interactions between the key variables identified from the mind map. Causal links between key variables outlined in the mind map provided a model of influences on current decisions.
Establish critical nodes	Reinforcing and balancing loops as sub-systems within the system are useful for "finding appropriate leverage and entry points for changing a situation" (Williams & Hummelbrunner 2011, p 43)	The causal loop diagram was analysed by the research team for reinforcing and balancing loops as a group activity. The critical nodes driving these loops were highlighted.
Identify leverage points	These are points in the system where decisions are often made and where interventions can change adverse dynamics or enhance positive dynamics.	Leverage points that addressed the gaps around each critical node were identified from individual and collective/combined decision maps and the mind map.
Identify intervention strategies.	Intervention strategies are mechanisms that can better facilitate a change in practice towards adaptation through multiple affordances.	Intervention strategies and novel mechanisms, described in Section 6.

Decision mapping: Decision mapping addresses *who* is involved in the decision making process and *how* they make decisions. The process of decision mapping, results in a visual representation of a decision that is built around choice options, consequences, outcomes and values/goals (Urbany et al. 2008). Causal loop diagrams were developed subsequently to determine *what* factors are needed to facilitate decision making regarding climate change adaptation mechanisms, and *what* dynamic impacts such factors may have on changes to practice and uptake of mechanisms (Clark et al. 2009).

The decision maps helped to clarify the decision making processes, the actors involved, their motivations and values, and how they did or did not utilise adaptation mechanisms (detailed findings provided in Section 5). The decision mapping process also enhanced our understanding of how decision makers view their current and desired future state as well as how they prioritise decisions and actions.

Causal loop diagrams: Causal Loop Diagrams (CLDs) "provide a language for articulating our understanding of dynamic, interconnected situations. They can be considered sentences that are constructed by linking together key variables and indicating the causal relationships between them. By connecting CLDs, a coherent story can be told about a particular situation or issue" (Williams & Hummelbrunner 2011, pg 31).

Based on the mind map, a CLD was developed as an initial step in understanding the context for decision making in the primary sector.

The individual decision maps, and consolidated mind map, can be thought of as representations of decision making influence at the micro-scale, while the CLD provides a macro-scale view of high-level influences impacting on the primary sector system. A number of factors affect climate change adaption, and that these are complex, operate at multiple scales and feedback loops, and include a mix of social, economic and biophysical drivers acting through multiple pathways.

The relationships between variables can be defined as either positive or negative, as seen by the "+" or "-" symbols next to each arrowhead. These symbols define the interaction between variables. For instance, the relationship between "Risk perception" has a positive reinforcing (or similar) effect on "Willingness and ability to act"; so, an increase in "Risk perception" will lead to an increase on "Willingness and ability to act", and a decrease in "Risk perception" will decrease "Willingness and ability to act". Conversely, for example, "Clarity of information" has a negative reinforcing (or opposite) effect on "Uncertainty"; so, an increase in "Clarity of information" will decrease "Uncertainty", and a decrease in "Clarity of information" will increase "Uncertainty". In summary, the narratives help to highlight important variables, sub-systems and critical node points where influence/intervention will likely afford the changes in the system.

4 CURRENT MECHANISMS: WHAT IS AND IS NOT WORKING?

The following section discusses the results of the document and interview analysis in order to provide an overview of existing climate change communications affordances in New Zealand. The scope of the project limited the review to selected case examples and is not representative of the breadth of adaptation research to date.

4.1 Current mechanisms for climate change communication in New Zealand

A review of selected climate change projects was completed in order to determine the current mechanisms used for climate change communication in New Zealand, Table 7 provides selected examples***Error! Reference source not found.***. A complete list projects reviewed can be found in ppendix A.

Table 7: Selected examples of reviewed climate change projects in New Zealand

Project Name	Partners	Purpose
Impacts of Climate Change on urban infrastructure and the built environment	NIWA and others	A tool box designed to help planners, engineers, asset managers, and hazard analysts in New Zealand urban councils understand and evaluate the potential impacts of climate change in their jurisdiction.
Climate Cloud	AgResearch and Scion	Web-based data base of research articles, reports and resources on any aspect related to climate change. Brings together range of information sources relevant to land managers and added new resources where substantive gaps identified.
Farm forestry for economic and environmental sustainability (calculators)	NZ Farm Forestry Association	Decision-support tool for identifying appropriate land-use for hill country at risk of soil erosion or accelerated runoff. Intended to support on-farm afforestation for climate change adaptation.
Adapting to climate change in eastern New Zealand (ACCENZ)	MAF and others	The ACCENZ project ran from 2004-2006 and pioneered 'bottom-up' approaches to climate change adaptation and impacts assessment. Research also incorporated visual imagery to interpret and visualise the resilience of farms in eastern New Zealand. Narratives and farmer case studies were also produced.
Adaptation Strategies for Dairy	DairyNZ, University of Waikato, Waikato Regional Council	The research is developing in-depth understanding of farming systems dynamics in order to support more effective climate change adaptation. The work is seeking to bridge 'top-down' and 'bottom-up' approaches. It has relied on small sample, in-depth stakeholder engagements through interviews and Soft Systems Modelling of individual farms. Research activities have also been presented to stakeholders at Field Days and online through a short web video.

In reference to Figure 6, projects have been classified by according to the degree of interaction with end-users (horizontal axis) and subject type (vertical axis). The far-left end of the horizontal axis represents the classic information transfer approach, where information is generated and

knowledge delivered to an audience with an expectation that the end-users would implement the technological solutions.

The next category involves increased interactions between scientists and practitioners in the development of the message or project. Practitioners may be local government staff, technical staff, industry organisation staff or key consultants. Once the scientists and practitioners have finalised the product or process it is delivered to the target audience.

Further along the spectrum, although scientists and practitioners still work on the project in isolation from stakeholders, they do have a 'trial run' with a selected sub-group of the target audience. Feedback from the trials provides improvements in the product or process before it is delivered to the remainder of the audience.

The far-right side of the spectrum represents a co-production of knowledge approach. Research is undertaken with the participation of key stakeholders or practitioners. Stakeholders – or selected members of the intended audience – are actively involved in elements of research design, implementation and information gathering. In theory, this ensures a higher degree of alignment between the production of knowledge, and end-users' information needs.

On the vertical axis the projects have been classified by focus. Three categories of research projects have been identified:

1. Projects in which adaptation to climate change and practice change are the stated purpose of the work;
2. Projects in which reference to climate change is more general and not necessarily targeted. Project may be aimed at awareness-raising or information provision; and
3. Projects in which the main objective is the management of climate-related impacts, such as extreme wind events, drought, fire or increased variability. Climate change may not be explicitly described or identified, but is an implicit component of the research/project.

4.2 Results and discussion

4.2.1 *Stakeholder interaction*

In New Zealand, the majority of research projects address the potential impacts of climate change with only limited stakeholder interactions, marked as "A" on Figure 6. Furthermore, those projects that do have higher levels of stakeholder interaction, very few of them specifically target adaptation or practice change ("B", Figure 6). These are focused on climate change generally or on particular specific climatic impacts often considered in isolation (i.e., drought management). The positioning of climate change research along the two continuums exposes strengths and weaknesses in New Zealand research projects and programs.

Weaknesses include:

- The majority of the research proceeds in a manner consistent with the information deficit model. This means that attempts to change practice in the primary sector will likely face substantial resistance because the social and economic contexts of the issues have not been accounted for. The weaknesses of an information deficit approach are well documented in the international and national literature.
- There is greater risk of maladaptation in dealing with single impacts without mentioning the wider climate change context or illustrating the interconnected nature of the

potential impacts. In other words, by adapting to drought farmers and growers may expose themselves to greater flood risk. Successful adaption to climate change will require a holistic response to a suite of risks. However, the sector will need to recognise and account for the trade-offs that exist in maintaining a production system which is robust to multiple diverse risks. For example, landowners will need to prepare for increased risk of drought *and* increased risk of flooding which may require some compromises within the production system. This is much more challenging if the conversations and research around potential impacts are broken into discrete units.

- Many of the conversations about the impacts of climate change are framed as a response to particular impacts without reference to climate change. Although this approach appears to ensure greater participation from landowners, it may perpetuate the perception that this is just about managing natural variability rather than coping with an underlying long term change in climate and biological systems.
- There are very few projects targeted towards adaptation. As some degree of climate change is inevitable (Burton 2011), adaptation is essential for the continued profitability of the primary sector. A continued research focus on impacts will not suffice.

Strengths include:

- Several successful projects have worked with key stakeholders to discuss climate change issues, and have developed information packages or discussed adaptation options. All these projects recognise the biological, social and economic complexity inherent in climate change related practice change and work with stakeholders to incorporate these factors into the research outputs. International literature suggests that projects of this nature are most likely to promote adaption and practice change.
- The diversity of projects spanning a wide range of the potential impacts of climate change show that research on key issues is being undertaken, but in a disconnected fashion.

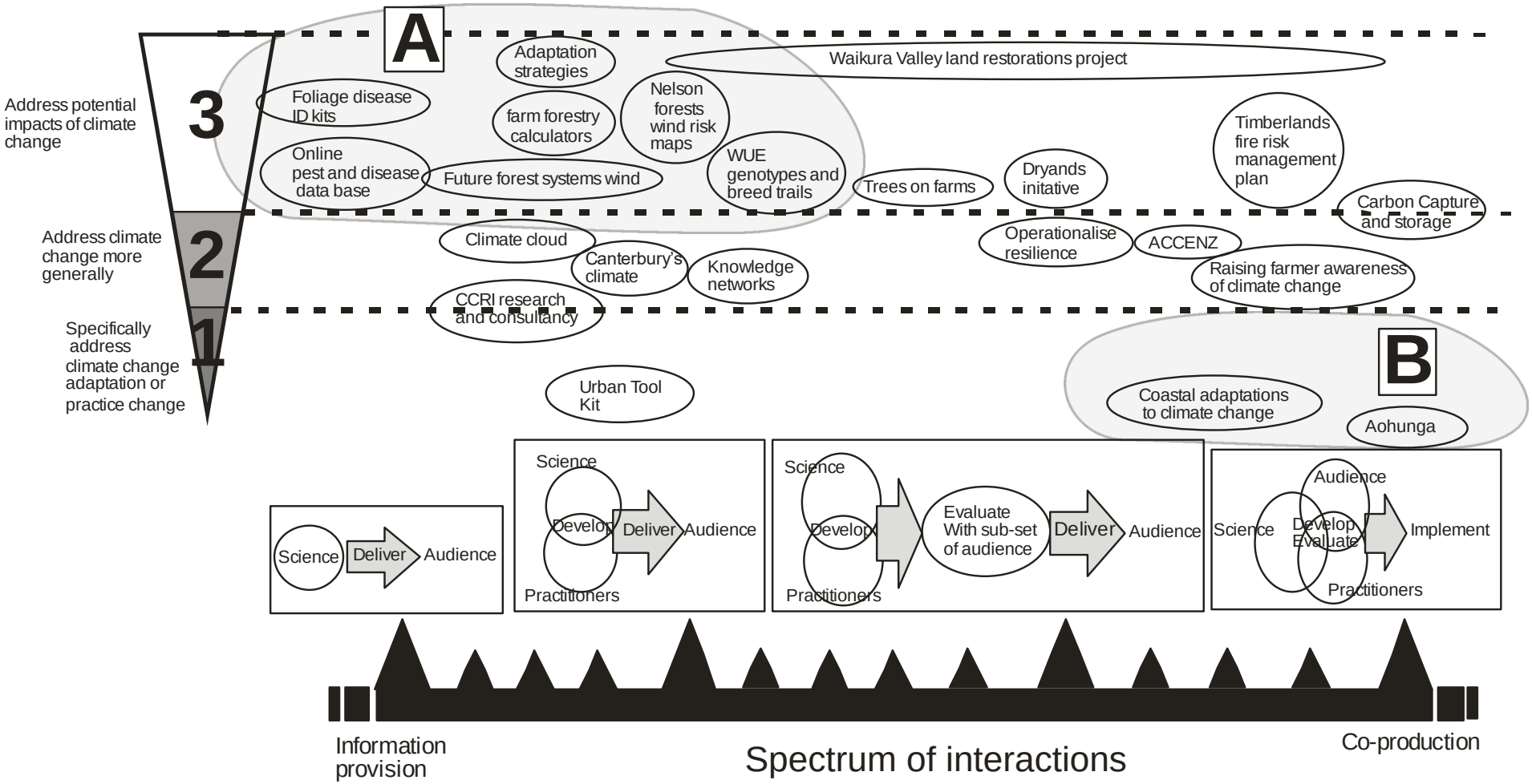

Figure 6: Classification of projects according to focus and degree of interaction and the interaction and focus of different climate change communications

4.2.2 *Mechanisms and their affordances*

Mechanisms have been evaluated according to two criteria: (1) their affordance (Table 8) and (2) the type of learning generated based on Bloom's typology (Table 9) as a means of identifying where the current gaps in communication or learning mechanisms occur.

Table 8: Mechanisms identified and there affordances

Mechanism	Key Affordances
Written reports on Impacts **Authoritative Reports (e.g. IPCC, PMCSA)** **Fact Sheets** **SLMACC reports** **Impact maps**	Authoritative source of information Transportable Highly accessible Permanence One-way No ability to address learning needs No ability to address learning styles No ability to assess up-take and understanding, or misunderstanding
Conference presentations	Audience engagement Clarification Misconception exposure
Videos **Websites** **Climate Cloud** **Urban Tool Box** **Coastal Explorer** **Adaption Strategies for Dairy**	Composite pictures, e.g. split screen, S/I Animated diagrams exploring processes Visual metaphor/analogy/representation Illustrating concepts with real examples Condensing time by editing real life Juxtaposition of contrasting situations Narrative power
Research programmes	Co-development of problems Co-development of solutions Information deficit Factual information Evidence based information
Train the Trainers **Coastal adaptation to Climate change school curriculum** **Canterbury's climate- teachers resources**	Co-development of transfer mechanisms Addressing misconceptions Addressing audience typologies, comprehension and targeted learning Addressing pedagogy
Websites	Updatable Correctable Tailored to perceived misconceptions Can be styled to suit different audiences Can include some forms of end-user participation Container to other forms of engagement (i.e. printed material, video, toolbox)
Webinars **Scion Climate Change webinar** **Knowledge networks**	Accessibility Limited, but some engagement Focused communication
Tool Box	Co-developed Adaptive
Workshops **Case Studies** **Workshops/** **Urban Tool Box** **Coastal adaptation to Climate change** **Aohanga climate change resilience project**	Highly co-develop Fitness for purpose Feedback on all aspects (e.g., information, misconceptions, misunderstanding, Prior knowledge.) Scaling out issues In depth learning

Carbon capture and storage **Raising farmer awareness of climate change** **CCRI workshops** **Adapting to climate change in eastern NZ** **Operationalising resilience in dairy agroecosystems**	
Digital Library	Relevance Accessibility Comprehensiveness Quality

Table 9: Learning objective model: Aligned to Bloom's taxonomy

		Knowledge Dimension			
		Facts	**Concepts**	**Procedures**	**Metacognitions**
Cognitive processes	**Remember**	Written* Video	Written	Written	Research programmes Train the Trainers
	Understand	Written Conference	Written Conference Train the Trainers	Written Conference Train the Trainers	(Conference) Research programmes Train the Trainers
	Apply	Conference Research programmes Train the Trainers Workshops	Conference Research programmes Train the Trainers Workshops	Conference Research programmes Train the Trainers Workshops	(Conference) Research programmes Train the Trainers Workshops
	Analyse	Train the Trainers Workshops	Train the Trainers Workshops	Train the Trainers Workshops	Train the Trainers Workshops
	Evaluate	Train the Trainers Workshops Case Studies	Train the Trainers Workshops Case Studies	Train the Trainers Workshops Case Studies	Train the Trainers Workshops (Case Studies)
	Create	Workshops Case Studies Tool Box	Workshops Case Studies Tool Box	Workshops Case Studies Tool Box	Workshops Case Studies Tool Box

Source: Iowa University, Centre for Excellence in learning and teaching. http://www.celt.iastate.edu/teaching-resources/effective-practice/revised-blooms-taxonomy/ (Creative common License).

(*) Where a mechanism is included in higher levels of cognitive processing, it is assumed that they could operate at lower levels. They have not been included in the lower order parts of the table for clarity reasons.

4.2.2.1 Results and discussion

We classified the affordances identified from climate change related projects into a typology of three broad classes, which are named as (1) one-way, (2) framed one-way-, and (3) interactive communications.

One-way communication mechanisms

One-way communication mechanisms (reports, video's, pamphlets, digital libraries, and webinars) have historically dominated climate change related communication in New Zealand. As a

consequence the transfer of knowledge has been about facts, concepts and general ideas (refer to Table 9).

For example, that average temperature will increase, or rainfall intensity could increase. Written material provides a very positive affordance for developing a baseline statement of the facts associated with the sources of climatic risk, and potential impacts. Examples include reports from various SLMACC programs (Cradock-Henry & Mortimer 2012), and other national and international projects and programs. Some afford a higher level of authority, based on authorship, or the rigour of the peer review process. Examples include the authoritative publications of the IPCC's assessment reports (IPCC 2007, 2014), its topical and thematic analyses (e.g. special reports) or other internationally recognised reviews (e.g. Stern 2006), or those that communicate official government views (Gluckman 2013).

However, with one-way mechanisms there is no ability for the writer to understand the end-users specific needs, their context and any misconceptions and misunderstandings held, or lack of pre-requisite knowledge. One-way mechanisms do not afford the ability for social and discursive learning, nor do they create a space for reflexive practise, or the ability to address some of the physiological factors addressing climate change adaptation (Centre for Research on Environmental Decisions 2009).

It is important to note that understanding facts is a critical step in the learning process because it provides the foundation for future learning and action. Outputs of this nature provide solid defensible science from which to facilitate on-going learning and future adaption. Use of one way communication is an essential part of any suite of mechanism designed to promote climate change responses in New Zealand. Nonetheless, it cannot be the only mechanism as the primary sector may not progress from understanding knowledge to co-creation of knowledge of climate change risk, impacts and implementing adaption strategies.

Framed one-way communication mechanisms

Framed communications mechanisms are an extension of the previous category. The main difference is that these have additional affordances because they are, to some degree, co-constructed with end-users to address their problems. Many more recent projects use stakeholders to assist with the development of the one-way communication to ensure it is appropriate for the target audience. Examples include:

- Niwa's urban tool box which was developed with local government and engineers; and
- Coastal adaption to climate change school curriculum which was developed through collaboration between teachers and researchers and tested with students.

