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A review of climate change research in New Zealand focusing on forestry

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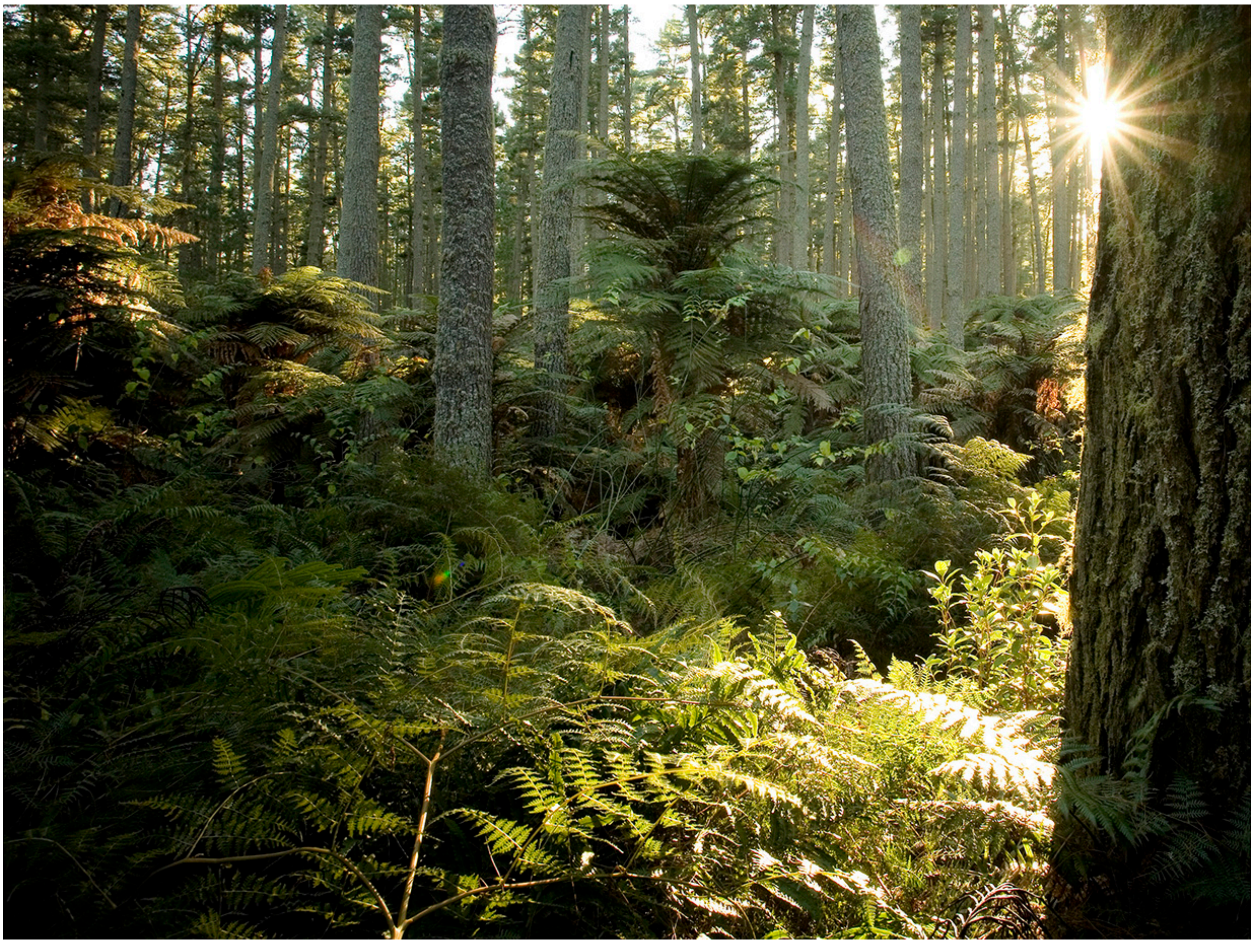

Report information sheet

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Executive Summary

Review overview

The Sustainable Land Management and Climate Change (SLMACC) research programme was established in 2007 and is administered by the Ministry for Primary Industries (MPI). It aims to address the impacts of - and adaptation to - climate change within the primary sector, mitigation of agricultural greenhouse gases, and enhancements of forest sinks.

This report assesses the impact and value for money of the $9.8 million SLMACC investment in 31 SLMACC funded climate change research projects from 2007 relating to *forestry* (2007 – 2017). It is one of five primary reports for the SLMACC Review. The other four are:

1. Adaptation Review (Flood & Cradock-Henry, 2018);
2. Mitigation Review (van der Weerden, Jonker, Fleming, Prescott, de Klein & Pacheco, 2018);
3. Technology Transfer Review (Payne, Turner & Percy, 2018); and
4. Project Leader and Stakeholder Survey Results (Payne, Chen, Turner & Percy, 2018).[1]

Technology Review	Adaptation Review	Mitigation Review	Forestry Review
SLMACC Project Leader survey			Authors Survey
SLMACC Stakeholder survey			End-users survey

Together these reviews have assessed the impact of the ten years' research to date, the barriers and enablers that have affected research uptake, and knowledge gaps and areas to be further developed or improved in future funding.

The SLMACC programme has three aims, which are relevant to this review:

1. Enhancing and supporting adaptation to climate change.
2. Encouraging the establishment of forest sinks.
3. Managing deforestation and capitalising on new business opportunities arising from the world's response to climate change.

[1] This survey was not used in this report. Two separate surveys more tailored for this review were developed and applied.

The Value of Forests

Forestry is New Zealand's third largest export sector. It has a key role to play in the global and domestic response to climate change. Trees and forest systems are a key *mitigation* tool. They sequester carbon from the atmosphere and offset greenhouse gas emissions produced by other sources such as agriculture. The 2015 Kyoto eligible forestry activities sequestered net CO_2 equivalent of 16 percent of New Zealand's gross emissions in their wood. Forestry completely offset New Zealand's Assigned Amount under its Kyoto target and New Zealand's total gross emissions during the Kyoto protocol first commitment period (Carver et al, 2017, p3).

There is a high incentive to maintain and expand forests, because New Zealand forests can:

- help meet domestic and international mitigation targets, e.g. the Paris Agreement, and the domestic goal to be carbon neutral by 2050;
- contribute economic, social and cultural benefits, with forests currently providing $12 billion in annual outputs (including providing regional jobs in forestry, recreation and tourism; and shelter); and
- provide a critical tool for other land users to help mitigate their emissions (e.g. through the Emissions Trading Scheme (ETS)).

Forests also provide a useful *adaptation* tool for other land users to adapt to the risks and opportunities arising from climate change, e.g. to combat soil erosion, and improve water quality.

Climate change affects forests, therefore an understanding of climate change impacts as well as adaptation strategies is critical to ensure the continued productivity of the forestry sector, protection of New Zealand's current and future carbon storage, and New Zealand's wider environmental management and health.

Within the New Zealand forestry sector there are two specific trends or issues, which demonstrate the need for targeted science research like SLMACC.

- Māori are becoming the largest exotic forest owners in New Zealand, because of recent Treaty settlements. This is expected to result in a significant shift in the intentions for plantation management with increasing emphasis on a wider range of species plantation and permanent forests.
- Timeframe differences in the returns on investment for plantation forests (28 - 60 years) are significantly longer compared with the much shorter cycle production systems in other primary industry sectors such as dairying. This impacts on how effectively foresters can plan or adapt to significant climate change risks (such as fire, or emerging biosecurity pests), and opportunities (such as more accurate tools to calculate carbon for ETS accounting).

Methods

This forestry review used a range of evidence-based methods as follows.

- Analysis of 31 forestry project reports for outcomes, gaps and identification of end users.
- Surveys and interviews of researchers, end-users and other stakeholders.
- Workshops with researchers, primary industry, policy, indigenous and adaptation stakeholders.
- A value for money assessment, including a cost benefit analysis of fire research.

"[SLMACC research] confirmed the very important place [role] trees and forests provide to sustainable land use, which now needs to be factored into the national landscape more broadly."

Key Findings: SLMACC forestry research has been successful

Using a common evaluative rubric (across all the SLMACC reviews), this review found the SLMACC funded forestry projects have achieved the criteria to a 'moderate' or 'high' degree (see Table 1 below).

Table 1: Common Rubric Assessment for the 31 Forestry focused SLMACC research projects

Evaluative criterion					Assessment
Build science capacity and capability enhancement					High degree
Influence on science					High degree
Engagement and networks					Moderate degree
Learning, awareness and knowledge exchange among end users					Moderate degree
Usability of research for end users					Moderate degree
Influence on stakeholders and impact for NZ					Moderate - High degree
Rating criteria					
1 Low degree (Never or seldom, with clear weakness)	2 Moderate degree (Mostly, or sometimes with few exceptions)	3 High degree (Always to almost always)	IE Insufficient evidence	E Emergent	N/A Not applicable (e.g. not asked for by SLMACC)

The SLMACC research projects rated **high** in building science capacity and capability; and in positively influencing science. New Zealand has gone from barely any science capability related to the impacts of climate change on forestry to SLMACC projects building and maintaining a small group of 3 – 4 researchers working in new areas and early-stage research. The researchers have developed detailed knowledge of key topics related to adaptation and mitigation, and are well-networked into sectors and communities.

A review of publications by SLMACC authors on these topics found at least 139 academic papers, demonstrating the integration of wider science and SLMACC funded research, and SLMACC projects being part of a wider science environment.

Furthermore, some of the key researchers have been able to build on previous SLMACC and non-SLMACC funded research to strengthen areas of expertise, and help develop subsequent larger research programmes - providing benefits to New Zealand and sector stakeholders, including improving New Zealand's international reputation and leadership in climate research.

SLMACC's influence on stakeholders and impact for New Zealand rated **moderate-high**. SLMACC has provided a significant funding source for forestry adaptation research in New Zealand. The findings from research have supported decision making with policy and sector stakeholders, including in areas of emissions trading, the real costs of harvesting steeplands, and responses to wildfire and pest risk. Mitigation research has supported Government policy and legal objectives, particularly in providing significant underpinning science for the Kyoto and UNFCCC[2] carbon accounting system.

Engagement and networks; learning, awareness and knowledge exchange; and usability of research for end users varied across projects, and were rated **moderate** overall. Some projects performed well in these areas while other less so, due to a variety of factors including accessibility of the reports; different degrees of stakeholder engagement or participation across different stages of projects; or the level of discussion of findings in ways that stakeholders could readily understand.

Positive value for money has been generated

A cost-benefit analysis (CBA) was conducted on the research addressing an expected and significant increase in the risk to forests arising from fire. The analysis showed 'exceptional' value for money, indicating that a relatively small investment can have important economic implications for the sector. The CBA relating to wildfire research found it generated a Net Present Value (NPV) of $15 – 18 million (in 2008 NZ dollars), and a positive benefit-cost ratio ranging from 38 to 48. The analysis has indicated, however, that the potential value will only be realised over time if foresters and other research users continue to implement insights from the research.

A Basic Efficiency Resource Analysis (BERA) evaluating impact against investment across six areas was also undertaken, showing that on average, all the impact factors returned more than invested.

Three areas where the qualitative analysis of investment showed greatest impact were policy engagement, coalition and partnership building, and changing practice. Research papers and industry engagement also generated greater impact than invested overall.

[2] United Nations Framework Convention on Climate Change

The research has created value for stakeholders

A review of value creation (using the Wegner, Trainer and de Laat framework, 2011) showed particularly **high** value (4 out of 5) was obtained *immediately* for end-users and stakeholders (including better understanding of the role of forests in mitigating climate change and novel approaches to predicting growth rates); through their participation. The nature of the conversation on climate change impacts and implications has changed dramatically in recent years, for which SLMACC research can claim a significant part. There is now more industry engagement and acceptance of the science behind climate change knowledge; and a greater appreciation of risks and opportunities for responding to climate change. SLMACC also rated **high** value for the potential of the research's later use or realisation, e.g. in developing new drought tolerant species.

Value was rated at a **medium** level (3 out of 5) in terms of *application* and *re-framing,* e.g. end users better considering climate change risks and effects such as pests, disease and fire or wind danger in localised contexts or business decisions; and using ETS look-up tables and other carbon accounting methods improved with SLMACC research.

And the long-term nature of climate change SLMACC research was reflected in a **lower** rating (2 out of 5) for *realised value*. In part due to the 28+ year time horizons in forestry, the ability to shift forestry practice to realise the full value of SLMACC research is still limited.

Enablers of the SLMACC research

The review identified three key enablers or strengths controlling the SLMACC forestry-related research: leveraging off existing networks and connections between researchers and stakeholders; the SLMACC programme and processes being responsive to stakeholder priorities and needs; and SLMACC providing a critical, near-sole source of ongoing funding for adaptation research in New Zealand.

Engagement and participation of researchers with their networks

Researchers and research organisations have used their networks to engage, formally and informally, stakeholders in the research. There has been a commitment of researchers to go beyond contracted engagement, adding significantly to the research impact.

The use of existing networks between Scion, university researchers and industry stakeholders have increased the research reach and helped significantly to create positive impacts. The sharing of research reports both by researchers and stakeholders has also increased reach, and confirmed the research value.

A particularly successful innovative research approach integrated community stakeholders as co-researchers to enable more inclusive and catchment based project knowledge, to better design and develop community outcomes and focus on policy barriers of action.

The network of researchers and stakeholders has managed the gap between basic and applied research, and addressed key areas of research need. Value has been added by researchers being adaptive in filling increasing funding gaps and maintaining capacity, though such approaches may not be sustainable over the long term.

SLMACC research has built on and leveraged off other research projects, using those networks, data and knowledge. For example, the fire research collaboration between Scion and NIWA, and linking to existing projects for managing steeplands in collaboration with University of Canterbury, has provided strong links and science advice into sectors as well as to stakeholders such as MfE and regional councils.

SLMACC responsiveness to stakeholder priorities

The SLMACC programme and processes have been flexible and responsive to sector, policy and researcher's priorities on climate change and the forestry sector. This has allowed funding decisions to be responsive to changing priorities and to new research themes. The process for developing key themes for each SLMACC funding round has been inclusive of research, policy and sector views and priorities.

SLMACC research has facilitated researcher conversations with end users, and in some cases this has enabled joint understanding of the policy questions and kinds of evidence required to answer them. Stakeholders that were engaged as part of advisory groups or industry review processes have increased awareness within their organisations and enabled an even wider network of engagement with SLMACC research.

SLMACC provides significant funding

SLMACC was largely, and continues to be, the sole long-term funding source for adaptation research for forestry (as well as for other sectors). SLMACC has enabled the development of capability within research organisations, maintaining a critical element of New Zealand based expertise in climate science. It has enabled some international collaboration and delivered high quality science-led policy advice that has been recognised as highly useful to policy and sector stakeholders.

Barriers: What has limited adoption of SLMACC research

Barriers to the usefulness or adoption of the SLMACC research have included limited communication with end-users; a lack of actionable and specific risk-based research for exotic forests and low community engagement for indigenous forests; and a reduction in funding, which has constrained the maintenance of science capability.

Limited engagement with end users during research

While SLMACC rated 'moderate' in its achievement of engagement and knowledge exchange, there have been limits or barriers to achieving this at an optimal level.

In many SLMACC projects, there was limited communication with end-users before, during and post research, and some projects end-users were not identified and it is doubtful whether some end-users were aware the research was being undertaken. This has limited the ability of research results to be fit for purpose in creating benefits in end-users. Similarly, the methods for disseminating research outcomes has been limited, creating barriers by end-users.

Limited communication has been mitigated to some degree by the use of informal networks and informal sharing of results.

SLMACC – as with other programmes – has only relatively recently realised the importance of incorporating end users into research design; including engagement as well as 'extension' activities such as knowledge exchange with end users, throughout the research process.

Exotic Foresters: lack of actionable and specific risk-based research

A related barrier has been the lack of freely available, *actionable* and *specific* risk-based research or tools to help foresters evaluate climate change data against their forests and businesses. This has led to limitations in foresters incorporating practical adaptation strategies into business models and decision-making processes, including ways to manage uncertainty (e.g. through scenarios and back casting, or reflecting back on how changes in the past have contributed to the current situation).

Indigenous Forest barriers: low community engagement

One of the barriers for indigenous forests is the low level of community engagement. There is limited Māori involvement in indigenous focused research, which may/will have improved indigenous forest coverage for SLMACC; and in selecting relevant research topics and associated applications of knowledge.

Reduced funding – risk to sustainability of science capacity and capability

Reducing funding level are constraining research. The reduction of SLMACC funding (from $8M/ year in 2007 to $2.82M/year by 2018) has limited the maintenance or growth of New Zealand's science capability, and scope of programmes. Some scientists have moved to different science areas such as advancing remote sensing technologies and developing knowledge of innovation practice. The pool of researchers in this field within forestry is so small (less than five nationwide), its sustainability is vulnerable to further funding reductions or policy changes.

Forestry climate change knowledge: What do we know now, and still need to know?

General Knowledge Gains

Seven years ago, the forestry sector identified the following knowledge gaps (Moore et al, 2011) in:

- understanding of climate change and policy;
- understanding of risks and impacts to forests; and
- understanding of adaptation strategies.

This 2018 review shows that SLMACC research has made major inroads to these knowledge gaps.

Most the research (60%) has built 'some awareness' of the impact of climate change in forestry businesses and with policy stakeholders; and a further 37 percent have built 'significant understanding' (see Figure 4 below).

A large majority of respondents (36 out of 38) have reported a change in their perspective towards climate change, due to SLMACC research projects (Figure 12). And 23 have indicated a significant change in perspective (rating of 4 or more out of 6).

Stakeholders' awareness has grown with the knowledge provided on how climate change could impact forestry and production regimes. Interviews with forestry industry stakeholders demonstrated that some of the sector know and can repeat spontaneously the details contained in the reports, especially Dunningham et al (2012).

In part, the SLMACC research has successfully built a body of useful knowledge because it has addressed industry stakeholders' climate change information requirements. For example, research has clarified climate change related risks.

Other areas of research benefit included alternative management approaches for steepland forests, new methods for plant breeding, using surveillance technology to target areas of greater risk; and other aspects of more targeted risk mitigation including alerting fire authorities to future fire danger.

Specific Knowledge Gains

Each research project has provided knowledge on a range of climate change impacts on exotic and indigenous forests and communities.

SLMACC research has provided end-users with new understandings of the risks that can impact exotic forests, understanding of the disturbance dynamics of indigenous forests, provided research supporting the ETS and Kyoto carbon accounting e.g. through carbon stock tables on different tree species, potentially enabling up to 3000 forest owners to more easily calculate the amount of carbon credits they can claim. Improving ETS accounting can provide up to a 30 percent difference, (some millions of dollars) in the carbon value of forests.

SLMACC research has provided management approaches for steep hills country and new methods for pine breeding.

The research has also provided an improved understanding of how to protect future forests from biosecurity pests and fire risk. For example, as noted above, the CBA on wildfire risk generated a Net Present Value (NPV) of $15 – 18 million (in 2008 NZ dollars).

Research has identified a range of specific findings under different climate change scenarios including the following five.

1. Pest vigour, new pests and pest distribution will increase, as will the costs of pest management.
2. Fire risk will increase with hotter, driers conditions, enhanced by more weeds, and mortality from pests.
3. Extreme weather events are expected to increase, and on steep and unstable slopes this will lead to more erosion; forests could reduce erosion on these unstable soils or slopes for most of the rotation.
4. Promising methods for breeding for improving water use efficiency in Radiata pine have been developed.
5. Different tree species are being identified as suitably productive options, e.g. Willows, Beech, Tauhinu, Redwood, Eucalyptus, and Manuka/Kanuka.

> "These reports add to the body of knowledge on impacts of climate change which need to be tracked over time since the stressors will change. Important to keep updating the research in an efficient manner. A risk management tool would help do this as well as monitor what the industry is doing to plan for the effects of climate change."
>
> Stakeholder survey response

Knowledge Gaps: What do we need to know?

SLMACC research into climate change and forestry has delivered a good foundation of knowledge, but there are gaps and opportunities to refine research in more strategic and practical directions. Gaps exist in areas of mitigation and adaptation knowledge and are significant for exotic forests. However very large gaps in knowledge also exist for indigenous forests.

Mitigation knowledge

In *mitigation*, knowledge and research capability now needs to focus more on supporting international commitments to reduce GHG emissions, including:

1. contributing to the rule book for global stock-taking and other technical mechanisms under the Paris Agreement (still being negotiated in 2018);
2. continuing to enhance and update data and methods in carbon accounting underpinning the ETS; and
3. developing more capacity to model and generate scenarios of different climate futures, land use systems and how different systems interact to affect forest productivity, the wider environment and communities.

Indigenous forests and mitigation knowledge

There are knowledge gaps, such as understanding the complexities of indigenous forest ecosystems for mitigation, understanding risks (vulnerability and sensitivity to climate change) to indigenous forests and hence their ability to continue to act as a carbon sink; and understanding carbon cycling for supporting emissions reduction and the interacting effects of disturbance impacts as well as policy actions.

In relation to indigenous forests New Zealand needs to progress its knowledge in areas such as:

- understanding the climate change impacts on indigenous ecosystem functioning and services, carbon cycling and disturbance;
- understanding the impact on indigenous forests arising from policy or market led incentives to address climate change; and
- improving carbon accounting for different species and forest types, e.g. mixed, single or indigenous dominated species.

> "These [SLMACC] reports add to the body of knowledge on impacts of climate change, which need to be tracked over time since the stressors will change. [It is] important to keep updating the research in an efficient manner.
> A risk management tool would help do this as well as monitor what the industry is doing to plan for the effects of climate change."

Mitigation and substituted wood products knowledge

Forestry as a mitigation strategy to date has focused on the role of trees as a carbon sink, omitting research into the potential uses of *wood products* as a carbon sink, i.e., through using long-lived harvested wood products as a construction substitute and using *wood products* as a biofuel substitute for higher emitting transport and stationary fuels.

Adaptation Knowledge

Exotic forests

With exotic forests – the mainstay of the commercial forestry sector - more research is required to provide businesses and communities with *quantifiable* and *catchment level* productivity and risk data that can be used to understanding impacts on operations and finances and environmental or social goals.

Climate change research, data, and tools need to be mainstreamed into current and future programmes addressing land use changes. For example, the 1BT programme needs to consider climate change impacts of where new plantings occur, to maximise returns, and ensure the forestry sector meets their ongoing social licence to operate.

