An Exploration of Knowledge Development, Dissemination, and Resource Mobilisation within New Zealand's Forestry Innovation System

A thesis presented in partial fulfilment of the requirements for the degree of Master of Environmental Management at Massey University, New Zealand

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Abstract

In New Zealand, plantation forestry is the third largest export earner, representing about 1.6% of GDP and offsetting over 20% of the country's carbon emissions between 2013-2020 (Ministry for Primary Industries, 2021a; Ministry for the Environment, 2022). However, despite the clear importance of forests for New Zealand, knowledge development, dissemination, and resourcing efforts are currently unable to fulfil the evolving needs of the forestry industry.

This thesis critically assesses the governance of knowledge development, dissemination, and resourcing in the New Zealand forestry sector. It focuses on Māori and small-to-medium forest owners (SMFOs), who hold a large proportion of the national forest stock (Ministry for Primary Industries, 2020; New Zealand Forest Owners Association, 2019). Key relevant policy documents were identified, and a range of actors engaged in New Zealand's forestry innovation system (FIS) were interviewed. The widely used Innovation System (IS) construct was applied as the conceptual framework, and interview and documentary data analysed using a structural-functional analysis framework, after Wieczorek and Hekkert (2012).

The analysis reveals systemic problems for knowledge development, dissemination, and resource mobilisation that are consistent with those identified within the literature. New Zealand's FIS can be broadly characterised as being fragmented, with little collective strategy or direction, and having a strong focus on existing systems and practices. These practices included norms such as low appetite for risk among investors, a preference for in-person interactions, and a high value placed on autonomy. The data also highlights that FIS actors tend to be disconnected from each other. Overall, knowledge and financial infrastructure is inadequately resourced and currently unable to fully support the diverse aspirations of New Zealand's forest owners. There is a clear need for more translation of technical knowledge into accessible formats and improved infrastructure for information storage, management, and access.

The systemic problems are often interlinked, with shared root causes that are long-standing and complex. The analytical framework enabled identification of systemic instruments that could mitigate these problems, including a national forest policy, broader industry and public engagement, and a resource prioritisation framework based on Treaty of Waitangi principles. The findings may inform and facilitate development of forest policy instruments that are innovative, conducive to deeper Treaty partnership, inclusive, environmentally and economically sustainable, and socio-culturally appropriate.

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List of Abbreviations

BC	British Columbia
CFO	Community forest owners
CRI	Crown Research Institute
DOC	Department of Conservation
ETS	Emissions Trading Scheme
FAO	Food and Agriculture Organisation of the United Nations
FGLT	Forest Growers Levy Trust
FIS	Forestry Innovation System
ITPF	Forestry Industry Transformation Plan
MAF	Ministry of Agriculture and Forestry
MBIE	Ministry of Business, Innovation, and Employment
MPI	Ministry for Primary Industries
NGO	Non-governmental organisation
NZFFA	New Zealand Farm Forestry Association
NZFOA	New Zealand Forest Owners Association
NZIF	New Zealand Institute of Forestry
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
RMA	Resource Management Act
RSI	Research, Science, and Innovation
SFFF	Sustainable Food and Fibres Futures
SMFO	Small- to medium-size forest owners
TUR	Te Uru Rākau – New Zealand Forest Service
UNDRIP	United Nations Declaration on the Rights of Indigenous People
WPMA	Wood Processors and Manufacturers Association of New Zealand

1 Introduction

The world's forests and the services they provide are estimated to have a total value of up to USD$150 trillion – almost double the value of the global stock market – and the contributions of the formal forestry sector are expected to increase over time (Food and Agriculture Organisation of the United Nations, 2022; Kappen et al., 2020). In New Zealand, forests deliver a range of economic, social, and environmental values. For instance, plantation forestry is New Zealand's third largest export earner, representing about 1.6% of the country's GDP and employing over 35,000 people (Ministry for Primary Industries, 2021). Forest ownership is diverse, delivering economic returns for a mix of commercial, community trusts, private, and public entities across New Zealand's regions (New Zealand Forest Owners Association, 2021). Small- to medium-size forest owners (SMFOs) make up about 94% of New Zealand forest owners (Ministry for Primary Industries, 2020a). While this ownership pattern is similar to other wood-producing OECD countries like Finland and Sweden (Finnish Forest Association, n.d.; Widman & Bjärstig, 2017), a key difference in New Zealand is that a significant amount of forestry is held by Māori in community ownership structures, such as the Central North Island (CNI) Iwi Collective, Lake Taupō Forest Trust, Taitokerau Māori Forests Inc, and Tuhoe Tuawhenua Trust. Forestry is an important component of the Māori economy and Māori account for 40% of New Zealand's forestry production (MFAT, 2020) and 40% of the forestry workforce (Reid et al., 2020). Despite the clear importance of forests globally, this thesis argues that there are significant challenges for forestry-related knowledge development, dissemination, and resourcing in New Zealand (Ministry for Primary Industries, 2020c; Ministry of Business Innovation and Employment, 2020; New Zealand Forest Owners Association, 2019b; Payne et al., 2018; Scion, 2022).

This thesis critically assesses the governance of knowledge development, dissemination, and resourcing in the forestry sector, and seeks to identify policy strategies and instruments that will facilitate forestry practices that are inclusive, innovative, economically and environmentally sustainable, and sensitive to New Zealand's socio-cultural context and environment. In particular, it focuses on Māori and small-to-medium forest owners (SMFOs), who are critical to future wood availability as they hold a large proportion of the national forest stock maturing in the coming decade (Ministry for Primary Industries, 2020b; New Zealand Forest Owners Association, 2019a). Given the increased focus on transforming the forestry sector by various industry associations and the government (Forest Research Committee, 2019;

Te Uru Rākau (New Zealand Forest Service), 2021) and the development of private-public-research partnerships in forestry (Dunningham et al., 2020; Millen et al., 2019), these two relatively understudied groups are potentially powerful change agents for shaping environmentally sustainable forest practices and delivering more value to regional and domestic economy.

Beyond its role in the economy, the forestry industry is also central to New Zealand's climate change strategy. Forestry activities have offset more than 20% (123.3 Mt CO_2-e) of New Zealand's entire carbon emissions budget between 2013-2020 (Ministry for the Environment, 2022). This figure is projected to increase as afforestation for long-term carbon storage was recently highlighted as a time-critical action, with a proposed annual native afforestation target of at least 25,000 hectares per annum until 2050 (Climate Change Commission, 2021). New Zealand's forests are also a key provider of ecosystem services such as climate regulation, erosion prevention, flood mitigation, and water filtration (Dymond et al., 2012; Forbes, 2021; Yao et al., 2017). Research by Patterson and Cole (2013) estimated that New Zealand's forest ecosystem services are worth over NZ$10 billion annually.

In addition, forest ecosystems in New Zealand offer crucial refugia habitat (Marshall et al., 2009), are valuable for evolutionary studies (Trewick et al., 2007), and contain some of the most diverse epiphyte (tree-dwelling) flora in the world (White, 2016). Both native and exotic forests have socio-cultural value for their owners and for the wider public (Aimers, 2021; Widman & Bjärstig, 2017). Māori, in particular, have an intricate and interconnected relationship with the natural world (Harmsworth & Awatere, 2013) and revere the forest for its physical and spiritual attributes (Miller et al., 2007; Taonui, 2007). Forests are also treasured by Māori and non-Māori for recreation, experiencing nature, gathering wild food, medicinal plants, and traditional weaving and building materials (King et al., 2013; Taonui, 2007; Turner et al., 2011; Yao et al., 2017).

Due to a strong legacy of research, existing management knowledge, and profitability, the development of forestry knowledge and capacity in New Zealand over the last century has largely centred on radiata pine (*Pinus radiata*) (Reid, 2001), which makes up 90% of the country's plantation stock (Ministry for Primary Industries, 2020c). From the perspective of optimising the social, economic and environmental value of forestry, the dominance of pine plantations for log exports is highly problematic, leaving the industry vulnerable to market shocks, threats like pests and disease, and extreme climate events like droughts and wildfire (Ministry for Primary Industries, 2020c).

Although there is growing acknowledgement of the importance of the management of forests for multiple purposes internationally (Almstedt et al., 2014; Haaland et al., 2011; Petrov et al., 2019) and in New Zealand (Yao et al., 2017), there is no cohesive forestry innovation system that spans across the multiple values of native and exotic forest. A recurring issue identified in New Zealand's forestry industry is that there is no national forest policy strategy articulating a common vision, goals, or action plan (Hall, 2021; McEwan, 2013, 2019; Wreford et al., 2019). In comparison, by 2010 143 other nations (73% of all countries) already had forest policy statements (Food and Agriculture Organisation of the United Nations, 2010). Instead, New Zealand's policy landscape is fragmented, with key actors across conservation and forestry industry such as the Ministry for Primary Industries (MPI), Scion, Forest Owners Association, Farm Foresters Association, and Wood Council of New Zealand (Woodco) pursuing separate strategic plans.

There is also a lack of policy stability and accumulation of capabilities in forestry. By illustration, New Zealand has disbanded and reinstated its Forest Service responsible for the management of New Zealand's state owned forests three times since 1920 (Roche, 1990). In the latest disestablishment in 1987, the New Zealand Forests Service's functions were split across three new entities: the New Zealand Forestry Corporation, the Ministry of Forestry, and the Department of Conservation (O'Loughlin, n.d.). The subsequent loss or re-assignment of about 2000 staff (O'Loughlin, n.d.) likely caused a loss of institutional knowledge, subject matter expertise, organisational memory, and network-based information (Parise et al., 2006). By comparison, other wood-producing OECD countries like Germany and Canada have long-standing forestry sector and technology encouragement policies, and have seen less disruption of organisational structures and functions (Federal Ministry of Food, 2011; Hayter & Clapp, 2020).

Multi-use landscape management in New Zealand is further compounded by the long-standing competitive relationship between agriculture and forestry, policy frameworks that favour agriculture, and a lack of policies to encourage domestic demand for wood (Hendrickson, 2021; Kanowski & Edwards, 2021; Roche, 1990). One consequence of this lack of cohesion is that investment in New Zealand's wood processing capacity currently lags behind increasing wood harvest volumes (Hilliard et al., 2011). For example, the most recent greenfield sawmill investment was in 2005 (Forest Economic Advisors, 2019). Other factors that negatively impact infrastructure investment in the forestry industry include free-trade agreements and market conditions that incentivise exporting raw logs instead of

processing them (Ballingall & Stephenson, 2019). Jack et al. (2013) add that the numerous small processing facilities limit economies of scale, with up to 1.0 million m^3 of unutilised processing capacity in existing sawmills; in turn, this reduces the return on capital investment. Furthermore, as carbon forestry becomes an increasingly attractive land use option, the prospect of large-scale permanent forestry for carbon capture is raising concerns about potential long-term social, biosecurity, fire, and productivity risks (BDO, 2021).

In summary, forests provide many benefits and are a valuable resource for New Zealand's economy, climate change strategy, biodiversity, and sociocultural wellbeing. However, managing forests for economic and environmental sustainability has been challenging due to many factors, including disruptive changes in forestry governance and policy settings that favour incumbent practices.

1.1 Aims, objectives, and thesis structure

This research aims to identify potential policy strategies and instruments that will facilitate forest practices that are economically and environmentally sustainable; innovative; and sensitive to New Zealand sociocultural context and environment. To achieve these aims, this research will:

1. Review international best practice policy for small to medium scale sustainable forestry, focusing on three innovation system functions: knowledge development, knowledge dissemination, and resource mobilisation (Wieczorek & Hekkert, 2012).
2. Characterise the barriers for small- to medium-scale forest owners (SMFOs) and community forest owners (CFOs) in sustainability knowledge development and dissemination in New Zealand.
3. Identify policy gaps in New Zealand and make recommendations.

Several types of forest practices that are economically and environmentally sustainable have been developed and implemented on a large scale in other countries. Examples of such practices that are understood but not widely practiced in New Zealand include continuous cover forestry, coupe harvesting, agroforestry, and mixed-age and -species planting (Cairn, 2016). The barriers to adopting these processes will also be assessed.

This thesis is structured as follows. First, Section 1.2 defines SMFOs and CFOs and reviews the barriers to innovation and the adoption of innovative practices for small to medium-scale forestry owners based

on international and domestic literature. Next, Chapter 2 presents the research methods used in this study, detailing how the data was gathered and analysed, and discussing ethical considerations and the limitations of the research. Chapter 3 then sets out the conceptual framework, introducing the functions of a forestry innovation system (Section 3.1), discussing the three functions of knowledge creation, dissemination, and resourcing that are the focus of this thesis (Section 3.2), and exploring how this conceptual framework can be applied to SMFOs and CFOs and setting out a vision of an inclusive forestry innovation system and what that might look like in the New Zealand context, drawing on examples from international and domestic literature (Section 3.3).

Chapter 4 presents the study's findings, opening with an overview of the findings (Section 4.1), then outlining systemic problems for knowledge development (Section 4.2), knowledge dissemination (Section 4.3), and resource mobilisation (Section 4.4) for SMFOs and CFOs. Other systemic problems related to these three functions are covered in Sections 4.5 to 4.6. Chapter 5 then discusses the findings using the conceptual framework set out in Chapter 3, making recommendations to address the problems identified by the study, and highlighting areas for further investigation. Finally, Chapter 6 summarises the study's findings, reflects on the limitations of the project, and suggests potential areas for future study.

1.2 Unique aspects and barriers to innovation for small- to medium-scale forest owners and community forest owners

The barriers SMFOs and CFOs face are different from those faced by large-scale forest owners (Hansen et al., 2019). This section discusses the main characteristics of SMFOs and CFOs in New Zealand and outlines key barriers to innovation for these groups.

In this thesis, SMFOs are defined as forest owners with less than 1000 ha of forest estate. Recent estimates suggest the total number of SMFOs in New Zealand is approximately 15,000 (Clark, 2018; New Zealand Forest Owners Association, 2019a). Note that the smallest surveyed forest size in New Zealand (40 ha) is far larger than those in other OECD countries like Norway (4 ha) and Finland (1 ha) (Ministry for the Environment, 2001; Official Statistics of Finland, 2021; Sjølie et al., 2016). The number of owners

with less than 40 ha of forest is difficult to determine accurately as this group is not surveyed for the National Exotic Forest Description reports (Ministry for Primary Industries, 2020b).

SMFO ownership of forests varies widely by country. For example, Finland's forests are largely privately owned by about 620,000 forest owners (Finnish Forest Association, n.d.). Ownership of New Zealand forestry across small versus large-scale owners is shown in Figure 1 below. Although SMFOs control a relatively small proportion (14%) of New Zealand's total forest estate, they make up a large fraction of New Zealand's forest owners (Table 1). SMFOs are a critical target group in terms of New Zealand's ability to realise prospects for sustainable forestry innovation. This is because they own 48% of the radiata pine plantation estate aged 21 and older (approaching maturity) in 2016, currently account for about 39% of the total net stocked area of radiata pine, and are the main domestic sources of specialty hardwood timber (Manley, 2016; Ministry for Primary Industries, 2016a, 2021b). As SMFOs are important contributors to the national wood supply, their planting and harvest decisions can have notable impacts on wood availability in New Zealand (Chandler, 2016; Ministry for Primary Industries, 2021b). It is therefore crucial to include SMFOs in national forestry-related planning to diversify timber species, create new niche markets, and promote entry into the existing supply chain.