Participants in co-development projects are afforded the opportunity to learn from each other's experience and provide both rigorous science and context to the final product. One interviewee felt their project was very successful because co-development allowed them to *"produce a logical packet of tools to manage the potential impacts of climate change"*.

Framed one-way communications are becoming increasingly common as researchers recognise the need for the social and economic context of end users to be incorporated into communication mechanisms in order to encourage learning. Within the co-development process, researchers learn from the stakeholders and the stakeholders gain access to knowledge which promotes a shift from understanding towards implementing knowledge. Several interviewees observed this process in their projects.

A common output from framed one-way communications are stakeholders narratives (stories) or case studies which demonstrate how knowledge was applied to a particular setting (e.g. urban tool box). Readers can gain insights into application of knowledge through the written experiences of others. However, because there is no opportunity to address the questions of readers, the application of knowledge may be limited.

We suggest that the use of framed one-way communications could be considered the second evolution in learning around impacts and implications. This is principally because it begins to contextualise rigorous science, through stakeholder involvement, as a means to produce one-way communications that are more relevant to end-users and thus more likely to generate change.

Interactive communication mechanisms

Interactive mechanisms are two-way methods that afford the ability for end-users and knowledge developers to enter into to discussion/discourse which can address comprehension, context and prior knowledge. The projects have utilised several interactive communication mechanisms including: conference presentations, seminars, workshops and case-studies. The mechanisms have different durations, audiences, objectives and scales which influence the types of learning likely to occur.

Conference presentations provide the ability to transfer knowledge to a wider audience and also allow limited two way formal and informal discourse about the topic. Practically all projects produced conference presentations, because it is one of the primary mechanisms for researchers to communicate. However, the degree of end user/stakeholder attendance and the accessibility of conferences (national or international) have a strong effect on what action the mechanism generates. The high affordance of conferences is the ability to talk with people outside of formal sessions. Webinars are conference-like, but significant two-way interaction is limited and is dependent on the video conferencing technology employed. It affords the ability for end users to participate irrespective of their location. However, webinars are not commonly used as a communication mechanism. Seminars have similar affordances to conferences except they are more local and may allow greater stakeholder attendance and may afford more opportunity for dialogue.

Many of the project identified they used workshops, although a distinction can be made between two different types: (1) training workshops, and (2) stakeholder workshops. Training workshops are where toolboxes, guidelines, curriculums, tools or new process are presented to participants and they are taught their use and application, for example, Niwa's Urban Toolbox. Workshops are designed using adult learning principles to encourage provide knowledge and encourage the use of the output in the participants context. Stakeholder workshops usually elicit knowledge from participants and stimulate discussion around particular issues. Both types of workshop provide the ability facilitate knowledge exchange to enable end-users to critique and evaluate climate change knowledge and adaptation strategies and apply this to their own problems and practises. This mechanism affords participants the ability move up the dimensions of Bloom's Taxonomy, from lower- to higher-order cognitive processes. A negative affordance of workshops is the time commitment required by participants.

Case studies, such as Aohanga, ACCENZ, and others focus on a particular location and a particular group of participants. Researchers work with participants to investigate and resolve an issue of concern. Interviewees reported this to be an effective mechanism for learning. Most of the

interactive communication mechanisms are effective at stimulating higher levels of learning and stimulate change but restricted in their impact by the small number of participants involved.

4.3 Critical messages

This section focused on mechanisms, on *how* information was communicated to end-users; the types of mechanisms used; their affordances; and their effectiveness. In other words, the 'medium' through which information about climate change is communicated to end-users. The review of existing programs and their affordances showed that the majority of communication is predicated on the information deficit model that assumes that information stimulates adaptation and that end-users require more, and more detailed information about climate change and its impacts. The analysis did identify examples of successful communications strategies that engaged with stakeholders to explore complexity and co-create potential pathways to adaptive solutions. Thus highlighting that understanding an actor's ability, willingness or capacity to act is fundamental to framing messages and mechanisms. This is especially true for the context of decision making and information needs analysis in climate change adaptation.

Many climate change projects in New Zealand address the potential impacts of climate change with limited interaction with stakeholders ("A" on Figure 6) meaning change in the primary sector will likely face substantial resistance because the social and economic contexts of the issues have not been adequately accounted for. Combined with the common use of use of one-way communication mechanisms (including framed communication mechanisms) this means that learning in the primary sector is likely to be restricted to recollection of factual information with some understanding of the likely impacts and implications of climate change. Although it is very important to understand impacts and implications before acting, one-way communications do not afford the higher level of learning required to adapt to a changing climate.

A number of projects have utilised two-way communication mechanism which afford participants the ability to evaluate analysis and apply learning to their own context. Projects and can be divided into two groups:

- First, those which deal with single impacts without mentioning the wider climate change context or illustrating the interconnected nature of the potential impacts. Subsequent adaptions be maladaptive if they do not consider the interconnected nature of climate change impacts and navigate the trade-offs inherent in resilience to multiple risks.
- Second, those which deal with adaption in a more integrated way. All these projects recognise the biological, social and economic complexity inherent in climate change related practice change and work with stakeholders to incorporate these factors into the research outputs. International literature suggests that projects of this nature are most likely to promote adaption and practice change. However, most projects have occurred at a local level (individual properties or communities); therefore the geographic distribution of adaption is low.

It is important to note all communication mechanisms and ways of interacting with stakeholders are useful and have a place. Nevertheless, each has it benefits and limitations in terms of learning to achieve practice change. Information is important because it affords increased understanding without information adaption can be ineffective. However, failure to account for social and economic context will affect the perceived relevancy of the information. Moreover, information on its own may not encourage change. In order to facilitate higher order learning (change within a

participants own context), two –way communication mechanisms are required, but these need to be underpinned by rigorous science information. In addition that can be time and resource intensive. In short, all communication mechanisms are useful but the choices between them should reflect the challenges faced and existing knowledge of the target audience.

5 INFLUENCES ON DECISION MAKING AND ADAPTATION

The aim of this section is to provide social and economic context to facilitate improved climate change information messaging, through:

- Documentation and analysis of current decision making processes in forestry and farming sectors to elicit major influences; and
- Describing and understanding the system in which adaptation to climate change occurs and the factors that influence climate change adaptation.

The combination of these two approaches provides insights into how individual and organisations make decisions and how the system in which they operate functions. Thus providing a multi-level understanding of the context in which climate change adaptation does (or does not) occur. This section provides the basis for the proposed new mechanisms described in the following section.

5.1 Decision making in primary sector businesses

A series of decision maps (Appendix D: Decision Maps), derived from the semi-structured forest sector interviews, aim to enhance our understanding of how the decision makers view their current and desired future state as well as how they prioritise decisions. In essence, decision mapping addresses '*who'* is involved in the decision making process and '*how'* they make decisions. Data from the interviews was structured into decision maps to illustrate individual or organisational decision making processes.

Results from decision maps were collated to identify and evaluate the combined and varied degrees of influence on decision making processes. The triangulation process compared and contrasted decision maps with the workshop transcripts. The resulting mind map revealed a number of influences on decision making including: information and advice, climatic risks, experience, adaptability, policy, productivity, and markets. The mind map is provided in Appendix E.

The resulting analysis provides a number of insights into how climate change adaptation factors in to the decision making processes. The mind and decision mapping processes identified key actors involved in making decisions for land management, including area managers and individual farmers; the level of influence they have; and internal and external factors influencing land operational decisions.

5.1.1 *Results and discussion*

5.1.1.1 Information and advice

Many of the interviewees felt that availability, accessibility, and accuracy of information and advice was a critical barrier in their decision making, limiting their ability to make management decisions that inform the potential impacts of climate change. Their sources of information included both formal:

- Fonterra, Zespri, "*Zespri employ four people to liaise with growers"*,
- Dairy NZ: *"good websites to get information easily",*
- MPI, farm advisors and consultants,

and informal:

- "*We have established a Facebook page to interact with the community/iwi*",
- "*Word of mouth will be the biggest way of us finding or hearing about news",*
- *"It's not just what you know, it's who you know and how well you're connected*",
- kiwifruit pack house groups offer a "*conduit of information*".

Technology, especially access to broadband, was identified as a barrier, particularly for remote rural areas. "*Joe Average farmer probably misses out on a lot of that stuff*".

The fact that forestry is a long-term land use led to the perception by some that there was a related increase in resilience to climate change risks and that ultimately there was less need for adaptive actions.

> *"Adaption in forestry context isn't quick – trees are pretty resilient and over the long rotation, many impacts are smoothed out – so need for adaption is seen as a lesser requirement by foresters",*
>
> *"Not too concerned about it…should I be?"*

A lack of information and advice is allowing this belief to persist.

There is an understanding of the importance of the physical aspect land on forest and farm management, as many management decisions are based on the capability of the land.

> *"…easier in flat areas to have total crop damage from wind than on hillier areas. So topography is key. It's a cost, but also an advantage to have a rolling terrain."*

Some interviewees where preparing for climatic risks in advance through changes in management practise e.g. felling forest stands earlier, planning for water storage solutions for crop irrigation, albeit driven by immediate climatic risks.

> *"Planting trials of different species on the slip areas",*
>
> *"Firebreaks in stand",*
>
> *"Thin earlier to a lower stocking".*

5.1.1.2 Climatic risks

In some cases there was awareness of potential threats, (such as strong wind events, high intensity rainfall, and drought) but there was no linkage to climate change as the threat was viewed as a cyclical occurrence, which would occur with or without changes in climatic conditions and not necessarily be enhanced or mitigated by it (e.g. *"Weather changes happen all the time"*). Due to the cyclical nature, rather than any gradual climatic increase, farmers may be less likely to see an imperative to adaptation.

> *"Pervading belief that wind events are in cyclical patterns, and it may never occur – so it's difficult to get adaption for wind. Last wind event of this strength was 45 years ago, and we're always thinking when will it happen next? So if it just occurred, farm foresters think there's less likelihood of it happening again",*
>
> *"There's nothing being measured to say that climate change will directly affect the fire or erosion risk. In saying that, we've probably had three 100-year floods in the last five years but whether that's a climate change issue we don't know",*

"We've seen some extreme rainfall events but is that part of the long-term trend?"

Respondents in the forestry sector identified diseases as a major risk:

"I think Climate is down the list of people's thinking. I'd be more worried about future biosecurity than climate. Because climate is really about is it getting drier, is it getting wetter, look you could say that is still pretty speculative what is happening with the climate."

But also one that was cyclical, "*it comes and goes"*. This identifies that climate change planning may be constrained by current issues lens, rather than using current issues to develop a strategic view of climate change related risk and opportunities. Single events may be seen as "anomalies" of climate, and lower the perception of impacts on livelihoods in the longer-term. For adaptation of climate change risks to be embedded into long-term strategic planning, evidence of climate change would need to be consistent and incremental, *"not just stochastic or one-off events".*

"Are you going to see a change in climate that will affect a forestry block within 5 years? Not likely."

Until climate change impacts were evident in major sections of forest stands, most respondents said little or no adaptation actions would be contemplated.

"If climate change consistently caused extreme seasonal variation or storm event then we'd start to get worried",

"The type of terrain we have means that wind shouldn't fell the whole block – there are gullies that would be protected. The wind might get one gully side, but the other would be okay".

This is consistent with Grotthman and Patt (2005), who suggests that risk appraisal and self-perception are decisive factors in adaptation. Protection motivation theory (Dang et al. 2014) posits that decision makers wait to assess the probability of the worst event occurring and the damage potential, and their ability to avert harm, and the cost this would take. This "wait and see" approach severely limits the value of climate change information and advice to proactively assist with adaptation measures.

In contrast to the forestry sector, kiwifruit growers identified a number of management practices that had already been adopted, or that they were aware of, that had the potential to mitigate climate change impacts. Overhead cloth protection, for vulnerable vines, could provide shade as well as protect the crop from hail events; and overhead frost protection was also widely referenced in order to manage the risk associated with greater climate variability. In addition to climate risks, such as temperature changes, changing frost patterns, hail- and wind-events, biosecurity incursions were the identified as the biggest current risk, especially as it is outside of growers' control.

5.1.1.3 Experience

Adaptive management decisions are based on current or past experiences and did not take into account the potential for risks to fluctuate under varying climatic conditions

"We use historical occurrence to help identify wind risk",

"There's a planning process around erosion and mitigating those risks. It's an intuition type thing and relying on the skill sets of the staff members that are involved in the process".

While farmers perceptions are linked strongly to their decisions, perceptions are greatly influenced by the past year's experiences, and by their own adaptive capacity (Bryant, 2000). Schwartz and Sharp (2006) note farmers require relevant experiential practice "practical wisdom" which cannot be taught, but builds sufficient flexibility, autonomy and confidence in the available options such that informed decisions can be made in a timely manner, and in the context of the farm business interests. Farmers at both workshops are beginning to consider the long-term impact of compounded drought events – whether they can "ride out" multiple "bad" seasons. For example, a comment from the North Canterbury workshop attendee stated:

"Most farmers seemed to be able to manage a drought but can they manage one, two, three droughts in a row?"

5.1.1.4 Adaptability

Farmers' management of their personal exposure to risk is a critical component of farm operations. Farmers apply knowledge gained from experience, using apply local resources and the self-reliance built up over time, to meet any challenges or risks that are apparent (Altieri & Koohafkan 2008; Gandure et al. 2013). Consistent with earlier studies on adaptation in New Zealand (Clark et al. 2012), strategies identified by interviewees and workshop participants were congruent in consisting of a combination of tactical, short-term measures, and more strategic responses operationalized over a longer (10+ years) planning horizon. Deliberate diversification, timing of management activities, and water management were among the most commonly identified adaptations by both farming and forestry sectors.

Foresters were aware of alternative investment streams from the trees, such as from carbon markets, and were looking at various silvicultural regimes to buffer against changing markets.

"I see it as an opportunity rather than a constraint that we can take advantage of several different markets and aren't tied into just one."

The majority of small forest owners (4 of the 5 we interviewed) have other off-site income streams and revenue streams as well. One farm forestry block contained a telecommunications repeater, which supplemented income, while others mentioned planting Manuka for commercial honey production, and developing a dairy support block following a significant wind-throw event. All the small scale forest producers were also employed in off-farm enterprises as their main income.

Diversification applied to the types of species grown including growing awareness of pest-, disease-, and drought-resistant varietals. Foresters, for example, described alternative species that might be better suited to future climatic conditions, as well as looking to develop disease-resistant clones and the trialling growing other tree species.

"We'll switch the species to Douglas fir to mitigate the risks from altitude and snow damage. We've started planting Radiata hybrids in very exposed places because they can withstand the extreme exposure."

Kiwifruit growers mentioned the switch from Hort 16A (Zespri Gold) to G3 (a PSA-resistant fruit).

Improved monitoring at the micro-scale can aid farmers to understand changes over time and the priorities for adaptation (Blennow, 2012). While there was no evidence found amongst the foresters we spoke to for such adjustments in timing, this type of management strategy may have potential as an adaptive response for the sector in the future. In the farming sector, dairy farmer participants have adapted to drier periods with less feed by supplementing feed with palm kernel, growing their own alternative feedstock or even reducing stock numbers.

None of the farmers we spoke with yet had a comprehensive adaptation plan around either climate change or adapting to the indirect impacts from climate change.

> *"These scientists have made these predictions but won't be held accountable if they're off target."*

However, most corporate foresters had a risk management plan, and some risks (e.g. fire, biosecurity) appear to be mainstreamed (i.e. embedded and institutionalised) into day-to-day forest management activities. The most common approach appears to be keeping a *"watching brief"* on climate and future climate forecast, as well as a high degree of influence from the actions of peers and neighbouring properties in terms of adjustments for climate risk reduction, in other words, most are reluctant to lead the way, preferring to follow on the experiences and actions of others.

Adaptability to reduce the exposure to risk is therefore seen as being dependent to some extent on the scale of the enterprise.

5.1.1.5 Policy

Key actors that affected the decision making process of small forest owners were often related to consumers and investors. Policy was generally not viewed favourably.

> *"Policy prevents, not enables decisions",*
>
> *"An attitude among farmers is that it's layers and layers between them and the policy makers",*
>
> *"The more time I spend regularly monitoring or complying with the regulations the less time I can spend managing my farm",*
>
> *"Compliance is something that just keeps coming at us and you're always wondering what's coming next; they don't add anything to productivity",*
>
> *"The compliance level is often static for a very long time and then leaps forward; production is incremental year after year and so should the compliance that supports it",*
>
> *"Constraints of compliance".*

However, respondents did seek the advice of councils and this can therefore be viewed as a potential intervention point where dissemination of information can be more actively pursued.

> *"I'd say that our future decision making processes will include a climate change component but that this may come through councils who determine that we should be doing more than what we are in a manner to mitigate more risks".*

Climate risk is still seen as speculative by some, though the speculation may be more related to uncertainty.

"Potential change in climate trends is not a risk as such, it's uncertainty. Unless you can put figures of probability around something it's not risk, it's uncertainty",

"If we had more certainty about the predictions for climate change and more confidence then we would put more effort into planning for increased risk".

In addition, a lack of clear direction from policy makers contributed to the uncertainty surrounding climate change and how best to adapt to it.

"There are a number of options and we haven't really gone down the road of what we might do yet because things like Regional Council rules are constantly changing."

Policymakers appear constrained by lagging scientific research (Biesbroek 2010) that provides little guidance for short-term action of relevance to today's farming challenges.

5.1.1.6 Productivity

In addition to risks and adverse impacts that respondents related to future changes in climate, positive responses were also recorded, particularly from the forest sector, where:

"Warmer temperatures will mean faster growth rates, greater wood density, better outturn"

Forests being in "good locations" might be able to realise productivity gains with warmer temperatures and milder winters. Reduced road construction and maintenance costs were also mentioned, as drier weather would, in theory, result in less erosion and slips on access roads. Kiwifruit growers did describe greater productivity – but feared that warmer temperatures would result in greater vigour, increasing green leaf production rather than more fruit**.** New Zealand famers increasingly need to manage farms for both water allocations and obtain consents for use of water resources such as bores or reservoirs. Management of water to mitigate runoff and leaching, and to manage water use alongside nutrient output, is also changing dairy management practice.

5.1.1.7 Markets

Financial considerations were of primary importance for small-scale foresters and individual farmers, as many could not afford to absorb a decrease in profits to minimise a climate change risk.

"From a budget perspective, we can't always rely on the 'it may occur' risks, we can't mitigate every potential risk factor."