Recommendations

Forestry provides significant benefits to New Zealand, underpinning our greenhouse gas reduction commitments. The recommendations identify key themes to support and enhance the mitigation role of forests to continue to provide sequestration services and to protect forests and their carbon sinks. These arise from the literature and experts and address the barriers identified and knowledge gaps or themes from the SLMACC research itself.

Stronger relationships with indigenous forest owners and those with an interest in developing future indigenous forests need to be built, in order to understand their needs and drivers for enhancing indigenous forests.

The final set of recommendations address the potential focus of future SLMACC research and the SLMACC process itself.

Recommendations for the focus of future SLMACC research

Recommendation 1: Develop a **strategic agenda** on the research required to support and enhance the **mitigation function of forests**, to better support domestic and international priorities for government and taking into account the existing strategic research agendas (including, e.g., National Science Challenges, and Conservation and Environment Roadmap). Specific suggestions are addressed in the full report below.

Recommendation 2: Increase significantly the adaptation research funding to enable forests and forestry businesses to more successfully adapt to a changing climate. This would support protecting and enhancing the forestry sector as the third largest exporter industry and a critical contributor to New Zealand's carbon mitigation goals.

Recommendation 3: Make data available to end-users for their own assessments and management of risk. As direct engagement with many stakeholders is not always practicable, a 'climate services' approach could be used to develop customised information products that include data, information and knowledge for specific sectors or regions.

Recommendation 4: Combine climate change research projects where suitable, to have a catchment or regional focus that is integrated across sectors. In addition to sector specific research needs, research is also needed to understand how sectors, communities, and other businesses interact.

Recommendations of how the SLMACC programme can be improved

Recommendation 5: Design SLMACC research proposals more explicitly with the expected end-users, and consider their intended uses of the research.

Include capabilities from social sciences, incorporating tacit knowledge and skills from end-users. Most of the recommended topic priorities listed need to include translation skills in addition to core science skills to ensure knowledge is taken up and used to inform decision making in different contexts.

Recommendation 6: Include an explicit handover process in the RFP and contract between science researchers and end users - including an ongoing communication strategy. This would greatly improve the likely uptake and use of SLMACC reports' data and findings.

Recommendation 7: Safeguard and grow research capability in both mitigation and adaptation research with increased and sustainable, longer-term funding of projects. The current $150,000 / year ($450,000 over a three-year project) makes up less than one FTE in total funding at a CRI; and continuing this lower funding approach risks New Zealand reaching a tipping point in losing its science research capacity and capability (and international reputation).

Recommendation 8: Include monitoring and evaluation across different scales as part of SLMACC contracts, funding and progress reporting components, to provide evidence and reassurance of value and impact, and to enable action learning**.** A key learning across these reviews has been discovering critical information gaps in how effective the past ten years' SLMACC research has been due to a lack of project-level monitoring and evaluation, to ensure relevance, saliency and legitimacy of outcomes.

Climate services translate the wealth of climate data and information into customised tools, products and information. This helps decision-makers to make informed decisions to boost resilience and adaptation capacity by addressing existing or emerging risks.

For example, Australia, Europe, and the UK have all given end-user access to high quality and user specific climate change information.
E.g.
https://www.climatechangeinaustralia.gov.au/en/
http://ukclimateprojections.metoffice.gov.uk/
https://www.climateurope.eu/climate-and-society/climate-services/

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1 Introduction

Forests are a key component of the global response to climate change. They are an essential part of the transition to a low carbon global economy, as a CO_2 sequestration mechanism and a source of materials for the development of the bioeconomy. Forestry's key role in addressing and responding to climate change is complex. Forest systems sequester and store carbon, and release carbon through harvesting and deforestation and can be vulnerable to risks from climate change.

Forestry helps New Zealand to meet its international climate change commitments previously under the UNFCCC Kyoto Protocol and, now, under the Paris Agreement. These commitments are a significant obligation for the New Zealand government, businesses and citizens, as endorsed by recent policy initiatives including the One Billion Trees (1BT) Programme, the Zero Carbon Policy, and the Zero Carbon Act (2018/19).[3]

Forests can assist other sectors to adapt to climate change, for example, through reducing impacts from increased extreme weather events such as flood management measures and protecting exposed soil from erosion, as well as offsetting CO_2-e emissions from other sectors.

Forests will also be affected by the impacts associated with climate change. An understanding of impacts as well as possible adaptation strategies is critical both to ensure the continued productivity of the sector, the retention of carbon sinks and ability to sequester carbon.

The forest sector is a major component of New Zealand's domestic and export economy. In 2017, forestry export earnings were $5.47 billion, or 13.8 percent of the value of primary industry exports.

Forests also have a significant social and environment role, e.g., providing sites for recreational hunting, mountain-biking, tourism, and adventure activities. Plantations also provide some level of biodiversity protection and habitat for indigenous species such as kārearea/falcon, and bats, e.g., there are 118 threatened species that are known to find refuge in plantations (MFE, 2018).

The Sustainable Land Management and Climate Change (SLMACC) Forestry Research fund, between 2007 and 2017, invested almost $10 million dollars into 32 forest climate change research projects across areas of mitigation and adaptation research, with a variety of uses and benefits for a range of stakeholders (Table 2). The goals of SLMACC is to address the mitigation and adaptation knowledge needs of government, the forestry sector and other users, concerning:

- the impacts of climate change and adaptation to climate change;
- mitigation of agricultural and forestry greenhouse gas emissions;
- cross-cutting issues, including economic analysis, life-cycle analysis, farm, catchment and systems analysis and social impacts; and
- policy research to address targeted climate change policy questions.

[3] At the time of writing the Zero Carbon Bill was still in preparation.

Table 2: SLMACC forestry review context

SLMACC Forestry Research 2007 – 2017 $9.8 million and 32* projects	
MITIGATION	**ADAPTATION**
$5.7 million invested in 18 projects	$4.1 million invested in 13 projects
Stakeholders	**Stakeholders**
• Central Government and policy • Forestry corporate owners (ETS)	• Forestry corporate owners and growers, including iwi. • Investors (Forestry and ETS). • Farm foresters (including individuals or communities planting trees for environmental, social and cultural benefits).
Uses of research	**Uses of research**
• Report on New Zealand's international commitments with increasing accuracy • Input to policy development • Predict amount of carbon in forests more accurately so forest corporate owners can make better use the ETS	• Better understand the potential risks and impacts of climate change on forestry as a productive sector, e.g., pests, weeds and diseases are risks/ interest areas for forestry owners. • Use the modelled information and data to feed into 30-year horizon decisions about forestry management, e.g. when and where to plant, to maximise positive gains/ minimise risks from climate change. • Protecting the investment in forest carbon sinks through managing or mitigating climate change risks and impacts on forest assets.
Benefits	**Benefits**
• Improved New Zealand reputation internationally as a leader in forest carbon accounting • Developed capacity and commitment to support the realisation of national climate action, e.g., policy initiatives and investment decisions for forests and the forestry sector	• Better management of risks across a range of climate change impacts including fire, wind and biosecurity. • Sustainability and productivity of New Zealand's forestry sector. • Strengthened relationships through researcher networks and engagement with sector and policy stakeholders for supporting climate change adaptation. • Developed collaboration across institutions and with stakeholders nationally and internationally.

*One project on Life Cycle Analysis (LCA) did not fit clearly within these categories. Another project was not reviewed as there was no report. Hence, only 31 projects were reviewed.

1.1 Objectives of review

This research **evaluates** the **impact** and **value for money** of the **SLMACC investment** that was focused on understanding climate change impacts on plantation and indigenous forestry in New Zealand.

This report is one of five reports (Table 2) reviewing SLMACC research. The other three are:

- Adaptation Review (Cradock-Henry, et al 2018).
- Mitigation Review (van der Weerden, Jonker, Fleming, Prescott, de Klein & Pacheco, 2018).
- Technology Transfer Review (Payne, Turner & Percy, 2018).

- Project Leader and stakeholder survey results (Payne, Chen, Turner & Percy, 2018).[4]

Figure 1: The four SLMACC reviews and their key data sources

Technology Review	Adaptation Review	Mitigation Review	Forestry Review
SLMACC Project Leader survey			Authors Survey
SLMACC Stakeholder survey			End-users survey

A rubric was developed that could generate data that could produce comparable results across the five project areas.

1.2 Structure of the report

In the next section the research context and methods are described (Section 2), Section 3 provides an overall summary of investment in mitigation and adaptation research for the research projects reviewed, along with climate impacts and risk analysis. Research stakeholders are identified in Section 4. Section 5 presents the evidence for the rubric assessment identifying and evaluating the key research outcomes and understanding of the impacts and value for money of the research. Sections 6, 7 and 8 respond to the key evaluation questions on knowledge gaps, enablers and barriers. In the final section the lessons and recommendations are detailed.

An Appendix provides a detailed rubric; a description of the impact and value for money assessment methods; the survey responses statistics and the key messages from each report with investment statistics.

[4] The Payne et al (2018) survey was not used in this report as it was not suited to the context of forest research which has a smaller pool of stakeholders. Instead two separate surveys, more tailored for this review, were developed and used.

2 Methods

The SLMACC forest research was evaluated against a common set of key evaluation questions and a rubric, assessing six criteria: i) science capability and capacity, ii) influence on science; iii) stakeholder engagement, iv) stakeholder learning and knowledge exchange; v) usability of research and v) influence on stakeholders and impact for New Zealand.

In addition, a more in-depth understanding of impact and value that forestry sector stakeholders derived, was developed and reported for this project.

2.1 Research context

Fundamental to understanding impact is that researchers cannot typically be expected to deliver end-user impact and benefit as the responsibility for this depends on the end-users and factors outside of researcher control such as availability of resources to change practice, disseminate findings or contextualise research.

The potential for end-user impact and benefit can be improved though active engagement and knowledge exchange between end-users and researchers. Engagement can help to ensure that research is fit-for-purpose and addresses end-user needs, understanding constraints and barriers to implementation, hence maximising the opportunity for research to be impactful.

SLMACC projects were undertaken at a specific point in time where policy and sector knowledge at the time affected the aims and expected uses and benefits of research, e.g., addressing ETS and carbon accounting needs. They also provided an opportunity for influencing areas of understanding and research need, e.g., on impacts of disturbance such as wind, fire and pests on exotic and indigenous forests.

2.2 Mixed methods used

This review used a mixed methods approach to evaluate the impact and value for money of completed forestry focused SLMACC projects. The following mix of methods were used to generate a robust and salient assessment of the SLMACC projects:

- Interviews with key informants on the nature of SLMACC research stakeholders and impact areas.
- Two surveys, delivered to end-users and researchers, gathering evidence of end-user engagement, the technology transfer process, and the applications and value of the research.
- Six workshops with other review researchers and forestry specific workshops around stakeholder analysis and indigenous forest research gaps.
- An application of cost benefit analysis of the fire research to illustrate how impact of risk-related research could be measured.

- An application of basic resource efficiency analysis (BERA) to measure impact against investment.
- Comparative analysis of previous climate change related research interviews.

Together these methods obtained multiple sources of evidence for assessing impacts and value for money to derive an overall rating for the rubric. The details of data sources are provided in Table 3.

Table 3: Data sources

Data Source	Description
Author Interviews	A small set of interviews were conducted with research leads, to better understand the context in which they conducted the research, their characterisation of stakeholders and to help guide the development of an appropriate set of questions for survey and further analysis of impacts.
Inter-team workshops	Workshops were conducted with other review teams for integrating the review process, including using the rubric, and appreciating the changing policy context for SLMACC research over the ten-year period (2007-2017) of research reviewed. Workshops were also held for analysing forestry stakeholders and indigenous forest climate research gaps.
Researcher and stakeholder surveys	A survey of researchers and stakeholders (policy and sector) was conducted. Methodologies for measuring research impacts (Appendix 2) reviewed for this research guided the development of a set of survey questions, enabling opportunities for researchers and stakeholders to identify impacts. This provided a rigorous way of examining the extent to which stakeholders were engaged in the research, the types of knowledge generated and whether the research contributed tools or knowledge that stakeholders could use to change their practice.
Basic Resource Efficiency Analysis (BERA)	The Basic Resource Efficiency Analysis (BERA) assesses a measure of input against output based on respondents' perspectives of investment and impact. A set of question gathered information from stakeholders and researchers on their perceptions of various aspects of the research comprising: • Coalition and partnership building; • Industry engagement; • Policy engagement; • Research papers; • Media exposure; and • Changing practice.
Cost-benefit analysis (CBA)	A cost benefit analysis of the fire related research illustrating return for investment.
Previous relevant research	The project also drew upon previous interviews conducted by Scion as part of the MBIE funded Climate Change Impacts and Implications project (www.ccii.org.nz, Lawrence et al 2016). This earlier research collected data on the approaches undertaken by the forestry sector for addressing climate change risk; understanding industry knowledge; and understanding research impact to provide a benchmark for stakeholder awareness and knowledge needs.

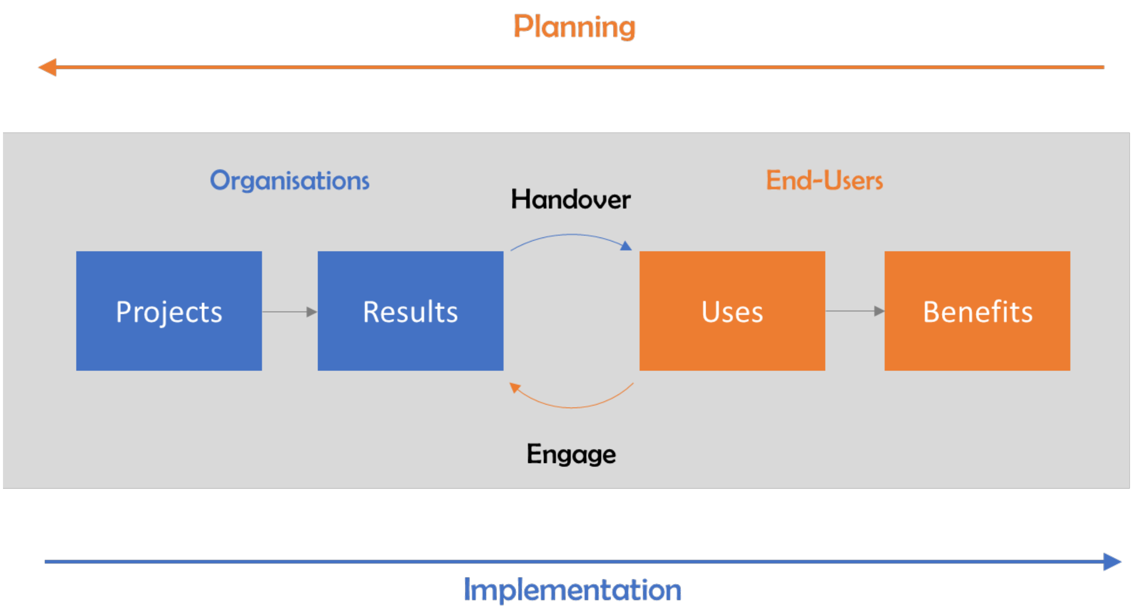
A summary of the survey statistics is given in Appendix Three.

2.3 Project summaries

Thirty-one research project reports were systematically reviewed using six steps to identify research aims, investment, audiences, key messages, potential uses, and recommendations.

Using a strategic methodology to define project, research results, end-user uses and benefits of the research (PRUB) (Figure 2) each research report was summarised and categorised. Detailed descriptions of the data and the outcomes, potential end-user uses and benefits for each report are available in the Annex to this report.

Figure 2: Project-Results-Uses-Benefits framework (from Driver, 2014)



Appendix Four summarises each of the research projects, identifying project authors, the investment and key messages. Potential uses of the research for different end-users (forestry, investors and policy) were also summarised and are part of this report (Section 5.5, Table 8).

2.4 Assessment of impact

The review included a comprehensive assessment of impact and value for money. Methods were developed to achieve reliable measures that could create comparative basis of evaluation as well as complement the methods used in the other reviews. These methods identified critical points for obtaining impact addressing:

1. How well did the researchers and stakeholders communicate about the needs, relevance, saliency, and rigour of the research?
2. Did the hand-over process hinder or enable research uptake?
3. Did the research provide fit for purpose uses that end-users could understand, implement and create benefit from?

Five methods from the literature on evaluating research impact (Appendix Two) were reviewed (along with interviews with research leads) to inform survey questions that considered the nature of the research conducted and evaluated the effectiveness of the engagement, the hand over process and the impact and expressed value of projects.

2.5 Value for money

Return on investment and value for money was determined using a qualitative resource efficiency tool across all projects (see Section 2.2 and 5.10). A cost benefit analysis (CBA) on one or two projects was requested by MPI, hence a CBA was conducted for the fire research programme building on preliminary Scion research (Section 5.11).

2.6 Limitation and disclaimers

This review cannot attribute its findings solely to SLMACC funded research. At the time of the research climate change was a fast-growing field domestically and internationally, with several different research programmes underway during the 10-year period of SLMACC funded research (2007-2017). SLMACC research complemented other activities already undertaken or in development during the same period of SLMACC research (e.g. a multi-million dollar MBIE funded forestry and climate focused research programmes being conducted by Scion, NIWA and other researcher providers).

Given the SLMACC funded research was not commissioned with resources or guidelines for creating impact or stakeholder engagement or specific addressing transfer of results in meaningful form, the rubric is aspirational. The use of the rubric – with three levels of assessment across six category areas – meant that some of the variation in those criteria has not been captured in the overall summary. Thus, it is recommended that the report be read in full to appreciate variations in assessment across the reports evaluated, types of value created and impact realised.

3 Investment in Mitigation and Adaptation research

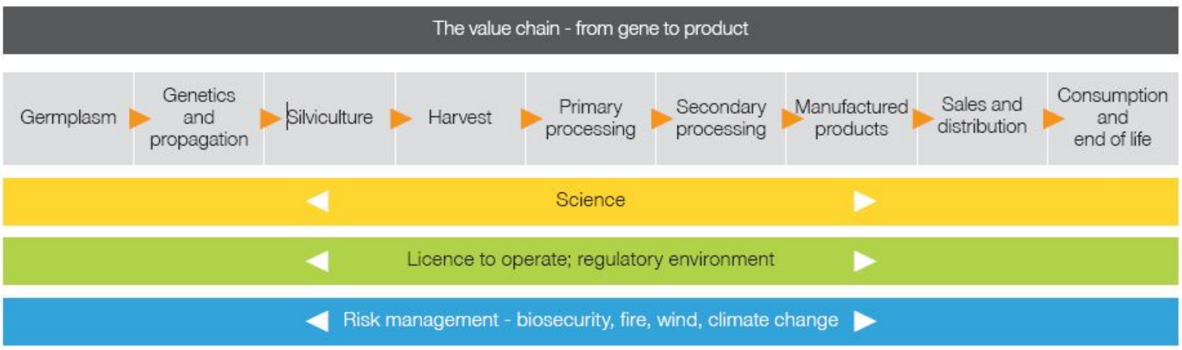
Most of the SLMACC research has been invested in mitigation related research (18 projects, $5.6m) with a smaller proportion allocated to adaptation (14 projects, $4.1m). The adaptation research has mainly focused on risk identification (4 projects, $1.9m) and risk evaluation (5 projects, 1.5m), with less attention on what actions could be undertaken to manage the risks (Table 4).

Table 4: Research undertaken by mitigation and adaption and ISO risk assessment stages

Risk Class	Count	Investment
Mitigation (total)	18	$5,785,000
Adaptation		
Risk Identification	4	$1,950,000
Risk Analysis: Understanding Impacts	4	$485,000
Risk Evaluation: Responses to impact	5	$1,520,000
Adaptation (total)		**$3,955,000**
Life Cycle Analysis	1	$108,000
TOTALS	**32**	**$9,848,000**

Forestry returns value through many steps in the process of maturation. The value chain depicted in Figure 3 illustrates how value is added in forestry (Scion, 2018) which identify different points of potential GHG reduction or production, and for adaptation action.

Figure 3: The forestry value chain from gene to product (Scion, 2018)



The following sections provide background and context to the relevance and importance of research for mitigation and adaptation of forestry for New Zealand.

3.1 Mitigation: Forests' role in CO_2 reduction and product substitution

Mitigation: An anthropogenic (human-enacted) intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001).

3.1.1 Direct sequestration

Trees directly sequester or store carbon dioxide (CO_2) from the atmosphere: around 50 percent of a tree is carbon synthesised from CO_2. Hence, trees and forests can help mitigate increasing CO_2 concentrations produced from other sources such as agriculture, manufacturing and transport.

Trees sequester or lock-in carbon via long-term storage in wood, e.g., for 28 yrs during the growing phase (for *Pinus Radiata* referred to in this report as Radiata pine), and for many decades beyond when timber is used in construction. Trees continue to add carbon as they grow, especially some younger and faster growing species such as Radiata pine. Currently, seven percent of New Zealand land is used in forestry and sequesters some 25 million tonnes of CO_2, some less than was the case when Europeans first settled in New Zealand.

Forests and timber play a role in reducing the level of CO_2 in the atmosphere and substituting for higher emitting products

From 2013 to 2020 the current level of forestry is expected to sequester 16 percent of New Zealand's gross emissions (105 mT CO_2-e (CO_2 emissions) against gross emissions of 646 Mt CO_2-e).

In addition, wood-derived products can be used to replace petrochemicals and materials, with alternatives such as biofuels and bioplastics. Replacing concrete in buildings, for example, can reduce emissions when producing a tonne of concrete emits 900 kg of CO_2, compared with producing a tonne of wood that sequesters 148 kg[5] of CO_2.

By 2030, a reduction of 2.5 million tonnes of CO_2-e pa is possible through faster growing trees and greater use of timber in construction. Bio-based manufacturing and processing is expected to reduce CO_2-e by 10 million tonnes by 2030. Uptake of SLMACC research can contribute to achieving these reductions, as well as new research responding to emergent knowledge needs.

3.1.2 Mitigation for other sources

Forests and trees can address management of climate change risk, mitigation and adaptation goals for other sectors and interests. Forests provide a significant range of ecosystem services for example,

[5] 1000kg * .65 dry mass * 50% carbon *3.67 (C to CO_2) * 120 to include roots

through natural flood management measures; combatting soil erosion; improving water quality; providing recreation and tourism opportunities; and protecting threatened biodiversity.

Forests can be used by industries to help offset carbon liabilities under the Emissions Trading Scheme (ETS), which may provide an important mechanism if agriculture emissions are traded within the ETS.

The use of forests as a mitigation tool is influenced by government and industry policy and market drivers. For example, initiatives like the One Billion Trees (1BT) programme, the Emissions Trading Scheme (ETS), Erosion Control Forestry Programme (ECFP) and the Afforestation Grant Scheme (AGS) provide incentives to invest in growing forests in New Zealand to deliver economic, environmental and social benefits.