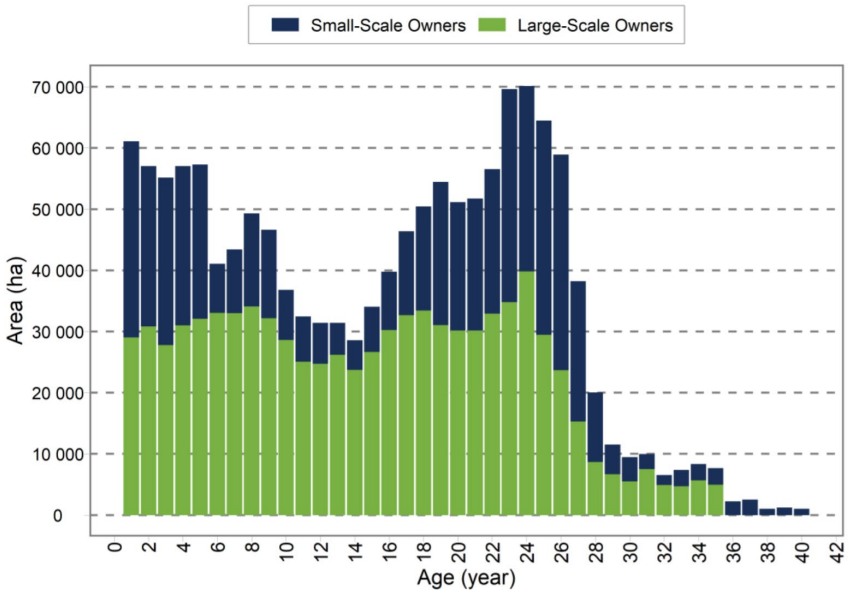

Figure 1 Age-class distribution of radiata pine by ownership type. Source: Ministry for Primary Industries (2021b).

Table 1 Number of owners by forest estate size (data from Ministry for Primary Industries (2020b)).

Forest estate size (ha)	Net stocked area ('000 ha)	Proportion of total forestry area (%)	Number of owners at national level
40-999	227	14	1,534
1,000-9999	210	13	66
Over 10,000	943	57	25

SMFO blocks tend to be distant from infrastructure, on steeper country, have a higher proportion of first rotation tree crops, and have fewer economies of scale (Chandler, 2016). These factors lead to SMFOs facing higher average costs of roading, harvesting, and cartage (Chandler, 2016). Harvest decisions by SMFOs tend to be opportunistic (Chandler, 2016) and sensitive to log prices (Manley et al., 2015) as forestry entities generally seek to maximise their benefits (Ministry for Primary Industries, 2016b). Research on Canterbury SMFOs revealed other factors that drive harvest decisions, including individual forest owner's objectives, forest age, demand by local wood processing plants, and perceptions about future log prices and future wood supply (Ministry for Primary Industries, 2016b). Furthermore, forest owners place a high value on independence and autonomy and collective models from the agricultural sector are not readily transferrable to the forestry sector (Ministry of Agriculture and Forestry, 2009).

Several barriers to innovation for SMFOs have been highlighted in domestic and international literature. These include limited financial and technical resources (Hall & Lindsay, 2020); communication problems across the value chain (Hilliard et al., 2011); and low engagement in technology transfer forums (West & Schrider, 2019). SMFOs are also sometimes excluded from data collection (Snyder et al., 2019) and less frequently surveyed than large forest owners (Ministry for Primary Industries, 2020b). By illustration, the various public documents consulted did not clearly indicate the number of Māori SMFOs (Ministry for Primary Industries, 2016a, 2016b, 2021b; New Zealand Forest Owners Association, 2019a, 2021). This is problematic because Māori and non-Māori SMFOs may have divergent challenges, goals, and forest management strategies that cannot be effectively addressed by generic measures for SMFOs.

Alongside SMFOs, this study includes Māori CFOs as this form of ownership is important in the New Zealand context but remains understudied in terms of innovation and adoption of sustainability practices. According to Hajjar and Molnar (2015), community forestry refers to decentralized forms of forest ownership and governance by local communities, smallholders and indigenous peoples, who manage their forests sustainably for multiple cultural, ecological and social benefits.

A key characteristic of Māori CFOs is that whenua, or land, is considered taonga tuku iho, an intergenerational treasure of deep spiritual value (Cortés-Acosta, 2019; Dewes et al., 2011; Hill, 2012). As such, any land-use decisions are considered carefully, guided by cultural imperatives such as tino rangatiratanga (right of self-determination), whakapapa (genealogy), whānaungatanga (tribal or family relationships), and kaitiakitanga (guardianship for the land through time and across generations) (Cortés-Acosta, 2019; Funk & Kerr, 2007). For example, before planting forests, Māori decisionmakers may consider community impacts up to 500 years in the future.

Māori are major players in the forestry industry, holding about 500,000 ha of Māori-owned land which is already afforested in some form, with a further 200,000 ha potentially suitable for further planting (Jones, 2020). The majority of this land is Māori freehold land and regulated under the Te Ture Whenua Māori Act 1993 (TTWM) (Cortés-Acosta, 2019). Māori ownership of forests is expected to increase further as Treaty of Waitangi settlements are resolved and land is returned (Clark, 2018; Dunningham et al., 2018). Unlike non-Māori SMFO-owned land, administration of Māori land can be complex, have high rates of absentee ownership and title fragmentation, and rely on close collaboration across corporations and trusts on incorporations and trusts to manage collective ownership (Bennion, 2009; Boast & Erueti, 2004; Kingi, 2008).

New Zealand CFOs suffer from a lack of expertise in governance and navigating legislation (Coffin, 2016); decision-making challenges (Cortés-Acosta, 2019; Pohatu et al., 2020); insufficient resources that align with aspirations (Edwards et al., 2018); and information asymmetries (Mercer, 2021). For example, many Māori landowners lack access to expert advice and information on land use options, which prevents them from realising the full value of their land asset (Mercer, 2021; Pohatu et al., 2020). Māori CFOs are also not visible in publicly-reported data on forest owners, as they are often grouped under "private owners" (New Zealand Forest Owners Association, 2019a, 2021). This aggregation of forest owners is problematic because the existing inflexible "one size fits all" policy approach to forestry is a systemic issue across central and local government, especially for Māori communities (Mercer, 2021; Pohatu et al., 2020).

Research shows that there are often tensions between economic versus environmental and socio-cultural imperatives (Dewes et al., 2011; Mercer, 2021). For example, many Māori land owners prefer permanent, mixed, indigenous forestry over monocultural exotic plantation forestry, despite potentially

lower economic returns (Ministry for Primary Industries, 2020c). There is thus a need for tools that facilitate the fulfilment of Māori aspirations and align with Māori values (Dewes et al., 2011), while promoting changes in key areas like management, legislation, education, and business (Davies et al., 2005).

Having outlined the main characteristics of SMFOs and CFOs and identified key barriers to innovation for these groups in this section, the next Chapter describes the methods employed in this thesis, as well as limitations and challenges of the study.

2 Methodology

Chapter 1 outlined the multiple social, environmental, and economic values that forests generate for New Zealanders, as well as the multifaceted problems that hinder innovation or adoption of more sustainable practices. This thesis aims to critically assess the governance of knowledge development, dissemination, and resourcing in the New Zealand forestry industry and to identify policy practices and strategies that will facilitate forestry practices that are innovative, economically, and environmentally sustainable, and sensitive to New Zealand's socio-cultural context and environment. To achieve these objectives, this thesis applies a structural functional analysis framework proposed by Wieczorek and Hekkert (2012) to identify problems in New Zealand's forestry innovation system and suggest solutions to these problems.

This chapter provides an overview of the methodology that was used in undertaking this research. Firstly, the data collection methods are explained (Section 2.1), including the sampling method, documents used, and the interview process. Section 2.2 then briefly outlines the research ethics considerations, Section 2.3 explains the data analysis process, and Section 2.4 discusses the limitations of the research.

As forests and the forestry industry have many values, and are perceived differently depending on the observer, this research took a constructionist-interpretivist approach, underpinned by two assumptions: (1) reality is subjective, constructed, multiple, and diverse; (2) science and therefore, knowledge, is not "value-free", but actually value-laden (Sarantakos, 2013). Further, the study approach examines the study object (the forestry innovation system) in its entirety. These assumptions and the study approach made a qualitative research approach the most appropriate choice for this research, given the exploratory and multifaceted nature of the work.

2.1 Data collection

This research employed two research methods to collect qualitative data: documents and interviews with key stakeholders.

2.1.1 Sampling methods

First, purposive sampling was used to identify and select documents and interviewees for this research. This method is especially suitable for creating an 'exploratory sample' as it enables collection of the best information by focusing on a relatively small number of deliberately selected instances (Denscombe, 2014). Interviewees were chosen for their knowledge about the FIS functions, to ensure representativeness of the FIS, and to discover 'outliers' that could be used to test mainstream findings (Denscombe, 2014).

Next, snowball sampling was used, where interviewees were asked to identify other potential participants. This technique is effective for building up sample size, particularly for small-scale research such as this thesis. The "nomination" process also enhances research credibility (Denscombe, 2014) and is especially useful given the importance of personal connection and whakapapa (genealogy) within the forestry industry and communities. Crucially, snowball sampling provided links to otherwise unknown or inaccessible information and participants.

2.1.2 Documents

In this thesis, documents were treated as a source of primary data (Denscombe, 2014). In addition to interview data, documentary data was gathered using online tools such as the Massey library and Google Scholar. Sources of documentary data included government publications, official statistics, journals, books, mass media, letters, and websites. Peer-reviewed journals were taken as mostly objective and credible. In contrast, the impartiality of government and industry publications depended greatly on the content (Denscombe, 2014), especially given the renewed national interest in forestry and the many sub-groups present in the industry.

As explained above, purposive sampling was used to identify the specific data required to achieve the research objectives. There is no single New Zealand forest policy or strategy for direct comparison with forest policies and strategies from other countries. As such, a range of policy documents that shape New Zealand's forestry innovation system were identified and compared to international best practice, including:

- Forests Act 1949
- Resource Management Act (RMA)

- National Environmental Standard for Plantation Forestry
- A Forestry Sector Study (Ministry of Agriculture and Forestry, 2009)
- New Zealand's Research, Science and Innovation Strategy (Ministry of Business Innovation and Employment, 2019)
- The National Exotic Forest Description (Ministry for Primary Industries, 2020b)

2.1.3 Interviews

Interviewing is one of the most common methods of data collection (Sarantakos, 2013) and is valuable for exploring complex issues, privileged information, opinions, and experiences (Denscombe, 2014, p.186). As this research is exploratory, interviews offered the following advantages over other survey methods like written questionnaires (Sarantakos, 2013):

- Completeness – the researcher is available to help respondent provide a complete answer
- Length – interviews can be longer than other survey methods, allowing more information to be gathered
- Accuracy – the researcher is able to address misunderstandings by respondents
- Flexibility and ability to handle complexity – the depth of interview can be adjusted to respondent capacity, which is not possible with a written survey
- Opportunity to observe non-verbal behaviour
- Able to record spontaneous verbal answers – in contrast, written responses can be more deliberate or self-censored and may not reflect the interviewee's true feelings about the issue

The aim of the interviews was to explore the role of actors in New Zealand's FIS, their interactions, and factors influencing interactions and processes (Minh, 2019). The interview questions were designed to cover three key FIS functions: knowledge development, knowledge dissemination, and resource mobilisation for knowledge development and dissemination. Semi-structured interviews were used, in line with most diagnostic IS work with a clear list of questions to be answered (Turner et al., 2016). The questions were informed by the diagnostic questions posed by Wieczorek and Hekkert (2012) as outlined in Table 2. A copy of the interview questions is provided in Appendix 2.

Table 2 Innovation system functions and corresponding examples of diagnostic questions (from Wieczorek & Hekkert, 2012).

Innovation System Function	Examples of diagnostic questions
Function 1, Entrepreneurial activity	Are there enough entrepreneurs? What is the quality of entrepreneurship? What variety of technological options are available? Are any entrepreneurs leaving the system? Are there new entrepreneurs?
Function 2, Knowledge development	Are there enough actors involved in knowledge development and are they competent? Is the knowledge sufficiently developed and aligned with needs of actors in the innovation system? Is the knowledge development demand-driven? What is the knowledge base in terms of quality and quantity? Which actors are particularly active? Is the knowledge basic or applied? Is there a leading international position, trigger programmes, many cited patents? Who finances the knowledge development? Does the technology receive attention in national research and technology programs? Are there enough knowledge users?
Function 3, Knowledge dissemination	Are there sufficient networks or connection between actors through which knowledge is exchanged? Between whom? Is there space for knowledge dissemination? Is the knowledge dissemination demand-driven? Is there strong competition? Does the knowledge correspond with the needs of the innovation system? Have any licenses been issued?

Innovation System Function	Examples of diagnostic questions
Function 4, Guidance of the search	Is there a clearly articulated and shared goal for the system? Is it supported by specific programs, policies, who are the system's frontrunners? Is the objective inducing government activities? What are the technological expectations (negative/positive)? Does the articulated vision fit in the existing legislation?
Function 5, Market formation	What does the market look like? Is the size of the market sufficient to sustain innovation and entrepreneurial experimentation? Who are the users (current and potential)? Who takes the lead (public/private parties)? Are there institutional incentives/barriers to market formation? Must a new market be created or an existing one be opened?
Function 6, Resource mobilisation	Are there sufficient financial resources for system development? Do they correspond with the system's needs? What are they mainly used for (research/pilot projects etc.)? Is there sufficient risk capital? Is there adequate public funding? Can companies easily access the resources? Are there sufficient competent actors/well trained employees?
Function 7, Creation of legitimacy	Do actors, formal and informal institutions sufficiently contribute to legitimacy? Is there much resistance to change? Where is resistance coming from? How does this resistance manifest itself? What is the lobbying power of the actors in the system? Is coalition forming occurring?

As discussed previously, the interviews designed and undertaken for this research adopted a constructivist approach. Interview questions were designed to explore the FIS functions, structural elements, types of systemic problems, and systemic instrument goals. Fourteen individuals representing SMFOs, processors, knowledge organisations, consultants, forestry-related resource organisations, industry good bodies, and the Government were selected from several regions nationwide (Table 3). This geographic dispersion necessitated that many interviews were done remotely via video or voice calls using software such as Zoom. Note that some interviewees represent more than one characteristic of interest.

Table 3 Key characteristics of the interviewees

Interviewee characteristics	Interviewees
Small forest growers (<40 ha)	4
Medium forest growers (40-1000 ha)	1
Community forest representatives	2
Wood processors	3
Knowledge organisations, e.g. Scion, Forest Growers Levy Trust, universities	4
Forestry consultants	4
Forestry-related resource organisations	2
Industry good bodies	3
Government and Crown Research Institutes	4
North Island	8
South Island	6
Gender ratio (Female:Male)	6 : 8
Number of interviewees identifying as Māori	2
Number of interviewees who regularly work with Māori	6

All interviews were undertaken by the author, with each interview taking one to two hours. The interviews were recorded, transcribed using Otter.ai software, and coded in Nvivo v12. Copies of interview transcripts were available to interviewees, but none were requested. Several interviewees did, however, request a copy of the completed report.