Funding constraints remain a major hurdle for most landowners as demonstrated in such comments as *"cost prohibits action"* and *"profit over risk".* The relationship between profit and risk leads to incremental adaptation strategies being chosen over transformative business change, where the latter would adequately provide a flexible buffer and enlarge adaptive capacity. Therefore, the efficiency of a farm may impact on the availability of adaptation options for the operation (Rodriguez et al. 2014).

Insurance coverage was also mentioned in relation to markets and was described as a responsive measure capable of protecting shareholders and their investment if climatic risks or threats destroyed the forest stand. Yet insurance is not always affordable, and indeed is not a climate change adaptation measure. However, the provision of insurance coverage was seen as an excuse not to invest in such adaptation steps. In addition, impacts have in many instances been mitigated

in part through subsidies or compensation for extreme climatic events. Gandure et al. (2013) suggest that some farmers may not adapt their farming strategies for climate risk due to the presence of, or reliance on, financial assistance and social support mechanisms.

Farmers seem reluctant to make changes to practice before they have to, and need to see the benefit and have confidence in the change mechanisms and adaptation practices being purported.

New Zealand on-farm adaptation strategies are similar to international practices, typologies of which generally identify four broad categories:

1. diversification of income streams from off-farm activities (adopting new techniques or technological equipment, or employing farm financial portfolio management);
2. varying crops and planting different varieties;
3. adjusting timing of farm activities (planting, weeding, harvest etc.); and
4. adopting new water management and conservation techniques (Below et al. 2010; Clark et al. 2012; Tengö & Belfrage 2004;).

However, where Howden et al. (2007) found major differences in adaptation response strategies between different primary sectors, our study shows a strong degree of overlap across the horticulture, agriculture and forest sectors within New Zealand, though responses do appear to differ by scale of enterprise.

5.2 Systems approach to analysing decision making

Following Maani and Cavana (2007), a generalised systems approach was used to proceed step-wise through the documentation and analysis of decision making processes, drawing upon the qualitative data collected from the forestry and farming sectors. For this research, systems thinking provided a structured approach to acquiring insight into the underlying motivators of actions, the identification of interventions and feedback loops that can affect the system under observation.

Based on the mind map, a Causal Loop Diagram (CLD) was developed as an initial step in understanding the context for decision making in the primary sector (Figure 7) identifying key variables and sub-systems.

The individual decision maps, and consolidated mind map can be thought of as representations of decision making influence at the micro-scale, while the CLD provides a macro-scale view of high-level influences impacting on the primary sector system. A number of variables affect climate change adaption. These are complex, operate at multiple scales and feedback loops, and include a mix of social, economic and biophysical drivers acting through multiple pathways. From the mind map, key variables driving the climate change adaptation were identified and their inter-dependencies and interactions mapped into a causal loop. Five critical nodes arose from the CLD, which are shown in bold in Figure 7: diversification potential, willingness and ability to act, profit and return on investment (ROI), productivity, and market demand.

Further analysis of the CLD reveals a series of reinforcing feedback loops around each of the five critical nodes of influence.

The first involves a social sub-system relating to the individual characteristics of the farmer – their information needs, degree of self-efficacy and social capital support as well as their individual

perception of the risk faced. This archetype converges around the critical nodal point of "willingness to act". Farmers' management of their personal exposure to risk is a critical component of farm operations. Adaptation generally takes place at the micro- and macro-levels, where different intervention needs are present: Farmers introduce practices at the local level, and the main factors influencing their diffusion are seasonal climatic variations, the agricultural production system, and other socioeconomic factors; the government, NGOs, or private companies introduce practices nationally, and long-term changes in climatic, market, and other conditions influence their establishment (Nhemachena & Hassan 2007). Farmers apply knowledge gained from experience, using apply local resources and the self-reliance built up over time to meet any challenges or risks that are apparent (Altieri & Koohafkan 2008; Gandure et al. 2013).

A second sub-system relates to the resource management and climate science sub-system, and congregates in a nodal point of productivity and farm profit. This develops from the biophysical characteristics of the farm and long –term sustainability of the business, alongside regional resource allocations and bylaws. Farmers take action across a temporal scale, but the decisions tend to be focussed on meeting more immediate needs than long-term strategic decisions. Therefore many adaptation strategies are more extensions or more intense versions of their existing strategies to manage climate impacts or limit loss in production due to the changed climate risk profile (Howden et al. 2007).

A third sub- system develops around the profitability and business capital investment, with a nodal point around potential to diversify the income streams, and the production mix of the land , by varying what is grown or developing new markets or off-farm incomes. A large driver behind this sub-system is the mitigation measures put in place to reduce impacts of climate change on the farm business and to buffer any variations in cost of supply for example feed, or market demand fluctuations.

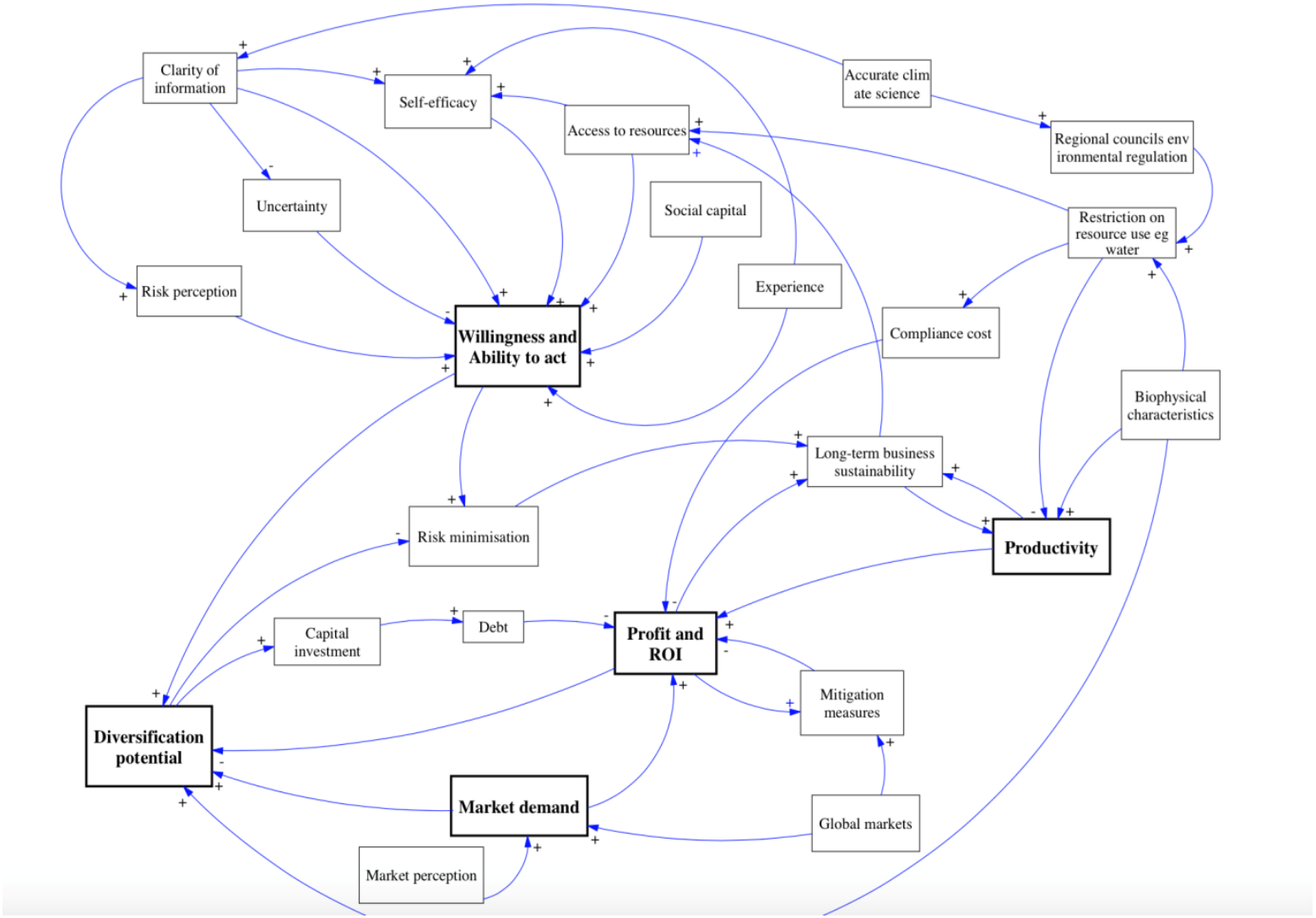

Figure 7: Causal loop diagram

Narratives can be useful as a means of explaining causal loop interactions to key actors, and to jointly explore implications. Three narratives have been developed based on the conversations in the workshops and interviews which follow what could happen when practice change originates through regional council policy (or regulation of some form), market demand or through climate change science and changing risk perception.

5.2.1 *Narrative 1: Changes in policy and regulation*

Based on climate science the regional council increases restrictions on water takes from surface water and ground water. A decreased availability of water acts directly to decrease on farm productivity, especially for dairy production and kiwifruit. Decreases in production results in, decreased farm profit and in decreased long-term business sustainability. If access to water requires further consents, regular inspections, or involves additional infrastructure then a compliance cost occur. The cost(s) of compliance acts directly on farm/orchard profit. A decrease in farm profit impacts on long term business sustainability. However, if landowners act to mitigate the reduced access to water (through an intervention i.e., change in process or new technology) then farm profit and long term business sustainability can be maintained or even increased. In addition, should the landowner be able to diversity the enterprise (perhaps new crops) then risk can be minimised and long-term business sustainability retained and perhaps improved. It is worth noting that the diversification potential is affected by market demand. Also diversification may require further capital investment and require increased debt loading which affect farm profit in the short term.

5.2.2 *Narrative 2: Market demand*

Global markets have considerable potential to influence the type of production systems operating in New Zealand as well the type of product grown. There are two pathways through which this influence is perceived to operate. First, the global demand of products allows New Zealand to diversity its production systems and minimise exposure to a changing climate. Of course this is contingent on the ability of the landowner to make the necessary capital investments and access the finances required to set new production systems (increase debt). Second, is through controls imposed on how products are produced for example requirements to mitigate greenhouse gas emissions or meet certain pesticide use standards. All these mitigation measures protect market access and ensure long-term business sustainability but may affect farm profit in the short term.

5.2.3 *Narrative 3: Change in climate science or risk perception*

If climate science provided a greater clarity over the impacts and implications of climate change within particular regions or catchments the clarity of information available to landowners would increase. An increased clarity of information will decrease uncertainty of possible impacts, create a shift in risk perception (land owners better understand the risk their business is exposed to) and provide a greater level of self-efficacy (confidence that the action taken will have a desirable result) around what sort of response to climate change may be appropriate on individual properties. All these factors influence the willingness to act. However, willingness to act is also influenced by access to resources (e.g. finances, land, water, labour), which is affected by long-term business sustainability and farm profit. Willingness to act is also affected by social capital (access to resources/ideas through the ties and relationships between people) if the community is responding to climate change and has the knowledge and resources for successful adaption then individuals will be more likely to change their practices. If willingness to act is increased risk to

individual properties derived from a changing climate can be minimised and long-term business sustainability retained. Also, willingness to act may lead to diversification of enterprises on the land, which is in turn influenced by market demand, any requirement for further capital investment and ability to increase debt load to fund the changes.

5.2.4 *Identification of leverage points*

In systems thinking, leverage points are places in the system where an action or intervention can make a lasting change in the system. The CLD contains a number of potential key leverage points, however the ability to influence the leverage points are likely to lie across the primary sectors, government organisations and institutions; and other entities. It is important to understand where different actors can act on leverage points. For example:

- Leverage points around market demand will mostly be influenced by overseas organisations (i.e., supermarkets), governments (trade restrictions), or consumers.
- Regulation can be influenced by government ministries and departments; local government, while industry organisations (e.g., Fonterra, NZFOA) can have influence.
- The availability, salience, legitimacy and credibility of climate science is influenced by international, as well as national research activities, as well as trends in science research and funding and investment priorities.

The following six fundamental leverage points clarify where the uptake of climate change adaptation mechanisms could be progressed:

1. Creating more confidence in climate change adaptation options;
2. Enhancing the clarity of information provided, including the use of more targeted messaging;
3. Pursuit of more cross-sector, multi-scale collaborative policy design';
4. Forming issue-based solutions;
5. Progressing ability to act under uncertainty; and
6. Increasing market foresight in relation to potential climate change impacts

The six potential intervention points focus heavily on adaptation mechanisms could allow individual behavioural change to occur, by facilitating the driving forces behind an actor' willingness and ability to act; and by building the farm-scale diversification potential; and by growing long-term business sustainability.

These leverage points address the driving needs under direct actor control at both the individual scale influences of decision making (from the consolidated mind map) and also the wider system scale critical nodal points (in the causal loop diagram). A focus on development or adoption of mechanisms which intervene in this manner is most likely to facilitate practice change towards adaptation for climate risk. Section 6 will explore these ideas further.

6 FACILITATING PRACTICE CHANGE THROUGH NEW MECHANISMS

In the previous sections this research has focused on how the messaging about climate change risk and impacts, as well as adaptation options for the primary sector is delivered to those whose prime responsibility it is to plan for climate change and the models and mechanism that have been used to communicate with the primary sector. This final section addresses the third and final research objective, to identify communication mechanisms that might facilitate and support practice change in the primary sector, through knowledge co-development for adaptive action. To begin, an overview of the previous findings will be provided, followed by a series of example mechanisms that afford enhanced learning, and address the decision making context, identified by the CLD and the leverage points. Much of the information relating to climate change is not fit for decision making purposes, namely the risks, impacts and implications are not specific enough for end-user's businesses. Punj and Staelin (1983) notes that it is not the amount but the relevance of the information that incurs change, and Newman and Staelin, (1982) further state that more resilient decision makers have acquired pathways that shortcut the ability to obtain relevant information quickly to enact decisions. Mechanisms to effect practice change must take into account: the environmental contexts (social, economic, cultural), and the affective and psychological predispositions of the individual decision makers involved at whatever level of influence. Ajzen's Theory of planned behaviour (1991) shows that while decision making through rational planning describe an individual's attitudes to behaviour change, decisions to act are also affected by the social context and the perception of an ability to act (self-efficacy).

Our thesis is that unless communication mechanisms allow for end-user learning of climate change impacts and adaptation options that are specific to the end-users' context, adaptation will either not occur or be limited, or result in maladaptation.

6.1 Summary of findings for research objective one

Objective one: To review and evaluate the existing methods, tools and mechanisms used in New Zealand climate change adaptation communication and research.

The research identified that the usability for decision making of most of the climate change communication was constrained as most mechanisms had low affordances for learning about impacts and risks in a business setting. Highlighted below are the issues identified from the project reviews conducted to meet the first objective:

- Some mechanisms used were somewhat limited due to the lack of affordance for dialogue. There were mechanisms that required higher levels of cognitive functioning, but these are limited in number and also in scope.
- Some mechanisms had restricted time or no engagement with end-users, so there is not the ability for the science to be adapted to changes in context of the end-users, nor to any new science understanding, especially in adaptation.
- Projects were contracted with little technology transfer requirements beyond science delivery via a dyadic route. The majority of projects sought to provide information or tools to farmers/ foresters that would allow them to monitor or establish the risk of climate change on their business, rather than to adapt to the risks already present.
- Projects hinted that adaptation mechanisms would be required but still advocated for a mitigation approach to be taken. Those that were looking particularly towards adaptation appeared to be only at a trial or initial research stage.

- Projects which specifically addressed practice change used co-development mechanisms, whereas the projects that are aiming towards indicators and calculators to identify and assess risk appear to utilise a dyadic arms-length transfer mechanism (after Stock & Tatikonda 2000).
- Several of the projects appear to be utilising a range of transfer mechanisms across the continuum, in an attempt to reach a wide range of very different audiences.
- Very few projects had followed-up, on either the effectiveness of the technology transfer mechanisms used or on the usefulness of the research, though they were not contracted to do so.

6.2 Summary of findings for research objective two

Objective 2: To identify the motivating levers of decisive action and decision makers' information requirements at different scales across primary sector activities.

The decision making model as the focus of the second objective, was used to develop an understanding of, in farming and forestry sectors, the decision making needs and environment. The decision analysis and maps have identified that the context for information requirement for climate change adaptation needs to address the following:

- a lack of confidence in the imperative for, and success of, adaptation options;
- messaging that is issues-based, rather than climate-change focussed;
- a more collaborative approach to policy that incorporates co-design amongst stakeholders at different scales;
- a weak resilience level to climate impacts and need for strengthened social capital within the primary sector; and
- lack of market security and certainty.

The system thinking analysis reveals a number of critical themes or nodes where new mechanisms can be developed to strengthen the primary sector and facilitate changed behaviour. These mechanisms would contribute to:

- creating more confidence in climate change adaptation options;
- enhancing the clarity of information provided, including the use of more targeted messaging;
- the development of more cross-sector, multi-scale collaborative policy design;
- focus on issue-based solutions;
- progressing the ability to act under uncertainty; and
- increasing market foresight in relation to potential climate change impacts.

From our analysis, it appears there are three key areas where intervention could result in a system change to increase the uptake of business-level adaptation:

1. At a *personal* level, by increasing social capital and enhancing the belief of ability to act and the reasons required for action. This would increase self-efficacy and through targeted information, allow a measured view of the risk and impacts on their business, thus activating the personal willingness and ability to act.
2. At the *farm* level, by exploring through extension or case study, the diversification potential of the land-based unit, and aiding farmers to develop a plan for long-term farm sustainability.

3. At a *governance* level, by adequately monitoring and collating climate science at the farm unit to allocate resources to maintain farm productivity, while also, reducing the level of subsidies or mitigation measures which limits the farmer from realising the full long-term impact of climate change on their business.

Nothing in this report diminishes the value of climate projections, the mechanisms enhance their usability.

6.3 Options for different communication mechanisms for climate change adaptation

Objective 3: To identify communication mechanisms that might facilitate and support practice change in the primary sector, through knowledge co-development for adaptive action.

Drawing upon the research findings, this section proposes other types mechanisms that enable the development of useable information. Table 10 provides the linkage between the identified leverage points, CLD nodes and potential mechanisms that can address the learning requirements.

Table 10: Relationships between leverage points, causal loop key nodes and proposed new mechanisms.