Primarily, mitigation research completed through SLMACC has addressed carbon accounting precision and accuracy for ETS users; carbon market development and regulation; understanding and improving the role of indigenous forestry; and understanding impacts of afforestation.

In 2050, through the power of forestry, New Zealand will have:

- A 10-fold increase in GDP from forests and manufacturing
- Zero carbon emissions
- Erodible land planted in permanent forests
- Water quality issues from land-use mitigated
- Sustainable communities and economies in all regions

Scion Strategy to 2030

3.2 Adaptation

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001).

Forestry is a significant source of economic, social and cultural benefit providing $12 billion in outputs and with export earnings between $5-6 billion per annum. **Forestry is the third largest export earner for New Zealand.**

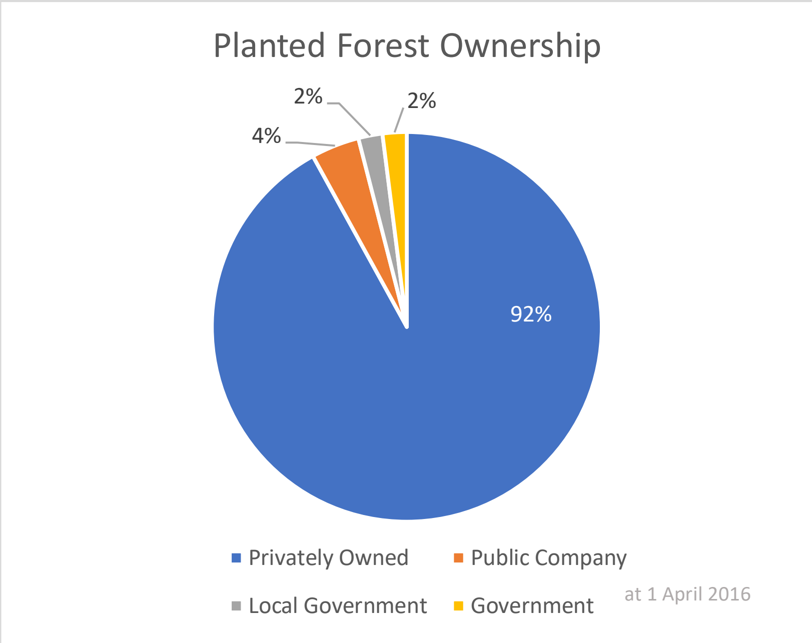
Managing forests is a long-term business. Radiata pine produces timber 28 years after planting and Douglas Fir between 45-60 years after planting. Hence, adaptation options are limited once trees are planted. Any strategic or transformative adaptation planning and implementation is a multi-decadal process requiring significant research and forward thinking (e.g. building in genetic resistance to disease, efficient water use, or productivity), as well as confidence of the forestry sector.

Forests will require adaptation to impacts of climate change to protect forest investment and to protect forests as a mitigation sink

Adaptive capacity is needed to react to impacts and risk, as and when they manifest. However, change in forest management practice is a long-term process and requires risk analysis that evolves over time, as new knowledge about localised climate impacts and the global effects of GHG emissions and reductions becomes available.

Much of the forest sector is in private ownership (as shown in Figure 4). As such individual businesses and owners hold the responsibility for adaptation planning and acting. The sector generally follows a **risk-based approach** to protect against likely impacts on the value of forest assets, e.g., fire, productivity, pests and diseases. Individual forest owners thus determine the level of risk they are prepared to accept before they start to adapt or mitigate the risk.

Figure 4: Planted forest ownership (NZFOA 2017)



3.2.1 SLMACC research in adaptation

SLMACC adaptation forestry climate research has addressed the impact of climate change largely on the Radiata pine growing forest sector, with some projects addressing other plant species, erosion control as well as carbon sequestration. Limited research has been undertaken on the impacts specific to Douglas Fir.

Forests will be affected by and are at risk from climate change, though changes in biological productivity and increased biotic risks (pests, diseases and weeds) to forest production and survival as well as increased abiotic risks (fire, storms, drought). An understanding of climate change impacts as well as adaptation strategies is critical to ensure the continued productivity of the forestry sector.

This report investigates at what has generated value for stakeholders to help guide future investments in forest climate change mitigation and adaptation research.

3.2.2 Analysing and assessing risk

Adaptation to changing risks of (for example) pests, fire and wind, will shape and influence the resilience of future forests. Risk is typically evaluated using standard risk frameworks (e.g. ISO 31000) enabling businesses, owners and other stakeholders to understand and adapt to the effects that a changing climate will have on their forests.

An example of climate change risk: Increased pests

Watt et al (2008) projected that the plantation area within New Zealand under current climate conditions as suitable for the establishment of the pest, pine processionary moth (T. pityocampa) is 6 percent; but this will increase to 82 – 93 percent under future climate scenarios.

Forest owners could lose up to 33 percent of their tree volume and value to this pest moth, under future climate changes.

While generic understanding of climate change impacts is required at a national scale, adaptation planning requires information at scales relevant to business and stakeholder's decision making. Risk and adaptation benefits and costs vary geographically and are influenced by individual choices and local contexts of decision making.

The ISO 31000 standard risk process requires different types of information to support decision makers move from risk identification through to risk management:

1. <u>Risk Identification</u>: Identifies the risks that arise from changing climatology: e.g. changes in temperature, precipitation, wind and storms.
2. <u>Risk Analysis and Risk Evaluation</u>: Developing information on potential impacts of identified risk on business operations and social licence, e.g. changes in productivity as well as fire, pest or drought risk and impacts on financials, the supply chain, downstream impacts and trade.
3. <u>Risk Management</u> – Adaptation or response to risk by developing information on management or other actions that enable adaptability in decision making depending on changing contexts of risk.

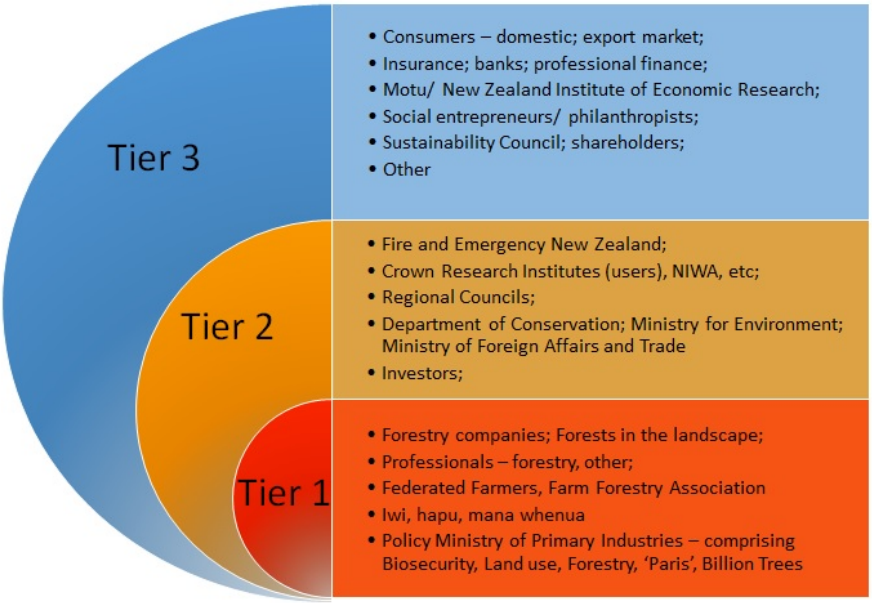
Effective risk analysis requires information that is salient, credible and legitimate (Cash et al, 2003) at each stage of a risk assessment and management process:

- Credible science is authoritative, believable and trusted; Credibility helps build confidence for decision making.
- Salient science is relevant to the contexts of decision makers, their choices and any choices made by others that may affect them.
- Legitimacy considers the perspectives of different stakeholders and how acceptable actions undertaken are.

4 Stakeholder identification

Three tiers of stakeholders were identified during a cross-review workshop: 1) immediate industry and policy stakeholders; 2) regulatory and research institutions; and 3) wider business, consumers, investors and community interests (Figure 5). Most of these stakeholders cut across areas of mitigation and adaptation research).

Figure 5: Three tiers of stakeholders



Mitigation stakeholders are those that develop and institute policy including central government and regional councils; are parties interested in the effect of any policy design or implementation, such as the ETS, for forestry businesses and other informers and advisors on mitigation actions and options.

Adaptation stakeholders can be defined as those that have either a direct or in-direct interest in protecting forest assets from the impacts of climate change, e.g., the asset value or potential liabilities from risks that affect their business such as fire risk, and the ability for New Zealand to meet mitigation targets.

Table 5 shows different mitigation and adaptation stakeholders. These are not mutually exclusive categories but show the alignment of the main audiences of the research at the time of this review, with other stakeholders who benefit indirectly from both areas of research.

Table 5: The characterisation of mitigation and adaptation stakeholders

Mitigation research stakeholders	Adaptation research stakeholders
Ministry of Primary Industries	Forestry companies; Investors
Ministry for Environment (MfE)	Fire and Emergency New Zealand
Ministry for Foreign Affairs and Trade (MFAT)	Crown Research Institutes
Forestry companies; Investors	Regional Councils
	Professional service providers
	Federated Farmers; Farm Forestry Association
	Ministry of Primary Industries
	Ministry for Environment
Domestic consumers; Export market; Insurance; Banks; Professional finance; Policy and economic research; Social entrepreneurs / Philanthropy; Sustainability Council; Shareholders	

Our survey respondents were predominantly from the forestry sector, government and research organisations.

The primary audiences of forestry research projects covered by SLMACC are summarised in Table 6. Twice as much funding had been allocated to the sector, compared to policy. Only one project, an innovative research project in the Waiapu focused on the community as its primary audience.

Table 6: Primary audience of research projects

End User	Count	Investment
Community	1	$500,000
Policy	11	$3,056,000
Sector	20	$6,292,000

Some of the research was conducted to provide policy advice while other areas of research impacted a wider range of stakeholders, e.g., directed at land management, risk reduction or to support decision making. None of the research was focused on actions that could be undertaken by forest owners or land managers specifically. This reflected the expressed need at the time of SLMACC funding initiation as addressing a lack of knowledge (basic research), rather than dealing with aspects of use (applied research).

5 Findings: Positive Impact and Value for Money

The results of our research assessment show that the SLMACC forestry research has had significant positive impact, particularly in building science capability and influence as well as in stakeholder's influence and impact for New Zealand.

Table 7 shows the assessment of SLMACC research measured against the agreed rubric areas of performance based on evidence from each of the research methods applied. More detailed subcategories of the rubric are shown in Appendix One, outlining the range of conditions assessed for each category.

Table 7: Rubric evaluation and sources of evidence

	Research lead interviews	Stakeholder surveys	Researcher surveys	Report summaries	BERA	Synthesis of evidence
1. Build science capacity and capability enhancement	High	High	n/a	High	n/a	**HIGH**
2. Influence on science	High	High	High	High	High	**HIGH**
3. Engagement and networks	Moderate	Moderate	Moderate	Low	Moderate	**MODERATE**
4. Learning, awareness and knowledge exchange	Moderate	Moderate	Moderate	Moderate	Moderate	**MODERATE**
5. Usability of research for end users	Moderate	High	Moderate	Moderate	Moderate	**MODERATE**
6. Influence on stakeholders	High	High	Moderate	High	High	**MODERATE - HIGH**

It is noted that creating impact was not a requirement of SLMACC research. Hence, the rubric provides for aspirational evaluation criteria, noting that the researchers cannot achieve high ratings for the rubric criteria 3, 4 and 5 as external factors have large and uncontrollable influences outside the control of researchers. They can however, take responsibility for criteria 1, 2 and to some extent, criteria 6 (Table 7).

The overall assessment does not capture the diversity of individual report ratings, which are now discussed to provide greater clarity for the assessment.

5.1 Science capacity and capability - High

One of the noted values amongst researchers of SLMACC was the ability to maintain New Zealand based science capability in climate change research. The extent to which research has been advancing science knowledge was demonstrated through the publication of papers, particularly in relation to future forest systems and their associated climate change impact risks and opportunities, such as forest pests and diseases as well as productivity. Other research was focused on providing information to policy analysts as well as to a more general audience e.g., the introduction of an ETS through carbon stock tables that could be applied to assess carbon sequestration of growing and mature forests.

SLMACC produced results that rated highly in terms of science capacity and capability engagement, including:

- Projects that were developed sustained capability, e.g. in critical areas of impacts and risks, and developed new areas of understanding, e.g., on disturbance impacts;
- Policy oriented research was targeted to specific issues that supported the efficacy of the policy development;
- SLMACC provided a significant funding source for adaptation research that maintained and built capability within New Zealand;
- SLMACC capacity lead to increased capability where some researchers were able to successful compete for other funding.
- SLMACC has enabled researcher interactions with end user and identified key risks for end-users to address, such as the impacts of fire and importance of preparedness
- SLMACC has increased awareness of asset vulnerability and the need for management interventions

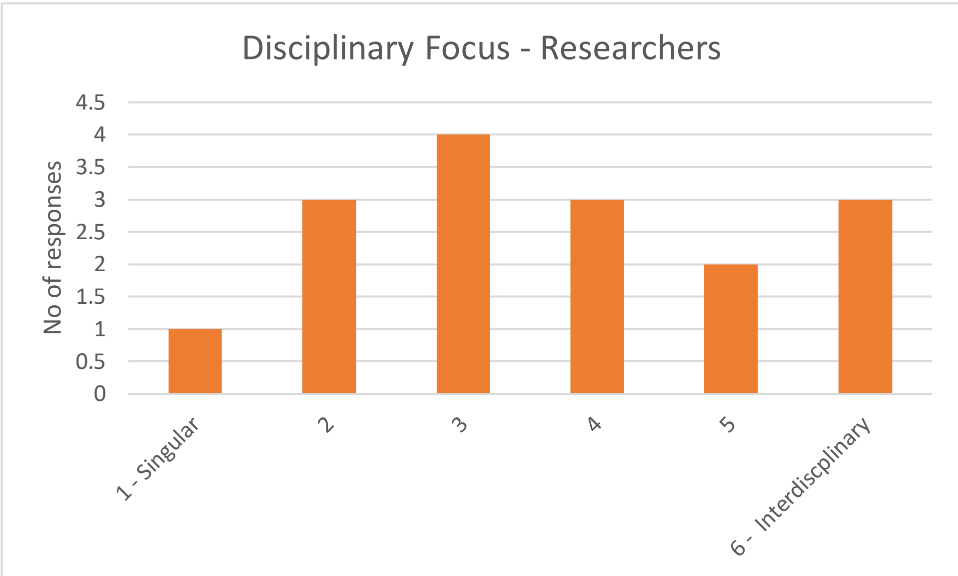
The SLMACC programme supported and maintained a small set of researchers that have developed detailed knowledge of the topics (adaptation and mitigation) and are well-networked into sectors and communities. Furthermore, some of the key researcher had the ability to build on previous SLMACC and non-SLMACC funded research to strengthen areas of expertise and provide benefit to New Zealand and sector stakeholders, as well as improved the international reputation of New Zealand climate research.

5.1.1 Developing collaborative capacity

One of the areas in which SLMACC funds contributed to increased capacity has been in developing collaboration amongst researchers. The results from the BERA indicate that for many of the projects collaboration and partnership building aspects of the research returned greater impact than was invested (see Annex and Figure 16).

Survey responses indicated that a range of disciplinary areas have been supported by research projects (Figure 6).

Figure 6: The disciplinary focus of the research



The indications are that the SLMACC projects deployed some degree of cross-disciplinary research across all projects, with only minor exception.

5.2 Influence on science - High

Most forestry focused research built and developed science knowledge, particularly through cross-disciplinary research, e.g., combining climate models with fire risk analysis. Although further influence on science was limited due to lack of follow-on SLMACC contracts, some areas of research have been taken up through other funding programmes, illustrating the strength and relevance of SLMACC research outcomes for New Zealand. Most reports identified gaps in knowledge, e.g. where new science questions were raised, and where further information was needed to improve knowledge. SLMACC influenced and supported complementary research, e.g., at Scion and NIWA, on developing understanding of the influence of changed weather patterns on wildfire danger.

SLMACC yielded strong results in terms of academic publications, averaging 14 peer review papers per annum, and with 139 academic papers by authors on the same topic as the SLMACC projects. This demonstrates the integration of science and SLMACC, and SLMACC projects being part of a wider science environment. Some reports were not expected to have an impact on science, as they were policy-related or communication projects primarily gathering knowledge and/or providing information.

It is notable that SLMACC was largely, and continues to be, the sole long-term funding source for adaptation research, a critical area of need for being able to respond to climate change impacts.

5.3 Engagement and networks – Moderate

The engagement was evaluated as moderate, as few projects had high levels of engagement and some projects had a low level of engagement with stakeholder networks. Only one report required engagement during the research process, and a few others had other limited forms of engagement or very high engagement levelling out the rating to moderate.

There was no stipulation in the contracts for the researchers to engage with stakeholders. Higher levels of engagement reported in stakeholder surveys reflected the initiative of researchers or research organisations and extent of their stakeholder networks. Some projects demonstrated a high level of sector engagement. Others were specifically linked to policy stakeholders and generated a good level of policy engagement.

Despite the absence of any formal requirements, Figure 7 shows that just over 50 percent of end-user respondents found that SLMACC research gave them access to new networks or new people.

Figure 7: Access to new networks people arising from SLMACC research

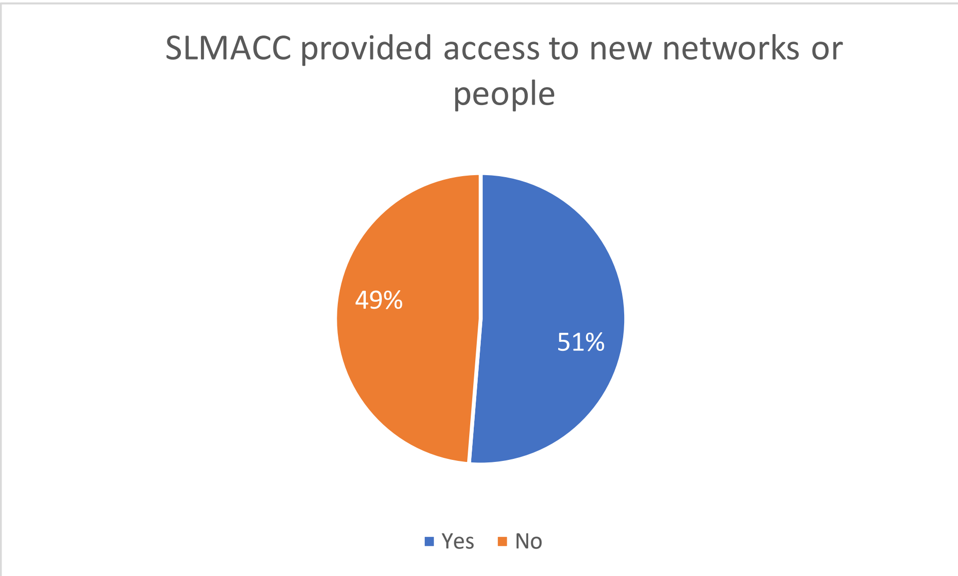
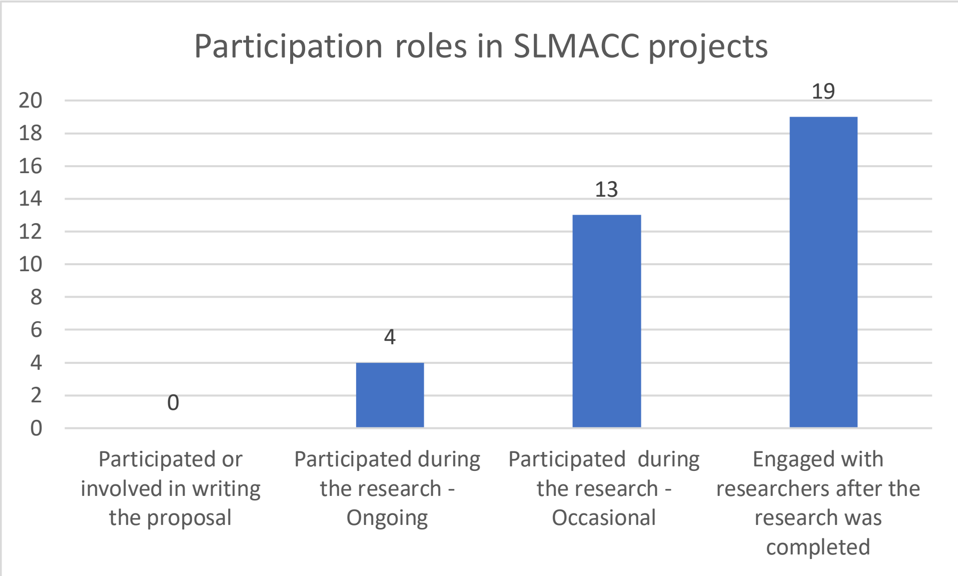


Figure 8 shows that engagement predominantly took place during or after the research. None of the stakeholders surveyed indicated that they were involved in writing the proposal.

Figure 8: Participation in SLMACC projects



Research and stakeholder survey respondents were asked about the nature of the networks participating in the projects. Perspectives on whether the projects' network participation was of a diverse (heterogeneous) or similar (homogenous) nature varied. Figure 9 shows that a slightly larger number of respondents (20) saw the research as more on the side of homogenous than heterogeneous (17). Researchers were more inclined to see research as involving more a homogenous network of participation than heterogeneous.