2.2 Research ethics

Prior to commencing interviews, ethics approval was obtained from Massey University. This process involved detailing the nature of the interviews, what type of data would be collected, how the

information would be used, and how confidentiality would be maintained. This research was deemed low risk. It is not expected to cause harm and discomfort to the participants or the researcher.

The main ethical considerations pertained to interviewee privacy and information confidentiality. Potential interviewees were identified and sent an introductory email with the Information Sheet attached, which detailed their rights as a participant (Appendix 1). Informed consent was also obtained verbally at the start of each interview. Before recording any interviews, participant rights were re-iterated to the interviewees. These rights included withdrawing from the study at any time, declining to answer any question, requesting any further information or speaking off-record. No identifying information is used in this study; only indications of interviewee roles in the Forestry Innovation System are provided where appropriate.

2.3 Data analysis

Thematic analysis of the coded interviews was undertaken to identify systemic problems by exploring recurring themes across interviewee sectors and organization types and exploring links among problems.

A four-step process was used to evaluate the performance of the FIS' functions of knowledge development and knowledge dissemination. First the FIS functions were evaluated by identifying functional failures or deficiencies and possible causes for the failures. Second, systemic problems were identified and classified by presence and quality/capacity/intensity of the FIS elements. Next, the main systemic problems were mapped to the FIS function goals, revealing which problems affect each goal, and any blocking mechanisms (Bergek et al., 2008; Wieczorek & Hekkert, 2012). Systemic instruments that support each goal were then identified based on the problems and opportunities identified (Wieczorek & Hekkert, 2012). Although this thesis is focused on innovation system functions of knowledge development, dissemination, and resourcing, findings relating to all the innovation system functions are provided in the Chapter 4 because innovation is a collective activity and the focal FIS functions interact with, and are influenced by, other FIS functions.

2.4 Limitations

This study was directly affected by public health-related measures taken to control the 2021 COVID-19 outbreak. Travel restrictions curtailed the ability to meet and interview CFOs and SMFOs in person. For

example, a field trip and numerous interviews had been planned for the North Island in August and September 2021. These interviews were to be conducted in person, with several opportunities for personal introduction to local forest communities, including site visits. However, Level 3 COVID-19 lockdowns in late August prevented travel, and all in-person interviews in the North Island were cancelled.

As a consequence of the Level 3 lockdown, all interviews and introductions to potential interviewees outside Christchurch were done via email or telephone, with very limited in-person interaction. This mode of working could have affected the ability to connect with SMFOs and CFOs who identify as Māori because all the North Island interviewees were central to the snowball sampling method mentioned in Section 2.1.1. These interviewees had been selected because they were considered New Zealand forestry experts closely connected to Māori forest grower communities. These interviewees had also advised that in-person introductions were essential for building the necessary relationships with Māori SMFOs and CFOs. As personal introductions were not possible due to the Level 3 lockdown, access to Māori SMFOs and CFOs was significantly lower than anticipated at the outset of the study. A related limitation is the small sample size of Māori interviewees (2), who were both CFOs. As no Māori SMFOs were interviewed, this study does not provide an accurate representation of the barriers and systemic problems experienced by this group.

In addition to reducing access to Maori SMFOs and CFOs, the inability to conduct in-person interviews may have affected the quality of the interview data. For example, the heavy reliance on videoconferencing limits the ability to build rapport with the interviewee via body language (non-verbal communication). Rapport and mutual trust were considered important for this study as the interview data could include sensitive information or controversial opinions (Weller, 2017). Efforts to increase trust and build rapport with the interviewee included providing the interviewee with the interview questions beforehand, actively engaging via email and telephone leading up to the interview, ensuring diction was clear, and positioning the video camera to allow the interviewee to clearly see the interviewer's facial expressions and hand gestures.

Another limitation of the study is the small sample size. Interviewing more actors including more Māori SMFOs, Māori and non-Māori CFOs, and actors with a wider range of ages and educational backgrounds would have added depth to the study. While forest advisors were interviewed, it did not include other

actors important to SMFOs and CFOs, such as seedling suppliers and small-scale sawmillers. These actors would have provided more context and details on the challenges SMFOs and CFOs face in implementing sustainability practices. For example, it is unclear if seedling suppliers develop or disseminate knowledge to SMFOs, how receptive SMFOs and CFOs are to suppliers as knowledge sources, and what effects such dissemination efforts may have had on planting of alternative non-radiata species. In addition, while small-scale sawmillers were mentioned in interviews and documentary data (Liempd, 2020; Millen, 2020; Raymond, 2018) as developers and holders of knowledge, it is not known if sawmillers actively disseminate knowledge to SMFOs and CFOs. The small sample size also limits the ability to generalise the findings.

A critical reflection by Turner et al. (2016) on the methods described above is that while interviews and literature analysis are commonly used in this type of study, some subjectivity may be introduced because few or no organisational internal documents such as meeting minutes and annual reports are available. Triangulation or expert review of research results can be used to reduce bias (Turner et al., 2016) and provides one potential avenue for future research building on this thesis.

The following chapter provides a literature review and an outline of the innovation system conceptual framework. It also includes analysis of documentary data gathered using the methods described in this chapter. Documentary data is drawn from domestic and international resources to illustrate how the conceptual framework can be applied to New Zealand SMFOs and CFOs and to describe what an inclusive forestry innovation system could look like. This information is useful for contextual understanding the findings of the study presented in Chapter 4, and for further discussion of the results in Chapter 5.

3 Conceptual framework: the Forestry Innovation System (FIS) and its application to SMFOs

The Innovation System (IS) construct is an established framework for analysing the emergence of innovations, actors, institutions, and effects and has been widely applied to understanding deficits in innovation capacity and informing innovation policy (Bergek et al., 2008; Borremans et al., 2018; Edquist, 2009; Fieldsend et al., 2020; Hayter & Clapp, 2020; Rametsteiner & Weiss, 2006; Turner et al., 2016). Several types of innovation systems have been conceptualised over the last few decades tailored for specific study scopes: national innovation systems (Freeman, 1995; Lundvall, 1992), regional innovation systems (Asheim & Isaksen, 1997; Cooke et al., 1997), sectoral systems of innovation and production (Breschi & Malerba, 1997; Malerba, 2002) and technological innovation systems (Carlsson & Stankiewicz, 1991).

An innovation system is generally defined as a group of interacting components which contribute to the development and dissemination of knowledge through constant learning, searching, and exploring (Bergek et al., 2008; Lundvall, 2016b; Rametsteiner & Weiss, 2006). For example, a National Innovation System (NIS) is a complex, integrated system within a country that translates ideas, scientific knowledge, and technologies into productive innovations (Feinson, 2003). From the IS perspective, innovation does not take place in isolation – interactive learning across actors and networks is central to innovation (Lundvall, 1992). Secondly, institutions in the form of laws, industry practices, and social norms play a central role in determining IS economic behaviour and performance (Smith, 1997). Thirdly, evolutionary processes shape the IS as elements are constantly interacting, generating feedback, and selecting across a variety of nascent innovations (Hauknes & Nordgren, 1999; Smith, 2000a).

In keeping with the growing field of IS and sustainability research, this thesis takes a broad view of innovation, acknowledging that innovation relies not just on discovery but also on cooperation and interactive learning (Lundvall, 2016a), recombination or adaptation of knowledge (Smith, 2000b), and multilateral flows of both tacit and formal knowledge (Fieldsend et al., 2020). Rather than taking a product or regional perspective on innovation, this thesis uses a National Innovation System construct to analyse innovation in the forestry sector from a national perspective as national boundaries infer a shared culture, language, governance and legislation (Kubeczko et al., 2006). Thus, a Forestry Innovation

System (FIS) for New Zealand can be defined as a forestry-focused innovation system based on domestic elements such as laws, regulations, sociocultural norms, and industry practices.

A key component to fulfilling the aims of this research is identifying problems that affect New Zealand's current FIS and impede progress towards sustainable and innovative forestry practices. This work defines these problems as "systemic problems", after Wieczorek and Hekkert (2012) who characterise systemic problems as underlying issues related to FIS structural elements. This framework defines eight types of systemic problems, after Wieczorek and Hekkert (2012): actor presence; actor capability; interaction presence; interaction intensity; institution presence; institution capacity; infrastructure presence; and infrastructure quality. Identifying systemic problems from the perspective of SMFOs and CFOs is important for both identifying factors obstructing system development and selecting appropriate systemic instruments to remedy these obstructions (Wieczorek & Hekkert, 2012). The following sections set out the components of Wieczorek & Hekkert's (2012) structural-functional framework which has been widely used to assess the health of innovation systems. Section 3.1 provides an overview of the structural-functional framework, including description of innovation system functions, structural elements, and systemic problems. Section 3.2 introduces the three main IS functions considered in this thesis – knowledge development, knowledge dissemination, and resource mobilisation (Wieczorek & Hekkert, 2012) – and explores how they relate to SMFOs and CFOs. Section 3.3 then provides examples of inclusive, sustainable Forestry Innovations Systems, drawn from international literature.

3.1 Structural-functional analysis of innovation systems

This thesis seeks to explore how well the New Zealand FIS is functioning in terms of developing and disseminating knowledge, and how well these activities are resourced. A structural-functional analysis approach is taken to identify both systemic problems and suitable instruments to address the identified hurdles (Bergek et al., 2008; Hekkert et al., 2007; Minh, 2019; Turner et al., 2016; Wieczorek & Hekkert, 2012).

3.1.1 Functions

Wieczorek and Hekkert (2012) define functions as "processes that are important for innovation systems to perform well". They propose seven key functions:

- Entrepreneurial activity
- Knowledge development
- Knowledge dissemination
- Guidance of the search
- Market formation
- Resource mobilisation
- Creation of legitimacy

The health of these functions may be evaluated with the aid of diagnostic questions that are used to identify specific problems (Hekkert 2010; Wieczorek & Hekkert, 2012). For example, an effective FIS with healthy entrepreneurial activity (Function 1) might be characterised as having abundant forest product entrepreneurs of high quality, demonstrating high degrees of experimentation, adopting a rich variety of technological options. Conversely, an FIS with a weak entrepreneurial function may be characterised by dominant incumbent actors and institutions that promote the status quo. The subsections below describe each function as defined by Wieczorek and Hekkert (2012) and provide an example of each function's role in New Zealand's FIS.

Entrepreneurial activity

According to Wieczorek et al. (2013), entrepreneurs turn new and existing knowledge, networks, and markets into actions that can generate or utilise new business opportunities. In an inclusive FIS, entrepreneurial activity could mean creating high-end timber goods using existing sources of locally grown specialty timber. It could also mean using traditional Māori knowledge and forestry techniques alongside current industry practices to create new, multi-use forests. A key point is that entrepreneurs are considered essential for well-functioning innovation systems (Wieczorek et al., 2013).

Knowledge development

Knowledge is considered a fundamental resource in the innovation process; knowledge development is therefore a cornerstone of all innovation systems (Wieczorek et al., 2013). For example, are there enough actors involved in knowledge development, and do they adequately represent the interests of

SMFOs and CFOs? The methods and priorities for forestry knowledge development should support not only the economic interests of the industry, but also the environmental and cultural aspirations of the people involved in forestry. Importantly, any knowledge developed needs to be accessible to all actors, including SMFOs and CFOs.

Knowledge dissemination

Knowledge dissemination, or the exchange of knowledge between actors, enables learning which is a core characteristic of innovation systems (Lundvall, 1992). In New Zealand's FIS, for instance, knowledge dissemination relies on effective interactions between researchers, SMFOs, and CFOs. These interactions can be influenced by the availability of resources, infrastructure, and prevailing social norms. Like for knowledge development, knowledge being disseminated has to be relevant and accessible for uptake by SMFOs, CFOs, and other actors in the forestry industry.

Guidance of the search

This function is defined here as processes that lead to clearly articulated development goals for the FIS (Wieczorek et al., 2013). For example, governance actors can influence guidance of the search in the FIS by providing clear and consistent support for marketing alternative timber products. As a result, researchers, investors, and entrepreneurs would feel confident in "searching" for new ideas in growing and processing alternative timber species. This FIS function enables selection of activities that contribute to achieving FIS goals and guides resource distribution (Wieczorek et al., 2013). Analysis of this function could elucidate how SMFOs and CFOs perceive the current suite of policies influencing forestry. For example, are policies working well to provide FIS actors with a clear understanding of the larger goals for the industry; and are these existing policies prioritising the right areas for forestry knowledge development, dissemination, and resourcing to meet climate goals? Note that although there is no national forest policy or strategy in New Zealand, existing policies, industry practices, and norms can guide the direction of the FIS.

Market formation

Market formation includes creation of markets for new forestry products, technology, and ways of using forests, as well as market expansion to incentivise entrepreneurs and facilitate cost reduction (Wieczorek et al., 2013). The New Zealand market for non-radiata species timber, for example, could be developed to enable use of more species in construction and for specialty applications such as grape vine posts. Market

creation may be challenging, however, as it is linked to consumer awareness, and other FIS functions such as resource mobilisation to obtain investment capital (Turner et al., 2016).

Resource mobilisation

As noted earlier in Section 1.2, financial, human, and physical resources are necessary to carry out activities (Wieczorek et al., 2013). In this context, resource mobilisation refers to how resources like technical and practical knowledge, human resources such as technical experts, funds, and loans are allocated and delivered to the people who need them (Wieczorek et al., 2013). Financial resources, for example, are needed to fund research, trial innovation, support knowledge dissemination via extension, attract investment, and enable SMFO or CFO participation in the FIS.

Creation of legitimacy

According to Wieczorek et al. (2013), a certain level of legitimacy is needed for actors to commit to changes in processes, technology, or systems. This is important because low actor commitment negatively affects technology adoption and investment, holding back innovation. To counteract uncertainty and build actor confidence, creation of legitimacy could involve lobbying, formation of advocacy coalitions, and facilitation of dialogue between disparate groups and development of consensus-based integrated strategies.

3.1.2 Structural Elements

The second part of the structural-functional analysis framework is comprised of "structural elements"; these are actors, hard and soft institutions, infrastructure, and interactions (Wieczorek & Hekkert, 2012). Wieczorek and Hekkert (2012) describe the first three elements – actors, institutions, and infrastructure – as "components" of the innovation system. Interactions are therefore the links or relationships between the components (Wieczorek & Hekkert, 2012). Structural elements of New Zealand's FIS are summarised in Table 4.

Table 4 Structural elements of a Forestry Innovation System (after Wieczorek and Hekkert (2012))

Structural elements	Subcategories
Actors	SMFOs and CFOs Civil society Companies, including start-ups Knowledge institutes: universities, research centres Government Non-governmental organisations (NGOs) Other parties: legal and financial organisations, intermediaries, brokers, consultants
Interactions	At network level At individual contact level
Institutions	Hard: laws, regulations, policies Soft: norms, expectations, common habits, traditions, established practices, expectations
Infrastructure	Physical: machines, roads, bridges, ports, buildings, power and telecommunication networks, and artefacts Financial: subsidies, grants, scholarships, and all financial programs Knowledge: knowledge, expertise, and strategic information

It is important to note that although interactions between these FIS elements may appear coordinated, actors may not necessarily share the same goals or be consciously working together towards them as a collective (Bergek et al., 2008). The order in which structures and functions are analysed is arbitrary, as system dynamics results from interaction of functions and "virtuous circles" may emerge from mutually reinforcing feedback loops (Johnson, 2001; Turner et al., 2016). The following sections outline the structural elements of this study.