Leverage Points	Causal Loop diagram nodes	Mechanisms that afford action addressing leverage point[2]s
More confidence in adaptation options	Experience, Self-efficacy Social Capital	Innovation systems Community of Practise Adaptation pathway frameworks Climate Champions Social networks Assumption-based planning
Information	Willingness and ability to act.	Adaptation pathway frameworks Sustainable livelihood framework Portals E-books / Story Maps
	Diversification potential	Social networks Innovation systems Community of Practise
	Certainty	Climate Risk Matrix Analytical Network analysis Assumption-based planning Scenario Planning
	Risk Perception & Risk Minimisation	Analytical network process Risk and adaptation frameworks Vulnerability Frameworks Assumption-based planning Portals
	Biophysical Characteristics	eBooks Risk frameworks Portals
	Productivity	Risk frameworks (component – access to information aka UKCIP

[2] This is in addition to mechanism identified in objective one, such as printed material.

		Portals
Collaborative Policy Design	Willingness and ability to Act	Participatory engagement - multi-scale Scenarios Community of Practise Pan sector primary industry roundtable Portals
	Environmental regulation	Participatory engagement - multi-scale Scenarios Adaptation pathway frameworks Portals
	Restrictions on resource use	Scenarios Adaptation pathway frameworks
	Access to resources	Scenarios Adaptation pathway frameworks
Issue-based solutions	Productivity	Risk frameworks CoP Innovation Systems
	Biophysical Characteristics	Risk frameworks Portal eBooks
	Risk minimisation	ANP/AHP Risk frameworks Assumption-based planning Portals CoP
	Profit and ROI	Risk frameworks
	Long-term business sustainability	Adaptation pathway frameworks Risk frameworks
	Diversification potential	Adaptation pathway frameworks
Learning to live with uncertainty	Self-efficacy Uncertainty	Portals CoP Innovation systems ANP/AHP
	Clarity of information	Risk frameworks Portals
Market Foresight	Market demand	Risk frameworks - Value chain
	Supporting transformational change	Innovation systems CoP ANP/AHP Adaptation pathway frameworks Scenario planning
	Sector/Regional transitioning	Innovation systems CoP ANP/AHP Adaptation pathway frameworks Scenario planning

This section identifies a range of alternative mechanisms that will afford better learning by decision makers in the primary sectors. The mechanisms described are sourced from the literature, and from organisations and institutions, such as governments, NGO's quasi-

government, businesses and community organisation. These mechanisms reflect the change in priorities that is been seen internationally, where there is a shift from the estimation of impacts and vulnerabilities, to developing information and processes for adaptation planning and action in a world that is looking less and less likely to stay within 2 C of global warming (World Bank, 2012).

In addition, adaptation by businesses is largely the responsibility of the business owner and/or manager. It is expected that their need for information will 'exponentially increase' in order to support adaptation (e.g. Kirchhoff et al., 2013). Hence these mechanisms support the information need to address and take advantage of opportunities associated with diversification and any increase in biological productivity, as well as overcome barriers such as the ability to act or access and use of capital.

These mechanisms are selected as those that can help address the key leverage points and the CLD decision nodes.

Most of these mechanisms consume and re-work the mechanisms identified in objective one, hence still require even more detailed science information on risk and impact. Some of the communication mechanisms are frameworks or processes made available in websites, workshops. They engage in different types of participatory engagement where there are interactions either between selected end-users within closed processes; while others have more open interactions between, for example, scientists and end-users or policy, public, scientists and business stakeholders. In the context of our research, these are all participatory mechanisms.

6.3.1 *Ability to address key levers*

6.3.1.1 Creating more confidence in climate change adaptation options

Most of the mechanisms reviewed provide an environment for developing confidence in adaptation options.

Communities of practise (section 6.3.2.1) provide an environment for shared development of a wide range of knowledge. The effectiveness of communities of practise (CoP) depends on the diversity of actors, the ability to define what the CoP is about and what it is aiming to achieve, and the ability of the CoP to create a discursive learning environment based on equality of thought and contribution. Specifically a CoP can provide the ability for high quality discussion and evaluation of different adaptation options or scenarios which, can assist in implementation, or avoiding maladaptation.

Innovation Systems (6.3.2.2) provide a mature framework for ensuring that adaptation options are developed in a manner that can significantly ensure successful uptake. It is one of the few mechanisms that specifically analyses institutional barriers to, in this case, adaptation innovation.

Adaptation pathway planning (6.3.2.3) assists by allowing decisions to be deferred until they are absolutely necessary, the requisite information is developed to enable robust decision making and by allowing the critical decision's, especially those that maybe conflicted, to be identified and resolved.

Decision maps (6.3.2.4) address the specific information requirements and assessment processes for robust and informed internal decision making based on internal and external constraints and internal criteria, hence building confidence for adaptation option assessment.

Risk management models (6.3.2.6) improve confidence by providing processes and tools for self-assessment of risk and opportunities, the setting of priorities, challenge assumptions and test

adaptive capacity. Each example listed provides different nuances and foci of the risk evaluation process. Risk matrixes provide a method for ensuring that all activities are considered through the use of the value chain as a check list. The climate champions add the ability of incorporating knowledge from trusted members of a community; also they provide the ability to trial new ideas so other users can see the adaptation in action.

6.3.1.2 Enhancing the clarity of information provided, including the use of more targeted messaging

The CLD identified nodes where information is required that is affected by climate change:

- Willingness and ability to act
- Diversification potential
- Productivity and Biophysical characteristics
- Market demand
- Profit and ROI

Mechanisms that address information requirements for different aspects of business include the decision making frameworks, the risk management models. CoP can inform on the useability of information, and also can co-develop information required. Adaptation pathways are strongly information orientated, where decision nodes require information in order to make informed choices and the wider decision contexts includes for community, special interests, Government, institutions and funding. Decision maps and Systems thinking can identify the critical decision points and the information needs (as demonstrated in this research).

Analytic network process (**6.3.2.11)** allows stakeholders to assess the relative importance of different climate change impacts on their forests or farms. The method is a reductionist as the outputs are spatial maps of combined risk and vulnerability, as well as formally addressing aspects of adaptive capacity. The SWOT component and subsequent analysis can prioritise different adaptation options e.g. using what strengths exist that can mitigate different threats and what is the exposure to the company in relation to threats that arise out of weaknesses.

6.3.1.3 Pursuit of more cross-sector, multi-scale collaborative policy design

CoP outcomes can address policy; the strength of the CoP is in the network. It is noted that official policy typically is developed under some form of legal framework (e.g. Resource Management Act, National Environmental standard) so this particular goal requires some understanding of the power distribution and the ability of the CoP to effect an agenda, though an example of successful CoP is the New Zealand land and water forum.

Using innovation systems allows the exploration of the role institutions, as core structural elements, on innovation (as adaptation) development. Hence, the method can be used to identify how well the institutions (policy, regulations, and incentives) help the functioning of the innovation system or whether they impede it.

6.3.1.4 Forming issue-based solutions

A critical component of CoP's is its purpose and goals. Communities of practise require clear purpose and processes for reflection on how it progresses its agenda in order to be effective in providing implementable solutions. Ensuring that the CoP network is comprehensive and diverse will also help ensure that solutions are issued based.

Innovation systems are inherently issue-based; typically innovation systems establish and evolve around a problem that needs to be solved, innovation systems can assist developing the technologies that address climate change impacts and risk.

The decision mapping and systems thinking mechanisms are focused on business drivers for adaptation to climate change hence are developing information requirements for the issues identified in the CLD, such as impacts on productivity, or diversification.

6.3.1.5 Progressing ability to act under uncertainty

The social learning aspects of the CoP allows for network actors to develop understanding on uncertainty and what how the level of uncertainty affect the ability or enact some form of action. This is complementary with the information driver as arguably more or better information can help quantify and reduce uncertainty.

Most technological innovations have inherent uncertainty and the functions address how this can be addressed. Innovation systems are focused on developing the knowledge and confidence in order to embed innovations in the sectors or society.

Adaptation pathway allows the decomposition of larger adaptation action into smaller processes that can allow for addressing uncertainty and to plan as to how critical level of uncertainty can be overcome. Bosomworth et al. (2015) framework also indirectly addresses uncertainty, where other mechanisms can address forming judgements and addressing adaptive learning under uncertainty.

The decision mechanisms (Decision maps, System thinking) and the risk frameworks inherently address uncertainty management as part decision making process. ANP allows stakeholders to rigorously rank relative risk.

6.3.1.6 Increasing market foresight in relation to potential climate change impacts

While adaptation pathways don't address market foresight explicitly, aspects of market foresight can include as individual decision nodes or as paths within a complete pathway. Such as managing changes in supply of imported inputs to a system that could be affected by climate change.

6.3.2 *Communication mechanisms*

6.3.2.1 Knowledge networks: Communities of practise

Knowledge networks or communities of practise (CoP) (Lave and Wenger 1991) assist in co-creating and disseminating knowledge, as a developing and sustaining a collective learning environment that is focused on a common and shared challenge (e.g., Bidwell et al. 2014), i.e., CoP's tailor information to a shared context. Knowledge networks allow for overcoming barriers such as the comprehension of climate change information ; the affective / social reasons that may inhibit information use, such a building trust, developing understanding of the context of the information, e.g., how information can be used and what are its limitations, including information accuracy, reliability and uncertainty. (Kirchhoff et al. 2013).

Knowledge networks enable an environment of developing science usefulness (Kirchhoff et al, 2013) as the actors, objects, institutions, interact to co-create of knowledge that can result in some form of action. Typically, networks address learning requirements in order to achieve some common aim, or agenda for change (Social learning reference). Kalafatis et al. (2015) notes that the analytical focus is on information that the characterised by values of credibility, legitimacy and

salience, which are negotiated within the network. They are inherently social learning processes where, for example, the network address incremental change in learning which result in changes in practise, which result in new learning requirements. Lave and Wenger (1991) states that communities stimulate learning through tension in learning together, while having to implement and test the learning individually, providing feedback loops that result from having assumptions challenged

6.3.2.2 Knowledge networks: Innovation Systems

Innovations systems (Edquist 1999) address a challenge or 'dilemma' and is a social construct formed from an agreement or commitment of actors to work towards some form of concerted and collective action. The system is dynamic and forms a mix of innovation and knowledge which flows between actors.

Knowledge is the catalyst that makes the system work and when combined with social interaction and reflexive/ adaptive practise, the system learns from itself and adjusts.

Innovation systems can assist in developing innovations for climate change adaptation, especially solutions that are technologically focused.

Innovation systems provide insight into the process of idea generation to technology diffusion and are mechanisms for effective problem solving (van Mierlo 2010). It allows for consideration of political and power dynamics in problem definition or with uncertainty, ambiguity, risk and unintended consequences, to the point where Vob et al. (2006) states that the "ideal of certain knowledge, unambiguous evaluation as well as planning and control become revealed as illusionary"(p. xiv).

Innovation systems are mechanism that are reflexive and where learning occurs through stimulation in 'the sense of a change of thinking and acting' (van Mierlo 2010, p. 145). The modernist ontology of complete knowledge and control cannot be achieved due to the dynamics of the system and is replaced by ontology of knowledge construction from continuous learning about a situation and an epistemology that learning is found in social interactions. van Mierlo (2010) states that reflexivity is where "participants scrutinise the relationships between the incumbent system, project activities, intermediate results and the long term, ultimate aim of system change" (p. 145) and learning is facilitated by "questioning participant's values, presumptions and practise" (p. 145).

In summary, Edquist (1999, p. 65) states that the innovation system approach:

- places innovation and learning processes at the centre of focus;
- adopts a holistic and interdisciplinary perspective;
- employs historical and evolutionary perspectives, which makes the notion of optimality irrelevant;
- emphasises interdependence and nonlinearity;
- can encompass both product and process innovations, as well as sub-categories of these types of innovation; and
- Emphasises the role of institutions.

Innovation systems can be assessed and improved by analysing the structures and functions present in the system. Wieczorek and Hekkert (2012) define the innovation system (IS) structure as comprising of actors, institutions and infrastructure as well as their interactions.

Actors consist of individuals and collections of people in business, Government, NGO's, knowledge institutions and other organisations and individuals from others such the services sector that are contributing to a technology by being involved in generation, diffusion and the utilisation of technologies (Hekkert et al. 2011). The actor network, is a critical component of innovation systems, these though are a lot less formal than CoP's with many actors not being aware of others. So they can include formal CoP's but also include the personal social networks that individuals have and may interact with, in large innovation system's actors can be competitors, where their engagement is governed by bounded common interest, as a well as by legislation (e.g. Cartels and anti-competitive behaviours)

Institutions are defined as the 'rules of the game' comprising (inter alia) laws and regulations, sociocultural as well as technical norms, use patterns and shared expectations. Institutions provide incentives for certain behaviours or penalise unwanted behaviours and this property affects the behavioural responses of actors that embedded within the institution.

Some behavioural cues can be changed by the actors, whereas others cannot. This ability to change institutions (or create new ones) is critical to innovation systems and the role of actors, in order to meet the desired change agenda and identify when the processes of how goals are obtained can restrict or inhibit innovation. Institutions developed in isolation to one another, can be in conflict with one another and have competing or contradictory goals (Wieczorek et al. 2012, 2013).

Infrastructure consists of the elements on which innovation is built, which include the typical physical infrastructure, as well as the current knowledge and financial infrastructures.

Functions are the emergent properties of the system; these are the processes that are important for the system to work and also to work well. Functions cannot be directly modified, so can only be changed by addressing structural elements such as sufficiency of actors. Hekkert (2007) outlines seven core functions of a TIS:

- Entrepreneurial activities: Entrepreneurs integrate knowledge potential, markets and networks into action that develop into business opportunities.
- Knowledge development: The active development of knowledge as it develops the new knowledge on which new business, opportunities and economies are built. How knowledge is developed and gained, and knowledge on processes of innovation are important to successful innovation.
- Knowledge diffusion/knowledge exchange. How actors they self-organise into 'the network' provides the critical learning environment. The actor's network(s) are basis for exchange of information. Within innovation systems, the 'width and depth' of the network is important where a too limited exposure to ideas can hinder diffusion. Hence, the network should include not just the producers and researchers, but also people that can inform on policy, markets, design, end-users as well as sceptics. The network is a location for learning-by-interacting.
- Guidance of the search are the other activities that are occurring within the innovation systems which provide credence and legitimacy (or not) to the technology, i.e. provide

'guidance' for finding useful technological innovations and have impacts on the system by encouraging entrepreneurs and early adaptors. This function aids the technology selection process (Negro et al, 2007) and enables the rational allocation of scarce resources. This function requires balancing so that resources can be used efficiently, but also that there is not a loss of variety especially early in the innovation system development.

- Market formation. Innovations typically have to supplant existing technologies. Market formation focuses on how to get product to market. The formation of a new market environment that enables new ways of working therefore improves innovation adoption.
- Resource mobilisation. This function addressed the resource requirements in order to run the innovation system and includes the availability of financial, human, social, cultural and economic capitals.
- Creation of legitimacy. This function addresses building legitimacy for the new technology. Through, enabling technological shift (e.g. the initial subsidy to assist in the move from incandescent bulbs to low watt bulbs) or by advocacy which can help develop an implementation trajectory for the technology.

6.3.2.3 Adaptation pathways

Developing adaptation pathways (Figure 8) is a decision-orientated approach which are able to address difficulties in planning for an uncertain future, one with changing and unpredictable values, preferences and vulnerabilities; and adaptation pathways can help address factors such as spatial and temporal scale effects as well as multiple forms of uncertainty (Wise et al, 2014). The pathways concept focuses "more on the processes of decision making, rather than the outcome; emphasising the adaptive nature of the decision process itself in the face of high uncertainty and inter-temporal complexity" (Wise et al 2014, p 326.) they have an advantage – they can provide a visualisation of adaptation. The pathways approach sequences possible adaptation decision points and options for particular actions based on interdependencies between uncertainty in the incidence and severity of climate change induced impacts, and the responses required on terms of resourcing, implementation time of adaptation options and the ability to reverse maladaptation. I.e., Adaptation pathways "emphasises the need for flexibility and iterative management of immediate decisions, informed by a strategic vision of the future and a framework to inform future actions based on decision triggers and monitoring." (Haasnoot et al., 2013).

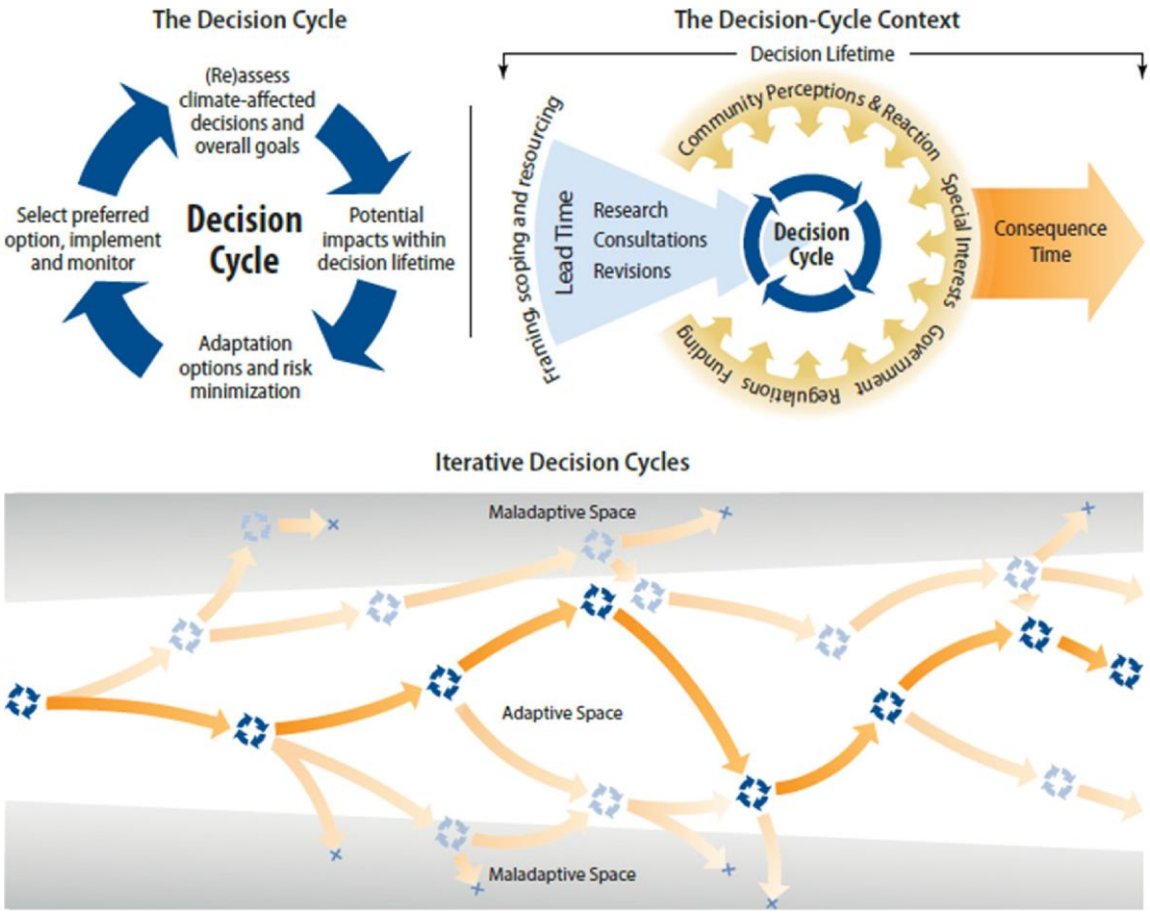

Figure 8: The conceptualisation of adaptation pathways

(From Blackett, pers. comm.)