Figure 9: Characterisation of Participation across SLMACC projects - Stakeholders

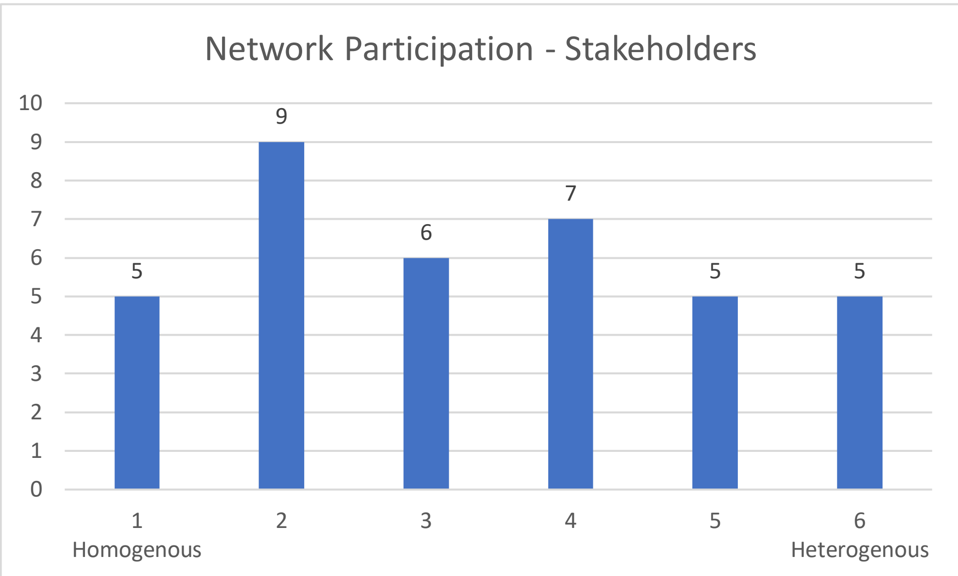
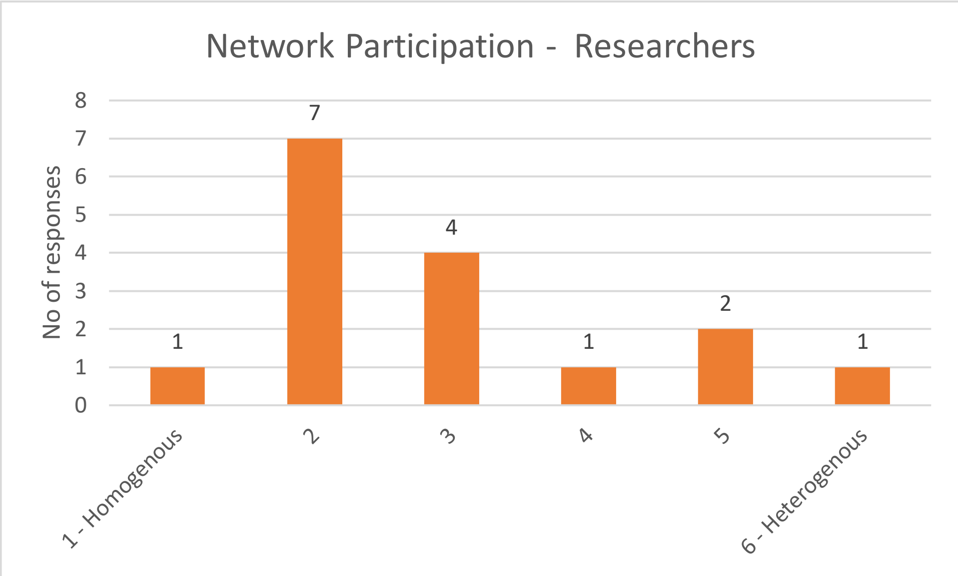


Figure 10: Characterisation of Network Participation across SLMACC projects - Researchers



5.4 Learning, awareness and knowledge exchange - Moderate

The technology transfer process of SLMACC followed a linear framing of research uptake and, in most projects, it was quite limited. Typically, technology or knowledge transfer followed mechanisms that limited learning and exchange of knowledge (Dunningham et al, 2014). One concern, in terms of creating impact for adaptation, was the finding that there were no requirements for data to be provided to stakeholders directly. This may have limited development of methods and tools that would enable detailed risk assessments for individual circumstances.

It is clear from survey responses and previous interviews that the reports have built climate change awareness in the forest growing sector. Indeed, some reports were shared both internally within stakeholder's organisations and externally with other stakeholders. Furthermore, some forestry companies had dedicated staff who managed research interactions and who took some responsibility for forwarding research to relevant staff.

Some of the research conducted had specific audiences, e.g. the life cycle analysis and the albedo research that may help inform or contribute to policy debates and discussion for raising new research questions. However, most mitigation projects provided immediately useful information for a policy audience such as analysts within MPI/MFE responsible for developing the ETS.

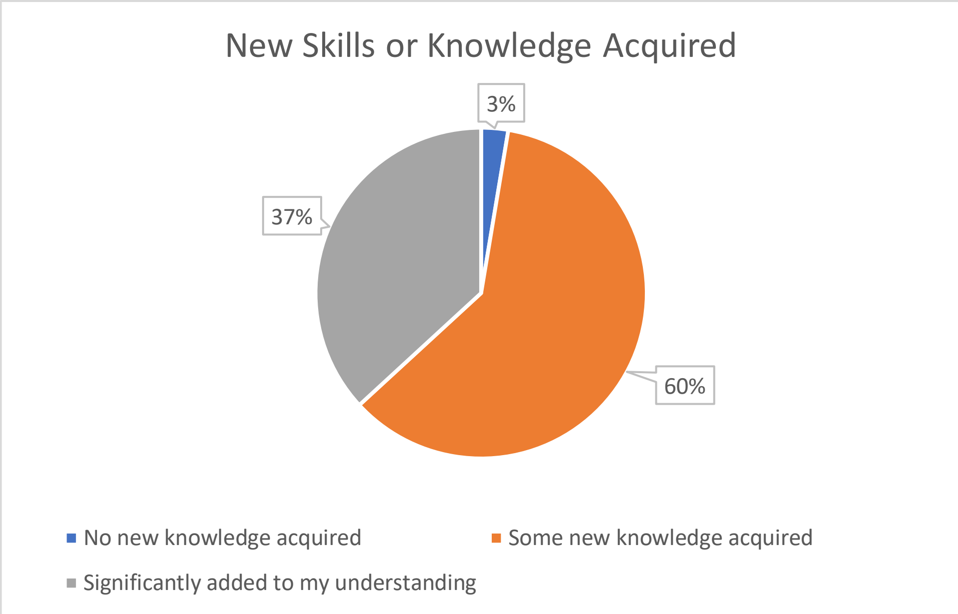
The findings from the stakeholder survey around the acquisition of new skills or knowledge indicate that learning, awareness and knowledge exchange among end users was high (Figure 11).

Much of the learning and knowledge exchange can be attributed to the initiative of the researchers and sector stakeholders. The findings from the surveys indicate that:

- the research provided new knowledge and new skills, and understanding to stakeholders; and

- the projects were successful in expanding networks across researchers and end-users.

Figure 11: New skill and knowledge obtained from the SLMACC research projects



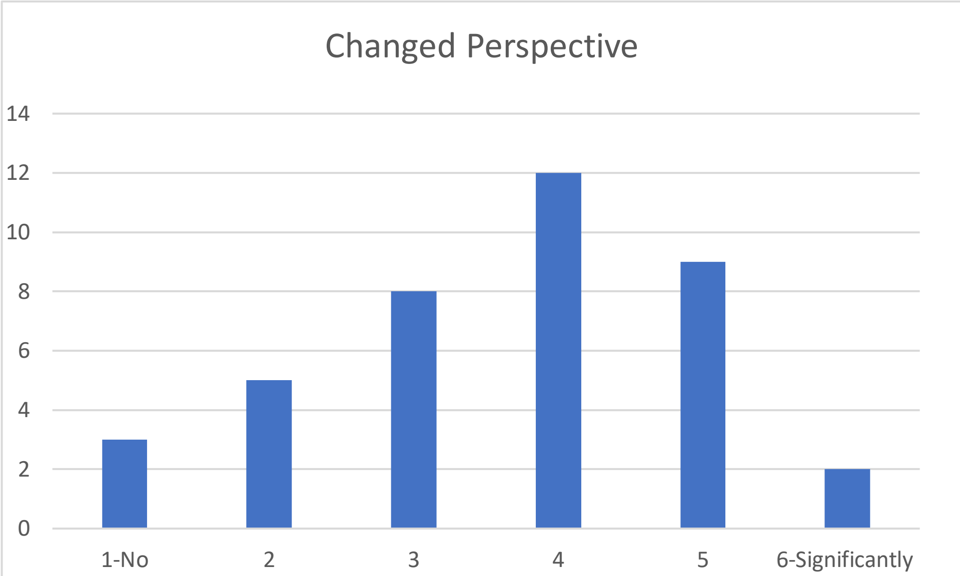
Overwhelmingly respondents acquired some new knowledge (60%), many of whom felt that the knowledge gained had significantly added to their understanding (37%).

Learning and awareness was highest amongst those sector stakeholders who had been involved in the research, indicating that opportunities for engaging with the research were valued and valuable for sharing knowledge. Furthermore, findings from the previously conducted interviews (see Table 3) supported these results, as illustrated by the following summary:

- SLMACC research has significantly contributed to raising the awareness of climate change risk to the sector.
- Industry stakeholders could articulate the risks to their forests and where risks will increase, while some referenced SLMACC reports that were critical to increasing their awareness.
- Interviews found evidence that industry had read, understood the messages and internally responded to the messages.

Respondents to the survey conducted for this 2018 review did find themselves with a change in perspective from SLMACC research projects (Figure 12), with only two indicating no change in perspective and 36 indicating a change. Twenty-three indicated a substantial change in perspective rating of 4 or more on a scale of 1 (no change) to 6 (significant change).

Figure 12: Change in perspective of End-Users from SLMACC research projects, by project



Additional comments received from survey responses indicated that the role of trees and forests was critical to the national response to climate change and that the need to manage the associated risks, such as increased fire danger, specifically increased awareness because of SLMACC research.

5.5 Usability of research - Moderate

Usability related to whether the research was salient, i.e., whether the research was delivered to end-users in a way that could influence their practice, considering the user's specific circumstances of knowledge need.

As part of the systematic review of report summaries, key research messages were assessed according to their usability for end-users. Table 8 below summarises the usability of the research with respect to different types of stakeholder for each project reviewed. A more detailed analysis of each report uses in given in the Annex.

Some examples of potential uses for different end users in the report summaries include:

- Developed understanding of the benefits and management options for end-users engaging in the ETS.
- Developed data and information that underpins the ETS Carbon credit calculations and for international (UNFCCC / IPCC) reporting.
- Provided detailed understanding of climate change related risks including pests, wind and fire.

"[SLMACC research] confirmed the very important place trees and forests provide to sustainable land use, which now needs to be factored into the national landscape more broadly."

Stakeholder survey

- Provided understanding on aspects such as drought tolerance for establishing alternative species, including other exotics and indigenous species.

Other areas of research benefit included alternative management approaches for steepland forests, new methods for plant breeding, using surveillance technology to target areas of greater risk; and other aspects of more targeted risk mitigation including alerting fire authorities to future fire danger.

Stakeholders responding to the survey had received significant benefit in terms of the knowledge and information that mitigation and impact research had provided

SLMACC research may not have been appropriately structured for delivering research usability, although, the strong networks of scientists and sectors helped mitigate this. Scientists were involved in other research which had sector engagement, and some had detailed understanding of forestry businesses through either professional training or long exposure to forestry.

Survey findings indicate that written reports were the primary means of transferring knowledge, which may have limited uptake. Written reports, without other forms of engagement (see Section 7.1, Figure 18), do not necessarily create high forms of impact in stakeholder's businesses or operations, especially where there is limited awareness or ability to adapt findings or highly technical knowledge to end-user specific needs.

Generally, SLMACC research did not develop tools, data or methods that supported decision makers in undertaking climate change risk assessment or vulnerability analysis for their specific businesses or operations. Rather the focus was on providing policy and sector guidance at a national scale.

There was an indication that general information was assisting with decision making, particularly around high-risk sites and understanding the impacts of extreme weather events such as wind, drought and the real costs of harvesting steep hill forests. Nevertheless, overall the findings indicate that tools and approaches need to be more context specific, so that they could inform end users, e.g., in making local business choices and risk management plans.

Table 8: Summary of end-users and potential uses for each report

Title	Lead Author	Type of user	Potential uses
Forest and forest land valuation-how to value forests and forest land to include carbon costs and benefits?	Meade	Forestry investors; Forest owners	Build awareness of issues and options of valuing pre-1990 and forests-within-ETS based on New Zealand Unit (NZU) prices, with an Illustrative scenario. The method allows for the inclusion of market (NZU price) uncertainties and how land-use decision making allows for optimising ETS forest management decisions over both carbon and timber value possibilities and other land use options for pre-1990 forests.
		Policy	• Identifies barriers to entry for new carbon forests, in exposing the issues of valuing forests that are managed for carbon. • Identifies potential issues arising from volatility (or low) pricing of carbon units in the development of carbon forests.
Carbon Stocks and Change in NZ's Soils and Forests, and the Implications of Post-2012 Accounting Options for Land-Based Emissions Offsets and Mitigation Opportunities	Kirschbaum	Policy	The report has analysed in detail the accounting options for the exotic and indigenous forestry and soil carbon. The report has detailed the weaknesses, information gaps, uncertainties and research priorities which can be used to address policy development and research priorities.
Implications of Changes in Albedo on the Benefits of Forests as Carbon Sinks	Whitehead	Policy	The research identifies that the carbon sequestration obtained from converting pasture to forestry is not 100% due to the change in the albedo effect. Forest cover has lower albedo meaning that more energy is absorbed which causes further warming. Better impact assessment of land-use changes is likely to be beneficial to carbon accounting.
Development of forest productivity surfaces	Kirschbaum	Forest investor; Forest owners; Policy	Forest productivity surfaces can assist decision making and reduce landowner uncertainty about land management. The surfaces support afforestation to sequester CO_2.

Effects of natural disturbance on forest carbon	Holdaway	Policy	Estimation of annual carbon emissions for both natural and planted pre-1990 and post-1989 forests, and for baseline natural disturbance estimates for Forest Management Reference Level and Afforestation/Reforestation reporting.
Gorse and broom to forest	Holdaway	Policy	Gorse can be used as a nursery crop for regenerating broadleaved native trees species. Allows Carbon in regenerating gorse stands to be predicted relatively accurately by measuring gorse height for C accounting.
Improved allometric functions for broom and tauhinu		Policy	Prediction of carbon stocks in broom and tauhinu
Allocation of New Zealand's harvested wood to domestic and export products	Wakelin	Policy	Roundwood removals during the second commitment period (Kyoto protocol) are expected to be mainly from pre-1990 forests. Accounting for these forests is against a reference level so the exclusion of exported raw materials from accounting will have a neutral effect since the same assumption is made in reporting as in the reference level. The issue is of greater importance for post-1989 forest harvesting, which will be more significant after the third commitment period (CP3) under Kyoto (now replaced by Paris).
		Forestry investors; Forest owners	Other accounting exclusions remove harvested wood products (HWP) originating from imports, deforestation and non-forest land uses, but the amounts involved are relatively small. The use of half-lives specific to New Zealand-grown HWPs in export markets may also have a negative impact as Radiata pine tends to be used in market segments with short life spans.
Building resilience through community generated forestry strategies	Warmenhoven	Policy	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. Led to further research, - MBIE funded “Weaving the Korowai” on Adaptive Governance.
		District councils	Livelihoods approaches offer a way of bridging the gap between macro-level policy and institutions and the micro-level livelihood options of communities and individuals. The development of the Livelihoods approach reflects wider shifts in approaches to development towards a focus on human well-being and sustainability rather than economic growth.

		Land use planners	The tool is useful in shaping future deliberations over land use in the catchment and in understanding both the benefits and impacts (both primary and secondary) of policy decisions in a more holistic way. .
		Community	The Waiapu community's ability to respond to impacts of climate change was found to be limited by their access to financial capital. This finding led to changes to the government's Erosion Control Forestry Programme (ECFP) payment schedule. This in turn increased uptake of the programme by allowing the community to participate in the ECFP without having to provide all the investment upfront.
Carbon sink potential of naturally durable hardwood species in comparison to alternative hardwoods species preferred for timber production.	Meason	Forest Investors; Forest Owners	• Calculating the productivity of three Eucalyptus species • Calculating the carbon sequestration of Eucalyptus spp.
		Policy	Calculating the carbon sequestration of Eucalyptus spp. for carbon accounting
Climate change and fire danger	Pearce	Forest Investors; Forest Owners; Rural Fire Authorities	• Provides evidence based analysis on the projected fire risk under climate change. • Projects increases in seasonal severity and the increase in days where fire risk is rated very-high and extreme. • The risk maps can be used by forest owners and rural fire authorities to modify risk management and response processes.
		Financial institutions	The information is also useful for financial institutions, e.g. banks, insurance who have exposure to forestry assets to update their risk exposures and potential liabilities.
Development of ETS look-up tables	Beets	Forest Investors; Forest Owners; Policy	• Will help better estimate carbon sequestration in forests using look-up tables based on growth indices. Improving the nitrogen fertility index surface is critical to better assess these indices, used as inputs for the Forest Carbon Predictor model. • Updated look-up tables are required to fill knowledge gaps to more accurately reflect tree growth rates and hence carbon sequestration of many species that are not widely planted.

			• Realistic estimates of carbon sequestration potential in a range of tree species can support decision making among land owners.
Douglas-fir Model Enhancement for Carbon	Beets	Forest Investors; Forest Owners; Policy	The research allows end-users to provide more accurate carbon stock estimates for D. Fir.
Drought Tolerant Species Selection	Dungey	Forest Investors; Forest Owners; Science	The application of the δ13C technique can be used to select water-use efficient genotypes throughout commercial orchards and /or the Radiata Pine Breeding Cooperative production population.
Future Forest Systems	Watt	Forest Investors; Forest Owners; Financial Institutions; Land use planners	This report detailed the productivity implications under climate change for four species: Radiata pine, Eucalyptus fastigata, coast redwood, and kanuka-manuka stands. Key uses • Understanding and awareness of changes in productivity of different species; • Understanding the geographic response to climate change impacts on productivity, especially areas when productivity is projected to reduce due to resource limitations; • Understanding the science, and limitations of potential productivity gains under climate change; • The productivity maps reduce investor risk particularly within new areas for which there are sparse productivity data. Maps also provide useful information for regional planning. This information could be useful: • To develop projections of afforestation that would facilitate planning around infra-structure requirements; • Data (if available) could be used to generate impact surfaces identifying site that are exposed to impacts and their sensitivities.
		Policy	At the national level, productivity data could be used to develop spatially explicit afforestation area targets to offset future emissions. This type of information could be

			used to make informed decisions at the national level on how to develop policy to expedite afforestation.

		Forest Investors; Forest Owners;
		Risk analysts and managers (Biosecurity policy and programmes; Rural Fire Authorities);
		Financial Institutions;
		Land use planners and managers
			<u>Report section on Climate change impacts on productivity – 'Indirect Effects'</u>
			This section identifies and models the impacts of climate change on disease severity, fire risk and wind risk.
			Key uses are:
			• Improved risk and impact awareness arising from the
			    • Detailed understanding of how climate change affects the severity of different diseases
			    • Detailed understanding of how climate can affect abiotic risks such as fire and wind.
			    • Improved risk understanding from how climate change could affect other diseases, or pests.
			• Develop spatial models and decision support systems that integrate complexities and appropriately weight risk factors can determine how climate change is likely to influence the future distribution of New Zealand plantation species.
			• Develop understanding on the impact on the economics of forestry and management options based on an increasing fire frequency with a resultant need for greater areas of productive forest land to be set aside for firebreaks, water points, or fuel breaks/buffer zones of less flammable (and less productive) species and the likelihood of increased expenditures on fire prevention activities, provision of firefighting resources and fire suppression.
			• Develop understanding of new risks arising from increased fire load based on interactions with potential insect damage, increased productive capability of weed and understorey species, increased wind and storm damage all adding to available fuel sources.

Future proofing plantation forests from pests	Watt	Forest Investors; Forest Owners	• Stakeholders can use the results to develop management plans that address the increased risk arising from range expansion and implied growth improvements. The data can help identify options for early detection monitoring programmes. • Can be used to develop generic pest management and monitoring programmes for other diseases, weeds and insects.

		Policy	The results can be used to address biosecurity policy and procedures at entry points and dispersion pathways as well as incursion management plans. More comprehension range of species may provide prioritisation for policy and incursion management.
Improving the Eucalyptus fastigata growth model	Meason	Forest Investors; Forest Owners	This tool allows foresters, investors to predict yield prediction which is a requirement of foresters being able to obtain ETS credits for carbon stored in trees.
		Policy	The tool provides a reliable carbon sequestration model which can meet NZ's commitment under the Kyoto protocol and IPCC LULUCF reporting.
New forest management approaches for steep hill country.	Amishev	Forest Investors; Forest Owners	• Provides confirming information on the problem of steepland harvesting • Provide information that end-users can consider in mitigating the effects • Identifies the issues of cost and returns in developing options for managing the downstream effects of steepland harvesting
Reducing Harvesting Costs	Heine	Forest Investors; Forest Owners	• The systems model developed can be used to define factors having a large influence on harvesting productivity. • This knowledge can help to identify opportunities for short term improvements in harvesting methods, and evaluate the potential for long term approaches to harvesting on steep sites. • Create systems that reduce the problems (economic and social) associated with steep country harvesting and that also reduce death and injury in this dangerous operation.
Resilient new indigenous forests	Dickie	Indigenous forest owners; Policy; Land owners	Mitigation through forests is not limited to exotic species. This report provides information for end-users on establishing beech spp. trees on grassland: • Prediction of indigenous forest distributional range may help landowner's decision making under NZ commitments for the Kyoto protocol.
Forest Management for Carbon and Carbon Price Risk	Turner	Forest Investors	Options for developing and managing forests for carbon, the potential management decision implications as well as implications for estate scale management.
		Forest Owners	Identifies the complexities in managing for traditional returns and for carbon returns. Methods for understanding the problem and options are discussed.
		Policy	Identifies drivers and potential barriers to the establishment of carbon forests

Life Cycle Assessment (LCA): adopting and/or adapting overseas LCA data and methodologies for building materials in New Zealand.	Nebel	Building and construction sector; Policy	• The research results provide some data that allows for NZ assessment of the life cycle of building products, and in combination with the greenhouse gas footprinting research for the forestry sector, can be used in research projects around the environmental performance of different building types. • The results can also be used to research building systems and the relationship of embodied environmental impacts vs. impacts due to the use of a building. • Assessing environmental impacts of building materials (including the CO_2 impacts) can promote commitment among stakeholders to use systems that reduce CO_2 emissions in production and use.
The Effect of Climate Change on New Zealand's Planted Forests: Impacts, Risks and Opportunities.	Watt	Forest Investors; Forest Owners	Developing qualitative understanding of risk as it potentially affects current and future estates. The report is not a risk assessment, but identifies a potential framework for considering risk, albeit with more research required.
		Policy	Identifies issues that could affect forests and the industry sustainability and the role of government institutions in mitigating or helping in adapting to the risks.
Novel poplars and willows adapted to a changing climate	McIvor	Land managers; New forest owners; Forestry science	Improve understanding of the adaptability of specific poplar and willow clones to projected climate change
Managing risks in carbon forestry	Manley	Forest Investors; Forest Owners	This research allows potential investors, existing forestry growers and farmers to understand the risk factors associated with carbon forestry.
Forest risk management strategies- how can forest owners manage risk and uncertainty associated with carbon prices?	Harkin	Forest Investors; Forest Owners; Policy	Allow end-users to assess a range of risks and possible risk management strategies associated with carbon forestry. This can feed into ETS participation decision, financial risk management and policy levers that can reduce risk.