Actors

In this research, actors are defined as public and private individuals and organizations that take specific roles in innovation processes (Edquist, 2009; Minh, 2019). Actors considered in this research include civil society; value chain actors like forest growers, companies, knowledge brokers, consultants, and processors; universities and research institutes like University of Canterbury, Scion, and Callaghan Innovation; the Government and its agencies such as the Ministry for Primary Industries (MPI), Te Uru Rākau (a business unit of MPI), Ministry for Business, Innovation and Employment (MBIE), and New Zealand Trade and Enterprise (NZTE); non-government associations like the New Zealand Farm Foresters Association (NZFFA), New Zealand Institute of Forestry (NZIF), Forest and Bird, and Tane's

Tree Trust; and legal and financial agencies. Major non-government actors are described in Table 5. Professionals like forestry advisors and forest managers are also considered important actors in creating, disseminating, and resourcing knowledge.

Table 5 Major non-government actors in New Zealand's Forestry Innovation System.

Actor	Description
New Zealand Forest Owners Association (NZFOA)	Aims to promote and protect the interests of persons from time to time engaged or concerned in New Zealand in the business, trade, or industry of forestry
New Zealand Farm Foresters Association (NZFFA)	A network for small forestry block owners, spread over 25 branches nationwide, and 8 special interest groups that focus on alternative species.
Farm Forestry Timbers Society	A not-for-profit society that provides information about the alternative timbers grown in New Zealand, sawmilling of alternative timbers (softwoods and hardwoods), and marketing services.
Forest Growers Levy Trust	Overseen by NZFOA and NZFFA joint committees, manages the proceeds of the levy on plantation timber products, and aims to help advance the New Zealand plantation forestry industry. The levy is used to fund activities defined in the Levy Order. The levy is based on 33 cents a tonne of harvested wood for the year to 31 December 2021.
Wood Council of New Zealand (Woodco)	A pan-industry body which represents the common interests of the forestry and wood processing sectors
Wood Processors and Manufacturers Association of New Zealand (WPMA)	Campaigns for fair trade and competition for the New Zealand wood industry, actively engages government agencies.

Actor	Description
New Zealand Institute of Forestry (NZIF)	Representative body for forestry professionals with an interest in all aspects of forestry, non-timber forest uses, and sustainability.
New Zealand Timber Industry Federation	Established in 1912, represents the sawmilling industry.
Tane's Tree Trust	Focused on indigenous forestry. Objectives include promoting, consolidating, and advancing knowledge; resolving obstacles to planting; maximising economic incentives for forest establishment; and facilitating knowledge-sharing. Manages the Northland Totara Working Group.
Scion	A Crown Research Institute (CRI) that specialises in research, science and technology development for the forestry, wood product, wood-derived materials, and other biomaterial sectors.
University of Canterbury	New Zealand's second-oldest university and the only domestic university offering professional degree programmes in forestry science.

Institutions

Institutions regulate or guide each actors' practices and the interactions between actors (Minh, 2019), and form the "rules of the game" (Rametsteiner & Weiss, 2006). In this thesis, institutions are defined as "a set of common habits, routines and shared concepts used… in repetitive situations" (soft institutions) (Wieczorek & Hekkert, 2012), structured by rules, norms, and strategies (hard institutions) (Crawford & Ostrom, 1995). Institutional capacities are determined by their specific sociocultural, historical, and spatial attributes and differ from organisations such as universities and state agencies (which are considered actors) (Wieczorek & Hekkert, 2012).

Interactions

This thesis examines interactions or relationships within the FIS at both the network and individual level. These interactions may be collaboration or other links between actors, and may exist for strategic reasons

or be unplanned (Minh, 2019). Although 'networks' have been used in other work to describe relationships (Johnson, 2001), this thesis considers that a network can also represent an organised collection of actors (Jacobsson & Bergek, 2011; Wieczorek & Hekkert, 2012). Examples of networks in New Zealand's FIS are the NZFFA and NZIF, which have networks at regional and national levels.

Infrastructure

Three categories of infrastructure will be considered, after Wieczorek and Hekkert (2012): physical, financial, and knowledge. Examples of physical infrastructure include machines, roads, ports, buildings, power and telecommunication networks, and artefacts. Financial infrastructure encompasses subsidies, research grants, forestry-related scholarships, and all financial programs. The knowledge infrastructure constitutes knowledge, expertise, and strategic information managed by the various actors in New Zealand's FIS.

3.1.3 Systemic problems

The health of a given system function is determined by the presence of systemic problems, defined here as underlying issues related to FIS structural elements (Wieczorek & Hekkert, 2012). This framework defines eight types of systemic problems, after Wieczorek and Hekkert (2012): actor presence; actor capability; interaction presence; interaction intensity; institution presence; institution capacity; infrastructure presence; and infrastructure quality. This thesis focuses on three FIS functions (knowledge development, knowledge dissemination, and resource mobilisation) and how they are affected by these eight systemic problem types, paying special attention to SMFO and CFO actors and their relationship with the wider FIS elements and functions.

Generally, presence-related problems for actors, interactions, institutions, and infrastructure occur when these structural elements are absent (Wieczorek & Hekkert, 2012). According to Wieczorek and Hekkert (2012), absent interactions can be caused by various issues like differing objectives, assumptions, capacities, or lack of trust between actors. In addition to presence-type problems, capability-type problems can affect the performance of an innovation system. An actor capability problem, for instance, may be actors lacking the ability to use knowledge resources effectively.

Meanwhile, interaction intensity problems could arise from interactions that are either too strong or too weak. For example, systems that strongly favour the incumbent configuration can block shifts to

different settings. Weak interaction between actors, on the other hand, hamper interactive learning and innovation (Wieczorek & Hekkert, 2012). Similarly, institution capacity problems may be linked to institutions that are either too stringent or too weak, where overly stringent institutions can favour incumbents while weak institutions block support for new developments (Wieczorek & Hekkert, 2012). Finally, infrastructure quality problems refer to inadequate or malfunctioning infrastructure (Wieczorek & Hekkert, 2012).

Based on the framework by Wieczorek and Hekkert (2012), these eight systemic problems can be mitigated or resolved using appropriate systemic instruments (Table 6). Wieczorek and Hekkert (2012) suggest using "systemic instrument goals" to link systemic problems to systemic instruments. These systemic instrument goals are useful because they describe what an appropriate systemic instrument should do, in order to address a systemic problem. For example, the systemic problem of low actor presence can be addressed by systemic instruments like workshops, which stimulate and organise the participation of various actors (see column 2, 3, and 4 in Table 6). The full list of systemic instrument goals and some examples of systemic instruments after Wieczorek and Hekkert (2012) are shown in columns 4 and 5, respectively. It is crucial to note that systemic goals can be achieved by carefully selecting existing tools such as regulations or industry practices for effective, reinforcing, and orchestrated interactions (Wieczorek & Hekkert, 2012). Well-designed policy instruments are expected to strengthen previously-weak functions, create opportunities for the FIS to develop, and result in higher innovation rates (Wieczorek & Hekkert, 2012).

Table 6 Systemic instrument goals by system function and type of systemic problem (after Wieczorek and Hekkert (2012)).

System functions	Structural elements	Type of systemic problem	Systemic instrument goals	Examples of systemic instruments
• Knowledge development • Knowledge dissemination • Resource mobilisation (for knowledge development and dissemination)	Actors	Presence	Stimulate and organise the participation of various actors.	• Public-private partnerships • Workshops • Venture capital
		Capabilities	Create space for actors' capability development.	• Backcasting • Scenario development workshops • Pilot projects
	Interactions	Presence	Stimulate the occurrence of interaction among heterogeneous actors.	• Cooperative grants • Bridging instruments (e.g. centres of excellence) • Tech transfer
		Intensity	Prevent ties that are either too strong or too weak	• Public demonstration sites / centres • Awards / prizes for innovation
	Institutions	Presence	Secure the presence of (hard and soft) institutions.	• Information and education campaigns • Lobbying • Voluntary agreements
		Capacity	Prevent institutions being too weak or too stringent.	• Principles
	Infrastructure	Presence	Stimulate the physical, financial and knowledge infrastructure.	• Public-private partnerships • Public research lab / library
		Quality	Ensure that the quality of the infrastructure is adequate.	• Problems/needs analysis • Knowledge transfer and management

3.2 Knowledge development, dissemination, and resource mobilisation as key functions for analysis of inclusive Forestry Innovation Systems

As explained in Chapter 1, this thesis focuses on three IS functions: (1) knowledge development; (2) knowledge dissemination; and (3) mobilisation of resources to support (1) and (2). These three IS functions were selected from the seven originally proposed by Wieczorek and Hekkert (2012) based on New Zealand white and grey literature, official reports, and expert elicitation. The main factors justifying selection of these functions are detailed below. While this thesis focuses on the study of three select IS functions, their interactions with the broader IS and other functions will also be discussed in later

sections, exploring the interconnectivity of all FIS functions. This section will also provide examples of how improved knowledge development, dissemination, and resource mobilisation could affect SMFOs and CFOs.

Firstly, creation and dissemination of accurate and timely knowledge across all levels of the forestry sector is crucial for policy and decision-makers (Ministry for Primary Industries, 2017; United Nations Department of Economic and Social Affairs, 2021; Wreford et al., 2019). There is a demonstrable need to enhance knowledge on SMFOs. For example, Table 7 shows that the survey data on SMFOs is irregular and medium to low quality (Ministry for Primary Industries, 2020b). In contrast, large holders have good annual survey data (Table 7). Considering that SMFOs make up a large proportion of the forest grower community and an increasing contribution to New Zealand's wood harvest, it is essential to improve understanding of this group.

Table 7 Survey frequency and data quality by increasing forest size (Ministry for Primary Industries, 2019).

Forest ownership size (hectares)	Survey frequency	Data quality
Below 40 ha	Infrequently	Low
999 to 40 ha	Every two years	Medium
1,000 ha or more	Annually	Good

Secondly, more inclusive research strategies could play an important role in expanding New Zealand's forestry knowledge base. This is important because while New Zealand is a leader on radiata pine knowledge, research on alternative non-radiata and indigenous species is scant (Ministry for Primary Industries, 2020c). A diversified knowledge base encompassing SMFOs and CFOs will enable New Zealand to reduce reliance on a single species (radiata pine) or product class (raw logs) (Clark, 2018) and mitigate the risk of trade dependence on China (McClure, 2021; Wang & Radics, 2021). In Gisborne, for instance, a global plummet in radiata log prices is already impacting livelihoods of local forestry operators (Robertson, 2021). Increased knowledge and production of specialty species could also promote market differentiation of New Zealand timber goods, reducing SMFO exposure to global supply inconsistencies that drive "boom and bust" cycles (Clark, 2018). Closer links between growers and industry may even accelerate overall FIS development as products, consumer demand, and process coevolve (Hayter & Clapp, 2020).

Thirdly, including SMFOs and CFOs in technological knowledge creation and dissemination could enable better resource-use planning. For example, New Zealand already designs and exports innovative

harvesting and milling technology that enables economically viable harvesting of difficult sites (Raymond, 2018). Improving SMFO and CFO engagement with technology firms may boost forest planning and harvesting capabilities. Forest siting and harvesting decisions are critical because harvesting can account for up to half the total cost of wood production (Ministry for Primary Industries, 2020c). Better land-use knowledge may also help cushion forest owners from market volatility. For example, an SMFO in Glen Dene generated an alternative income from carbon credits when agritourism and hunting income dried up over the 2020 Covid-19 lockdown (Gray, 2021).

Knowledge development and dissemination is constrained by a heavily siloed primary sector economy which weakens links between forest owners, knowledge producers, and markets (Bayne et al., 2021; Wreford et al., 2019). This is problematic as forest-related business models may be cross-sectoral. A beef or lamb farmer, for instance, may wish to grow forestry blocks to diversify their portfolio. However, this farm diversification might be hampered by sectoral boundaries and lack configurations to support cross-sectoral knowledge development and dissemination (Wreford et al., 2019). As a consequence, forest owners often have to rely on knowledge specialists such as forest managers to coordinate planting, harvesting, and marketing their products (Clark, 2018).

Knowledge creation and dissemination challenges are compounded by problematic resourcing of scientific research in New Zealand. Despite "no shortage of strategic documents… showered down over the last decade or so" (Parliamentary Commissioner for the Environment, 2020), research, science, and innovation (RSI) levels remain low, at 1.37 percent of GDP (Ministry of Business, Innovation & Employment [MBIE], 2019). In contrast, countries in the Organisation for Economic Co-operation and Development (OECD) spend on average about 2.4 percent on research (MBIE, 2019). New Zealand does not yet have a publicly funded knowledge transfer system, relying instead on sectoral-based institutions and private investors (Wreford et al., 2019). Funding is also not strongly aligned with articulated Government priorities due to numerous and complex funding mechanisms (Parliamentary Commissioner for the Environment, 2020). Importantly, funding structures are competitive instead of collaborative, and Māori researchers are noticeably underrepresented in New Zealand's public research institutions (Ministry of Business Innovation and Employment, 2019). Other issues can arise when researchers and potential users of research knowledge are disconnected, have different motivations, and have access to different knowledge areas (Ministry of Business Innovation and Employment, 2019).

Specifically, some Māori do not see how they can benefit from engaging with the New Zealand's RSI system (Ministry of Business Innovation and Employment, 2019) and, by extension, the FIS.

Equally critical to scientific research resourcing is intelligent investment and capitalising on New Zealand's unique heritage of mātauranga Māori (Māori knowledge systems) and Te Ao Māori (Māori world view) (Ministry of Business Innovation and Employment, 2019). According to Harmsworth, Te Ao Māori and mātauranga Māori refer to a range of cultural concepts, values, and knowledge systems founded on traditional knowledge and philosophy, which in turn give rise to sociocultural practices and values. International studies have demonstrated the predictive power of traditional knowledge systems for bioprospecting (Buenz et al., 2018; Saslis-Lagoudakis et al., 2012). In New Zealand, for example, mātauranga Māori has informed selection and screening of native plants for anti-pathogenic compounds to help fight kauri dieback disease, leading to the discovery of three new compounds after studying only four plant species (Lawrence et al., 2019). Māori researchers may be instrumental in leading long-term forestry research projects as Māori value creating inter-generational wealth and extensive planning horizons (Beall, 2012; Prime, 2021). For this to happen, policy settings need to promote partnership and exploration beyond the status quo as commercialisation models in New Zealand are currently more appropriate for established sectors than for new ones (Wreford et al., 2019).

Overall, there is urgent need for a realistic and inclusive knowledge strategy to overcome the inertia hindering the development of New Zealand's FIS (Ruckstuhl et al., 2013; Wreford et al., 2019). In 2019 MBIE drafted a Research, Science, and Innovation (RSI) Strategy to communicate the government's objectives for RSI in New Zealand; to highlight priorities for government action within the Research, Science and Innovation portfolio; and to signal its intentions and directions (Ministry of Business Innovation and Employment, 2019). In public consultation on this draft, New Zealand's leading R&D investment firms noted that the strategy was problematic because lucrative research opportunities based on existing knowledge is neglected in favour of pursuing high-risk frontier knowledge (BusinessNZ, 2019). This concern was echoed by Forest Growers Research Limited (2019). Forest Growers Research Limited (2019) and New Zealand Forest Owners Association (2019b) added that other knowledge-related needs related to the RSI Strategy included better partnering with end users (i.e. forest growers), acceptance of mātauranga Māori and increased focus on translating science into accessible information (Forest Growers Research Limited, 2019; New Zealand Forest Owners Association, 2019b).