Bosomworth et al. (2015) details a "playbook" for adaptation pathways planning for Australian natural resources management. A topology is defined across the degree of scientific uncertainty and the degree of agreement/divergence on the goals which provide four sets of issues (Figure 9). The playbook's process consists of five steps:

1. Define the objective and goals,
2. Analyse the current situation using the four criteria
   a) Computation issues ,
   b) issues requiring judgement,
   c) issues requiring bargaining, and
   d) issues requiring inspiration;
3. Analyse the potential futures of each of the four issues type using a range of tools
4. Develop pathways
5. Ongoing monitoring, evaluation, reporting and learning

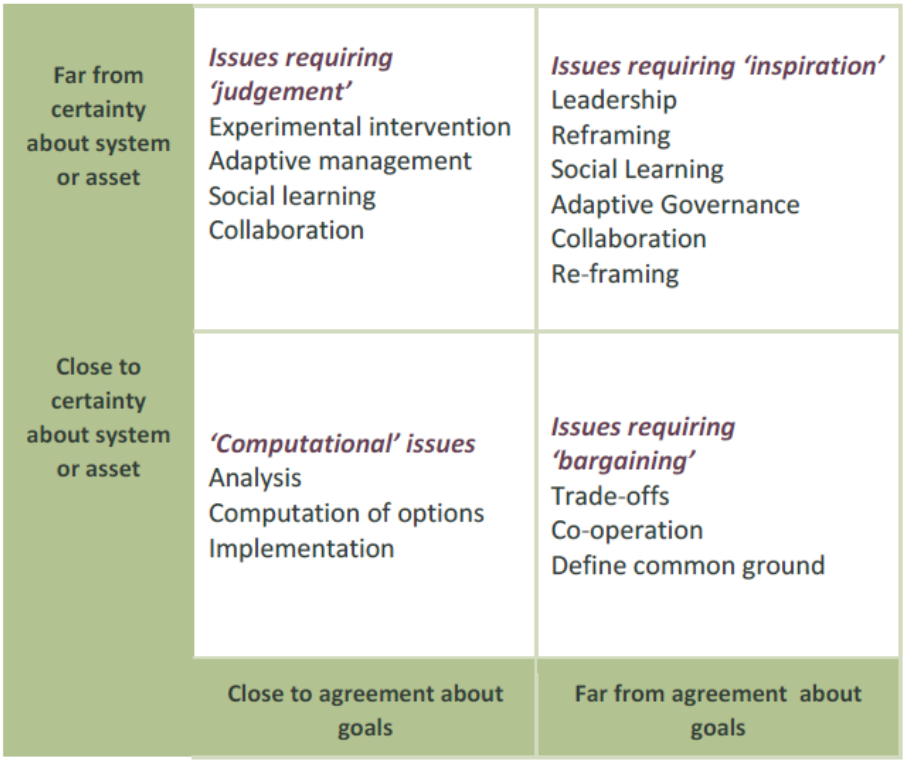

Figure 9: Adaptation Pathways planning tools to use against a typology based on certainty and agreement

(Source: Bosomworth et al. 2015)

Leith et al. (2010) uses adaptation pathways as a diagnostic approach to climate change adaptation for the management of common pool resources (where there is collaborative management of the resource) in this case fishery management. The diagnostic approach focuses on how the processes of adaptation and development of adaptive capacity can be structured to achieve desired outcomes through participatory approaches where pathways are collaboratively created as there is understanding that many constraints are not scientific but institutional and social. The approach disaggregates complex systems into two tiers, in order for the system to be made more accessible to stakeholders. The first tier of the disaggregation framework, which was adapted from social-ecological systems (Ostrom, 2007, 2009), has four subsystems: resource systems, resource units, governance systems and users, within a contextual category of the social, economic and political setting to include external factors to the system. The 2nd tier underpins the structures and function of the system being modelled, Leith et al. (2010) identifies 52 2nd tier variables using a multi-stage participatory process.

6.3.2.4 Decision Mapping

A form of decision mapping is used in this report and is described in section 3.

Decision mapping allow for comprehensive analysis of complex situations, thus creating valuable and necessary context from which further progress can be made. Each decision maker has a unique set of goals and values which underlie each decision. The collaborative process of decision mapping creates an illustrative representation of these previously un-visualised elements. For example, values from decision makers who are progressive action takers and values from those who are cautious conformists may be applied to the mapping framework to signify points where mechanisms and information must be adjusted to reflect such values. The application of values occurs in the final stage of decision-mapping (Urbany et al. 2008).

6.3.2.5 Systems Thinking

The process used in the research is also applicable as a communication mechanism. CLD's help identify the critical components of a system, and then identify the critical leverage and can be used to improve adaptation options. The systems thinking is fully described in section 5.2.

6.3.2.6 Business Risk / impact management models

The internet abounds with different forms of risk frameworks that address business (and communities, and other institutions) risk management requirements. These are typically cyclical set of steps from standard risk management processes that have been tailored to address climate change. Risk framework and analytical methods are business methods that are familiar to corporate enterprises, and are comprehensive across the total risk profile, hence being able to incorporate risk and impacts from a variety of sources.

6.3.2.6.1 PREP Value Chain Climate Resilience

The PREP – Value chain climate resilience uses a value chain approach to building climate resilience. The ADAPT cycle consists of 1: Analyse the issues; 2 Develop internal strategy; 3) Assess risks and opportunities; 4) Prioritise actions and 5) Tackle actions and evaluate progress. The value chain approach addresses risk that arises from the support resources utilised and business environment e.g. access to finance; the primary activities beyond the business boundary – raw inputs, distribution, sales and the primary activities within the business such as assets and infrastructure, production and operations.

Key reference

http://www.oxfamamerica.org/explore/research-publications/prep-value-chain-climate-resilience/

6.3.2.6.2 Scotland's Adaptation Framework and Adaptation Scotland

The aim of these frameworks is to lead planned adaptation to increase the resilience of Scotland's communities and the natural and economic systems on which they depend to the impacts of climate change.

The framework has three pillars:

- to improve the understanding of the consequences of a changing climate and both the challenges and opportunities it presents ;
- to equip stakeholders with the skills and tools needed to adapt to changing climate; and
- to integrate adaptation into wider regulation and public policy so that it is a help, not a hindrance, to addressing climate change issues.

The model is directly applicable to developing processes and procedures for addressing vulnerability analysis

Adaptation Scotland provides advice and support to help ensure that Scotland is prepared for- and resilient to- the impacts of climate change. It is a website based system managed by a knowledge broker. The site provides practical tools and advice on adapting to climate change; examples are the five steps to managing you Climate risks and a climate risk management plan template – Towards resilient business

Key Reference

http://www.gov.scot/Topics/Environment/climatechange/scotlands-action/adaptation/AdaptationFramework

6.3.2.6.3 UKCIP Adaptation Wizard

UKCIP defines a comprehensive, risk-based, frame work for adaptation planning (Figure 10) with tools and guidance for each of the eight steps. The UKCIP framework address:

- Decision making for adaptation
- Exchanging knowledge & ideas
- Creative adaptation

The framework includes the adaptation wizard which uses a five step process with tools and resources to:

- raise awareness of climate change and adaptation
- access information, tools and resources
- assess vulnerability to climate change
- Develop the adaptation business case
- develop a climate-resilient project, programme, policy or strategy
- develop and implement a climate change adaptation strategy.

Example tools are

- The local climate impacts profile (LCLIP) is a tool to assess how the current weather affects the organisation.
- The Business areas climate assessment tool (BACLIAT) workshop assist in identifying potential future climate change impacts. It is a generic framework that takes into account markets, logistics, process, finance, people, and premises.

The risk framework is a step-by-step process to help you assess what adaptation measures are most appropriate for your organisation or business.

Key references:

http://www.ukcip.org.uk/wizard/

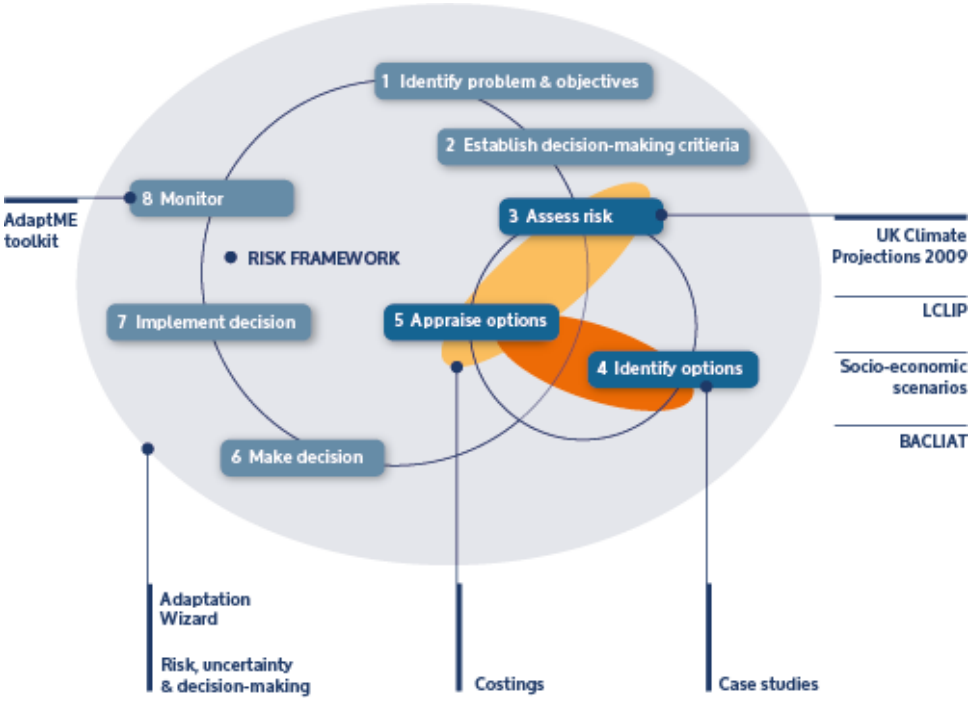

Figure 10: UKCIP Climate change adaptation framework

Working on a one-to-one basis with a number of organisations, our case studies show the application of the Wizard in practice:

6.3.2.7 Assumption-based planning (ABP)

Assumption –based planning helps firms prepare for change in the environment by identifying possible disruptions to their plans. It explores interrelationships, boundaries and perspective sat a systems level. Similar to Scenario planning's use as a strategic tool. ABP was developed by RAND Corporation to assist planning for the US Army through uncertain political environments.

ABP works on the basis that most plans hang off a number of key assumptions, and that plans often fail due to lack of due consideration around these assumptions. ABP therefore identifies key assumptions in strategies and business planning, and monitors these closely over time – in other words, it protects the plan from assumption failure.

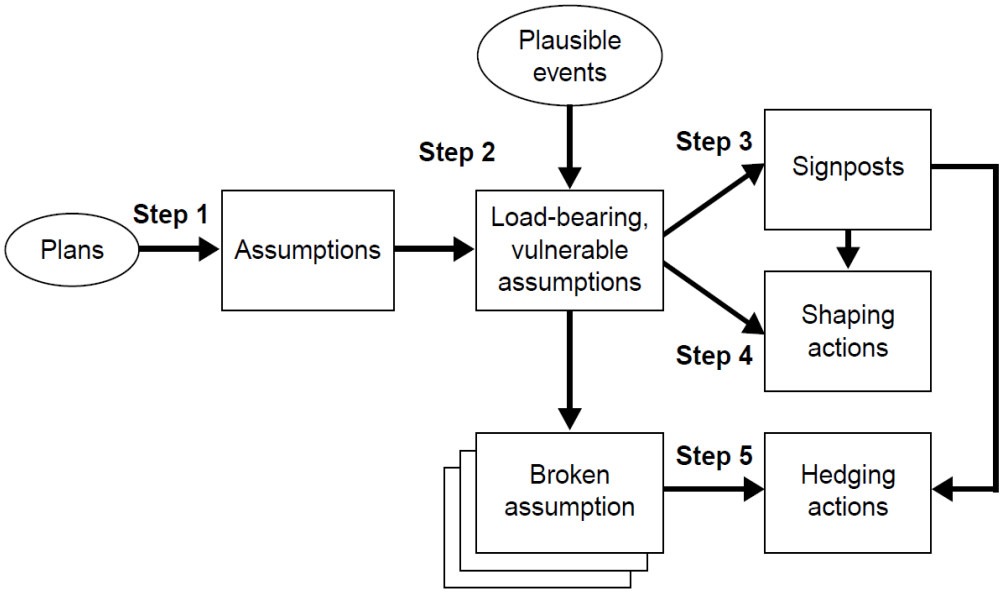

Figure 11: The basic steps and flow of assumption based planning, (from Dewar 2002)

The key steps in the toolkit (Figure 11) are:

1. Identify the underlying assumptions
2. Identify business vulnerabilities (this assumes a long-range view on elements of change from today, over a long-term time horizon)
3. Define signposts (these are mechanisms for monitoring the vulnerability to change of an assumption)
4. Define shaping actions that take control of the uncertainty, either by maintaining the assumed environment, or preventing a modified negative environment to eventuate.
5. Define hedging actions to prepare businesses as a contingency against an assumption failure. This differs from shaping actions as it may require re-planning.

Key References

http://www.rand.org/pubs/monograph_reports/MR114.html

6.3.2.8 Risk matrixes

Risk matrixes undertaken evaluations of risk and impact through assessment of the impacts of climate change variable across a value chain, e.g. forestry value chain in Dunningham et al (2012) or key elements of a business, e.g. climate impact across 19 key elements in the grazing industry, northern Australia (Cobon et al. 2009). Cobon et al. produced impact and risk, adaptation responses and vulnerability tables, where respectively the impact and adaptation where textual, and the risk and vulnerability components used shading in the cells.

Dunningham (2012) et al. reviewed literature and results from workshops to address impacts from climate changes in forestry and then categorise potential adaptation options for tactical, strategic and transformational adaptations across major aspects of management operations over the lifespan of trees.

6.3.2.9 Participatory Mechanisms

Participatory processes help develop whole-of-system (Adger et al. 2009) understanding and it also allows for the scaling of climate change impacts to the local context, through the inclusion of end-users. Impacts are complex, intersecting and compounding especially at a local-level scale (e.g. farm or forest) hence require joint learning spaces (Ross et al., 2015). Ross et al. (2015) further state that for effective adaptation required shared understanding of impact and risks which requires in inclusion of all participants.

Participatory mechanisms are those that empower, inform and involve parties, they are inherently a social learning process.

Ross et al. (2015) describes a community based participatory process using roundtables. Critical to the success of the workshops, was clear and intentional preparation and planning , then a structured workshop that that allowed sharing of ideas, communication of science and brainstorming (in this specific case study) of the local knowledge and influences of each climate variable and opportunities for adaptation – having an outcomes focus.

6.3.2.10 Climate Champions

Climate champions are farmers recognised for their willingness and expertise with climate issues, who can share experiences with others. Champions are leaders in their industries and are actively taking steps to change their business and farm practices to better deal with increasing climate variability. They help farmers manage climate risk by:

- giving farmers the best climate tools, products, practices and seasonal outlooks, and an understanding of how they might use that in their farm business;
- giving climate researchers a chance to interact with farmers and get feedback about what regions and industries need from research.

Champions could be:

- Excellent communicators or educators, actively communicating the knowledge needed for climate change adaptation;
- people, groups and governments actively involved in making decisions that take climate change impacts into account;
- leaders in their field, helping others to adapt to a changing climate, or
- inventors, designers and businesses leading the way with creative ways to adapt.

Key References

The Managing Climate Variability (MCV) Climate Champion program: http://www.managingclimate.gov.au/

http://www.climatekelpie.com.au/farmers-managing-risk/climate-champion-program

6.3.2.11 Analytical Hierarchy / Network process

Communicating information about the risks and impacts of climate change on production forests is difficult due to the lack of site specific information about climate change, the large lag between risk identification and potential impacts; the uncertainty above whether risk will eventuate, such as new pest introductions or the scale of projected impacts, and a lack of concrete, immediate and cost effective adaptation options and a multiplicity of different risks and impacts that are

independently presented. Much data exist as spatial layers detailing under different climate change scenarios (SRES), these detail the spatial distribution of different vulnerabilities, opportunities and risk.

Developing adaptive capacity so that they can react to and plan for climate change is an effective way in developing industry resilience which requires anticipatory learning and identification of risk across all aspects of a changing climate.

Analytical hierarchical / network process (AHP/ANP) allows for the exploration of how risks are perceived by individuals, through quantifying the relative importance of the different projections of risk, impacts and opportunities in conjunction with exploration of other factors that may affect business resilience. AHP / ANP can provide different estimates of risk and opportunities based on users weighting of the criteria. The method can be employed to provide data for elements of the strengths, weakness, opportunities and threats (SWOT) framework; it can provide more provide quantitative evaluation of risk and opportunities (ANP provides relative values, not absolute values).

The strength of this type of approach is users weighting the relative importance of different risk / opportunity theme and data as well as weight the severity or impact values provided by GIS based impact layers. Non spatial based sub models for the strengths and weaknesses SWOT elements are included to address more qualitative and institutional issues of climate change preparedness and adaptive capacity.

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6.3.2.12 Sustainable Livelihood frameworks

The **Sustainable Livelihoods Approach** (SLA) provides a useful framework for analysing individual and community livelihoods and the factors influencing those livelihoods, including unplanned events and changes. It is also a way of thinking about the objectives, scope, and priorities for environmental, community, social and economic policy interventions that may build resilience. Understanding and describing the assets and capitals a community holds allows institutions and policy agencies to better design effective interventions that either build from existing community strengths and assets by addressing environmental challenges such as climate change or by addressing weaknesses that may be eroding resilience (Marshall 2010).