Quantification and Management of the Risk of Wind Damage to New Zealand's Planted Forests	Moore	Forest Investors; Forest Owners	The research enables end users: • To be able to quantify the risk posed by wind damage to planted forests; To investigate different options that owners of forests registered under the Emissions Trading Scheme (ETS) can use to manage this risk; • Evaluate different wind damage adaptation strategies; • Evaluate whether to use wind damage probability models to assess localised impact probability and test different management (silvicultural) strategies; • Consider the risk of wind damage when decisions on thinning and harvesting of stands are made.
Forestry Accounting Options	Roberson	Policy	This research provided input into how carbon accounting can be undertaken in NZ. It evaluates three different options as well as challenges arising from the (then) current accounting system.
Carbon Accounting: Forest Growth Rates and Changing climates	Mason		Models that consider climate can be used to evaluate changes in productivity as climate changes. '
Impact of the ETS on Forest Management	Maclaren	Forest Investors; Forest owners	Stakeholders knowledge on the drivers of profitability for carbon forests

5.6 Influence on stakeholders and impact for NZ – Moderate to high

The influence of research on stakeholders and impact for New Zealand was evaluated as moderate to high. Many of the reports have been successful in providing information on impacts to stakeholders, and by inference to New Zealand. The major impact has been in building awareness, based on science, and on the potential impact and implications of climate change on forestry.

5.6.1 Mitigation via improved carbon accounting

The research has underpinned positive impacts in terms of decision influence or change in several mitigation policy and science areas, e.g. it has:

- Enhanced New Zealand's ability to report to UNFCCC and meeting our Kyoto targets (forestry sinks are a priority to meeting commitments).
- Provided understanding on components of tree carbon sinks, such as roots and branches, and thus improving the accuracy and reliability of the carbon accounting system.
- Provided more detailed and accurate understanding on soil carbon dynamics in shifting land use, e.g. from pasture to forestry.
- Enabled New Zealand to retain capability with carbon calculations, which is a highly technical skill (mainly within Scion, not so much within MPI). Carbon calculation skills have facilitated the internal trading of carbon in a more accurate way (ETS), which a key policy stakeholder noted, "This is worth millions ($)".
- Developed 'look-up tables' on different species for the ETS, enabling up to 3000 forest owners to more easily calculate the amount of carbon credits they can claim. Improving ETS can provide up to 30 percent difference in the value of a forest.

"These reports add to the body of knowledge on impacts of climate change, which need to be tracked over time since the stressors will change. [It is] important to keep updating the research in an efficient manner.

A risk management tool would help do this as well as monitor what the industry is doing to plan for the effects of climate change. "

Stakeholder survey response

5.6.2 SLMACC is meeting industry knowledge needs

The research has met previously identified industry information needs on climate change: understanding impacts and opportunities arising from climate change policy, understanding risk and impact, and understanding potential adaptation strategies.

Climate change and policy knowledge needs have been addressed by the above (Section 5.6.1) as well as an understanding of the:

- implications of the ETS policy on the sector, and other research focused on mitigation research, e.g. developing data and information for Kyoto reporting; and

- modelling of carbon in forest and other systems to support the development of carbon cycling and storage knowledge, underpinning participation in GHG reduction.

"The case for trees is supported … we need to ensure the values [are] able to be provided to the wider community by planting the right tree in the right place is widely understood."

A lack of understanding of impacts and risks on forests has also been met by new knowledge of the:

- direct and indirect impacts on forest management, based on increasing temperature, increasing CO_2 concentrations, and changes in precipitation, and the potential increase or decrease in whole tree productivity; and
- impact of climate change on other influences on productivity within the forest ecosystem, including physical (abiotic) risks arising from changing wind and fire environments and biological (biotic) risks of the competitive impacts of weeds, and the destructive impacts of pests and disease.

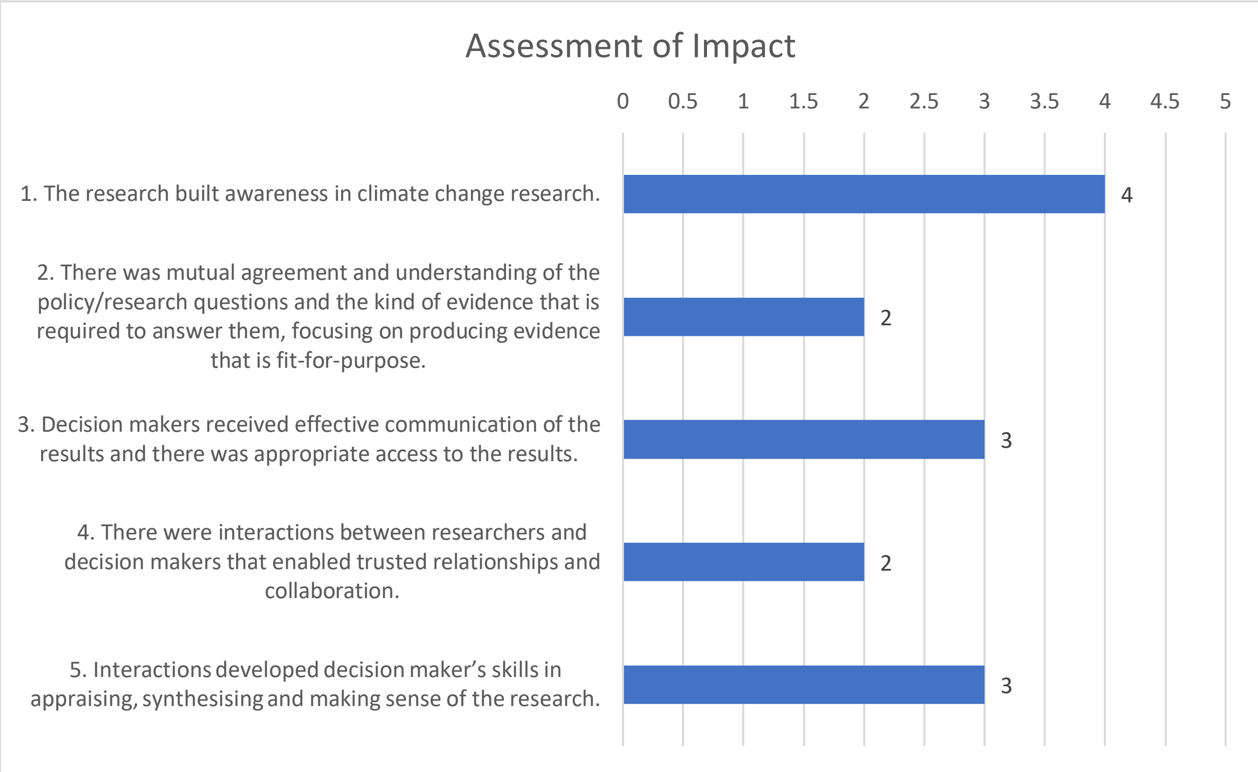
A lack of understanding of adaptation strategies has also been addressed:

- The review project chapter on forestry (Dunningham et al., 2012) has provided a comprehensive understanding of forest management adaptation options for the sector.
- Research has enabled some organisational adaptation, e.g., actively managing environmental risks such as snow and wind through changes in planting regimes towards use of Douglas Fir in some sites; and to some changes in practices, and a clearer understanding of fire danger (now well understood and a priority for most forest owners).
- The productivity surfaces were a useful guide for end-users understanding changes in productivity and ETS benefits and could benefit from additional consideration of risk surfaces.

5.7 Assessing impact: Evidence of research informing decision making

This forestry review also examined the nature of impact, evaluating how research can facilitate evidence-informed decision making (see Appendix Two). Langer et al (2016) developed a hierarchy of six types of impact that increases the use of research evidence in decision making. Based on the review of research reports and data collected for this evaluation, SLMACC forest climate change research has been assessed against each of the six impact statements adapted from Langer et al (2016), as shown below in Figure 13. Rating criteria range from no evidence (0) to very strong evidence (5) of impact on decision making.

Figure 13: Assessment of impact by stakeholders



1. **Built awareness (4 out of 5):** There was a good degree of understanding demonstrated and indications that the research was shifting stakeholder perceptions towards systems change and willingness for further knowledge generation.
2. **Agreement (2 out of 5):** There was limited engagement with end-users in discussing research areas or the way evidence could be used to address specific policy or end user questions, with fit-for-purpose information provision to stakeholders restricted to summarised material in written reports; although some exceptions provided data[6] that could be used by stakeholders.
3. **Communication and access (3 out of 5):** Communication with end-users varied from none (only one project had no report) to significant communications where communication built on the existing researcher networks and researchers' understanding of the forestry sector. Research results were generally provided via written reports, and occasionally through presentations, although not all reports were available, limiting the level of access.
4. **Collaborative interactions (2 out of 5):** Initial development of trusted relations is evident with many projects although only one directly involved stakeholders in developing the research questions, also the extent of meaningful collaboration in research design is encouraging but limited to only one project directly involving stakeholders in developing the research questions.

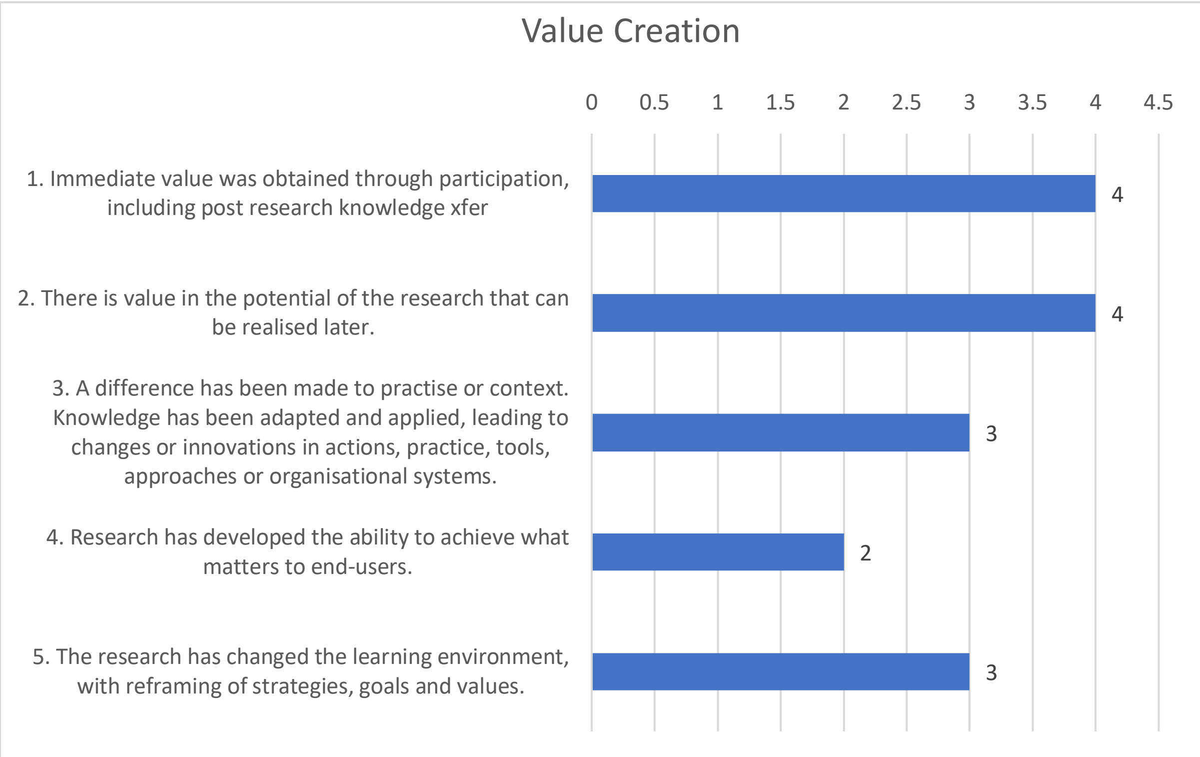
[6] Some of the mitigation focused projects provided codes and carbon stock tables to enable more robust predictive accounting and forestry planning under the Emissions Trading Scheme.

5. **Skills and capability (3 out of 5)**: SLMACC has benefited from the sector investment in significantly improving implementation of research results. However, issues with reach and access to reports limited the impact created to date. Mechanisms for engaging stakeholder in research processes and ensuring results are disseminated were limited.

5.8 Assessing impact: Evidence of value creation realised

Based on the data collected for the review and previous interviews the SLMACC research has been evaluated against five types of stakeholder value creation (Wenger, Trainer and de Laat, 2011) (Figure 14). Wegner et al. 2011 identified value that can be immediate, potential, applied, realised and reframed.

Figure 14: Assessment of stakeholder value creation from SLMACC research



As with the previous impact on decision making assessment, the rating criteria for value creation ranged from no evidence (0) to very strong evidence (5), and is summarised by the following:

1. **Immediate value (4 out of 5)**: Most of the research provided immediate value to end-users including better understanding of the role of forests in mitigating climate change, e.g. carbon accounting, new approaches to predicting growth rates, and realising the magnitude of harvest costs in steeplands.
2. **Potential value (4 out of 5)**: Much of the research conducted has potential to be further developed and with value to be realised later, e.g., in developing new drought tolerant species, shifting carbon stock tables to focus on alternative species and understand of what species will be best suited to different regions.

3. **Applied value (3 out of 5)**: Some of the research provided underpinning understanding of climate change impacts or has addressed policy questions. For example, research has already provided knowledge and benefit that has been adapted by end-users including better consideration of risks associated with climate change such as pests and disease and fire and wind risk; as well as policy and sector benefits for using forests for climate change mitigation such as developing ETS carbon stock tables and other carbon accounting methods.
4. **Realised value (2 out of 5):** The nature of the conversation on climate change impacts and implications has changed with more industry engagement and acceptance of the science behind climate change knowledge; and a greater appreciation of risks and opportunities for responding to climate change including changing in risk management and development of alternative plantation species and systems to meet productivity as well as carbon credit and other environmental benefits, however shifting forestry practice change is still limited (partly as a result of long lead times for change).
5. **Reframed value (3 out of 5)**: While most respondents indicated that there had been no change on their or other organisation's goals or reframing of strategies, there were some key areas of change, e.g., in responding to the effects of wind and fire danger along with changing species selection and realising the need to factor in adverse impacts of forest harvests on erosion, thus providing some indication of shifting goals and priorities.

5.8.1 Applied value – Changes in practice

SLMACC research has provided new resources to end-users, with new understandings of management approaches for steep hills country and new methods for pine breeding, as well as the revision of surveillance technology to target areas of greater risk. Other aspects of more targeted risk approaches have included:

- alerting fire authorities to future fire danger and partnering response preparedness;
- understanding the magnitude of wind impacts;
- Impact of drought on hill country trees and the magnitude of costs for harvesting in hill country;
- understanding the impact of albedo on sequestration under land-use changes; and
- developing spatially based productivity value across all of NZ also provided new areas of analysis for forest investors and owners.

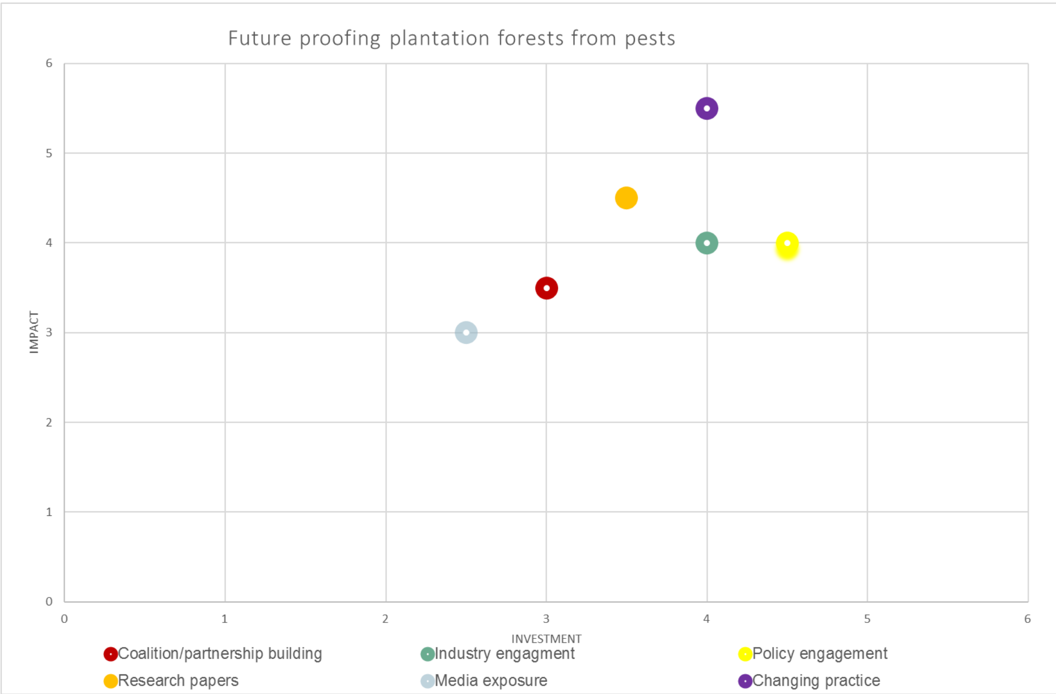
"Probably the significant one for us has been … changes in the sort of disease vulnerability of our forests and we've relied on some of what the research has done in the past to show us what the long-term risk profile is for our region with climate change."

Stakeholder interviews (CCII, 2016)

Survey results indicated that better understanding of risk was leading to practice changes, including decisions around development and use of plantation species and models to minimise pest and wind risk. There has been some limited adaptation, included reviewing whether to plant Douglas Fir in the North Island due to increased projected levels of Swiss Needle cast. Research into breeding for disease resistance has also increased (e.g. Dothistroma) levels of preparedness for anticipated climate change impacts.

Protecting against plantation forest pests is an area in which significant risk to the sector results in benefit from investments in research and the development of tools to mitigate or eliminate risk. With respect to the research on future proofing plantation forest from pests, stakeholders have indicated that the impact or benefit of research has outweighed the investment in areas of building partnership, research publications and changing practice. However, it has been less significant in terms of policy and industry engagement (Figure 15).

Figure 15: Stakeholders assessment of six areas of impact against investment using basic efficiency resource analysis for the Future Proofing Plantation Forests from Pests research



5.8.2 Reframing value – Redefining success

There were some key areas of reframing by stakeholders based on SLMACC research. For example, there was a greater focus on reverting forests from cleared land more broadly, and interest in getting better information around ETS for some species, as well as understanding how to protect future forests from biosecurity pests. A wider selection of species was a key aspect of shifting organisational goals. The ETS was also seen as an important instrument for realising environmental services from forests, but was thought to need further development.

An earlier research programme looking at climate change impacts and implications (CCII) (Lawrence et al., 2016) noted limited understanding of inter-dependencies between climate changes and the range of species endemic to New Zealand. The social costs of dealing with the impacts of climate change on endemic flora and fauna and changes in pest management funding models associated with changes in land use are all significant for changing organisational goals.

In terms of redefining success or organisational directions towards changes in understanding of what matters, some general comments were made by survey respondents. These indicate positive appraisal of SLMACC funded research and how it has contributed to understanding of what matters to address stakeholder needs.

5.9 Uses and Benefits of research

It was clear from comments in Table 9 that stakeholders responding to the survey benefited from the knowledge and information that research had provided. SLMACC-created knowledge and tools were assisting with decision making, particularly around high-risk sites and understanding the impacts of extreme weather events such as wind and drought, and the real costs of harvesting steep hill forests.

Table 9: Provision of new knowledge, methods or processes arising from SLMACC research by project

Report	Comment
Implications of Changes in Albedo on the Benefits of Forests as Carbon Sinks (2 reports) (Kirschbaum, Shepherd, Ausseil; Whitehead, Kirschbaum, Dean, Beets, Ausseil, Shepherd)	Understand the importance of albedo and carbon sinks
Development of forest productivity surfaces (Kirschbaum, Mason, Watt, Tait, Ausseil, Palmer, Carswell)	New approach to unknown area growth rates; Spatial surfaces; Productivity GIS surface layers
Improved estimates of the effect of Climate change on NZ fire danger (Pearce, Kerr, Clark, Mullan, Ackerley, Carey-Smith, Yang)	Able to alert Rural Fire Authorities of future danger to fire; Shifted focus to more at risk areas
Future proofing plantation forests from pests (Watt, Ganley, Kriticos, Palmer, Manning, Brockerhoff)	Has led to a revision of surveillance technology appropriate to areas and species of greater risk
Defining options to reduce tree harvesting costs on steep slopes (Heine, Amishev)	Identifies the magnitude of harvesting costs in hill country
Drought Tolerant Species Selection (Xue, Dungey, Clinton, Henly, Niollet, Leckie)	Identifies new method for pine breeding
Development of ETS look-up tables (Beets, Meason, Todoroki, Paul, Oliver, Pearce)	Has shifted focus to species more likely to contribute [to GHG mitigation] but needs to be regularly updated
New forest management approaches for steep hill country (Amishev, Basher, Phillips, Hill, Marden, Bloomberg, Moore)	The range of approaches that could be used
Carbon sink potential of naturally durable hardwood species in comparison to alternative hardwoods species preferred for timber production. (Almeida, Manning, Meason, Herrman, Dungey)	Important to keeping focus on right species and regions to ensure investment is well targeted
Novel poplars and willows adapted to a changing climate (McIvor, Jones)	Highlights the impacts of drought on trees in hill country
Impacts of the ETS on forest management (Maclaren, Manley)	The ETS has added an environmental payment for non-timber services for the first time and has lifted the credibility of forestry as a land use - which now needs to be built on.
Quantification and Management of the Risk of Wind Damage to New Zealand's Planted Forests (Moore, Manley, Park)	Details the magnitude of the wind impact

5.10 SLMACC has provided good value for money

Across the 25 projects evaluated using Basic Efficiency Resource Analysis (BERA), the analysis shows that SLMACC research has generated value for money. Three areas where the research has been most impactful based on survey responses are policy engagement, coalition or partnership building and changing practice (Figure 16).