Having outlined the significance of knowledge development, dissemination and resource mobilisation in context of SMFOs and CFOs in New Zealand, the following section turns to international best-practice policies to illustrate the role of policy in supporting each of these three functions.

3.3 Knowledge development, dissemination, and resource mobilisation in inclusive Forestry Innovation Systems

It is widely recognised that institutional change is a key factor needed for radical innovation, and development of knowledge for radical innovation depends on appropriate institutional changes (Vihemäki et al., 2019). By extension, development of knowledge for radical innovation also depends on appropriate institutional changes. In Finland, for example, the development of wood use in multi-storey construction has been supported by changes in building regulations, roles and practices of actors in the regulatory environment; presence of regulatory frameworks and resources; and encouragement of entrepreneurship (Petrov et al., 2019; Vihemäki et al., 2019). International forest policy literature offers a range of best-practice policies that support knowledge development, dissemination, and resource mobilisation for SMFOs and community forestry. This thesis considers an inclusive FIS one that enables participation of all groups who can contribute to – and are affected by – innovation goals and processes (Refsgaard et al., 2017). An inclusive FIS would also encompass social, ecological, and relational values, based on inclusive development research by Pouw and Gupta (2017).

3.3.1 Knowledge development

In an inclusive FIS, knowledge development would be characterised by engagement with all sources of knowledge, including forestry and ecological science (Franklin et al., 2018; Landcare Research, 2013); indigenous and informal ways of knowing (Harmsworth & Awatere, 2013); and knowledge embodied across the different types of forestry practitioners, including scientists, processors, and end-users of forest products (Ministry of Business Innovation and Employment, 2019; Ruckstuhl et al., 2013). This requires relationships and networks across a wide range of stakeholders, agencies and sectors facilitated by long-term, integrated management across regions (Hayter & Clapp, 2020; Ministry of Business Innovation and Employment, 2020). Cross-sectoral and inter-agency actor engagement has been shown

to be critical for knowledge flow and can bridge the fragmented nature of forest ownership and research institutions (Niskanen et al., 2007; Rametsteiner & Weiss, 2006; Rimmler et al., 2011).

Including a wide range of actors is beneficial as innovation ideas, resourcing, and networking connections often come from outside the forestry sector or their customers (Rametsteiner & Weiss, 2006; Weiss et al., 2007). For example, research in rural Europe by Weiss et al. (2017) suggests that the knowledge needs of small forestry businesses could be supported through industry clusters. Cluster policy is wider than sector-focused policy and links geographically co-located actors from different sectors throughout the value chain (Rimmler et al., 2011; Sölvell et al., 2003). Cluster strategies can have narrow targets like business network formation, broader ones such as shaping industrial districts into innovation environments, or be a mix of both (Rimmler et al., 2011). The Finnish forestry industry, for example, uses a cluster system that comprises the forestry industry as well as a range of other actors including logistics companies, machine manufacturers, energy producers, consultants, research agencies, and the construction industry (Klitkou et al., 2020). This system arose from reflexive innovation policy changes in the late 1990s (Innes, 2009; Klitkou et al., 2020). There is no formal cluster structure or barrier to membership; instead actors within clusters interact via established platforms and programmes (Klitkou et al., 2020; Rimmler et al., 2011). Clusters are influential, and can steer third-party funding decisions, broader policy strategy, and knowledge creation and infrastructure (Rimmler et al., 2011). Finland was also the first country in the world to adopt the innovation system concept as a basis for national policy and to integrate forestry into its broader national innovation system (Laasonen et al., 2020).

The Canadian FIS could be considered an inclusive FIS as the forestry industry is connected with many sources of knowledge, considers evolving socioeconomic needs and values, and is linked to broader national strategy. These knowledge sources include equipment suppliers, chemical firms, urban design and planning communities, and provincial government agencies that have long-standing relationships with the industry (Hayter & Clapp, 2020). The foundational innovation policies for the Canadian FIS focused on new higher value uses for forest products and addressing changing socioeconomic patterns that are intertwined with climate change (Canadian Council of Forest Ministers, 2008, 2015). The outcomes of this framework were a range of multi-stakeholder agencies, including the public-private entity FPInnovations (FPI), the world's largest not-for-profit forest research organization; the Future Bio-pathways Project, which analyses economic and employment impacts of developing bioeconomy

applications; and the Investments in Forest Industry Transformation (IFIT) program, which partners with provincial or territorial initiatives and builds on Bio-pathway research (Canadian Council of Forest Ministers, 2015). FPInnovations takes a collaborative approach and was developed by a working group of the Canadian Council of Forest Ministers that embraced forest experts from industry and government, including the existing forestry R&D agencies (Hayter & Clapp, 2020). Further, FPInnovations engages in relatively long-term R&D programs (5 years or longer), often in association with a variety of public and private sector actors.

A schematic illustrating the interlinkages between government, industry, and academia in Canada's FIS is shown in Figure 2. In addition to the actors already mentioned, other important actors include the Forest Products Association of Canada (FPAC), Canadian Wood Fibre Centre (CWFC), and Forest Innovation by Research and Education (FIBRE). The Canadian forestry sector is also linked to the wider economy through the Canadian Bioeconomy Strategy (2017) and the Canadian Council of Forest Ministers' Forest Bioeconomy Framework for Canada. Similarly, the Finnish FIS relies on high levels of cross-sectoral networking and inter-actor connections (Woiceshyn & Eriksson, 2014).

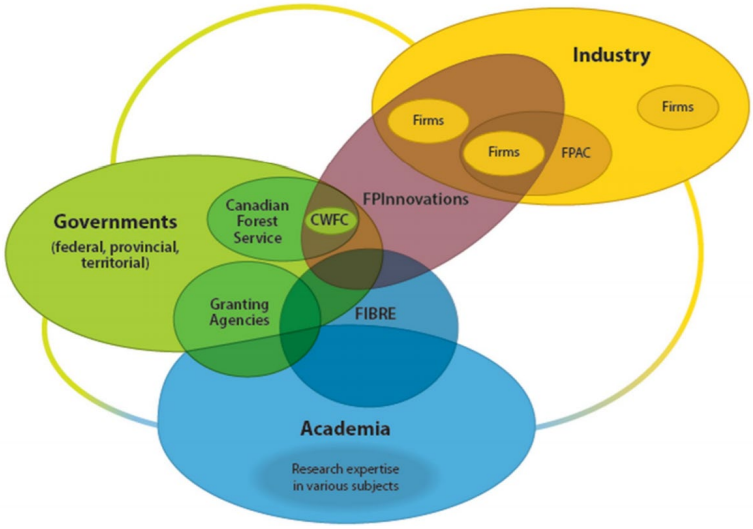

Figure 2 Major players in Canada's forestry innovation system (Canadian Council of Forest Ministers, 2015).

In developing a more inclusive FIS, New Zealand could consider adapting elements from the Canadian FIS to the domestic context. For example, useful elements might include an interconnected structure linking actors inside and outside the FIS, forestry research programs that support broader socioeconomic and climate change goals, and longer time horizons for forestry initiatives.

While there has been a shift away from actively excluding Indigenous Peoples in forestry decisions, modern approaches to forest management often continue to disregard the multi-generational social, cultural, economic, and environmental needs of forest-based Indigenous communities (Caverley et al., 2020). An example of a framework for including indigenous knowledge can be drawn from British Columbia (BC), Canada, as described by Caverley et al. (2020). The BC province is a useful comparison for this thesis because it has an established forestry sector and 203 First Nations (Canada's indigenous tribes) (Caverley et al., 2020). Caverley et al. (2020) assert that a key component of an inclusive system is meaningful engagement, which is substantially different from consultation at it entails empowerment and genuine collaboration between government and non-government actors. In contrast, consultation is generally intended as information sharing and gathering feedback, with no obligation to empower stakeholders (Caverley et al., 2020).

Caverley et al. (2020) articulate six criteria for inclusive development, which can also be applied to knowledge development in an inclusive FIS. These criteria are: 1) recognising indigenous title and rights, including rights to economic diversification; 2) not diminishing indigenous title and rights; 3) recognising the right of indigenous people to self-government; 4) ensuring equity in the decision-making process; 5) adapting forest policy to include indigenous knowledge and information from indigenous experts; and 6) reducing forest policy impact on indigenous peoples' connection to the land (Caverley et al., 2020). These criteria align well with Māori aspirations and international conventions on indigenous knowledge such as the United Nations Declaration on the Rights of Indigenous People (UNDRIP) (Johnstone, 2011).

3.3.2 Knowledge dissemination

Knowledge dissemination in an inclusive FIS would empower forest owners to meet changing policy and market expectations (Lawrence et al., 2020) through well-resourced information transfer strategies that serve the heterogenous and fragmented forestry sector (Rummukainen et al., 2006). Given the diverse

needs and differing levels of complexity in decision making for New Zealand SMFOs and CFOs, it is important that appropriate communication tools are developed for each group. International research suggests that communicating sustainability knowledge to forest owners hinges on trust and acceptance of the advisor, relevance of the information to the forest owner's motivations, and ability to comprehend the information being relayed (Davis & Fly, 2010; Hujala & Tikkanen, 2008). A study on Finnish family forest owners found that trust is tied to personal connections and shared local perspectives (Hujala & Tikkanen, 2008).

Rimmler et al. (2011) add that knowledge exchange can occur by observation (with or without interaction), which can be facilitated by clusters that promote spatial proximity and social contact between actors. Importantly, methods for delivery of forestry-related knowledge should be updated regularly to reflect current cultural and societal trends and be tailored to increasingly diverse forest owner types (Karppinen, 2012; Weiss et al., 2019). This is especially relevant for SMFOs, as the small scale of ownership is often compounded by asymmetric information problems, whereby SMFOs may not understand the potential value held in their forests (Niskanen et al., 2007).

It is also necessary to create communication channels that actively facilitate knowledge sharing within the forestry industry and bridge the barriers between forest subsectors. In Canada, IFIT facilitates knowledge transfer by developing an open innovation platform, providing project information sheets, documenting and promoting case studies, and publishing fact sheets on project replicability for IFIT-funded technologies. This knowledge enables SMFOs and CFOs alike to access information and make informed investment decisions on emerging technology.

3.3.3 Resource mobilisation

New Zealand faces several resource mobilisation issues that hinder the development of an inclusive FIS. In 2020, New Zealand's Parliamentary Commissioner for the Environment stated that resourcing of environmental research is fragmented, with no single agency tasked with ensuring that research investments are delivering the required outcomes or reaching potential end-users who can translate knowledge into practice. In contrast, Canada's FPInnovations is a 'collaborative, one-stop hub' for creating and diffusing technology research (Canadian Council of Forest Ministers, 2008; Hayter & Clapp, 2020). Hayter and Clapp (2020) add that this organisational structure provides an easily identifiable

access portal for any actors seeking FPInnovation's expertise; increases administrative and facility efficiency; and consolidated declining in-house research functions into a visible, influential research organisation.

In addition to scarce funding, research agencies in New Zealand sometimes compete with each other and other actors in the science system in an unproductive way (Ministry of Business Innovation and Employment, 2020). This issue is linked to competition for core funds and the siloed nature of Crown Research Institutes (CRIs) (Ministry of Business Innovation and Employment, 2020). Ownership and arrangement funds could be allocated to provide stable funding for core and high-priority activities, which are determined at a cross-sectoral level. This is seen in Finland and Canada, where public-private forest entrepreneurship remains a key development strategy (Hayter & Clapp, 2020; Petrov et al., 2019).

MBIE (2020) notes that an inclusive, integrated approach to funding research programmes is needed for better medium-term planning. For instance, in Canada, priority-setting is done by FPInnovation in partnership with academia and the CWFC (Canadian Council of Forest Ministers, 2015). This approach ensures strong alignment of research activities nationwide and high responsiveness to market demands and sector needs (Canadian Council of Forest Ministers, 2015). Vertically integrated planning and co-ordination in the domestic forestry supply chain is important to enable SMFOs to engage in innovation in processing and forest products. In Norway, for instance, the Norges Skogeierforbund association represents 36,000 family forest owners who control approximately 80% of the country's timber market, supports these forest owners in forest management, and plays an active role both in advocacy and marketing privately-owned timber (Hansen et al., 2019). Finally, coordinated national and sectoral strategies – where sufficiently credible and detailed – can set a direction for innovation and work together with incentives to provide stability and better allocation of resources (Ministry of Business Innovation and Employment, 2020). For example, in 2015, Finland adopted the National Forest Strategy 2025, which sets the direction and main objectives for forest-based business and activities until 2025 (Ministry of Agriculture and Forestry of Finland, 2019). Implementation of Finnish Forest Strategy is integrated with other national strategies, such as the Finnish Bioeconomy Strategy, the national energy and climate strategies, and the National Biodiversity Strategy (Ministry of Agriculture and Forestry of Finland, 2015).

The concepts and examples of best-practice inclusive forestry innovation policy outlined in this Chapter provide useful comparative material against which to interpret this study's results and provide policy recommendations, and will be drawn upon to do so in Chapter 5. The next Chapter presents the main findings from interviews and documentary data for the three focal FIS functions. Findings linked to other FIS functions that affect the three focal FIS functions are also described.

4 Identifying systemic problems for knowledge development, dissemination, and resource mobilisation

The interviews revealed barriers for SMFOs and CFOs in the areas of knowledge development, dissemination, and resource mobilisation. Understanding barriers to SMFOs and CFOs enables understanding of how structural and functional problems arise, how they interact with each other to hinder innovation uptake, and what interventions may be appropriate. Here, barriers are characterised as factors that hinder or prevent SMFOs or CFOs from adopting a range of innovative and sustainable forestry practices. These barriers contribute to formation of systemic problems, which constrain the development of the FIS or inhibit the FIS from functioning well (Kieft et al., 2017). Systemic problems, on the other hand, hinder progress on innovation, socio-economic, and environmental goals (Kieft et al., 2017).

This chapter explores how barriers for SMFOs and CFOs cause systemic problems for FIS functions. Section 4.1 presents an overview of the main barriers to achieving the multiple uses and aspirations for forests as identified by interviewees. Next, these barriers are linked to systemic problems according to the framework detailed in Chapter 3.

Although the interviews focused on knowledge development, knowledge dissemination and resource mobilisation (which will be discussed in detail in Sections 4.2-4.4), the barriers and systemic problems that emerged also related to other FIS functions, illustrating the interconnected nature of New Zealand's FIS. As such, findings relating to entrepreneurial activity, guidance of the search and market formation will be outlined in Sections 4.5 – 4.7. Note that the actors involved in knowledge dissemination were sometimes also knowledge developers. As such, the results presented below draw on the reflexive nature of the interviews where participants sometimes played more than one role in New Zealand's FIS. The chapter concludes with a summary of the barriers and systemic problems (Table 8). Key challenges that affect all three focal FIS functions, and potential systemic instruments that could be employed to address them, are then discussed in Chapter 5.