The SLA framework is set out diagrammatically in Figure 12. A livelihood refers to the means by which an individual, whanau or hapu obtains the things necessary for their existence and presence in a geographic space. A livelihood therefore does not simply refer to sources of income or employment. We are not only interested in the means of peoples' existence, but also the extent to which they are or can be made sustainable without undermining the assets and capabilities on which they are built.

The assessment of different capitals that contribute to livelihood at the level of the individual, household, group, or community is central to the SLA. These capitals or assets can be classified as:

- Natural (N), the resources and services provided that are available from the biophysical environment, including water, land, plants, minerals, energy, animals, and environmental/ecosystem services etc;
- Physical (P), covers the 'hardware' of people's lives, such as infrastructure (roads, bridges etc.), facilities (schools, meetings houses, houses etc.), equipment (cars, implements etc.) and technology;
- Social (S), the social relationships that people have, including their social networks, organisations, affiliations and obligations;
- Human (H), people's skills and education, physical and mental capabilities (to think, communicate, labour, etc.), good health, i.e. the capabilities that are embodied in human beings; and
- Financial (F), including cash or equivalent, savings, and credit.

'Cultural capital' (not shown in Figure 3) may also be added to this list.

- Cultural capital refers to the unique attributes and values such as language, traditions, arts, customs, knowledge system, special places and ways of doing things

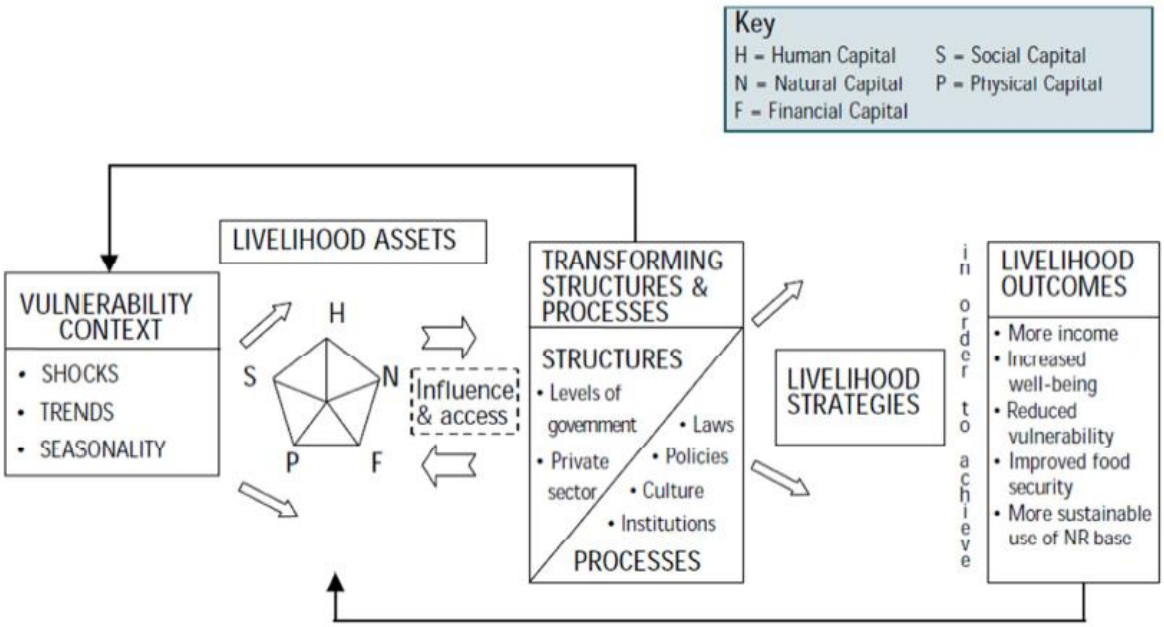

Figure 12: Sustainable livelihoods framework

(www.ifad.org/sla/)

The 'vulnerability context' within the SLA refers to the risk (and opportunity) environment in which people exist. Its consideration draws analytical attention to complex influences that directly or indirectly impact on livelihoods. 'Shocks' (or sudden happenings), seasonality, and critical trends over which people have limited or no control may significantly affect people's livelihoods and the wider availability of assets and capitals. While such changes most often represent risks to people's livelihoods, they can also provide opportunities. 'Shocks' destroy or damage assets or access to them as in the case of floods and storms and sometimes force people to abandon or dispose of assets prematurely or to change their overall livelihoods strategy. 'Trends' are more

predictable and, while they may or may not be more benign, they have a marked influence on the success of a chosen livelihood strategy. 'Seasonal changes' in production, food availability and associated employment opportunities may undermine livelihood potential and represent hardship for some people. In each of these types of vulnerabilities, historical factors may be very important and there may be cumulative risks, for example, the flooding of productive fields due to on-going upstream catchment erosion.

As defined by the SLA, the vulnerability context is the aspect of life that lies furthest outside people's control. In the short-to-medium term, less can be done at an individual, group or community level to alter it directly. In such circumstances, the role of institutions, organisations and agencies may become critical.

The SLA is depicted as being a linear process but, in practice, it is more complex and involves partnerships with, and the genuine participation of, diverse groups of people. As such, the SLA is described as a 'rights-based approach' to sustainable development. This means that it has the potential to support the United Nations Millennium Development Goals for 20156 and the Treaty of Waitangi, through the principles of partnership, protection, and local participation and empowerment. (Warmenhoven et al. 2014)

6.3.2.13 Scenarios

In a planning context, the term "scenario" is used to describe a story of a possible future that the organisation might encounter. Scenarios are very useful devices for organising a large amount of seemingly unrelated economic, technological, competitive, political, and societal information in a logical manner and stimulating discussion about the choices that lie ahead.

Scenarios have two main purposes: anticipating and understanding risk, and discovering new strategic options. Scenario planning acknowledges that the future is unpredictable; the scenarios are distinct, plausible pictures of the world in which we might one day live and work. It is a valuable tool for evaluating alternative decisions—a good decision or strategy to adopt is one that would work well in any one of a number of possible futures. Equally, scenarios can help identify what actions or situations should be avoided. In a situation of uncertainty, planning becomes a learning process which never stops. Scenarios facilitate learning by increasing awareness of long-term interactions between the driving forces. By providing the opportunity to rehearse the future, scenarios enable an organisation to adapt more quickly to what is happening and to better anticipate what could happen.

The process begins with identifying the focal issue or decision. Once this has been agreed upon, the key forces in both the local environment, for example, competitors, industry structure, and the macro environment need to be highlighted. Examples of the latter include science and technology trends, demographics, economics, politics, and social dynamics.

The psychology component of scenario planning is at least as important as, if not more important than, all the other parts put together. The real task of the scenario planner is not to produce a documented view of the future business environment 5–10 years ahead, but to present other ways of seeing the world, and show people the significance of information they would otherwise have completely overlooked or considered irrelevant.

Scenarios structure data about the future in multiple stories that reflect the uncertainty inherent in the future, have been derived using a multi-disciplinary approach, present the information in a tangible real-world context, and use a cause-and-effect mode of thinking.

The goal of exploratory first-generation scenarios is not action but understanding of the system, the pre-determined elements, and the connections between the various forces driving the system. These scenarios need to be checked for internal consistency in order to produce the second-generation (or decision) scenarios.

The aim is to produce a set of three or four scenarios that illuminate the major driving forces, their interrelationships, and the critical uncertainties. The real future will not be any single one of the scenarios; it will contain elements from all of them.

A solid understanding of what makes an organisation unique is required to make the scenarios useful for reaching strategic insights. The Business Idea of an organisation encapsulates the forces behind its current and future success. Scenarios have a role to play in gauging how strong this formula is.

Used correctly, scenario planning is a valuable tool for evaluating alternative decisions (it should not be used to find good decision alternatives). The objective of scenario planning is not prediction therefore, but influencing better decisions. One of the basic premises of scenario planning is that, given the impossibility of knowing exactly what will happen in the future, a good decision or strategy to adopt is one that would work well in any one of a number of possible futures. Equally, scenarios can help identify what actions or situations should be avoided. This is how scenario planning helps strike a balance between prediction and paralysis. They do not pinpoint future events; instead, they highlight the major forces that could push the future in different directions. Scenarios should always be defined such that they are independent of the decision(s) in question. A good set of scenarios does not need to portray the future accurately—the main objective is to allow the organisation to learn and adapt (Bates 2000).

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6.3.2.14 Knowledge brokers

Knowledge brokers act as intermediaries between the knowledge creator, and the knowledge user. They seek to facilitate knowledge exchange through building of relationships and networks between those who hold knowledge, and those who can apply knowledge in a practical manner.

By linking those already utilising knowledge with those new to the knowledge application, the brokerage can provide evidence-based decision making.

Good knowledge brokers excel in critical thinking and strategic planning, and need to be 'big picture' thinkers who can see the whole view of an issue and assess which information and in what context it would be best applied. Knowledge brokers are also entrepreneurial and are trusted and credible practitioners in their field.

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6.3.2.15 Portals

Web portals provide access to data, services, information, analytics and consulting services. There are a multitude of web-portals on the internet. We identify a few below

Organisation	Description	Links
US Government	A large website that provides "Science and information for a climate-smart nation" Access to reports, climate change data as active graphs and reusable maps The US Climate resilience toolkit How to teach climate change	http://climate.gov/
Europe	'Scientific Knowledge for Decision makers" Reports and discussion documents on issues and on sectors	http://climatepolicyinfohub.eu/
World Bank	The Climate Change Knowledge Portal (CCKP) Beta is a central hub of information, data and reports about climate change around the world. Here you can query, map, compare, chart and summarize key climate and climate-related information	http://sdwebx.worldbank.org/climateportal/
	Climate planning portal	http://www.climateplanning.org/
NOAA Climate Change Web Portal	This portal accesses and display as maps the immense volumes of climate and earth system model output that informed the	http://www.esrl.noaa.gov/psd/ipcc/

	recently released Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).	
The European Climate Adaptation Platform (Climate-ADAPT)	Allows users to access and share information on: • Expected climate change in Europe • Current and future vulnerability of regions and sectors • National and transnational adaptation strategies • Adaptation case studies and potential adaptation options • Tools that support adaptation planning	http://climate-adapt.eea.europa.eu
The National Center for Atmospheric Research	NCAR's GIS Program Climate Change Scenarios GIS data portal. This provides access to downloadable climate change projections.	https://gisclimatechange.ucar.edu/
IPCC	The Data Distribution Centre (DDC) provides climate, socio-economic and environmental data, both from the past and also in scenarios projected into the future. Technical guidelines on the selection and use of different types of data and scenarios in research and assessment are also provided.	
Australia	A comprehensive website providing: • Climate campus – learning • Projections and data • Impacts and adaptation • Climate change explorer • Publications	http://www.climatechangeinaustralia.gov.au/en/
Virtual Laboratories	Virtual labs are cloud portals that provide access to large data sets and the analytical computing environments. This environment simplifies and makes the analysis of climate data more accessible by removing the requirements to manage data, or develop and manage models. An example is the **Biodiversity and Climate Change Virtual Laboratory**. It allows for	https://app.bccvl.org.au/login (Requires login) http://www.nectar.org.au/virtual-laboratories-1

	species distribution modelling and experiments using biological, climate and environmental data. Users can load their own biological data to run experiments, or use the information already loaded into the system	

6.3.2.16 E-based publication

With the growth in tablets, and smart phones, are also alternative methods for developing and presenting information to a wide range of users. Three examples are

Publishing books: IBooks and eBooks

This free application from Apple authors textbooks. iBooks allow for photo , video, interactive figures, 3d-objects to become part of the publication. Being on an iPad or iPhone allows for user to use touch technology to interact with the publication, though, the resultant book is limited to using within iBook apps.

eBooks are online books which have the ability to present text, image, video, and audio, though different publishers have size limits of the final product. There are many different e-book author packages, and can have some form charge. A leading author package is Atavist (help.atavist.com).

https://www.apple.com/ibooks-author/

http://help.atavist.com/ebook

Story Maps – Esri.com

A story map is a web map that has been created, given context, and provided with supporting information so it becomes a stand-alone resource. It integrates maps, legends, text, photos, and video and provides functionality, such as swipe, pop-ups, and time sliders that help users explore this content. It is a fully functioning information product. While map stories are linear in nature, their contents can also be perused in a nonlinear fashion by interacting with the map.

Using the templates, a story can be published without writing any code. You simply create a web map, supply the text and images for the story, and configure the template files provided according to the instructions in the download. (www.esri.com)

http://www.esri.com/esri-news/arcuser/summer-2013/what-can-you-do-with-a-story-map

7 CONCLUSION AND NEXT STEPS

This research has identified key drivers for primary sector business and the options for providing information to them on how climate change will impact on their business. Not unexpectedly, climate change is not considered separate to the normal business operations and the influences for a range of externalities on them. At an individual farm and forest level, decision making processes regarding adaptation to climate change risks are complex and is incorporated into the following seven key influential factors:

1. Information and advice;
2. Climatic risks;
3. Experience;
4. Adaptability;
5. Policy;
6. Productivity and
7. Markets.

At a wider primary sectoral systems level, decision making processes of forestry and farming sectors are primarily affected by the following five variables:

1. Willingness and ability to act
2. Diversification potential
3. Productivity
4. Profit and Return on Investment
5. Market demand

Analysis of data derived from a comprehensive literature review and active multi-scale stakeholder engagement has highlighted six fundamental leverage points with which the uptake of climate change adaptation mechanisms could be progressed:

1. Creating more confidence in climate change adaptation options
2. Enhancing the clarity of information provided, including the use of more targeted messaging
3. Pursuit of more cross-sector, multi-scale collaborative policy design
4. Forming issue-based solutions
5. Progressing ability to act under uncertainty
6. Increasing market foresight in relation to potential climate change impacts

The analysis of mechanisms that have been used to date indicated that most of these would not provide the contextual information, nor is specific enough for individual requirements, and had limited ability to communicate with users of the information. The new mechanisms provided are those that have address those failings, providing dialogue, discovery, require learning and higher levels of cognitive functioning - addressing many of the key drivers of the sectors. Other

mechanisms are provided in order to assist end-users in robustly evaluating their risk profiles, impacts on their business and what adaptation needs to occur and when.

We recommend:

- Future SLMACC, CCTTP and other funded programmes seriously consider how the result of the research will address end-user drivers.
- That MPI consider funding implementation of tools such as risk frameworks based on New Zealand climate data and climate change scenarios.
- That consideration is given to the establishment of a national review of climate change adaptation.
- That MPI consider initiating the establishment of a pan-sector roundtable on adaptation, to facilitate greater discussion about the pathways to greater resilience in the primary sector, and
- Consider working with industry stakeholders to identify innovative and influential farmer-grower practitioners, to develop demonstration projects or implement adaptation practices on focus farms and forests

Further feasibility research is needed to determine how the recommended mechanisms can be progressed and applied, including assessment of associated costs and benefits.

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9 APPENDIX A: PROJECT SUMMARIES

Project	Partners	Purpose	Mechanism	Strengths	Weaknesses
Impacts of Climate Change on Urban and Built Environments	NIWA, MWH New Zealand, Building Research Association of New Zealand	Tool box to help planners, engineers, asset managers, and hazard analysts in New Zealand urban councils understand and evaluate the potential impacts of climate change in their jurisdiction.Toolbox contains multiple tools capable of proving insight within specific areas. A total of 57 downloadable tools are available, able to be used together or independently to obtain information regarding potential climate change impacts and how these might be managed. Each contains worked examples and provides contact details for the key authors or links to other relevant material.	Tool box, websites, case studies, workshops	Team provided both scientific and practical input into designing the toolbox. Working with the council on specific case studies provided practical insights into the issues and pragmatic basis to discuss the tools and their use with others Working with NZPI and IPENZ helped publicise and distribute the toolbox.	Website was getting lots of hits at first, but unclear how much it is now being used. No M&E of toolbox included.
Coastal Adaptation to Climate Change, included various components (1-4, following)	NIWA (lead) AgResearch Robin Britton Resource Management/Planning Consultant, Economos, Waikato Regional Council, Thames Coromandel District Council, Waikato University	NIWA (lead) AgResearch Robin Britton Resource Management/Planning Consultant, Economos, Waikato Regional Council, Thames Coromandel District Council, Waikato University			

1 Building a national coastal sensitivity profile		Coastal Sensitivity Index (CSI), provides a snapshot of the potential sensitivity of New Zealand's non-rocky coastline to coastal inundation (flooding) and coastal erosion as a result of climate change in the future.	Website (coastal explorer)		
2 Engaging and informing Communities	Local communities at Whitianga and the Maori community at Manaia	Developed and tested a method/process to engage with local communities at Whitianga and the Maori community at Manaia on the potential impacts of climate change and begin community based discussions on how adaptation could occur.	Three documents on the methods and two papers were written. Conference presentations – NZPI and NZCCC		
3 Develop a high school curriculum on coastal adaptation to climate change	Teachers and students of Mercury Bay Area School	High School curriculum for science, social science and maths on coastal adaptation to climate change. Developed and tested with teachers and students of Mercury Bay Area School	Train the trainers (coastal adaptation to climate change school curriculum)		
4 Encouraging best practice planning	Regional, unitary and district/city councils	Following written and verbal interviews with 30 regional, unitary and district/city councils on Local Government planning practice and limitations to adaptation, a guidance document called Pathways to Change was developed. This document presented a four-step process to help councils and communities adapt to climate change on the coast Each step contained references to potentially useful tools and proved examples and case studies.	Guidance document (Pathways to change), 2 workshops	The team had a mix of experience and knowledge which provided an interdisciplinary focus on all the project activates. More importantly it ensured all the outputs and interactions were technically correct and practically relevant. The community participatory process worked particularly well both at Whitianga and	Overall the project went very well, however more time to trial the community engagement process in another area would have been helpful. The engagement process do not go as far as developing (with the community) an adaptation plan for Whitianga

				Manaia. Methods have potential to be used to assist with the development of adaption strategies	
Aohanga Climate Change Resilience Project	Aohanga Incorporation, AgResearch, Landcare Research and NIWA	The purpose of the project was to, in collaboration with Aohanga Incorporation, develop a science-based climate change resilience strategy for Aohanga's multiple owned Owahanga Farm Station and to develop a social process framework for engaging rural communities and land-owning Iwi Incorporations in climate change mitigation and adaptation"	Produced a climate change adaptation plan for Owahanga Station and a report to MPI on the process used to produce this document.	The Process worked very well it was very inclusive and allowed the group to follow their own interests/concerns ask questions and make plans for their land. Science was part of the process but not driving it.	• Climate change is not a pressing issue – engagement sometimes challenging and displaced by more pressing issues. • When working with a group researchers must work on their time frames • Milestones and working with groups does not function well • Short funding horizon only 12 months to do the work • Unsure if the community are acting on anything on the plan

Climate Change Research Institute – Research and consultancy projects	MBIE, local government	These projects are typically research outputs or reports to particular organisations. They are usually in the form of transferring knowledge from the researchers to the audience. In some cases is co-development between science and practitioners For a list of projects see: http://www.victoria.ac.nz/sgees/research-centres/ccri/research	Provide written reports, presentations and workshops for target audience		
Deliberative engagement process around carbon capture and storage	Iwi, Urban communities, landowners, councils, oil and gas representatives	To establish and test a full scale deliberative engagement process in Taranaki on carbon capture and storage. This project brought together key groups from the community (Iwi, Urban communities, landowners, councils, oil and gas representatives) to take a solution focused approached to discuss on actions should carbon capture and storage ever be proposed for Taranaki. The assumptions were that it was 2030 (a scenario) and carbon storage and capture was proposed for Taranaki as a climate change mitigation. The process was set up so that groups could present their view point the order of presentations was carefully orchestrated to tease out the key issues. The aim was to promote understanding of different viewpoints, to encourage dialogue and learning	presentations and workshops	Worked very well – groups did their own research and some of the views presented were surprising Organisation and the order of the group presentations was very important as the first group set the tone for the others. Iwi went first. There were a few surprises in the views expressed from the participants, Iwi supported carbon capture and storage (believe that you have a responsibility to look after your waste) however Oil and gas not supportive – too expensive.	