Individual project BERA analyses are available in the Annex.

Figure 16: Perceived Investment and impact average for all SLMACC forestry projects by stakeholders and researchers

It is notable that media exposure and changing practice are two areas with the lowest levels of investment. Policy engagement, coalition and partnership building and industry engagement are the three highest areas of investment. They have delivered greater impact than has been invested and research papers have generated greater impact than invested overall.

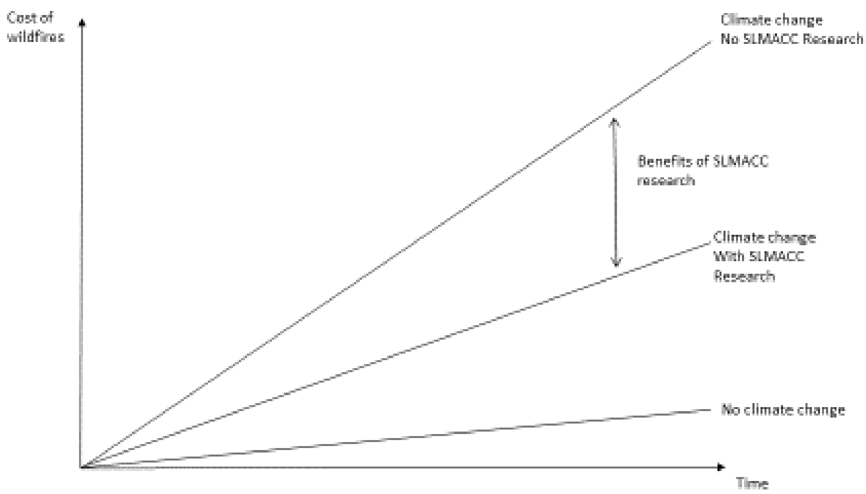
5.11 Fire research delivered exceptional value for money

A cost benefit analysis (CBA) was applied to the fire research examining the level of investment in the research against the benefit derived.

The results, show that the SLMACC research relating to wildfire under climate change generates a NPV of between $15 - $18 million (in 2008 NZ dollars), with a benefit cost ratio ranging from 38 to 48. This indicates exceptional value for money based on this research, indicating that a relatively small investment can have important economic implications for the sector.

A robust and detailed CBA is challenging for a number of reasons, including the availability of data. Some assumptions have been used to generate this analysis. The CBA does not account for reduction of fire risk through changes in practice based on other sources of knowledge including using findings from other research. The biggest limitation of the methodology is identifying and monetising the benefits of the research, and attributing any changes directly to the research.

Figure 17: Stylised representation of the costs of wildfires with and without climate change or SLMACC research



The analysis compared the area burned based on actual data between 2008 and 2015. It is assumed a 15 percent increase in area burned 2016- 2030, based on the assumption that if SLMACC research had not occurred and no resulting changes in management practice, there would be an increase in wildfire incidence.

Calculation of benefits is based on the representation in Figure 17, where climate change results in increasing costs of wildfires over time. Without any adaptation, this becomes the counterfactual scenario, but it is assumed that the SLMACC research prompts changes in practice resulting in lower costs of wildfires, i.e.:

$$\text{Net benefit} = \text{Costs of wildfire}_{\text{NO SLMACC RESEARCH}} - \text{Costs of wildfire}_{\text{WITH SLMACC RESEARCH}}$$

The values used are approximate estimates of the types of future benefits and their associated economic value and costs, which can be converted to present day values as net present value (NPV). It was assumed that pre-suppression costs would increase because of greater awareness about the increased fire risk under climate change, but would remain constant under the counterfactual scenario of no SLMACC research. It is assumed that an increase in pre-suppression costs of one percent each year beginning in 2013 (when the last SLMACC fire research project ended) occurs.

The results summarised in Table 10, are presented for the three different assumptions regarding area burned of 5%, 10% and 15%.

Table 10: Results of CBA for SLMACC forestry wildfire research

Difference in area burned	5%	10%	15%
PV Fire Costs Counterfactual (no SLMACC research) ($m)	594	594	594
PV Fire Costs SLMACC research ($m)	558	563	554
PV benefits ($m)	36	32	41
Costs	0.419	0.419	0.419
NPV	**18**	**15**	**20**
Benefit:Cost ratio	**43**	**38**	**48**

The assumption that only 50 percent of the benefits can be attributed to the SLMACC research was tested. In this scenario, the investment still generates a positive net present value (NPV).

This analysis has demonstrated the potential value that investment in research can have, however this will only be realised over time if practice continues to implement insights from the research.

6 Knowledge Gaps: What we need to know

Understanding of knowledge gaps for New Zealand climate change and forestry has been developed through analysis of the literature, report summaries and through interactions with the other review teams through two workshops: the indigenous forest gaps workshop and the adaptation research gaps workshops. A detailed account of gaps is provided in the Annex containing all the report summaries (see also Section 2.3).

More research and capacity is required to develop knowledge (data, services, scenarios) on climate impacts that are relevant to business and other decision-making processes.

The knowledge gaps identified in the review are as follow.

1. Mitigation aspects of forests, to:

   a) support UNFCCC reporting and Paris Agreement goals for New Zealand (See side bar);
   b) underpin emissions trading schemes; and
   c) support new research into substitution roles of timber and wood products.

2. How to enhance forests and forest managers' ability to understand, manage and adapt climate change risk.
3. Understanding different climate futures, land use systems and product innovations that can increase the reduction of GHG emissions (developing capacity to model and generate scenarios).
4. Knowledge on interacting systems of plantation forests and climate change impacts, and their effects including:

   a) understanding how different risks affect forest productivity such as pests, drought and plant health; and
   b) how forests and their risks interact with the wider landscape and communities.

5. How to transfer knowledge or inform new stakeholders of the research findings.

These knowledge gaps are given more attention through a specific focus on indigenous forests and exotic forest research gaps below (including avoided emissions and substitution research or that pertaining to new and existing products for the bio-economy).

6.1 Indigenous Forests

There are knowledge gaps in relation to indigenous forests and the importance of their role in climate change mitigation and adaptation as indigenous forests are a significant component of New Zealand's response to the UNFCCC Paris Agreement (see side bar). Indigenous forests and their role in carbon sequestration can be affected by climate change impacts on:

- Critical ecosystem functioning and services - there is relatively limited understanding of the inter-dependencies between climate and tree plants, insects, fungi and soils, and systems.
- Changes to forest community makeup and phenology - there is limited or no understanding on phenological[7] inter-dependences that could be affected by climate change.
- Changes in rate or scale of disturbance and their impacts on carbon sequestration (and other ecosystem functions) from changes in climatology and events such as storms, wind, erosion, and fire.
- Increased risk from pests, disease (e.g. myrtle rust), weeds, wind and fire under climate change.

Continued research is needed to underpin the sequestration potential of indigenous forests:

1. Improving carbon accounting for both timber yields and different species, improving the ability to assess and report carbon sequestration (to update reporting and ETS mechanisms), and provide options for indigenous carbon forests.
2. Understanding the climate change impacts on indigenous forest growth and sequestration including further understanding of disturbance impacts on carbon sequestration and on current carbon stocks to enhance the ability to more accurately assess carbon sequestration rates and stocks for reporting purposes.
3. Understanding impacts arising from new and changing distribution of external biological risks such as from weeds, pests and diseases to allow assessment of the impact of risks on sequestration rates of indigenous forests (and on biodiversity).

Paris Agreement Goals

- A goal to hold warming well below 2 degrees with efforts to limit to 1.5 degrees;
- Greenhouse gas emissions to peak as soon as possible, and to achieve net - zero emissions in the second half of this century;
- Mitigation measures are to be expressed in nationally determined contributions;
- Nationally determined contributions (NDC's) revised every 5 -years;
- Countries can meet their NDC targets by transferring 'mitigation outcomes' internationally – emission trading;
- A mechanism for private and public entities to support sustainable development projects that generate transferrable emission reductions;
- A framework for enhanced transparency and an expert review of NDCs;
- A global stocktake to review progress
- A global goal of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, and commitment to providing enhanced support for adaptation.

UNFCCC

[7] Signs of periodic life cycle events corresponding to stages of development that are influenced by seasonal and inter-annual variations in climate and other habitat factors such as pollen collection.

4. Building on previous research, understanding the most suitable approaches for establishing and managing indigenous forests on non-forest sites and expand the forest area available for sequestration.
5. Understanding the socio-economic enablers and barriers to establishing indigenous forests – 'what trees, where, and for what purposes' – and participation in existing institutions such as the Afforestation Grant Scheme (AGS)[8] or Erosion Control Forestry Programme (ECFP).
6. Stronger relationships with indigenous forest owners and those with an interest in developing future indigenous forests need to be built, in order to understand their needs and drivers for enhancing indigenous forests.

For further detailed understanding of climate change and biodiversity, including knowledge gaps see the Doc report (McGlone and Wiser, 2011).

6.2 Exotic Forests

Forestry has been well served by SLMACC research on identifying impacts of changes in climate. As shown in this analysis, the reports have been used, and have had some wide coverage (especially Chapter 7 of the NIWA-lead adaptation report, Dunningham et al, 2012).

However, more research and capacity is required to develop knowledge (data, services, scenarios) on climate impacts that are relevant to business and other decision-making processes, such as quantifiable estimates of risk and risk effects (e.g. Task Force on Financial Disclosures (TCFD) guidance, 2018) and productivity changes. Such research should be aimed at enhancing decision making in the sector, e.g., develop tools and data that can be used by the sector to evaluate current management strategies, and mainstream climate change risk into long-term planning.

The current descriptions of risk and productivity changes are largely qualitative and are at a national scale. Data arising from the analyses are not part of the knowledge being exchanged in the final reports and as has been noted do not always provided the best mechanisms for supporting changes in practice. Accordingly, the SLMACC reports are sometimes unable to be used by end-users for their business specific analysis of risk and vulnerability.

1. Tools are required to project various productivity and risk scenarios under climate change[9]. For example, productivity data to match the geographic and temporal precision of existing climate change projection data; so, individual businesses can relate productivity to profit and loss, cash flow and capital planning, and understand why productivity changes as well as the associated uncertainties, including known risks.

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[8] Anecdotal comments state that the AGS has not be used to its fullest potential, limiting the establishment of indigenous forests. There are initial indications that the mechanisms need to be better tailored to practical needs and opportunities.

[9] It is noted that this is required across all the primary sectors.

The use of projections and scenarios underpins adaptation planning. More precise information on productivity also underpins engagement with the ETS. However, capacities to act under conditions of uncertainty are also required.

2. The climate change data used in the analyses is now old, either from the IPCC Assessment four reporting (2007) or even earlier. New and more accurate and comprehensive datasets based on regional climate models (RCM) data are available and could be used to update risk and impact assessments.

   The new RCM projections have been more spatially and temporally refined and precise information, enabling better understanding of site specific risk, production and other derived values, e.g. more precise information on frost free data provides insight for businesses with crops that require frost days for fruit production.

3. Understanding risks specific to sectors. While fire research funded under SLMACC has helped (with other funding sources) to address response mechanisms to fire risk, there is much more research that can help with the identification of climate change risk landscapes with fire behaviour models.

   There are limited data on the geographic distribution of climate change risk or mechanisms for developing composite risk indices arising from changes in climatology, and changes in incidence and intensity of extreme events.

   Precise and specific understanding of risks is required for adaptation decision making. This becomes more important as the cost of adaptation increases, such as for drought reduction.

4. There is a need to focus on catchment or regional scale analyses with holistic understanding of climate change impacts and implication across land-uses, institutions and communities, to enable consideration of the social impacts of climate change. Specific tools and methods include using potential future scenarios of different socio-economic conditions (Frame and Reisinger, 2017), or integrated modelling and scenarios (www.impressions-project.eu).

   Integrated assessments allow analysis of climate change impacts and the adaptation of catchments, regions and countries, which in turn enables understanding across land uses and of scarce resources such as water, labour (employment) and impacts on economic activity and social-economic indicators.

   Scenarios are very effective in exploring the uncertainties that surround climate change risks and opportunities, focusing on exposing causal processes; crucial decision points and fundamental uncertainties in strategic decision making, leading to better and unbiased decision making (TCFD, 2018).

5. Research and capability is required on developing and validating forest management tactical, strategic and transformational adaptation methods (Clothier, Hall and Green, 2012) – particularly where there is an expected increased risk (inter alia): steep land harvesting, fire, pest and diseases and water. Information is needed for adaptation decision making,

available adaptation options, community engagement frameworks and methods, and cost benefit analysis methods for changing risk profiles.

Currently, there is very limited understanding on the options and costs for forestry adaptation options. While some have been identified (Dunningham et al, 2012), these have not been formally evaluated for feasibility, efficiency, and cost.

6. There are a lack of tools and processes with data that empower end-users' adaptation decision making. Key components are a lack of freely available data, a lack of tools to help with evaluation, and a lack of capacity in adaptation planning. Data that is currently available is in terms of climatology, rather than in business parameters, such as productivity, cost, revenue, cash flows, and investment risks.

   New Zealand and sector specific tools and data that enable a structured approach to climate change risk management can improve sector, local government and community understanding of risk and costing adaptation options. International examples that could be adapted to a New Zealand context include the UKCIP (www.ukcip.org.uk) "Decision making for Adaptation"; WeAdapt (https://www.weadapt.org/); and Climate Services (https://www.weadapt.org/knowledge-base/climate-services/climate-in-tandem-online-guidance-for-climate-services).

7. Climate change research, data, tools and understanding need to be mainstreamed into current and future programmes. The 1BT programme needs to consider climate change impacts in where new plantings occur – in terms of future increased risk from fire, pests, productivity and water availability.

6.3 Avoided Emissions - Substitution research

Forestry as a mitigation strategy has to-date focused on the role of trees as a carbon sink. Wood products can be used as to substitute for other high emitting product. However, no research has been completed under SLMACC that addresses wood based mitigation strategies that could reduce emissions by, for example:

- increasing the carbon retention through using long-lived harvested wood products; and
- using harvested wood products to substitute for high emissions products from other sectors such as biofuels and construction.

This is a positive opportunity for New Zealand to consider, with both environmental and economic value add potential. Research is needed on understanding the trade-offs of different mitigation strategies, i.e., between enhanced carbon storage in forests, or increasing utilisation of long-lived harvested wood.

7 Enablers: What has enabled SLMACC research

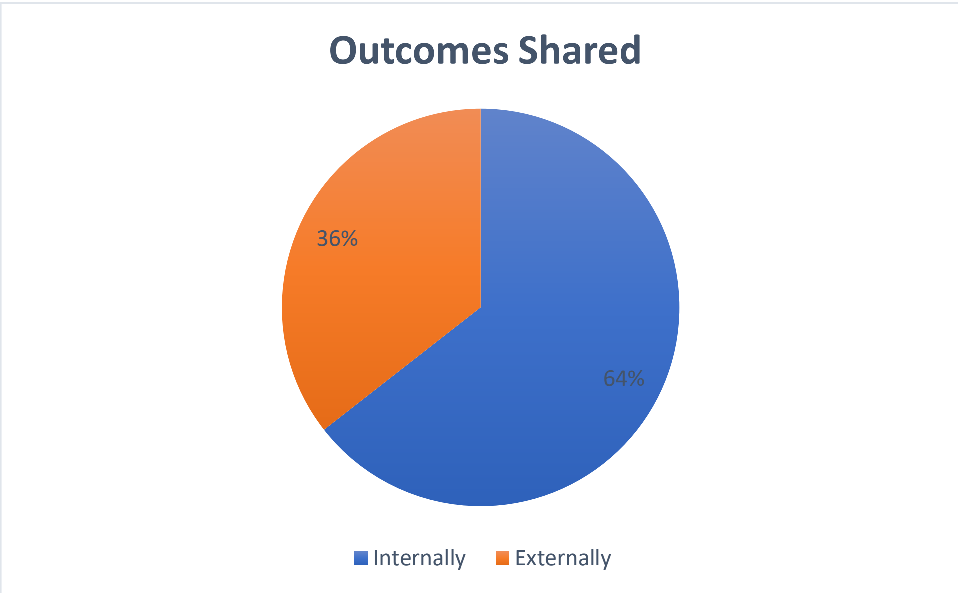
Enablers are the formal or informal structures including policies, processes and practices that contribute to or support successful outcomes. The review identified three key enablers or strengths in the SLMACC forestry-related research: leveraging off existing networks and connections between researchers and stakeholders; the SLMACC programme and processes being responsive to stakeholder priorities and needs, and increasing capacity to act; and SLMACC providing a critical, near-sole source of ongoing funding for adaptation research in New Zealand.

7.1 Engagement and participation of researchers with their networks

Researchers, stakeholders and research organisations have used their networks to engage, formally and informally, stakeholders in the research in sharing of research outcomes, increasing the reach, and reinforcing the value of the research. There has been a commitment of researchers to go beyond any contracted engagement, adding significantly to the research impact. The research interactions are part of the success in achieving the levels of impact attained by SLMACC forestry climate change research.

Networks were largely used to communicate research outcomes across a range of different mechanisms (Figure 19). Respondents shared the outcomes of research both internally (64%) and externally (36%) with others in the sector (Figure 18), which helped to disseminate awareness of the SLMACC research.

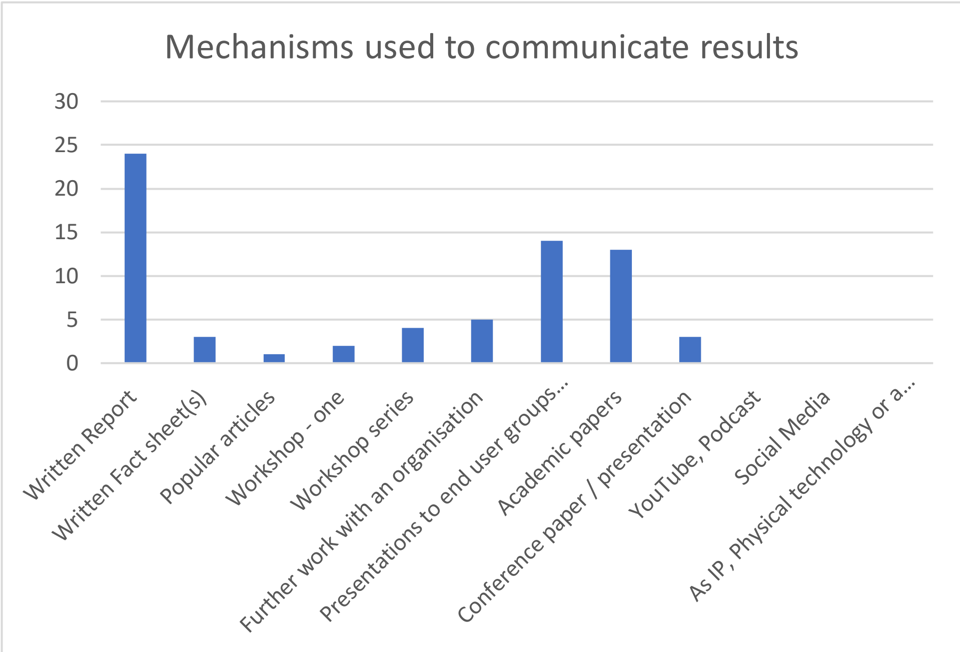
Figure 18: Where stakeholders shared outcomes from SLMACC projects



Improved learning and awareness was assisted within larger forestry companies, particularly those involved in MBIE/Scion programmes, who had staff who managed research interactions and who had some responsibility for forwarding research to relevant staff.

The use of researcher sector networks counteracted the limited focus and investment in knowledge extension given by the SLMACC fund. For example, in most if not all cases, the researcher and/ or MPI were the knowledge agents, and no research was communicated by other knowledge brokers or extension specialists. Survey data shows that most respondents (24) received the communication of outcomes via written reports, while quite a few (14) also saw presentations, during end-user group meetings, or via academic papers (13) (Figure 19).

Figure 19: Mechanisms used to communicate SLMACC research results



While the use of networks enabled uptake, value and awareness building, the lack engagement preceding and during research process and a lack of effective handover processes has limited impact. For example, one project had high levels of engagement through integrating end-user stakeholders as co-researchers. This enabled more inclusive and catchment based project knowledge, the better design and development of community outcomes and a focus on policy barriers of action, which in the end, providing value in terms of changes in government practise and institutions, rather than just awareness building. This is discussed in the Barriers section.

7.2 Science-led research addressing end-user needs

An important enabler has been having a network of researchers and stakeholders willing to help manage the gaps between basic and applied research, and address key areas of research need. Researchers in CRI’s have been adaptive to filling government funding gaps and maintained their capacity, whilst also addressing areas of immediate research need.

SLMACC research has built on and leveraged off other research projects, using those networks, data and knowledge. For example, the fire research collaboration between Scion and NIWA, and linking to existing projects for managing steeplands in collaboration with University of Canterbury, has provided strong links and science advice into sectors as well as stakeholders such as MfE and regional councils.

Most stakeholder survey respondents either saw research as generally apply across a range of contexts (N=13) or applying to a specific setting (N=10), indicating a fairly strong dichotomy between these two aspects. However, it is also interesting to see the range of spread in the middle group. Thus, a variety of general and context specific research needs could be said to have been addressed by SLMACC funded activities.