4.1 Overview

SMFOs and CFOs interviewed had varying understanding of more environmentally sustainable, innovative, and inclusive forestry systems. While both SMFOs and CFOs were familiar with sustainable practices like continuous cover forestry, planting of alternative (non-radiata) species, agroforestry, and multi-use forests, these two groups had different experiences when trying to implement what they believed were sustainable practices. Some shared barriers preventing both these groups from implementing sustainable or innovative forestry practices include low commercial interest in timber from alternative species, lack of market access for novel products, insufficient support for entrepreneurs, and lack of support for higher cost sustainable practices such as selective logging. In addition to these common shared barriers, CFOs encountered barriers from legislation and industry practices when exploring multi-use forests and using native species for forestry.

All the interviewees identified gaps between current and internationally recognised best practices. A systemic problem identified in the FIS was the lack of a collective and inclusive strategy for the forestry industry. Almost all interviewees, including SMFOs, CFOs, researchers, and industry experts, believed that there was an urgent need for a clearly articulated forestry industry strategy. However, there was no clear consensus on how SMFOs or CFOs could be better included in the forestry industry or what roles they should play in innovation. Regarding a shared forestry industry strategy, several interviewees highlighted the independent and resourceful nature of New Zealand SMFOs, noting that this characteristic has previously hindered collective strategic action. In contrast, interviewees did not mention CFOs as inhibitors of collective action.

All the interviewees believed that more interaction was needed between SMFOs and CFOs, industry, researchers, government agencies, and the wider public to realise the economic, environmental, and cultural benefits associated with forests. The desired outcomes of interactions, however, were quite varied. For example, SMFOs generally sought transactional interactions, such as the exchange of information or increased access to resources and market opportunities. CFOs, researchers, and industry experts, on the other hand, wanted more interaction between actors to enable greater understanding, facilitate collaboration, and express needs or concerns.

Many interviewees, including both SMFOs and CFOs, emphasised that the barriers they faced for knowledge development, knowledge dissemination, and resource mobilisation were rooted in the lack of a supply chain that included SMFOs and CFOs. There is currently very limited efficient harvesting,

processing, or marketing support that enables SMFOs and CFOs to get novel products to the customer. This was characterised as a "chicken and egg" problem – without assurance of a market for novel products, actors are unwilling to make investments; however, without investment, a market for niche products cannot develop. Interviewees also mentioned that supply chain problems are exacerbated by a strong focus on the incumbent system centred around radiata pine. Instead of continuing to focus research and marketing initiatives on radiata pine, SMFOs and CFOs suggested that other species – both native and exotic – be given more attention.

Sections 4.2, 4.3, and 4.4 set out systemic problems linked to the three focal functions of knowledge development, dissemination, and resource mobilisation. Sections 4.5 to 4.6 then describe systemic problems that were discovered while conducting this study but are related to other FIS such as entrepreneurial activity, market formation, and guidance of the search.

4.2 Knowledge development

In New Zealand, knowledge development within the forestry sector is driven by Scion, universities and MPI. For example, Scion has articulated its long term aspirations and priorities in a strategy document, emphasising partnership with Māori (Scion, 2018). MPI intends to transform the forestry and wood processing industry via the Forestry Industry Transformation Plan (ITPF) (Hendrickson, 2021). Researchers at the University of Canterbury and Lincoln University actively research and publish work on forest growing and management. Some research by these actors is funded by the Forest Growers Levy Trust, which comes from an industry-wide levy.

The interviewees revealed five key systemic problems that hinder knowledge development. These were a lack of strategic collaborative leadership, a lack of direction for researchers, low interaction between FIS actors, a strong focus on the current forestry model, and low certainty in the policy environment.

4.2.1 Actors

Lack of leaders for strategic collaboration

Interviewees all agreed that knowledge development is hindered by a lack of actors leading collaboration in New Zealand's FIS. This perception was also highlighted in a report by MAF (2009, p. 53), which found that "there tends to be limited industry-wide leadership at a strategic level".

Most interviewees considered the forestry industry to be highly diverse, with many actors and different objectives, which makes achieving strategic collaboration challenging. As an interviewee described:

> First of all, we need to acknowledge that the forest industry itself is quite disparate, there are a number of different organizations. We're not all pulling in the same direction. At the same time, we don't necessarily even talk to each other a lot. So you know, that is certainly one of the issues. I think it makes it difficult for the government to talk to… the industry and get a simple and straightforward answer.

These findings are consistent with the results of the Forest Sector Study by the Ministry of Agriculture and Forestry (2009), which found that New Zealand has a "complicated mix" of shifting forest ownership models and strategies, where small scale owners lack "collective views" and power. This consistency of findings despite this study occurring 11-years later indicates that the issues of leadership and strategic collaboration in the FIS are complex and challenging.

The lack of strategic leadership seems to affect research agencies as well. Several interviewees observed that researchers struggle to identify priorities without clear articulation of government direction. As one researcher commented, "with a kind of a lack of national strategy, … we don't know where the government wants to go. We're kind of having to read between the lines all the time and think, "Tell us some information."" The researcher's observation is echoed by other stakeholders and CRIs who noted that more clarity is needed on the government strategy and expectations for CRIs (Ministry of Business Innovation and Employment, 2020).

There is a strong need for leaders in strategic collaboration to streamline the various forestry industry initiatives and enable SMFOs and CFOs to contribute in meaningful and efficient ways. According to a forester/researcher:

> Currently, what's happening in the ministries is you've got these different views, a lot of them overlapping, a lot of them conflicting. And New Zealand is supposed to implement, you know, our response or compliance or economic development but it's so confusing to everyday New Zealanders.

As a further example of the need for strategic collaborative leadership, several interviewees perceived Te Uru Rākau as an independent agency, when it is in fact a part of MPI. One interviewee also suggested that "Te Uru Rākau should be setting a vision for this country in terms of forestry." These observations suggest that MPI and Te Uru Rākau have not clearly communicated their linked structure and function to stakeholders. As such, MPI and Te Uru Rākau could be misunderstood as being competing agencies instead of a government agency and one of its business units, potentially confusing FIS actors and hindering collective action.

One interviewee, an industry expert who works closely with SMFOs and CFOs, suggested that decision-making actors may lack capacity to lead change and transformation in the forestry industry:

> They [forestry industry leaders] are fearful of change. Change is always something be feared for many, but I think it would be helpful… we need to have some radical transformation, in the way we do things, from land use to markets to consumerism, and it's not a case of just tweaking minor tweaks to the 20th century models. It is a case of redesigning and reimagining how it should be or could be to make those changes occur in a manageable way. But we need that visioning process. And I think there should be a constant process of evolving a vision and trying to make changes.

This comment suggests that there is a need for space in the FIS to nurture leadership skills alongside novel ideas and products. This need for spaces where nascent ideas and new methods can develop is revisited in Section 4.5. In the past, MAF (2009) has offered some "radical" and "possibly controversial" ideas for the future of forestry, indicating that MPI could potentially lead conversations on industry transformation.

4.2.2 Interactions

Low interaction between FIS actors causes siloes and disengagement

All interviewees agreed that New Zealand's forestry industry is fragmented with low levels of interaction between actors. As noted by an industry body representative:

> I think, you know, each organization in New Zealand... they protect their own area of activity. There isn't as much talking across... agencies and across the entire community as I would like to see, and I think… the fact that there are so many organizations isn't necessarily helpful.

The issue of low interaction in the FIS was echoed in other research, characterised as a "fragmented" supply chain (Forest Growers Research Limited, 2020) and "poor collaboration" among SMFOs (Wang & Radics, 2021). There is also "little or no collaboration" between key actors like small scale sawmillers and the broader value chain, including SMFOs and CFOs (Forest Growers Research Limited, 2020). Low interaction between actors is also considered problematic in the broader research system. For instance, MBIE (2020) notes that there is "low engagement" with Māori researchers in the New Zealand RSI system. This is concerning as Māori are key stakeholders in the forestry industry.

Several interviewees mentioned the problem of fragmentation and low frequency of interaction in the research system and academia. As a researcher explained:

> I do have concerns about sectoral silos. In particular, I do not like the barriers in the CRI system. There are also some kind of silo issues in academia. Ivory tower, intellectual snobbery, call it what you like, but it's, it's present within disciplines where… a journal editor will not publish certain teams' or groups' work because it disagrees with what they particularly want to put forward… So, a lack of willingness to look at other points of view.

This researcher's concerns about silos in forestry research echoes the Te Pae Kahurangi report, which identified "largely siloed" strategy development and priority setting across CRIs as "adversely affecting the collective ability of CRIs to meet New Zealand's research needs" (Ministry of Business, Innovation, and Employment, 2020, p. 19). These two interview quotes indicate that there are systemic interaction problems in the FIS. Interaction problems can lead to actor disengagement from the industry, as one CFO described:

> I don't like working with the forestry industry in New Zealand, because they are so up themselves… And I just look and I think, why do you think you know so much? You know, why do you think you've actually really got it worked out for New Zealand?... I'm not in the forestry sector. We [community forest owners] are not in the forestry sector.

This quote suggests that some forest owners have chosen to avoid participating in the wider forestry sector due to past experiences with other actors in the FIS. This is a problem because negative perceptions of more prominent actors may discourage FIS actors like SMFOs and CFOs from participating in collaborative efforts.

4.2.3 Institutions

Overly strong focus on the current forestry model

Many interviewees identified the current focus on radiata pine as another barrier to knowledge development. This focus is influenced by soft institutions, such as investor preferences for better-researched forest species with lower uncertainty. As radiata pine is well researched, investments in radiata pine appear more attractive compared to other species. In turn, the preference for radiata pine influences other institutions such as research and investment priorities. This challenge was summed up by a forestry professional who argued that "we in fact, know far less about our native forest than we do about the exotic forest for commercial purposes. What that does, is it pushes interest more towards the commercial trees that are well researched."

Compared to the radiata pine industry, the alternative timber industry receives less resourcing for research and marketing. According to an industry professional, there is "… very little alternate species development… [and] very little understanding or assessment of market opportunities outside of radiata in its raw form." MAF (2009) similarly observed that radiata pine was the "utility species of choice", and that there was limited interest in alternative species aside from Douglas fir. Forest Growers Research Limited (2020) add that the alternative timber industry has higher uncertainty than the radiata pine model as it has "no monitoring" and lacks reliable data, industry standards, and marketing. This is concerning because the combination of current research priorities and existing uncertainties in the alternative timber industry could reinforce investor and research focus on radiata pine, hindering transition to a more diverse FIS.

In addition, several interviewees remarked that investor and research interest in radiata pine remains strong although the industry understands that dependence on a single plantation species increases risks of disease, pests, adverse events, and market fluctuations. As one forestry advisor commented, "I couldn't think of a more high-risk model, and being dependent on a single species and on a single market." This quote illustrates that SMFOs and CFOs are aware of the risks associated with the incumbent plantation forestry model, and are interested in efforts to reduce these risks. However, the existing strong focus on radiata pine and the absence of support for alternative species and products limits their ability to contribute to diversification initiatives.

Low certainty in the policy environment hinders long-term efforts and needs urgent action

Dunningham et al. (2020) argue that the forestry industry is vulnerable to changes in legislation and to regulation by government and local authorities. This observation refers to the broader forestry industry and is consistent with the data gathered in this study. According to several interviewees, soft institution problems at the governance level hinder long term efforts necessary for knowledge development, dissemination, and resource mobilisation in the forestry industry. These interviewees mentioned the need for policy environment certainty for forestry. For example, an industry expert explained that "trees take a long time to grow… we can't have every election cycle changing the course [of the forestry industry strategy]" and that policy stability needs "broad government buy in". The need for policy stability was previously noted by MAF. According to MAF (2009), providing "leadership in partnership" with the industry, sending clear and consistent signals on policy direction and recognising the long-term nature of forestry investment are essential for creating a favourable environment for sustainable development.

Many interviewees believed that the need for a long-term shared vision is urgent and applies to the broader forestry industry, beyond the three focal IS functions. For instance, one interviewee stated that:

> If there's ever a need for New Zealand forestry Inc., to get in a room and sort out strategy – and a strategy built around sustainability, around adopting good forest practice, but also at marketing and market development and international context – there is a very, very strong need now.

The urgent need for collective, future-focused strategy expressed by several interviewees has openly been emphasised by larger FIS actors too. For example, the executive director of Sequal, a major New Zealand wood processor, believes that the industry transformation plan "needs to happen now, not six months or 12 months in the future", and that the lack of investment in processing technology was "one of the greatest violations of responsibility left to the young generation" (Kennedy, 2021).

4.2.4 Infrastructure

Existing infrastructure does not facilitate SMFO and CFO participation in knowledge development

All the interviewees considered current research funding mechanisms – or financial infrastructure – inadequate to support SMFOs and CFOs because the focal issues change frequently, application processes are challenging to navigate, and grant applications often require a significant 50% contribution.

Interviewees all felt that New Zealand's funding application mechanisms lack certainty. According to one interviewee, "roles and responsibilities change, strategies change. The policy of yesterday may not be the policy today." Many interviewees believed that shifting government priorities affect the focus of funding programs, which creates challenges for SMFOs and CFOs. For instance, a CFO said, "it's all about a particular topic, that you need to somehow adapt your project or your research to address those topical flavours, which is not always a good fit." Long-term funding is not assured either, because "once other interests come into the room, it will go in a different direction altogether".

One interviewee described how the lack of clarity in funding application guidelines affects them:

> I said [to the funding agency], first of all I want to know, are we eligible?... And they say, well, we won't know whether you're eligible or not until you make the application. So I went through weeks and weeks of work to map everything because you got to make everything right… And then they came back and they said, "Oh, you're not eligible.

In addition to the shifting funding requirements and co-funding challenges, grant applications are often competitive rather than collaborative in nature. For example, one of the researchers interviewed stated that: "I think that certainly the culture of the contestable funding nature of research has been a huge barrier." This researcher's view is consistent with an MBIE (2020) report that identified "existential financial risk" for CRIs in general, causing time-consuming competition for contestable funds "for survival", with "limited prospect of success".

Many interviewees agreed that requirements for co-funding put SMFOs and CFOs at a disadvantage relative to other larger actors. As an industry expert stated: "one of the key barriers to us to generate research or do more work is usually the requirement for 50% co-funding and getting that co-funding to get projects even considered, that is a significant hurdle." Another interviewee explained that securing funds for co-funding is more challenging for SMFOs and CFOs compared to larger industry players because of the large amounts needed. For example, the Mid-Rise Wood Construction project is a multi-million-dollar innovation collaboration between Red Stag and MPI, with co-funding of $3.45 million and $1.5 million, respectively (Ministry for Primary Industries, 2022b).

4.3 Knowledge dissemination

Seven structural problems for knowledge dissemination within the forestry sector were identified. These structural problems were spread across all four structural elements. The breadth of structural problems

reflects the diversity of forest owners, their values, and many motivations for planting forests. Some common root causes for these problems are industry fragmentation and disconnect between FIS actors as well as across sectors.

4.3.1 Actors

Limited actor capacity to translate and use available information

All the interviewees mentioned that SMFOs and CFOs lack the capacity to use available information effectively. These capacity-related challenges ranged from having to digest large amounts of information, to lacking specialised knowledge needed to translate research into practical information. On research translation, an industry expert commented:

> … a lot of good work is being done but translating it into action in the field is a pretty difficult area. And I don't think small growers, Māori landowners, even the larger growers are not necessarily picking up on it, or able to pick up on it as well.

Similarly, the need for "practical, realistic and immediate take-home options" for New Zealand forest growers was highlighted in a report on technology transfer in the Sustainable Land Management and Climate Change research programme (Payne et al., 2018). This research focuses on climate change, forest sinks improvement, and agricultural greenhouse gas mitigation (Payne et al., 2018).