Raising farmer awareness of climate change	AgResearch, NIWA and others Farmer groups, and representatives from Maori and Women's groups	The aim was to raise farmer awareness of climate change and greenhouse gas issues by establishing a forum where groups of farmers could interact with experts and discuss issues which concerned them. The project followed adult learning principles where the learning is directed by the participants. A total of 14 farmer groups, nationwide, were established over the course of this work. New groups were continually established as interest grew. Membership comprised sheep and beef farmers, dairy farmers, as well as representatives from Maori and Women's groups. The design was such that the groups dictated what they wanted to learn about and the team facilitated this through inviting experts. The emissions trading scheme was a key issue for the groups. One of the key discussion tools was the use of a "farm model" to explore issues, demonstrate potential impacts and generate discussion.	workshops	A key success was that all the 14 groups remained together for the length of the project. The participants gained a lot from the work and had the opportunity to present their views (principally on the emissions trading scheme) at large climate summit attended by the then Minister for Climate change. The groups had wanted to learn and influence policy and felt they had achieved this. Also this has led to other work – notable the Climate Cloud which is a resource data base for land managers. Advantages Farmer centred learning allowed the group to control their own learning and seek answers to the issues that concerned them	"The team very happy with the way the process went"
Climate Cloud	AgResearch, Scion	The climate cloud is a web-based data base of research articles, reports and resources on any aspect related to climate change. It has brought together diffuse sources of information	digital library, workshops	Workshops used a structured workbook to be able to get a consistent coverage of	Limited funded, no repeat end-user review after changes

		pertinent to land managers and added new resources where there were substantive gaps.		any issues on the climate cloud web design.	were made to the website
Farm forestry for economic and environmental sustainability (calculators)	NZ Farm Forestry Assn	A percentage of most hill country farms is either at risk from soil erosion and accelerated nutrient run-off, or is unsuitable for the further intensification necessary to stay ahead of the game. It is also becoming obvious that environmental concerns will be the next big trade barrier for New Zealand agriculture. With that in mind, the New Zealand Farm Forestry Association has set out to produce a simple easy to use calculator for farmers to employ when deciding what use to put this land to. The calculator will compare different forest species and regimes with current stock production figures from the existing farming operations, and provide the cross-over point where either forestry or farming is more profitable. Aiming for on-farm afforestation as an adaptation route.	Provide simple-to-use Excel calculators complete with manual, to farm foresters at a nominal cost. • Present the results at five regional seminars and workshops. Written material publicising the project and submit regular articles to newspapers, and the New Zealand Tree Grower. Developed a training package and held five training workshops in the South Island	Over the period June - September 13 training workshops were held throughout the country, attended by 140 users. Based on the experience from these courses, effective promotion by several NZ FFA branches in each region would seem to be the key to getting a good turnout. During the training courses, users provided many ideas for improvements. Attendees and local branches of the NZ Farm Forestry Association organized the training venues, and made financial contributions to the hire of the venues. In total the direct financial contribution to the eight courses was around $3000.	Licence holders in some regions did not attend the workshops. The co-authoring of the manuals was a large cost, and the manuals sent along with the calculator to all licence holders.

Establishing forests of genetically improved durable eucalypts in NZ drylands	New Zealand Dryland Forest Initiative (NZDFI); Marlborough Research Centre Trust	In practical terms, the NZDFI aims to develop a valuable, complementary land-use for farmers in the warmer parts of eastern New Zealand where rainfall is low and unreliable.	• Research transferred via a seminar workshop • Trial sites established at 5 dryland locations, demonstration trials planted. • Onsite workshops on how to establish, and also how to prune the resource, targeting farmers via extension • Website • Newsletters • Establishment leaflets created as downloadable pdf files for each of 3 dryland Euc species. • A dedicated extension team in place to take results and transfer to farm foresters	• The strength of our project lies in our strategic, scientific approach, backed by our on-farm network of trials. • Dedicated extension team • Backing of a wide variety of partners, due to 5 sites, and multiple research objectives in the one programme (market development opportunities, erosion control, drought resistance and pest resistant breeding)	

Technology transfer packs for foresters to identify and control pine needle disorders	NZ FOA	Many forest growers, both large and small, are largely not aware of the key foliage diseases that could affect their pines, how to assess which needle disease is affecting their pines, or the most effective methods of control for each disease. The opportunity is to better inform all forest growers in order to help them make decisions on what steps to take to reduce the economic impact of foliar diseases.	• Field assessment and identification guides of foliar diseases will be produced, along with a web based identification tool. Prepare written material publicising the project and submit regular articles to newspapers, and the New Zealand Tree Grower. • Develop a training package and hold five training workshops in the South Island.		
FIRE – Implementing Risk Management plans	Scion	Reduce risk from fire and other natural events. Scion provides consultative advice and reports on wind risks; fire risks and pest incursions – how to assess the forest, how to identify any changes that may be CC contributed. Scion advocating for improved planning, and implementing risk management plans to combat the impacts of CC events	Forest management risk management plans. • MAF Adapting to a changing climate Case study #26 (Timberlands) • Increased wind maps - wind maps of forests and where wind events will likely occur (Nelson Forests)	• Active management of the increased risks helps to minimise impacts• Proactive response to the CC threats	• Requires changes in FM practices and protocols • Some actions taken not popular (Lack of forest access) • More expense involved in monitoring, testing (pests and foliage etc), and management tasks.

Improving water-use efficiency and adaptation to drought constraints under future climate	Radiata Pine Breeding Coop; MPI	To assess the potential use of 213C technique in a future breeding program for selection of Radiata pine genotypes with high WUE for better growth performance under drought prone conditions	• Genetic selection of high-resistance genotypes using trial and applying the 213C technique; Established a progeny trial at Rolleston in 2004, with RPBC, and measured at age 7.5 yrs. • A report for MPI was generated, and a presentation to both RPBC and Scion All Staff Forum.	Nothing noted	Nothing noted
On-line pest and disease database for forestry	NZ FOA	This project was aimed at cataloguing the extensive range of forest related pest and disease leaflets and forest health newsletters archived at Scion into a user friendly on-line database where browsers can access an alphabetical listing of pests and diseases of forestry for information, or search the database by tree species for pests/diseases which might affect candidate tree species.	Online searchable html database. The complete forest pest and disease leaflet series published by Scion were converted into electronic format and categorised according to the pests or diseases. Photos and information were assembled into a html database format and published on-line.	The provision of this information in an easily searched and user friendly database has dramatically improved accessibility of information and many comments have been received from forest growers, forest consultants and those involved with forest health about the ease with which information can now be accessed. This project has been a great success in bridging the gap between	Nothing noted

				specialist knowledge of forest health to laypeople who can research exactly what they want in a user friendly format in order to just get the information they require.	
SLMACC Climate change impact studies	Mainly CRI's	To define and report on climate change impacts and risks to the primary sectors. Reports address the latest knowledge on impacts and adaptation for the primary sector	Written reports, include a report written in a style suitable for stakeholders	Detailed scientific assessment Evidence based assessments	• Stored on web, • Highly technical reports and science • Limited use for land managers • Don't general identify adaptation options
CTTP MPI Resources – Companion reports	AgResearch, Scion, Niwa, Wrightson PGG.	A large program focusing on making resources on climate change available to others. This component of the programme is the development of short summaries of science based reports.	User oriented 'companion reports' or science highlights	• Language suitable for end-users • Easy to read • End-users can obtain knowledge, then make decisions as to whether they need to learn more.	• One-way communication, No opportunity for feedback. • Doesn't address misconceptions

Scion Climate change Webinars	LCR, Inra, University of Canterbury.	To communicate to the sector and other resources about the learnings developed in climate change	Video conferencing based engagement using short (8 mins) presentations to communicate current research to end-users. Sessions video-recorded, with some sessions put on YouTube.	• Researchers are presenting, but have to slim down the presentation to key points to keep inside time limits • Low level of time commitments from those watching AND Strengths of approach • Researchers are presenting, but have to slim down the presentation to key points to keep inside time limits • Low level of time commitments from those watching	• Largely one way • Video conference does not afford high quality interactions • Some science does suit this form of presentation • Still low engagement from end-users
Adapting to climate change in eastern New Zealand (ACCENZ)	MAF, Environment Bay of Plenty (now Bay of Plenty Regional Council), Hawke's Bay Regional Council, Environment Canterbury, the Climate Change Office/Ministry for the Environment, AGMARDT, and Merino NZ Inc.	The ACCENZ project ran from 2004-2006. Kenny was a pioneer in recognizing the need for more 'bottom-up' approaches to climate change adaptation and impacts assessment. These are distinguished from 'top-down' (end-point, or 'outcome vulnerability') assessments by their engagement with stakeholders. By beginning the assessment from the perspective of stakeholders, there is evidence to suggest that the resulting assessments are more widely accepted by the community. Kenny led the research program, and was supported by Fisher. Robertson – a visual artist – produced imagery to interpret and visualise the resilience of farms in eastern New Zealand. Narratives and farmer case studies were also produced.	Case studies, workshops, focus groups. The project outputs included a publication, a slide presentation, summary report, website, leaflets and a series of farmer workshops.	Working from the 'bottom up' was a pioneering approach at the time. It provided an example for subsequent research. The work engaged with farmers directly to identify relevant concerns, "climate models or a top-down approach" didn't drive it. The team was from diverse backgrounds, including applied climatology, resource management,	Time-consuming. The project was built on interpersonal relationships, and involved significant time that wasn't fully costed.

				farm-systems and visual artist. In-depth, small-scale, qualitative focus allowed for relationship building with stakeholders, and close examination at farm-scale. Popular format of outputs (website, leaflets other publications) continue to be widely accessed. The visual representations were well received, and have proven to be a useful tool in subsequent work. The project outputs included a publication, a slide presentation, summary report, website, leaflets and a series of farmer workshops.	
Operationalising resilience in dairy agroecosystems	MPI, Bay of Plenty Regional Council, DairyNZ	Effective monitoring and evaluation mechanisms for climate change adaptation have been recognised as a significant gap in the literature. While resilience concepts provide a useful framework for considering the buffering capacity, adaptability and self-organisation of farming systems, there is little work to date, on developing operational definitions and tools to assess those characteristics in social-ecological systems. With funds from MPI, a one-year SLMACC project looked at how indicators for	A final report, conference papers and manuscripts (in review) were produced. Case studies, workshops	The work was designed as a small-scale, in-depth series of case studies. The research team furthered existing relationships with stakeholders, and was able to generate meaningful results through the 'bottom-up' approach.	It took some time to find a representative samples. We were looking to compare three different farm-types, within the same geographic area in order to ensure that the level of exposure to drought was roughly

		resilience might be developed. Nineteen 'proxies' for resilience were identified, and then applied across 16 case-study farms (organic, low-input, high-input). The framework highlighted differences in resilience over the short- and long-term, and the capacity of different farm types to respond effectively to climate-related stressors. A final report, conference papers and manuscripts (in review) were produced.			comparable. Recruitment took up a significant amount of project resources.
Knowledge Networks: Perspectives on climate change adaptation	CSIRO, NCCARF, PIARN, SARDI	Through core-funding at Landcare Research and in conjunction with the Knowledge Networks research program (2011-2013), a series of webinars were hosted that brought Australian researchers to present on topics of interest to a New Zealand audience. Topics ranged from different methodologies for climate adaptation research, to managing uncertainty in decision making and climate scenarios. A diverse audience of researchers, local- and central government (MAF, MfE), and industry (DairyNZ, Fonterra, Westland Milk Products) attended the webinars.	Five webinars were produced	Able to reach a targeted audience of interested stakeholders. The webinars were an efficient mechanism for information delivery, and allowed for some audience interaction. There was a lot of positive feedback from participants and from presenters, who appreciated the opportunity to share their work. The work also built linkages between CRIs in New Zealand and Australian colleagues.	Disadvantages The first two webinars were not as well attended as later ones. What did you learn/what would you improve: -- In the future, the webinars would be scheduled in advance, and advertised as a regular, or on-going series. It was difficult to maintain consistency across the life of the program. The webinars were a good format – people found it was easy to use, they were able to interact with presenters, and

					produced useful insight into different tools, methods and case examples.
Canterbury's Climate	Environment Canterbury	Environment Canterbury's Climate Change activities set out the climate change projections for Canterbury, and discusses how the changed climate might impact on Canterbury, including coasts, water, plants and animals, communities, and the local economy. Much of the work was prepared as part of the Review of the Canterbury Regional Policy Statement. The Youth Engagement team also produced materials to support teachers in developing new knowledge and ways of thinking among children and young people to achieve a sustainable future for Canterbury.	A Changing Climate: A resource for educators (produced for elementary school students)	The programmes and resources are used to support future-focused learning opportunities. They are widely accessed, and intended to encourage students to make connections across learning areas, and incorporate values and key competencies. The team has diverse disciplinary backgrounds but are all qualified teachers.	

Adaptation Strategies for Dairy	DairyNZ, University of Waikato, Waikato Regional Council	The research is developing in-depth understanding of farming systems dynamics in order to support more effective climate change adaptation. The work is seeking to bridge 'top-down' and 'bottom-up' approaches. It has relied on small sample, in-depth stakeholder engagements through interviews and Soft Systems Modeling of individual farms. Research activities have also been presented to stakeholders at Field Days, and online through a short web video.	in-depth stakeholder engagements through interviews and Soft Systems Modeling of individual farms. Research activities have also been presented to stakeholders at Field Days, and online through a short web video.	The adaptation framework is a step towards a more integrated approach. It is linked to the DairyNZ Whole Farm System Model, and also Overseer. It has legitimacy as a result of its endorsement by DairyNZ. There are still barriers to adaptation, unrelated to this mechanism, including low levels of belief in climate change among certain segments of the farming population.	What did you learn/what would you improve: -- A lot was learned from the interaction with farmers. It is a work in progress.

10 APPENDIX B: FOREST INTERVIEW QUESTIONS

10.1 Farm forestry scale

Which increased natural risks are likely to impact on your forestry business in the short-medium term?

1. As a forester, if the threat of [first mentioned] greatly increased, how would that impact on your current forestry activities?
2. What steps would you need to take to adapt to such impacts?
3. Do you feel adequately prepared now to take those steps? **Why; Why not?**
4. If **yes**, what preparations have you made?

a) Within your role, how did you help react/respond to the threat of flooding/drought/erosion/etc?

b) Who have you interacted with to be better prepared? Why?

5. If no, what preparations would you need to make / what's missing that would make you able to better prepare?

a) Within your role, what would you personally need to do to react/respond to the threat of flooding/drought/erosion/etc?

b) Who would you need to interact with to be better prepared? Why?

6. Who is involved in deciding what actions to take on your land? Who else has a role to play?
7. Who makes the ultimate decision around risk management regarding X threat in your forestry blocks? Any gatekeepers or critical informants?
8. How much room is there to influence their decision?
9. Have you discussed these issues with anyone to get assistance in deciding whether to make some changes, or what changes might be required?
10. Have you adopted any guidelines, frameworks or attended any workshops or seminars to get help or assist in adapting your business to be ready for the impacts of these natural events?
11. What information would you/ four firm need to help you develop a decision?
12. How do you access this information?
13. What are the pros and cons of this information and its accessibility?
14. What would you do if you find inadequate information to make a decision or know what action to take?
15. What other factors might affect your ability to make a decision? (e.g. policy, funding, availability of info, time)
16. What would make other farm foresters take more action around these issues do you think?

10.2 Enterprise level

1. What are some of the main business decisions you've had to make in recent times?
2. Are any of your business activities likely to be affected by changing climate?
3. How are you managing that risk/opportunities – any strategy docs or white papers/ policy etc. at corp level being developed??
4. Who's been involved in these decisions?
5. What climate parameters are critical for your forestry activities?
6. Do you think your org is equipped to deal with these potemtial impacts?
7. Are you aware of other forestry companies taking action around CC impacts?
8. What could help to equip the sector to prepare better for Cc?

11 APPENDIX C: WORKSHOP AGENDA

Table 11: Workshop Agenda

Time	Task	Who
10 am 10 mins slippage	Welcome – project overview Workshop overview	
10 mins	Introductions - short intro from each start with project team	
15 mins	Question 1: What are the biggest challenges on your property with regards to environmental management/climate change Take a minute or two to think about – write on a sticky note and lets organise them Use sticky notes – collate and pick the top 3 (number dependent) Choose top 2/3 break into groups around these. (could be biodiversity, water avail, pasture, etc.) If we don't have enough for two groups work as one and cover all topics	
10-30 (45 mins)	**For each group** <u>Part one</u> Facilitator: What do you do now for each of these who influences your decision round managing this aspect (use Stefania's questions as a guide) What info do you rely on What more would be useful Who helps make or support you decision - who is a trusted source of info? What constrains your decisions (physical environment, social, economic legislation) Why do you do things this way – what are your other choices?	Each group will have a facilitator
11-15 (45 mins)	<u>Part 2</u> What might you do if things change as a result of climate change?	