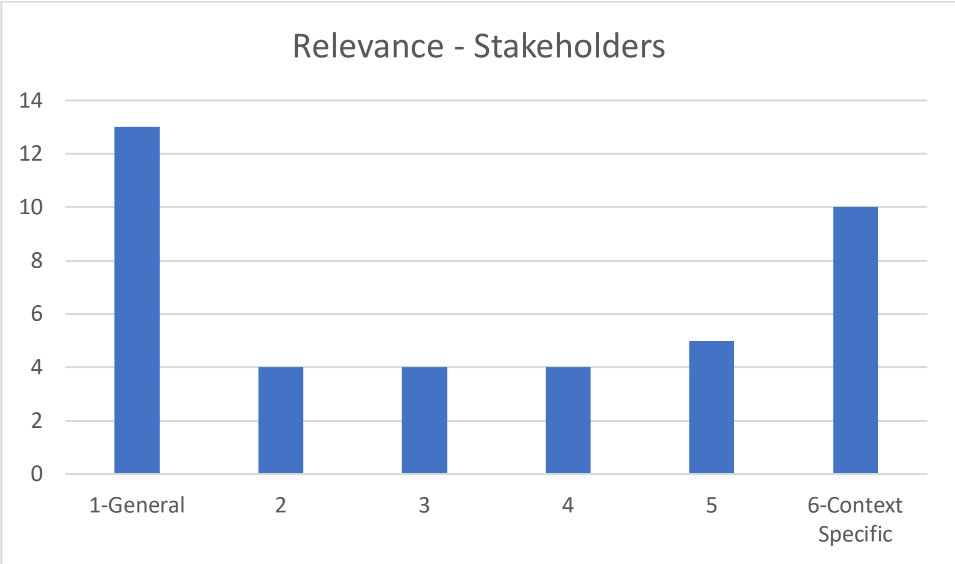


Figure 20: The source of relevance for the research projects - Stakeholders

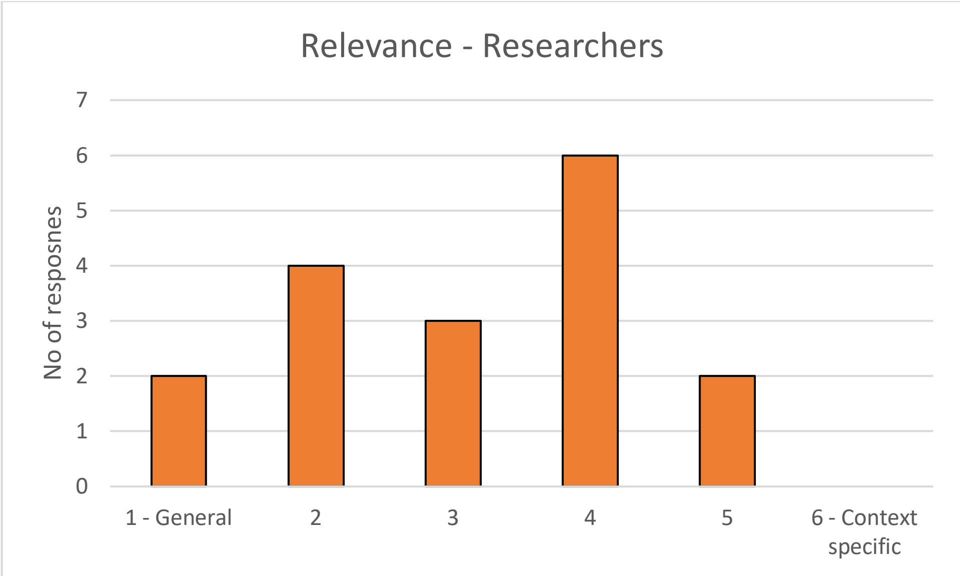


Figure 21: The source of relevance for the research projects – Researches

The researchers' responses to the relevance of the research also indicated a range from general to context-specific. Responses were like the stakeholders in diversity, however were less inclined to think of the research in the polarised way that the majority of stakeholders seemed to.

None of the researcher respondents thought of the research as purely context-specific. Nine responses were inclined to think of the research on the general side of relevance while eight saw the work more on the context-specific side, close to a ratio of 50:50. Stakeholders also saw the research as 50:50 of general relevance (N=19) and context-specific (N=19).

7.3 SLMACC responsiveness to stakeholder priorities

The SLMACC programme and processes have been flexible and responsive to sector, policy and researchers' priorities on climate change and the forestry sector. This has allowed funding decisions to be responsive to changing priorities and to new research themes. The process for developing key themes for each SLMACC funding round is inclusive of research, policy and sector views and priorities.

7.4 Increased awareness and capacity to act

SLMACC research has facilitated researcher conversations with end users, and in some cases this has enabled joint understanding of the policy questions and kinds of evidence required to answer them (such as with the fire and steepland harvesting research). Stakeholders that were engaged as part of advisory groups or part of industry review processes have increased awareness within their organisations (e.g. dedicated staff in larger forestry companies), and enabled an even wider network of engagement with SLMACC research.

7.5 SLMACC provides significant funding

SLMACC was largely, and continues to be, the sole long-term funding source for adaptation research for forestry (as well as for other sectors). SLMACC has enabled the development of capability within research organisations, maintaining a critical element of New Zealand based expertise in climate science. It has enabled some international collaboration and delivered high quality science-led policy advice that has been recognised as highly useful to policy and sector stakeholders.

8 Barriers: What has limited adoption of SLMACC research

Barriers to the usefulness or adoption of the SLMACC research have included limited communication with end-users; a lack of actionable and specific risk-based research that can be applied in different contexts; and a reduction in funding, which has constrained the maintenance of science capability.

8.1 Limited engagement with end users

While SLMACC rated 'moderate' in its achievement of engagement and knowledge exchange, there have also been limits or barriers to achieving this at an optimal level.

Engagement across the research process, from developing research questions, undertaking research and handing over useable research results is critical to high levels on impact and value in stakeholders. In many SLMACC projects, there was limited communication with end-users before, during and post research, and some projects end-users were not identified and it is doubtful whether some end-users were aware the research was being undertaken. This has limited the ability of research results to be fit for purpose in creating benefits in end-users. Similarly, the methods for disseminating research outcomes has been limited, creating barriers by end-users.

SLMACC – as with other programmes – has only relatively recently realised the importance of incorporating end users into research design; and including engagement as well as 'extension' activities such as knowledge exchange with end users, throughout the research process.

8.2 Exotic Forest barriers: long timeframes and limited use of research in private foresters' decision making

As a primary industry, forestry is inherently resilient to the volatility of a changing climate because of the long-term investment and management timeframes, i.e. 25+ years versus annual cycles or less for most other primary industries. For example, foresters can keep trees in the ground to ride out market fluctuations or passing drought, albeit with reduced growth rates. The downside of the longer-term timeframes in forestry, and the fact that is largely a *private* economic activity, is that there is little incentive or need for forest adaptation: foresters are only going to adapt if it's something that affects the viability of a significant portion of their estate.

Accordingly, foresters' adaptation-related decision making tends to be mainly in response to identified (residual) business risks that arise from climate change. Risk assessments and decisions mostly relate to how, for example, foresters can adapt to (or tolerate) changing fire or pest risks within existing business models. Although these risks are potentially more threatening to the forestry sector's viability than other primary industries, there is limited adoption of risk mitigation practices such as fire danger management during harvest times.

Although stakeholder interviews found that SLMACC research has successfully been used by foresters to analyse potential or actual climate change risks to existing business operations, a barrier is the lack of information that is specific to stakeholders' contexts and end uses. Nor has it been presented in such a way that enables learning to comprehensively address change practices and to adapt forest systems. For example, for the report '*Improved estimates of the effect of climate change on New Zealand's fire danger*' the coalition/partnership building scored very highly but changing practice scored relatively low against the perceived level of investment.

This lack of stakeholders' understanding about SLMACC research impact on their businesses has been a barrier to risk-based decision making. More positively informed decisions across the areas of pro-actively managing uncertainty and accessing precise and useable data are important for using tools that build confidence in decision making where outcomes cannot be clearly predicted.

A risk to manage is being able to answer the questions *where* to plant forests, e.g., with implications for the 1BT programme in terms of managing risks to such an investment. However there has been limited research at a catchment-level to provide this type of applicable research.

So, there is a barrier from the lack of freely available, *actionable* and *specific* risk-based research or tools to help foresters evaluate climate change data against their forest and business. This has led to limitations in foresters incorporating practical adaptation strategies into business models and decision-making processes, including ways to manage uncertainty (e.g. through scenarios and back casting, or reflecting back on how changes in the past have contributed to the current situation).

8.3 Indigenous Forest barriers: low community engagement

One of the barriers for indigenous forests is the low level of community engagement. This has implications for the 1 Billion Trees programme, not just for exotic but indigenous forest growth. Communities will play an important role to the extent that they support choices over where trees are planted and how the risks of forests in place are being managed.

The barriers for indigenous forests include inadequate research into how communities will respond (particularly in comparison to exotic forests) in areas where knowledge gaps have been identified, such as:

- mitigation research, to understand the complexities of indigenous forest ecosystems as carbon sinks;
- risks (vulnerability and sensitivity to climate change) to indigenous forests and hence their ability to act as a carbon sink; and
- understanding carbon cycling for supporting emissions reduction and the interacting effects of disturbance impacts as well as policy actions.

The implications of SLMACC's relative lack of engagement with communities and stakeholders outside of the forestry sector include:

- limited Māori involvement in indigenous focused research, which may/will have improved indigenous forest coverage for SLMACC; and
- design aspects of research, such as selecting relevant research topics and associated applications of knowledge.

8.4 Reduced funding – risk to sustainability of science capacity, capability and effectiveness

Even though science capacity and capability was rated highly in the evaluation there have been constraints and barriers in this area. The reduction of SLMACC funding (from an average of $8 million per year in 2007/08 to $2.82 million by 2018) has led to smaller, annual projects. This has limited the scope and value of SLMACC research, and the ability of science researchers to build teams or maintain their relevant science capability. A lower number of researchers overall have been involved in SLMACC work and this has increasingly impacted the research reach into researchers' and stakeholder networks, and New Zealand-based capability development.

Some scientists have moved to different science areas, such as advancing remote sensing technologies and developing knowledge of innovation practice, limiting New Zealand's overall science capability. The pool of researchers in this field within forestry is so small (around four researchers for forestry nationwide, and about 20 researchers overall), its sustainability is vulnerable to further funding reductions or policy changes.

8.5 Administrative processes

The administrative processes of managing SLMACC have provided some barriers to maximising the impact and value for end-users as indicated by the following examples.

- There have been limited monitoring and evaluation processes within contracts, with no budgets or ability to assess impact specifically related to the outcomes of climate change research.
- Some research projects were information gathering only and not necessarily designed to engage with stakeholders beyond providing policy advice. Other reports were not made publicly available, and some remained in draft format.
- No projects have required post-contract engagement with end-users.

There is more work to be done to keep up with the changing context of research needs for sector and other stakeholders, particularly new investors in forests including Māori as significant land/ forest owners and developers.

9 Recommendations

Forests and forest businesses are vulnerable to the impacts of climate change, especially impacts under higher temperature, and drier or wetter catchments, hence there is a need to further understand and manage the risks associated with climate change and develop opportunities. This is even more important under the Government's One Billon trees policy and the ambition to be carbon neutral by 2050.

For example, Swiss needle cast, a Douglas-fir disease, is likely to increase with climate change throughout the country as pathogen abundance is strongly correlated with winter air temperature. Changes to weed composition and growth rates resulting from climate change are also likely to have a detrimental effect on tree growth. In dry regions, young trees could have increased weed competition for water and warmer average temperatures that will generally result in greater abundance of insect pests due to their better survival over winter. More detailed and extensive understanding of impacts and adaptation options are given in (Dunningham et al., 2013)

Given that forestry provides significant benefits to New Zealand's ability to meet climate change reduction commitments, the recommendations below identify key themes to support and enhance the mitigation role of forests. Research needs to continue to provide sequestration services and to protect exotic and indigenous forest and carbon sinks from impacts of climate change, as well as manage the increased risks of fire wind, biosecurity and erosion.

9.1 The focus of future SLMACC research

Recommendation 1: Develop a strategic agenda on the research required to support and enhance the mitigation function of forests, to better support domestic and international priorities for government and taking into account the existing strategic research agendas (including, e.g., National Science Challenges, and Conservation and Environment Roadmap). The agenda should address:

1. Continuing research into the productivity and sequestration of radiata and other exotic species under climate change. Consider funding data collection and trial establishment, especially for new species in the 1BT programme.
2. Updating the data on climate change impact using the new climate projection data and invest in models that can be widely accessed by sector, consultants, government and researchers.
3. Researching the requirements for mitigation aspects of the Paris Agreement.
4. Understanding the socio-economic and community factors that enable forest establishment and that minimise deforestation.
5. Research and development of the other mitigative roles of forests such as petroleum substitution (biofuels, bioplastics) and long-lived timber products.

Recommendation 2: Increase significantly the research funding for risk management and adaptation that enable forests and forestry businesses to successfully adapt to a changing climate, protecting and enhancing the sector as the third largest exporter industry and critical contributor to New

Zealand's carbon mitigation goals. Information on the spatial distribution of climate risk is required to ensure that 1BT are planted in less-risky sites.

Further research is needs to address:

1. Develop practical and easily accessible tools, models and approaches to support more context-specific needs of forestry related businesses, communities and regions for their adaptation planning and decisions. This include models that predict productivity across sectors, integrated assessment models at different scales, models that include socio-economic variables.
2. The continued and improved quantitative assessments of the biotic and abiotic risks (pests, diseases, weeds, fire, wind, rain, and storms), which could threaten the economic, social and environmental viability of New Zealand forests.
3. The climate change socio-economic risks that arise from interactions with economic drivers, value chains, and how risks (direct, upstream or downstream) combine and interact.
4. Risk assessment should consider very recent guidance from the Task Force on Financial Disclosures (TCFD, 2018).
5. The longer-term strategic and transformational options for adapting to climate change and building resilience.
6. The behavioural barriers and enablers of adaptation action or inaction for the sector and community.

Recommendation 3: Make data available to end-users for their own assessments and management of risk. As direct engagement with many stakeholders is not always practicable, a 'climate services' approach could be used to develop customised information products that include data, information and knowledge for specific sectors or regions.

Recommendation 4: Scope climate change research to be holistic within catchments and regions. While there are sector specific research needs, research is also needed to understand how sectors, communities, and other businesses interact.

The Waiapu case study is a good example of where this type of holistic research identified practical benefits and improvements for government (e.g. matching its funding processes better to the realities of users), industry and communities alike, as well as developing understanding of the strengths and weaknesses of a community to be able to adapt to climate change.

9.2 Recommendations of how SLMACC can be improved

Recommendation 5: Design SLMACC research proposals more explicitly around the expected end-users and their intended uses of the research, embracing transdisciplinary research – Other skills from social sciences, and tacit knowledge skill from end-users need to be included and funded within teams. Most of the recommendations listed need to include other skill sets in addition to core science skills

Recommendation 6: Include an explicit handover process in the RFP and contract between science researchers and end users - including an ongoing communication strategy. This would greatly improve the likely uptake and use of SLMACC reports' data and findings by policy, forestry and financial institutions; and communities and individual farmers or foresters.

Recommendation 7: Safeguard and grow research capability in both mitigation and adaptation research with increased and sustainable, longer-term funding of projects. The current \$150,000 pa (\$450,000 over a three-year project) makes up less than 1 FTE in total funding at a CRI; and continuing this approach risks New Zealand reaching a tipping point in losing its science research capacity and capability (and international reputation).

Recommendation 8: Include (scaled) monitoring and evaluation as part of SLMACC contracts, funding and progress reporting components, to provide evidence and reassurance of value and impact; and enable action learning**.** This has been a key learning across these reviews, i.e. discovering critical information gaps in how effective the past ten years' SLMACC research has been due to a lack of project-level monitoring and evaluation.

Specific science recommendations for further research is detailed in many of the science reports, (See example of Fire in the text box on the previous page). Also, recommendations can arise from addressing Gaps, enhancing the enablers and removing barriers.

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Appendix One: Detailed Rubric results

1 BUILD SCIENCE CAPACITY AND CAPABILITY ENHANCEMENT	RATING
Builds **capacity** for NZ to research in topic area (e.g. climate change and sustainable land use) at all levels	HIGH
Improves capability and skills among emerging or early career researchers.	HIGH
	OVERALL: HIGH
2 INFLUENCE ON SCIENCE	
Promotes collaboration among research providers, and/or between different disciplines	MODERATE
Generates high-quality research related to topic area, which is credible and legitimate (e.g. citations, impact factor) with relevant stakeholders (e.g. Intergovernmental Panel on Climate Change)	HIGH
Utilises robust, **best practice research methods** (poor: may use random or unexplained methods; excellent: may use novel methods or techniques, sound results)	MODERATE
Results in **uptake and use of research** within science community (excellent would result in strong uptake and use of research within science community)	HIGH
	OVERALL: MODERATE
3 ENGAGEMENT AND NETWORKS	
Builds **collaborative networks** of key stakeholders and/or end users (poor: may include homogeneous networks that disperse following project, and excellent networks are heterogeneous (e.g. different epistemologies, type of expertise, values) and enduring	MODERATE
Uses **participatory research processes** appropriate to level of engagement needed to achieve outcomes (based on MPI Extension Framework); e.g. where end users have the opportunity to shape research approach, sources of knowledge and outcomes	MODERATE
Uses **structure or processes to guide stakeholder engagement** (poor: may have no clear processes for stakeholder engagement; excellent: may use processes like a community of practice)	LOW
Practices **action learning** (if applicable)	
	OVERALL: MODERATE
4 LEARNING, AWARENESS AND KNOWLEDGE EXCHANGE AMONG END USERS	
Generates **new knowledge** in topic area (e.g. climate change and sustainable land use)	HIGH
Promotes **knowledge exchange** (particularly dissemination of research findings)	MODERATE
Builds increased **awareness and knowledge** in topic area	MODERATE
Promotes **practice or behaviour change** among intended end- or next-user groups	MODERATE
	OVERALL: MODERATE
5 USABILITY OF RESEARCH FOR END USERS	

Generates specific, usable, fit for purpose **knowledge and research** for policy and trade/negotiation, research, science and stakeholder communities	MODERATE
Aligns **research with the needs of next- or end users** of the research, and is responsive to next- or end user needs and knowledge gaps (poor: may lack alignment; excellent: may involve iterative research to meet user needs)	HIGH
Acknowledges context and **effects of the research knowledge** or recommendations on the broader climate system or topic area	MODERATE
Creates **accessible, available outputs**	LOW
	OVERALL: LOW
6 INFLUENCE ON STAKEHOLDERS AND IMPACT FOR NZ	
[How the research is designed and delivered] maximises how wide-reaching the **research influence** is (inter/national, across relevant sectors and functions; e.g., policy, industry and community attitudes and behaviours)	MODERATE
Results in uptake and use of research by stakeholder groups (policy, government, industry or community)	HIGH
Influences stakeholders positively in their awareness/ consideration of decision-making, and/or action around topic area (e.g. climate change and sustainable land use) (e.g. policy, government, industry or community)	MODERATE
Achieves significant direct impacts or benefits for NZ (poor: may be no impact; good: incremental; excellent: may be wide ranging or more immediate impact)	HIGH
Achieves significant direct **spill-over** impacts or benefits for NZ (poor: may be no impact; good: incremental; excellent: would be wide ranging or immediate impact)	MODERATE
	OVERALL: MODERATE

Appendix Two: Brief description of the impact assessment methods

Four methods or typologies are introduced for accessing research impact and outcomes. Each provides a slight different aspect of how research can be developed and what impacts are and how they can be achieved.

Assessing the Role of Users (McNie et al 2014) developed a typology that allows classification of research on a scale between science focused (fundamental research and use focused (applied research). This framework develops understanding of how research can be developed for end users while still understanding the critical science aspects of research. Fundamental is the where research is focused on user needs and where missed opportunities arise from a lack of understanding user needs or user inability to utilise research, the framework also allows the assessment of where research is needed to address areas where users do not 'know' their needs into the future.

Figure 22: McNie's typology for Assessing the Role of Users in Scientific Research

Activity	Attribute	Spectra of Research Criteria: Science Values	User Values
Knowledge Production	Expertise	Epistemic	Experiential
	Relevance	General	Contextual
	Disciplinary Focus	Singular, Narrow	Transdisciplinary, Diverse
	Uncertainty	Reduce Uncertainty	Manage Uncertainty
	Goals for Research	Exploratory	Outcome Oriented
Learning & Engagement	Learning	Theoretical	Social, Practical
	Knowledge Exchange	Restricted, Linear	Iterative, Influential
	Network Participation	Homogeneous	Heterogeneous
	Social Capital	Negligible	Significant
Organizational & Institutional Processes	Accessibility	Constrained	High
	Outputs	Narrow	Diverse
	Evaluation & Effectiveness	Science-Centric	Public-Value Oriented
	Flexibility	Constrained	Responsive
	Human Capital	Narrow	Broad
	Boundary Management	Limited	Broad

The contingent effectiveness model (Bozeman, 2014) identifies three complexities in technology transfer – what is being transferred? How is it being transferred? and how impacts of transfer can be measured. Impacts are categorised in six areas of effectiveness, one of which is market impact and economic development.

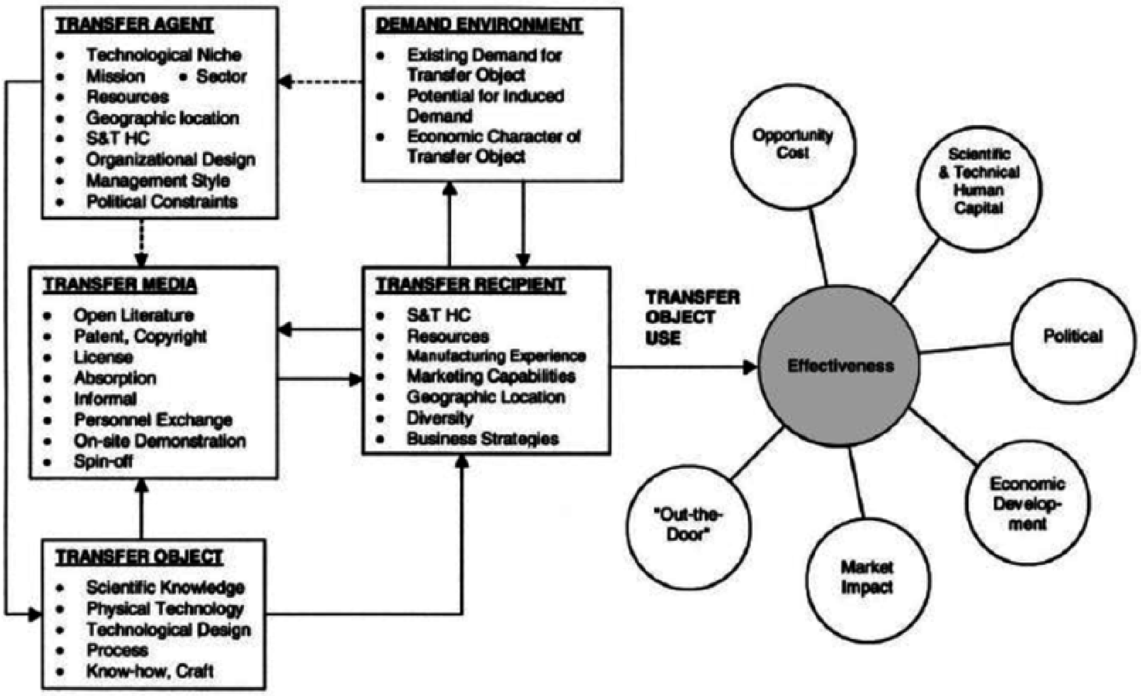


Figure 23: Contingent Effectiveness Model of technology transfer

Science of using Science (Langer et al, 2014) asks questions of what mechanisms can be used by researchers to facilitate the use of research for evidence informed decision making (EIDM). It addresses purposes of using science in a wide range of organisations and by the public. Langer et al identified six mechanisms which have been shown to increase the use of research (Table 11): for evidence informed decision making and, with an existing framework of behavioural change, developed a theory of change for evidenced based decision making.