One outcome from the lack of translation capacity was described by an interviewee who noted a "disjunct between knowledge and application", especially on how forests could be integrated into farm landscapes. Several interviewees mentioned that the translation capacity issue is compounded by the fact that industry bodies like the New Zealand Farm Foresters Association lack capacity to translate research for their SMFO and CFO members because they are largely volunteer-run. The challenges posed by the voluntary nature of the NZFFA have been described as resting "unfairly" on volunteers who were "advanced in years" (New Zealand Farm Forestry Association, 2021).

Knowledge dissemination actors sometimes lack personal credibility

All interviewees who had regular interactions with SMFOs or CFOs agreed that personal credibility was crucial for effective knowledge dissemination. Factors that influence an actor's credibility include practical experience, reputation within the local community, and appropriate education. For example, an

interviewee said, "you can't just waltz up with a degree and no outside experience." These expectations, however, can hinder knowledge dissemination and interaction as knowledge dissemination agencies do not always have staff with local credibility. For example, a forestry professional observed that:

> When they [Government] say they're going to set up a whole lot of advisors that will be recent forestry graduates, … they'll have a hell of a lot of problem being credible... Whereas these old guys [foresters] were credible.

Furthermore, actors who are qualified but unfamiliar to the community may not be recognised as credible. As an interviewee reflected, "it can be difficult to get the respect… even if you have the actual title and authority."

4.3.2 Interactions

Limited interaction between actors

Most interviewees felt that SMFOs and CFOs have insufficient interaction with larger actors and decision makers. According to one interviewee, there seems to be a reluctance from government organisations to form partnerships or "bring in some volunteer or outsiders to help them [government agencies] do it properly". There is also limited interaction between farmers and forest-growers which impedes collaboration on sustainable land use across industries. As observed by one interviewee, "Farmers almost view foresters as a threat to the business." This lack of integration between farming and forestry has been identified in earlier reports by the Ministry of Agriculture and Forestry (2009).

Several interviewees, including forestry advisors and SMFOs, believe that landowners are less likely to engage with professional forestry actors like advisors and consultants compared to agricultural advisors. According to interviewees, this is because tree-growing is often perceived as a relatively simple activity, not a specialised one like agriculture. The cost of engaging a forestry advisor may also be a barrier to interaction and knowledge dissemination. For instance, a researcher observed that "not everybody has the resources to pay for a consultant to do work." This is concerning because forestry professionals are important knowledge disseminators and could link SMFOs and CFOs to other actors or resources.

Strong preference for in-person interaction limits knowledge dissemination

All interviewees agreed that SMFOs and CFOs prefer in-person interactions compared to less interactive methods. For example, one interviewee pointed out the strong appetite for in-person knowledge dissemination, with "people travelling up to 3 hours to attend a [forestry] meeting." Interviewees also indicated that SMFOs regularly seek information from informal sources, such as neighbours and forestry "gurus". For instance, through undertaking an unpublished survey, an industry expert found that up to 39 percent of farm foresters got their information by "talking across the fence to their neighbour." This information is consistent with a survey of SMFOs by West and Satchell (2017) which found a "clear preference" for workshops, seminars, web pages and field days.

Almost all interviewees recognised that the independent nature of SMFOs and CFOs coupled with their preference for in-person events was challenging for efficiently disseminating knowledge. For example, one interviewee suggested that "some type of association to get landowners starting to think collectively and behaving collectively" might be needed. There were mixed opinions on whether knowledge dissemination efforts would benefit from further policy support to "involve the public closely in science", or if existing systems could be adequate if sufficiently resourced.

Despite the preference for in-person engagement, one interviewee commented that the advent of Covid-19 restrictions and the subsequent event cancellations had seen more SMFOs adopting online meeting technology such as Teams to maintain regular engagements.

4.3.3 Institutions

A high level of actor autonomy has hindered efforts to develop a collective forestry model but enables change leadership and citizen science

Like knowledge development, knowledge dissemination is strongly influenced by soft institutions, which include social norms and values. Interviews revealed that autonomy is a core value for both SMFOs and CFOs and can be a problem for knowledge dissemination. Many interviewees noted that the independent spirit of forest owners has thwarted previous initiatives to develop a more collective forestry industry. According to interviewees, forest growers are inherently "independent" and often have resources to support their personal interests, reducing the need to maintain membership in a cooperative organisation. Forest owners were described as "individual thinkers" and actors who "act on their own

behalf", "like to do their own thing", and do not like being "told to do something differently" even if it is for long term collective benefit.

This problem appears to be a long-standing one for New Zealand forestry. In 2009, MAF observed that small-scale forest owners highly valued independence and self-management, which made developing collective forestry models challenging. According to MAF (2009), forest owners would rather forgo significant price-negotiation benefits than join a forest co-operative, for fear of losing decision-making control, especially about harvest timings.

Conversely, autonomous actors can champion environmentally and economically sustainable forestry practices alongside official channels. For example, local champions, skilled community coordinators, and holders of knowledge can be instrumental in shaping a shared vision and driving change. As a CFO explained:

> What you've got are these smattering of different groups that are empowered, and they usually empowered by a combination of things. One, by good leadership… like rangatira. They've usually got a rangatira that's kind of driving a vision. They've got taukanga or the knowledge holders... And then they've got the people that are capable of implementing a vision.

SMFOs can be influential advocates for change and supporting government initiatives. One SMFO, for example, had been "bleating" about the benefits of the ETS for several years to other landowners. They described their most recent success in promoting uptake of the ETS at a local workshop: "I printed out the lookup tables for hardwoods… to hand them out. After that field day that neighbour planted 10 hectares."

In addition, actor autonomy combined with an interest in trialling sustainable forestry practices can result in citizen science projects that promote legitimacy of new methods. As one SMFO remarked, "I've already produced a couple of little trial reports on our work, which no one's interested in, but maybe sometime they will be."

The quotes presented above suggest SMFO and CFO autonomy is an important factor to consider when designing and implementing any initiatives for the forest industry. If common goals can be articulated, these two groups could accelerate adoption and innovation of sustainable practices and novel products.

4.3.4 Infrastructure

Limited and dispersed infrastructure for knowledge dissemination

Forestry information is dispersed among disparate, largely independent actors. These actors include industry bodies, researchers, government organisations, universities, and individuals. As one interviewee put it: "There's no sort of centralized activity in that [knowledge dissemination] regard."

Almost all interviewees mentioned frustration with this dispersed body of knowledge, which has hampered efforts to collate and exchange information. Even when knowledge has been collated for a specialised area, challenges for dissemination remain, including funding issues and a lack of appropriate channels to disseminate existing knowledge. As an industry expert describes the experience of a respected cypress expert:

> You'll get a picture of success and frustration. Funding for his area of cypresses has waxed and waned over the last 30 years, and even when the knowledge has been put together, it can be very hard to disseminate through strategic plans for cypresses.

This illustrates how problems with existing financial and knowledge infrastructure has affected knowledge dissemination, including the ability to use available information for strategic decision-making.

Existing knowledge infrastructure is not optimised to support knowledge dissemination

New Zealand's knowledge dissemination infrastructure comprises mostly of websites, research publications, and professional consultants or forest managers. However, this infrastructure is problematic because not all SMFOs are able to translate available research information into practical knowledge, as mentioned earlier. Consequently, forest owners depend heavily on professional advice (Ministry for Primary Industries, 2022c), but not all forest owners who need advice are able to afford it.

Many interviewees believed that extension was a key instrument for knowledge dissemination, and that extension services should be increased. Similarly, Payne et al. (2018) recommend focusing on "fit for purpose extension" approaches and advocate for more use of MPI's extension services. Several interviewees recalled personal experiences where previous extension programs provided by government agencies had enabled communal knowledge development and dissemination, as well as infrastructure for resource mobilisation. Extension services then became cost-recoverable with New Zealand's decentralisation in 1984 (Rhodes & Novis, 2004).

This articulated need for extension services was interesting because during the time the interviews were being conducted, MPI announced the creation of Te Uru Rākau - New Zealand Forest Service (TUR), which would offer professional advisory service and share forestry management expertise with all forest owners and industry actors (Te Uru Rākau (New Zealand Forest Service), 2021). These services are similar to those interviewees described as "extension services". While re-establishing extension services is beneficial to SMFOs and CFOs, it is unclear how TUR will resolve the existing issues of personal credibility and long-term financial and political support. As one interviewee remarked: "You don't want it to forever rely on the state purse".

4.4 Resource mobilisation

This section outlines the problems related to mobilising knowledge and financial resources, and the lack of infrastructure needed for effective resource mobilisation.

4.4.1 Institution

Economic factors drive decision making

Both interview data and published reports (Carver et al., 2017; Ministry of Agriculture and Forestry, 2009) MAF (2009) agree that FIS actors are reactive to short-term market signals. This appears to be an industry norm, soft institution. Several interviewees mentioned that the expectation to reap economic rewards in a relatively short time frame affects resource mobilisation to explore alternative species and novel products. This expectation is also a soft institution. For instance, an interviewee commented that "one of the challenges that we have here in New Zealand is that people expect to make money out of trees in their lifetime." A researcher added that plantation forestry is seen as "a crop to be managed, harvested, and a return to be given to the investor without thinking about other measures and other means of giving value."

In addition, one interviewee asserted that investors "have little regard for anything else that would interfere with the lowest cost/highest return." As the radiata pine plantation model is a relatively quick and well-understood investment model, it is perceived as the most attractive compared to investments in other slower-growing and lesser-known species. General investor sentiment is expressed clearly by the New Zealand Forest Growers Levy Trust (2017):

> Everything else, including all other product types, all other species, carbon markets, ecosystem services etc, is of secondary importance to the main purpose for NZ plantation forests – which is to make a profit.

This view of forests primarily as a cash crop, with little regard for other values can be problematic. For example, volatile log prices can cause "temptation" for SMFOs and CFOs to harvest immature trees when prices are high (Clark, 2018). Forest owners seeking to capitalise on high prices in a short time could potentially cause net deforestation and threaten New Zealand's ability to meet its carbon sequestration and climate goals. This trend has already been observed between 2015 to 2020, as strong prices for export logs has caused harvesting to outpace replanting, resulting in net deforestation in 2020 (United States Department of Agriculture, 2020). Further deforestation of about 10,100 hectares by small-scale owners is projected between 2020 to 2030 (Manley, 2021).

Low appetite for investment risk

Several interviewees believed that SMFO and CFO adoption of innovative practices is hindered by strong aversion to failure or poor economic returns (a soft institution) and a lack of research to improve returns on innovation investments. These interviewees highlighted that this is a circular problem: research requires funding, but funding is contingent on positive outcomes for investors, which is often not possible without prior research. As an illustration, an interviewee stated that:

> There is kind of a chicken and egg problem in that folks don't want to invest money until they have kind of a better guarantee of returns and outcomes, but we can't get the guarantee for good returns and outcomes without the research.

Although several interviewees commented on the need to develop and disseminate supply chain knowledge to build confidence in novel forestry products, there was no agreement on who should be responsible for this initiative. A few interviewees noted that the industry expects the government to contribute funding for de-risking activities for the forestry industry, as in the quote below:

> I think they [investors] are looking to the government to put funding and to try and get past that [risk] barrier to be able to provide at least enough information that folks feel sure that they're going to get good outcomes, you know, then they'll be able to put investment in.

This quote suggests that more accessible government support for initial research could be useful in attracting investment interest and building confidence in forestry innovation efforts. For example, co-

investment research funding for projects that benefit all New Zealanders and go beyond business as usual is available through various programs like MPI's Sustainable Food and Fibre Futures (https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/).

4.4.2 Infrastructure

Publicly-funded research is not always easily accessible for free

Sometimes, publicly funded knowledge is not easily accessible or in a usable form for SMFOs and CFOs, further limiting the pool of knowledge available to SMFOs and CFOs. One researcher asserted that "New Zealanders expect that they can get the knowledge, anything that's produced by public funding… A lot of knowledge, however, is embargoed, so it sits inside of the institutions, and it's never released." This issue of low knowledge flow between researchers and potential users is also a problem for the broader New Zealand RSI system (Ministry of Business Innovation and Employment, 2019).

There was also some concern that publicly funded research was being withheld for profit. For instance, an industry representative stated:

> I have experienced some frustration in the past with Scion. Clearly, they generate knowledge, but they have been wanting to sell it. I think there's a culture change happening there too, but I think it is a sad situation when knowledge is held, and IP is so tightly defended.

For context, CRIs like Scion are bound by the CRI Act to "undertake research for national benefit", but CRI directors are also required under the Companies Act to "act in the best interests of the company" (Ministry of Business Innovation and Employment, 2020). These two competing priorities have contributed to CRIs "retaining publicly funded IP and seeking to monetise it directly rather than making the new knowledge widely available via an appropriate mechanism" (Ministry of Business Innovation and Employment, 2020). This organisational form was recently identified as a barrier to innovation and recommended for review by MBIE (2020).

Another interviewee commented that government agencies sometimes lack the necessary knowledge infrastructure to mobilise knowledge resources. This then leads to the knowledge not being readily available to the public, including SMFOs and CFOs. As one interviewee explained, "There is a huge amount of knowledge sitting on the shelves in reports. We're good at funding research but not very good

at the extension of that research." Note that "extension" here refers to mobilisation of knowledge resources, not to be confused with "extension services" which is a method for knowledge dissemination.

Lack of capacity to store information leading to loss and reduced access to knowledge

A crucial part of knowledge resource mobilisation is storing existing knowledge for easy retrieval by knowledge developers and disseminators, and the wider public – including SMFOs and CFOs. Several interviewees believed that knowledge was being lost through organisational or staffing change. This quote illustrates the interviewee's concerns around long-term knowledge management, such as when the New Zealand Forestry Service was being restructured in the 1990's:

> … a lot of information was lost. I know of some pieces that came to Scion, some that went to DOC, some went to Landcare. And some of it just disappeared, probably went to landfill or something like that. We don't know. And so we don't really even know what's in those old files, and who's got them and how much still survives… And a lot of the older folks who were really active at that time as researchers have either retired or, sadly, some of them have passed away. And there is some work to try and recover or catalogue what we can, before the last of those people retire, but we've already lost a whole lot.

This quote illustrates how "foundational science functions" like knowledge management can be compromised as a consequence of "CRI financial fragility" (Ministry of Business Innovation and Employment, 2020). It also underscores the interlinkage of knowledge and financial resources, and the importance of maintaining sufficient resourcing to protect existing knowledge.

Short funding cycles

Financial resources are essential for meaningful, practical forestry research that benefits SMFOs, CFOs, and the wider industry. However, several interviewees commented that research funding cycles are relatively short term, which is problematic as forests are complex and take longer to mature than crops or livestock. As one researcher explains, "Research can take literally decades or longer than decades. And funding cycles are typically what three, maybe five years if you're lucky… So yeah, there's a real mismatch there and it can be really challenging to deal with that and figure out how to get those long-term results on short pockets, small pockets of short funding.

The issue of short funding cycles also affects CRIs. For example, Scion (2022) recently highlighted the problem of short funding cycles in a letter to the Minister of Research, Science and Innovation:

> While Scion was successful in the recent MBIE contestable round this result does not provide a long-term solution. Our capability remains at risk as well as our ability to deliver on our strategy... Without a long-term funding solution Scion continues to be highly constrained in how we deliver on our core purpose.