	Fill in map/time frames What actions when (see below)	
12-30	Lunch	
1-00 45 mins	Part 3 Barriers Based on the map/table of what you might do and when – what might be the barrier to change? Describe and capture data	
10 mins share		
5 mins wrap up and thanks		
2pm Finish		

12 APPENDIX D: DECISION MAPS

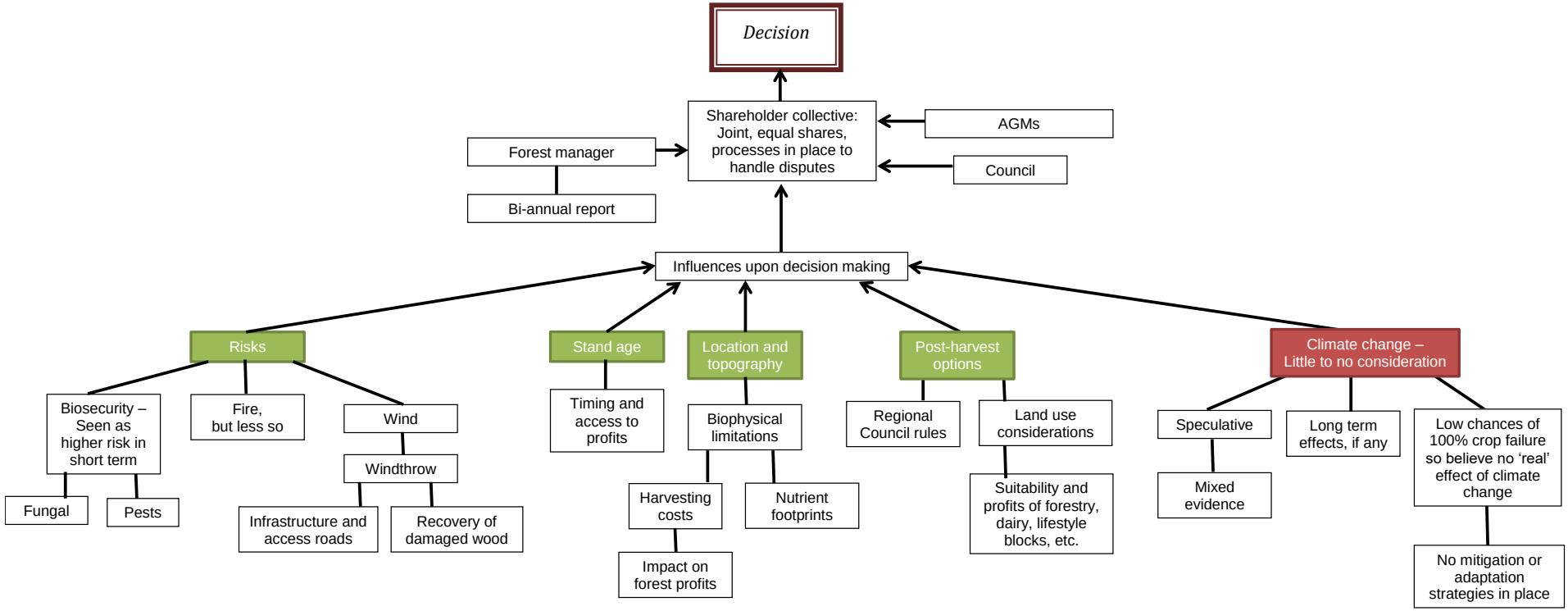

Figure 13: Forestry 1

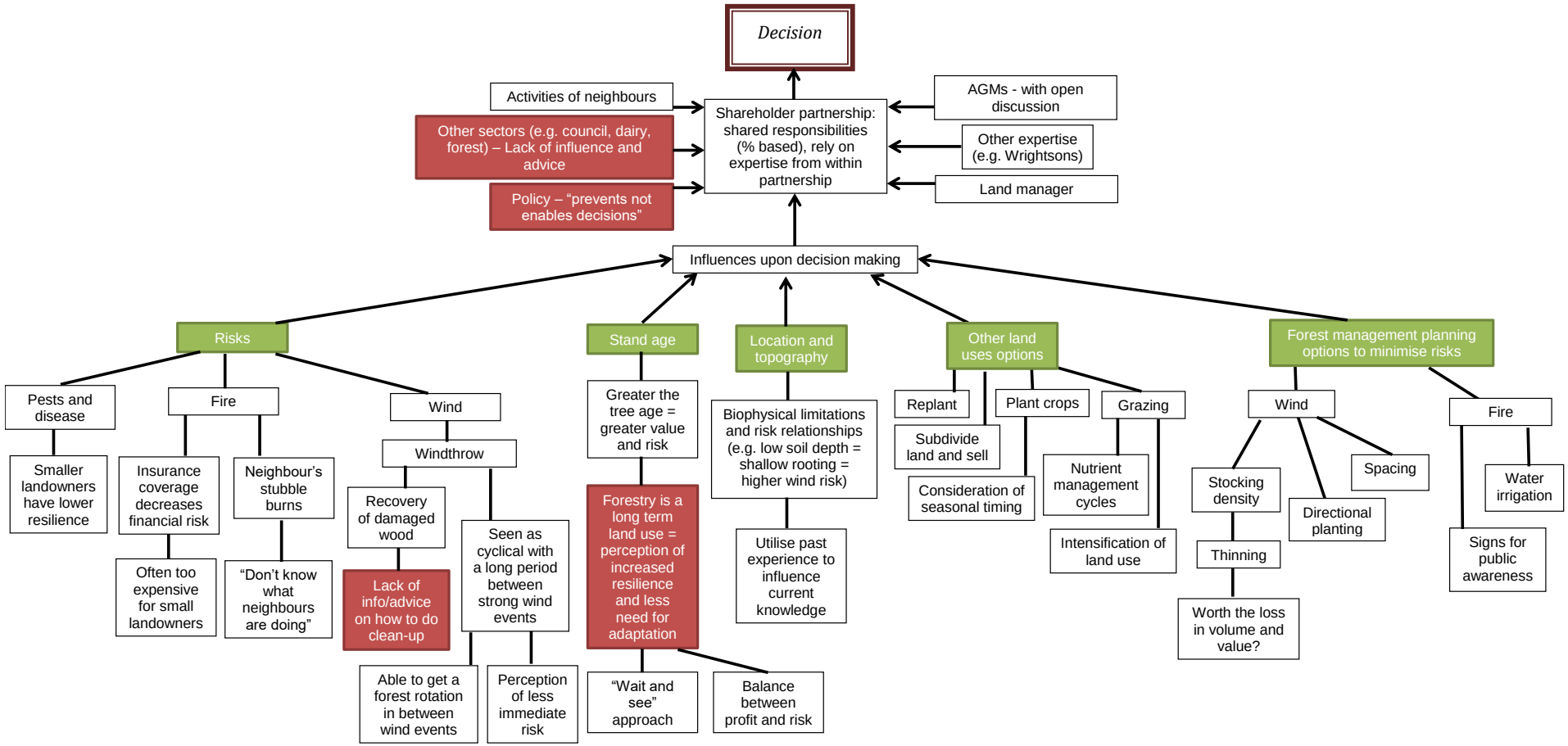

Figure 14: Forestry 2

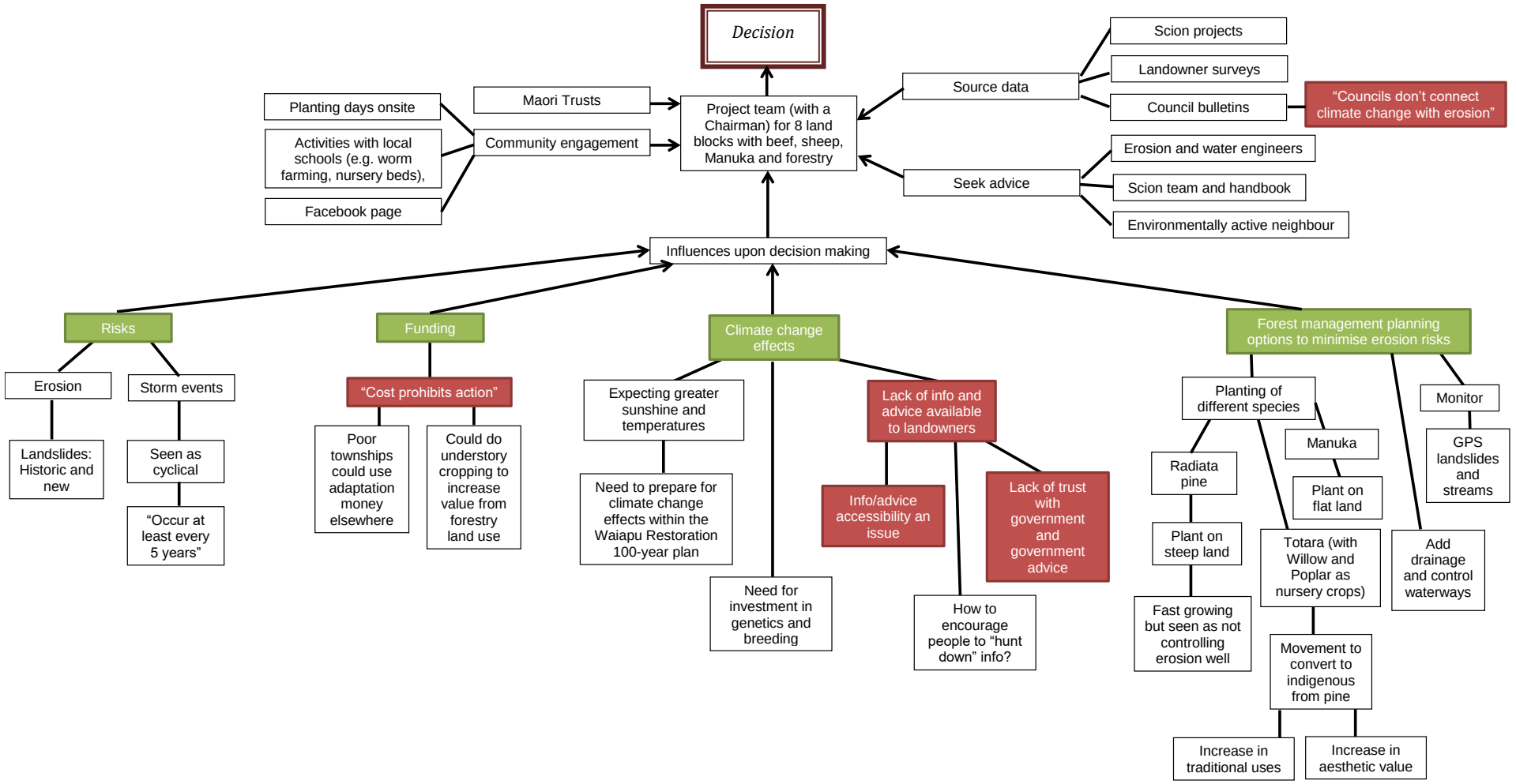

Figure 15: Forestry 3

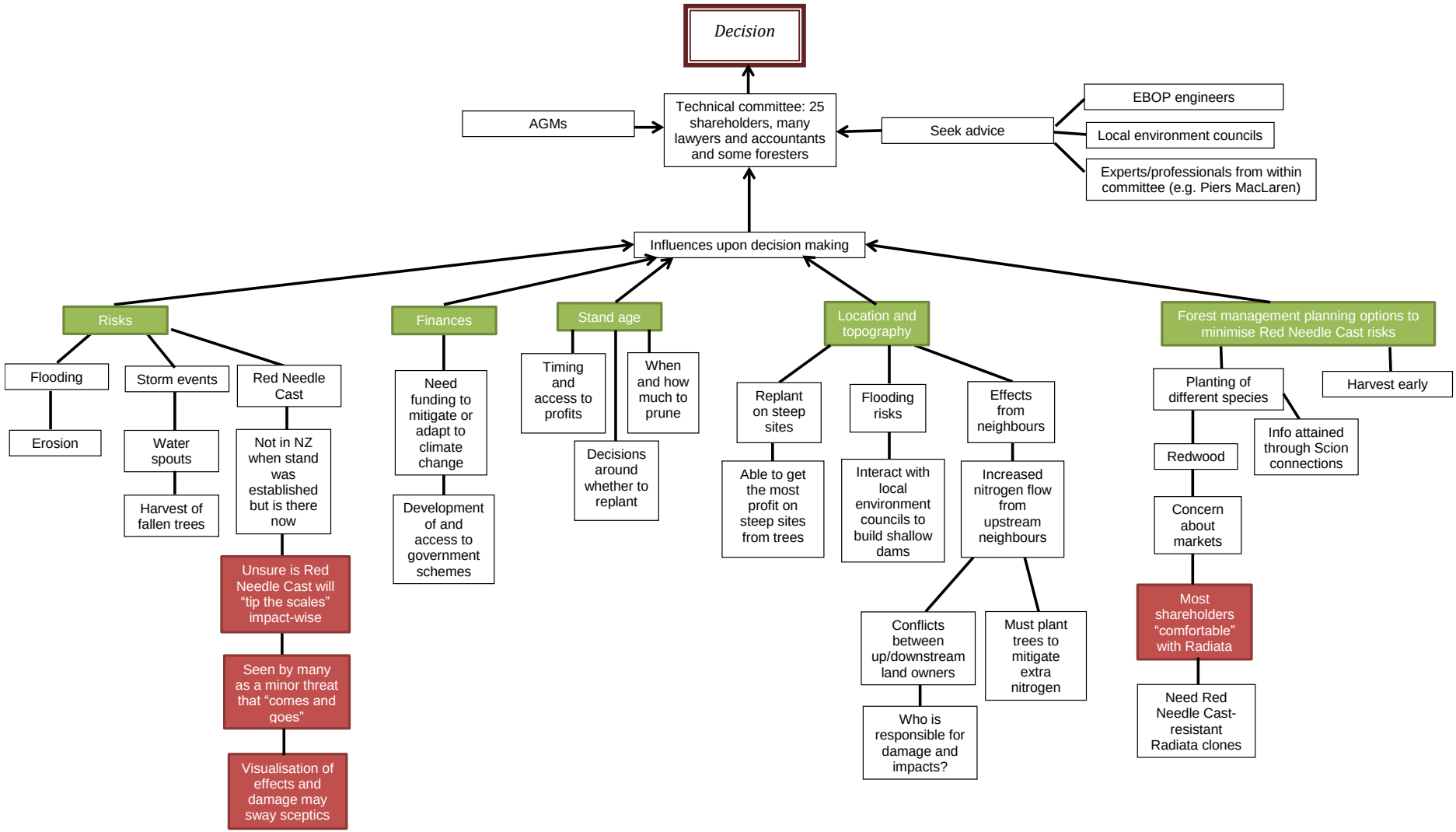

Figure 16: Forestry 4

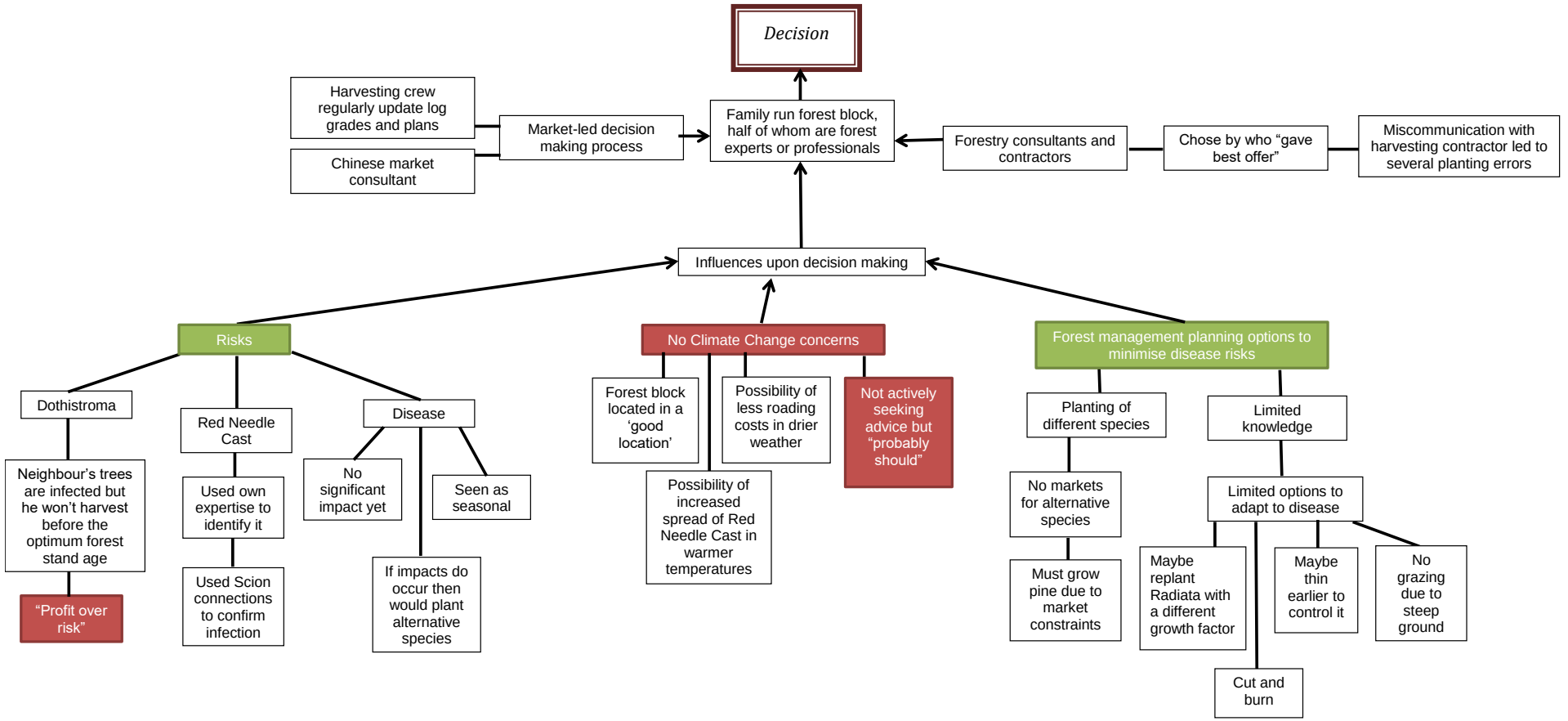

Figure 17: Forestry 5

13 APPENDIX E: MIND MAP