Table 11: Six mechanisms that have been shown to increase the use of research

Mechanisms	Description
Awareness	This mechanism builds awareness of the need for and positive attitudes to the use of evidence in decision making. I.e. Decision makers need to value in the role of evidence in decision making.
Agree	This mechanism addresses the co-development ('mutual agreement and understanding') of the policy questions and the kind of evidence that is required to answer them. This focuses on producing evidence that is fit-for-purpose.
Communication and Access	This mechanism addresses that importance of decision makers receiving effective communication of evidence and importance of appropriate access to the evidence.
Interact	This mechanism addresses the level, and type of interactions of researchers and decision makers that enablers trusted relationships, collaboration and access to different form of influence.
Skills	This mechanism develops and supports interactions that support decision maker's skills in locating, appraising, synthesizing, integrating with other evidence and needs and making sense of evidence.

Structure and Process	This mechanism supports the decision makers understanding and management of psychological, social, environmental structures and processes in providing means and barriers to action.

Value creation stories emerge from an interest in learning and transformation of thinking that occurs when something of value is created. Wenger, Trainer and de Laat (2011) identify different cycles of value creation that lead to changes in interactions, knowledge, practice, performance and realising improvement. These, in turn, create opportunities to recraft stories that reshape the way evidence of change is picked up and potential measured.

Immediate values - Activities and interactions – What happened and what was my experience of it? Value can and is obtained just through participation. The can be skills, awareness and knowledge development of the topic, of how science is undertaken, how business operates etc.

Potential value – Knowledge capital – What has all the activity produced? Value isn't produced immediately, knowledge capital recognises that value can lie in the potential of information that can be realised later, even if it isn't realised, but is useful just in case. Knowledge capital includes human capital, social capital, tangible capital, reputational capital, and learning capital.

Applied value – Changes in practice – What difference has it made to my practise or context? Knowledge capital has potential for value, to leverage knowledge capital it must adapted and applied to a situation. This process can lead to changes or innovations in actions, practice, tools, approaches or organisational systems.

Realised value – Performance improvement – What difference has it made to my ability to achieve what matters to me or other stakeholders? Performance improvement isn't a guaranteed outcome from changes in practise nor can changes be assumed to come from changes in practise.

Reframing value – Redefining success - How has it changed my or other stakeholders understanding or definition of what matters? This is where the knowledge capital changes the learning environment – it may lead to reframing of strategies, goals and, importantly values. This can be seem as changing the definition of success

Appendix Three: Survey responses

Surveys were sent to two groups of stakeholders and researchers, with a slightly different mix of questions reflecting their roles in the review. The first was made up of, primarily, actors in the current planted forests sector and government agencies. The second was researchers involved in the projects directly or in associated projects. A total of 196 surveys were sent and the number of responses are given in Table 12.

Table 12: Returned survey responses

	No of Surveys sent	No of Responses	No of reports with responses	No of responses with no engagement with any reports	No of reports from no engagement but respondents were aware of
Stakeholders	116	30% (35)	22% (25)	9% (11)	8% (9)
Researchers	80	31% (25)	29% (23)	1% (1)	na

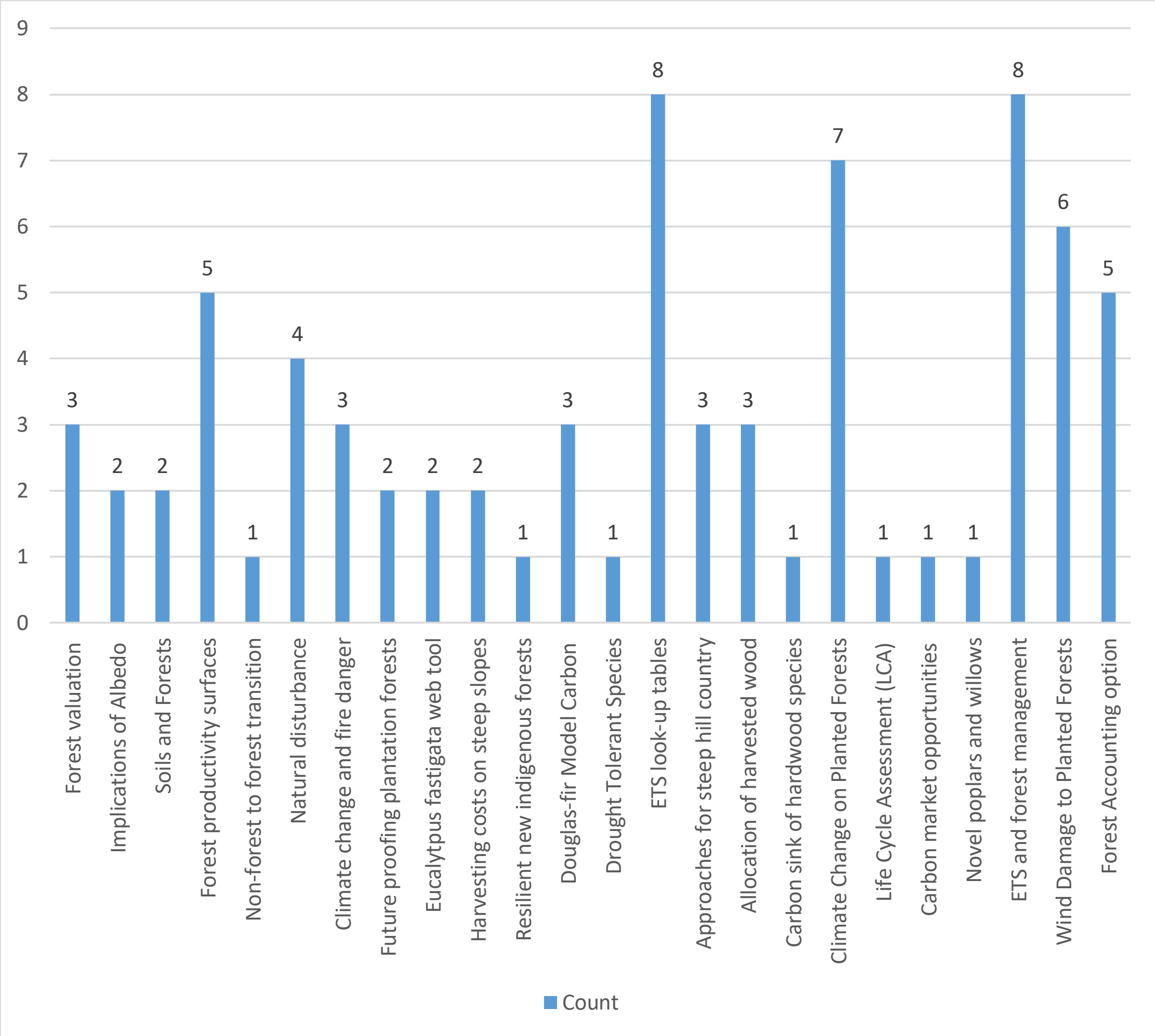
A total of 60 responses were received (about a 30% response rate), and 18 reports contained both stakeholder and researcher open ended comments in addition to closed question responses.

An understanding of the extent of reach and impact of the research is indicated by the number of reports identified by stakeholders (as being research they were aware of or had read reports).

Of the 31 projects, the stakeholders provided feedback on 25 reports. Figure 24 shows the reports that which stakeholders said they had been involved with or had used in their survey responses, and how many responses each report obtained.

Seven reports had a single response, five reports had two and three responses each, and eight reports had four or more responses. 11 respondents were not aware of any of the reports.

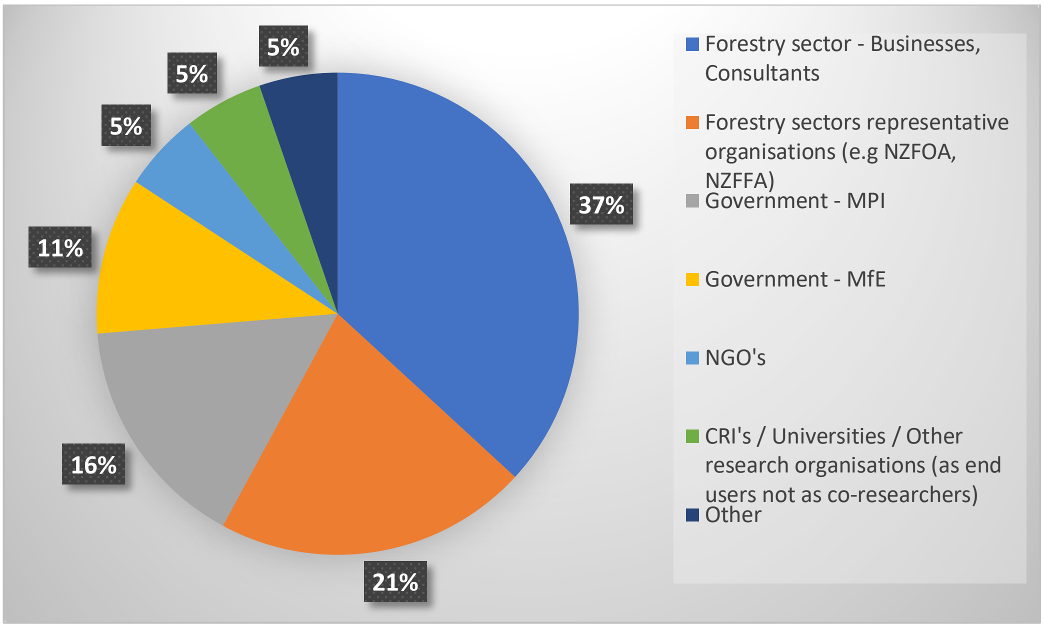
Figure 24: *Reports where stakeholders provided responses and number of responses for each report*



The range and number of reports seen demonstrates that reports did get circulation. In addition, one forestry report (Dunningham, 2012) - was allocated to the adaptation review project. Earlier interviews conducted with sectors stakeholder show that this report was utilised by the sector.

Figure 25 shows the breakdown of stakeholders who responded to the survey by occupational group. The survey of stakeholders achieved a 31.25 percent response rate and the survey of researchers achieved a 30 percent response rate (Table 12).

Figure 25: Breakdown by occupational group for the Stakeholders who responded to the survey



Appendix Four: Costs and Key Messages of Research

Table 13: Amount invested in each research project and key messages derived from project report summaries

Title	Entity	Lead Author	Amount	Key Messages
Forest and forest land valuation-how to value forests and forest land to include carbon costs and benefits?	ISCR	Meade	$117,420	Developed a methodology for valuing forest and forest land that is rich enough to capture the complexities for forest management introduced by the ETS
Carbon Stocks and Change in NZ's Soils and Forests, and the Implications of Post-2012 Accounting Options for Land-Based Emissions Offsets and Mitigation Opportunities	Landcare Research	Kirschbaum	$398,500	This research is a collection of research on carbon stocks in forests and soils with implications for carbon accounting. The topics are exotic and indigenous forest stocks, Soil carbon stocks, Biochar, Forest, Pastoral, Horticultural and Cropland management and Erosion.
Implications of Changes in Albedo on the Benefits of Forests As Carbon Sinks	Landcare Research	Whitehead	$30,126	Increasing carbon storage by forests leads to a decrease in atmospheric CO_2, though the amount depends on the change in albedo. The decrease in albedo means more energy is absorbed, which causes further warming.
Development of forest productivity surfaces	Landcare Research		$150,000	Aim: Determining an improved understanding of the effects of climate change on productivity. For indigenous forests, the research produced spatial models of tree diameter increment. Surfaces were produced for 10 indigenous species, Beilschmiedia tawa, Dacrydium cupressinum, Elaeocarpus hookerianus, Myrsine australis, Nothofagus fusca, Nothofagus menziesii, Nothofagus solandri, Podocarpus hallii, Prumnopitys ferruginea and Weinmannia racemosa.
Effects of natural disturbance on forest carbon	Landcare Research	Holdaway	$150,000	Aim: Assessing impact of natural disturbance on NZ forests within context of Durban reporting agreements. What are NZ's baseline emissions? How large a role does natural disturbance play in NZs forest carbon budget?

				New Zealand's background level CO_2 emissions from natural disturbance were quantified. Net carbon implications were estimated, providing a dynamic and explicit treatment of carbon stock change.
Gorse and broom to forest	Landcare Research		$300,000	Aim: Aimed to better understand timing of natural forest succession in the context of ETS, where stand age is critical to determining eligibility. Regeneration to forest becomes more likely as gorse or broom gets taller/older and on steeper ground. Ten to twelve years are required for 3% of the crown cover to be achieved after tree establishment. Gorse sites tending to transition to forest more quickly than broom sites.
Improved allometric functions for broom and tauhinu	Landcare Research		$150,000	Aim: The research aimed to improve the precision of biomass estimates and make models available for biomass prediction Mean canopy height can be used to accurately predict carbon stocks both in broom and tauhinu.
Allocation of New Zealand's harvested wood to domestic and export products	Scion	Wakelin	$150,000	Aim: Meet Kyoto Protocol and UNFCCC reporting requirements. Under Kyoto protocol commitment period 2. Different accounting methods may be developed to sort Harvested Wood Products (HWPs) and assess how they should contribute in NZ inventory. Results have shown that only a third of the carbon harvested in roundwood is captured in HWPs manufactured in New Zealand.
Building resilience through community generated forestry strategies	Scion	Warmenhoven	$500,000	Aim: To describe livelihood strategies, community capitals and vulnerability for those in the Waiapu catchment. In the Waiapu deforestation has exacerbated high natural rates of erosion and sedimentation. Climate change is expected to add more disturbance and trigger more shocks to the already degraded environment and low socio-economic profile of Waiapu communities. The economic, social and biophysical trends, processes and events that have contributed to the current degraded state of the environment and low-socio-economic profile of the community will continue if unchecked. Climate change, will to add another layer of stressors and generate further shocks (floods, drought and storms) that the community must overcome.

Carbon sink potential of naturally durable hardwood species in comparison to alternative hardwoods species preferred for timber production.	Scion	Meason	$299,300	Aim: Investigate the carbon sequestration potential of three Eucalyptus species in New Zealand; E. fastigata, E. regnans, and E. globoidea. The results showed that each species warranted the development of separate carbon sequestration models. The results showed that all species sequestered the most carbon near the coast and in the North Island. Overall, E. regnans sequestered the most carbon on average nationwide for a 40-year carbon forest regime.
Climate change and fire danger	Scion	Pearce	$150,000	Aim: Summarise present state-of-knowledge and/or latest understanding of the effects of climate change on forestry and fire risks Fire climate severity is likely to rise significantly with climate change in many parts of the country because of increases in temperature or wind speed, and lower rainfall or humidity. Results indicate that changes in overall fire climate severity are also associated with significant changes in the contributing fire danger ratings.
Development of ETS look-up tables	Scion	Beets	$1,500,000	Aim: To improve current tree growth models. Compiling existing data and acquiring new data will help landowners to better estimate carbon sequestration in their forest using look-up tables based on growth indices. Improving the nitrogen fertility index surface is critical to better assess these indices, used as inputs for the Forest Carbon Predictor model.
Douglas-fir Model Enhancement for Carbon	Scion	Beets	$150,000	Aim: To improve a tree growth model. Using a new wood density model, the FCP can support carbon stock assessment for Douglas-fir.
Drought Tolerant Species Selection	Scion	Dungey	$150,000	Aim: To develop a simple and reliable protocol to identify drought tolerant Radiata pine genotypes. Carbon isotope composition (δ13C) can be used for indirectly selecting Radiata pine genotypes with high WUE and better growth performance under drought prone conditions.
Future Forest Systems	Scion	Watt	$1,500,000	Area suitable for future afforestation Three scenarios identified available areas ranged from 7 to 1.1 M - 2.9 M ha. All scenarios targeted nonarable land classes for afforestation. Exotic forest species for marginal hill country Three main species show good potential for establishing on marginal land are Pinus radiata, Sequoia sempervirens, Eucalyptus fastigata and Kanuka.

				Results – Direct impacts of climate change There were only slight growth responses with a constant CO_2 scenario. Wood productivity projected average increases of 19% by 2040 and 37% by 2090 with increasing CO_2, Influence of climate change on key diseases Predictions of disease severity made to 2090 show the risk from both diseases will increase significantly in parts of the South Island. In the North Island predicted disease severity to 2090 is likely to remain relatively static for Cyclaneusma needle cast and markedly decline for Dothistroma needle blight. Influence of climate change on fire and wind risk Projections show areas of elevated fire danger in Canterbury, Gisborne, Marlborough and Central Otago/South Canterbury expand along the east coast of both islands by the 2040s and develop further in Marlborough, Hawkes Bay and Wairarapa by the 2090s. Fire dangers in Wanganui, the Bay of Plenty and Northland would also increase. Fire climate severity in Southland, south Taranaki and the Coromandel, would increase but remain comparatively low. For Pinus radiata increased tree growth rates had the most significant impact on the risk of wind damage and was increased by modest increases in the projected wind climate.
Future proofing plantation forests from pests	Scion	Watt	$150,000	Aim: to determine the potential distribution of four high impact invasive species (Buddleja davidii and Dothistroma needle blight, pitch canker and the insect Thaumetopoea pityocampa (pine processionary moth) under current and future climate within New Zealand. Under future climatic change, there is strong evidence that pests spreading, distribution and abundance over New Zealand will shift. On-going vigilance through monitoring and early detection, prediction and decision making are required. Pitch Canker Under climate change, it is projected that most the North Island and northern and coastal areas of the South Island will have optimal climatic conditions for pitch canker. Buddleja davidii

				The potential distribution of B. davidii increased under all future climate scenarios these increases showed marked regional variability within New Zealand. In the South Island, show considerable potential range expansion particularly in high country areas. Pine processionary moth (Thaumetopoea pityocampa) Under climate change there were marked increases in climatic suitability with projections showing between 82% and 93% (from 6%) of the plantation estate was suitable under future climate scenarios. Under future climate the average national reductions in merchantable and total stem volume, range from 29% to 33% between scenarios, as climatic suitability for T. pityocampa increases.
Improving the Eucalyptus fastigata growth model	Scion	Meason	$150,000	A statistical growth model for E. fastigata was designed to predict carbon sequestration.
New forest management approaches for steep hill country.	Scion		$300,000	Aim: Review information on the nature of the steepland forest harvesting problem. Risk management approaches should be implemented for forest managers to minimise the risk of landslides and debris flows during post-harvest window of vulnerability. Forest planning and regulation requires alternative management practices could include debris-capturing systems and partial cut thinning that would minimise the impact of clearcuts. Protocols are needed for the forest industry to better support responses when such events occur, among others: clean-up operations, communication and remediation plans for damaged infrastructure.
Reducing Harvesting Costs	Scion	Heine	$150,000	Identifies adaptation options for harvesting systems for forests that are located on sites that will be more exposed to extreme weather events under climate change. Improved harvesting systems on steep country will act as an economic incentive to enhanced reforestation on marginal lands.
Resilient new indigenous forests	Landcare	Dickie	$1,500,000	The study identifies that a lack of mycorrhizal inoculum can limit seedling establishment. Developed quantitative data for spatially explicit models of woody establishment.

Forest Management for Carbon and Carbon Price Risk	Scion	Turner	$193,760	Identify how planted forests can be managed to increase sequestration of carbon for economic benefit while recognising the risks associated with the expected volatility in the price of carbon.
Life Cycle Assessment (LCA): adopting and/or adapting overseas LCA data and methodologies for building materials in New Zealand.	Scion	Nebel	$108,000	Increasing amounts of greenhouse gases, such as carbon dioxide or methane, enhance the natural greenhouse effect and lead to an increase in global temperature. CO_2 emissions were calculated using New Zealand specific CO_2 coefficients for the different fuel types
The Effect of Climate Change on New Zealand's Planted Forests: Impacts, Risks and Opportunities.	Scion	Watt	$185,000	Climate change is likely to have a significant impact on the future growth of trees in planted forests because tree growth responds directly to changes in CO_2 concentration, temperature and nutrient and water availability Climate change is also likely to affect many abiotic and biotic factors, which may in turn affect plantation growth and productivity. The main factors that are considered here include weeds, insects, pathogens and the risks from wind and fire. These factors currently cause significant economic losses in planted forests.
Identification and Analysis of Voluntary Carbon Market Opportunities	The Karo Group Limited	Karo	$120,000	This report has been superseded largely by international developments in carbon markets since it was written.
Novel poplars and willows adapted to a changing climate	Plant and Food	McIvor	$450,000	Improved understanding of the adaptability of specific poplar and willow clones to projected climate change.
Managing risks in carbon forestry	University of Canterbury	Manley	$102,222	The purpose of this report was to identify how planted forests can be managed to increase sequestration of carbon for economic benefit while recognising the risks associated with the expected volatility in the price of carbon.
Forest risk management strategies-how can forest owners manage risk and uncertainty associated with carbon prices?	URS New Zealand Ltd	Harkin	$23,599	The report informs post-1989, exotic forest owners in their decision as to whether to opt in to the ETS; and to provide guidance on potential risks and risk management strategies for both pre-1990 and post-1989 forest owners that are required to, or are voluntarily participating in the ETS.
Quantification and Management of the Risk of Wind Damage to New Zealand's Planted Forests	University of Canterbury	Moore		The risk of wind damage to should drive decision making towards less exposure, better response to economic impact on forests.

Forestry Accounting Options	Force Consulting	Roberson	$300,000	This project explores the greenhouse gas accounting systems for forests and their products. It draws IPCC guidance and related political decisions, and identifies key aspects of different accounting systems in place to measure emissions reductions and assess compliance with national commitments.
Carbon Accounting: Forest Growth Rates and Changing climates	University of Canterbury	Mason		Forests responses to higher concentrations of carbon dioxide are expected to be positive, although uncertainty is high concerning other factors affecting tree growth such as nutrient availability. It is likely that trees will show transient acclimation period before going back to normal growth rate.
Impact of the ETS on Forest Management	Piers Maclaren	Maclaren		(2008) Revenue from annual sales of carbon units greatly increases the profitability of all species and regimes. For a price carbon at $30 per tonne of carbon dioxide equivalent then nearly all forestry investments – regardless of site quality – can pay $3000/ha for the land and still achieving a reasonable real rate of return.