Existing funding mechanisms are not conducive to SMFO and CFO participation in knowledge development or dissemination

Many interviewees noted a lack of infrastructure to mobilise resources for SMFOs or CFOs. For example, an interviewee stated that "there's no sort of investment tool" to enable the flow of financial resources. Interviewees also remarked on a disjoint between forestry and financial organisations like banks, which limits funding for innovation. As an SMFO observed, "Small growers and their forestry assets for a very long time have been disjointed from banking… Bankers don't really understand forestry because it doesn't have cash flow and they sometimes won't loan against the forestry asset."

The following sections provide insights into the other FIS functions that were gained while exploring the focal FIS functions in depth during interviews. These findings are included here as they are linked to, and therefore, affect the performance of the focal FIS functions.

4.5 Guidance of the search

The guidance of the search refers to processes in the FIS that set expectations for policy and practice. When the guidance of the search is functioning well, these processes lead to clear goals for innovation in the forestry industry. Interviewees mentioned several systemic problems for this FIS function, including challenges in negotiating a collective vision, a lack of clarity on collective goals, and low actor confidence in searching for new ideas in growing and processing alternative timber species. These problems deserve mention because they prevent development of shared expectations and can affect other FIS functions.

4.5.1 Interactions

Low levels of interaction between actors hinders development of a collective vision

Several interviewees perceived the low interaction between actors as hindering the development of forestry policies and practices. For example, an industry expert stated that, there is a "lack of discussion" around "setting the vision for what forestry could be in this country". This interviewee further emphasised the need for an effective and inclusive communication platform, such as the previous Forestry Council:

> In the past, we had our Forestry Council… It ran for about 15 years, but it's fallen over… simply because people are not prepared to work together as well as they might. And you know that that's a little sad. But I think that it's exactly another initiative that we really need: a way of ensuring that people get together, that they do talk about the issues and that they do find solutions to move forward. Again, we don't have good mechanisms for doing that.

The low interaction levels are an issue because effective interaction is essential for creating a collective industry strategy, especially in the highly diverse New Zealand FIS. In turn, the lack of a shared industry strategy can make it challenging to conduct targeted research, as noted in earlier sections.

4.5.2 Institutions

Lack of collective strategy for the forestry industry

Many interviewees mentioned that the lack of strategic direction and a clear vision for the forestry industry hinders the search for innovative solutions in the FIS. For example, an industry expert identified the lack of a "clear", "coherent", and "cogent" strategy as "the number one issue" for coordination between governance actors and local communities to deliver on FIS objectives. This interviewee also explained that a clearly articulated vision – a hard institution – of New Zealand's forestry industry is necessary for independent actors to engage and collaborate in new niches. For example, the lack of a well-understood strategy makes it difficult for interested parties to identify how they can contribute to innovation in the FIS, illustrated in this quote:

> There just isn't anywhere, any sort of … coherent policy or strategy that people can observe and contribute to or see how they fit into it. And I think that's probably one of the biggest gaps in New Zealand.

Due to the interconnected nature of FIS functions and elements, this problem is also linked to problems for knowledge development and dissemination mentioned in Section 4.2 and 4.3.

4.5.3 Infrastructure

SMFOs and CFOs lack ability to influence decision-making

Several interviewees observed that efforts initiated at SMFO or CFO level seem unable to influence broader decision-making in the FIS. For example, a researcher and CFO explained that grassroots actors faced difficulties when seeking to articulate their forestry-related aspirations to decision-makers:

> The biggest barrier to action is communication; it's the inability to communicate. This, you know, the grassroots layers trying to communicate desperately a vision and a desire and a goal and an aspiration and a contribution that they want to make. And then the powers that be that control the policy design and funding and decisions at this level, just aren't listening.

This is a concern because SMFOs and CFOs may not be fairly represented in processes that lead to development of industry goals or guide resource allocation. For instance, a few interviewees mentioned that organisations like the Forest Growers Levy Trust (FGLT) are increasingly able to facilitate interaction between industry stakeholders, including SMFOs. However, interviewees were uncertain if such organisations were able to effectively represent SMFO and CFO interests. As highlighted by one interviewee, "How are you getting to hear the views of the whole sector? And not just the most outspoken people or the bigger players?"

4.6 Market formation

This FIS function refers to processes that lead to creation of new markets for novel products or products produced using new methods (Wieczorek et al., 2013). Three systemic problems constraining the development of new markets were identified including the perception that some laws are too stringent, a lack of support for developing new markets, and inaccessible knowledge resources.

4.6.1 Institutions

Some laws and practices perceived as overly stringent

Several interviewees commented on hard institutions that impeded forestry-related innovation and creation of new markets. For instance, the Forests Act 1949 was critiqued by several interviewees as

being overly restrictive and narrowly focused on protecting native forests instead of enabling forest use alongside preservation. According to one interviewee:

> It's about stopping forestry, you know... It should be about "Stop Forestry Act"; it shouldn't be called Forests Act. It's about protecting native forests; it's not about realizing their potential as an economic development."

The challenges recounted by this interviewee are similar to those reported by the Totara Industry Pilot. This Pilot was a 2-year study of market opportunities for a new industry based on naturally regenerating totara in the Far North District (https://www.totaraindustry.co.nz/). Under the Forests Act, harvesting and milling of native trees is only legal with Sustainable Forests Management (SFM) Permits and SFM Plans. Obtaining these permits and plans for the Pilot was time-consuming and expensive, even using totara-specific document templates (Dunningham et al., 2020). For instance, registration of a new permit can take up to 9 months and field surveys for kiwi adds costs of at least $\$20/m^3$ of rough sawn timber (Dunningham et al., 2020).

4.6.2 Infrastructure

Lack of support for developing markets for new or alternative forestry products and techniques

Many interviewees commented on the lack of niche markets within the New Zealand FIS to encourage knowledge development and exchange, and entrepreneurship. As explained by an industry expert and SMFO:

> The policy settings should be very encouraging to these alternative species… But what we need is a full supply chain… It's also the same for non-timber forest products if we're encouraged to develop them. We can supply them in the off-season but we need a whole supply chain to establish that and demonstrate that it's highly profitable.

In an interview with Radio New Zealand, the executive director of Sequal, a wood processing factory in Kawerau, explained that development of business models that prioritised community and the environment over shareholder expectations was hindered because multifaceted "policy disadvantage" and market distortions make it more appealing to send logs offshore instead of adding value domestically (Kennedy, 2021).

There was also uncertainty around which actors would be responsible for creating these market niches and facilitating transformation of the supply chain to encourage investment in alternative species. According to an interviewee:

> [Creating a market for alternative species is] a big job, you really have to have a whole functioning supply chain cobbled together to make it work. And until that's happening, it's very difficult to have confidence and investing money in that. And yet, you know, to, to say, well, who should do that? Should it always be the forest owner?

When asked if the current settings were favourable for innovation, an industry expert stated, "No, because innovation ultimately needs to have a market." This interviewee explained that actors focused on knowledge development may be "pretty good for 15 years out", but lacked understanding of the consumer's current needs and the costs of bringing a new product to the market. MBIE made a similar observation in 2018, noting weak connectivity between researchers and "large markets for new innovations".

In addition, a researcher observed that, "for a long time, forest education in New Zealand has been really focused on radiata," which has resulted in a lack of knowledge on other forest management techniques. The combination of historical accumulation of commercial and research interest in radiata pine has resulted in prioritisation of radiata pine at the expense of species diversity. As a researcher explained, "our industries ended up being fairly locked into radiata pine just because of processing facilities and how markets work and those kinds of things."

The depth of this systemic lock-in issue was aptly expressed by a forest advisor, who exclaimed: "anything other than radiata pine in New Zealand is kind of new. So, just go wild and plant anything other than radiata pine!" This comment reflected the advisor's firm belief in species diversity, and that more forest owners should be planting species that suited their aspirations and environment instead of defaulting to radiata pine.

Knowledge sources for market formation are dispersed, reducing accessibility

Just as there is no single access point for forestry knowledge, market-related knowledge is scattered, hindering development of a supply chain for niche forestry products that would support SMFO and CFO initiatives. According to one interviewee, "All that information around natural competitive advantage,

competitor analysis, market opportunities, hasn't been coalesced together in any succinct document. It's all sitting here in different people's minds."

4.7 Entrepreneurial activity

While this FIS function is not a focal one for the study, several interviewees believed that problems in this function negatively affect knowledge development and dissemination. For example, problems hindering entrepreneurial activity could block opportunities to demonstrate economic viability of new innovations and increase investor confidence. Interviewees did not explicitly mention problems with actors, interactions, or institutions for the Entrepreneurial Activity function, which may be linked to the lack of a clear vision for the industry and a strong focus on the pine plantation model.

4.7.1 Infrastructure

Lack of space to develop and nurture novel products

Many interviewees explained that the purpose of their participation in knowledge development and dissemination activities was for economic benefit – for themselves and their community. Several interviewees also mentioned that even if SMFOs and CFOs want to embark on entrepreneurial activity to develop specialty forestry products, there is a lack of space for new inventions to mature and reach commercial viability. The risks of entrepreneurship were detailed by an interviewee, who was an SMFO and industry expert:

> One of the corporates I know well invested for a long time into an alternative species with the expectation that would support the furniture industry. The furniture industry then disappeared, largely. Trying to get a stable revenue flow from these alternative species is incredibly difficult… Why would you voluntarily go into a very challenging business model when you've got a very straightforward, essentially "sausage factory" [radiata pine processing].

As there is a lack of support for entrepreneurial activity, several interviewees noted that it can be challenging to achieve commercial viability in the current system. For example, a CFO described their experience in harvesting and marketing alternative timber species, "We weren't making any money, and we couldn't sustain it. So it wasn't economically sustainable. So there's no incentive for you to do it. It's so damn hard".

4.8 Conclusion

The results presented in this chapter are summarised and mapped to the respective systemic instrument goals in Table 8 below. Based on the interview findings outlined in this chapter, the key systemic problems identified from the study are:

(1) a lack of strategic direction;

(2) limited interaction between FIS actors; and

(3) infrastructure problems hindering SMFO and CFO participation.

The first column in Table 8 lists all the systemic goals investigated in this study. The next six columns summarise the systemic problems identified in this study, by FIS function. The function "creation of legitimacy" is not included in Table 8 because no systemic problems related to this function were mentioned by interviewees in this study. The systemic problems, which contribute to the three key systemic problems listed above, are highlighted by graduated colours as noted in the key below Table 8. The last column provides examples of systemic instruments that could be used to mitigate the problems identified and contribute to fulfilling the eight systemic goals (Wieczorek and Hekkert (2012). Although systemic problems identified include non-focal FIS functions, the Discussion and Recommendations (Chapter 5) will specifically focus on those related to knowledge development, dissemination, and resource mobilisation.

Table 8 Goals, systemic problems, and examples of systemic instruments by Forestry Innovation System function (Table by author, systemic instruments drawn from Wieczorek and Hekkert (2012)).

Goal of systemic instrument	**Forestry Innovation System functions**						**Examples of systemic instruments**
	Knowledge development	**Knowledge dissemination**	**Resource mobilisation**	**Guidance of the search**	**Market formation**	**Entrepreneurial activity**	
Stimulate and organise participation of **actors**							• Public-private partnerships • Workshops • Venture capital
Create space for **actors'** capability development	• Lack of leaders for strategic collaboration	• Limited actor capacity to translate and use available information • Knowledge dissemination actors sometimes lack personal credibility					• Backcasting • Scenario development workshops • Pilot projects
Stimulate occurrence of **interactions**	• Low interaction between FIS actors causes siloes and disengagement	• Limited interaction between actors • Strong preference for in-person interaction limits knowledge dissemination		• Low levels of interaction between actors hinders development of a collective vision			• Consensus development conferences • Cooperative grants/research programs • Bridging instruments (e.g. centres of excellence) • Tech transfer
Prevent **interactions** that are too strong or too weak	• Some very weak interactions cause actors to disengage	• Weak interactions between forestry and farming sector					• Public demonstration sites • Awards for innovation
Secure presence of **institutions** (hard and soft)	• Overly strong focus on current forestry model • Low certainty in the policy environment hinders long-term efforts and needs urgent action	• A high level of actor autonomy has hindered efforts to develop a collective forestry model but enables change	• Economic factors drive decision making • Expectations to reap rewards from forestry investment in short period	• Lack of collective strategy for the forestry industry	• Some laws and practices perceived as overly stringent		• Education campaigns • Public debates • Lobbying • Voluntary agreements

Goal of systemic instrument	Forestry Innovation System functions						Examples of systemic instruments
	Knowledge development	Knowledge dissemination	Resource mobilisation	Guidance of the search	Market formation	Entrepreneurial activity	
		leadership and citizen science	• Low appetite for investment risk				
Prevent **institutions** that are too weak/stringent	• Weak focus on developing alternative forestry practices						• Regulations • Principles
Stimulate physical, financial and knowledge **infrastructure**	• Existing infrastructure does not facilitate SMFO and CFO participation in knowledge development	• Limited and dispersed infrastructure for knowledge dissemination	• Publicly-funded research is not always easily accessible for free • Lack of capacity to store information leading to loss and reduced access to knowledge	• SMFOs and CFOs lack ability to influence decision-making via existing systems	• Lack of support for developing markets for new or alternative forestry products and techniques	Lack of space to develop and nurture novel products	• Public-private partnerships • Public research lab / library
Ensure adequate quality of **infrastructure**	• Co-funding requirements inhibit SMFO and CFO participation	• Existing knowledge infrastructure is not optimised to support knowledge dissemination	• Short funding cycles • Existing funding mechanisms are not conducive to SMFO and CFO participation		• Knowledge sources for market formation are dispersed, reducing accessibility		• Analysis of problems/needs/solution • Knowledge exchange and management • Trends monitoring

Key:

	Systemic problems related to a lack of strategic direction
	Systemic problems related to limited interaction
	Infrastructure problems hindering SMFO and CFO participation

5 Discussion and recommendations

Building on the findings from the interview and document analysis, this chapter characterises the key challenges associated with knowledge development, dissemination, and resources within the New Zealand FIS, and discusses the systemic instruments that could help address these challenges. For fuller exploration of systemic instrument selection and design, and to enable understanding of New Zealand forestry governance in a wider international context, it draws on current and historical governance context, as well as international forest governance and policy literature.

Three key challenges were identified, each representing systemic problems that that affect multiple FIS functions:

(1) a lack of strategic direction;

(2) limited interaction between FIS actors; and

(3) infrastructure problems hindering SMFO and CFO participation.

Each of these challenges will be discussed in turn below. In keeping within the objectives of this thesis, the recommendations in this section are focused on addressing these key systemic problems for the three focal FIS functions but may also help remedy key systemic problems for other functions.

5.1 A lack of strategic direction

A lack of strategic direction emerged as a recurrent finding across interview data and stakeholder types. Most of the institution problems and some of the actor problems flagged by interviewees could be linked to a lack of strategic direction. FIS functions and elements are highly interlinked, as both affect and are affected by each other. This reflects the interconnected nature of elements in the FIS and suggests that the challenge of a lack of strategic direction is related to many problems identified in Table 8.

According to Wieczorek and Hekkert (2012), systemic instruments that could be used to address institution problems include voluntary agreements and principles (Table 8). A potential instrument that both articulates collectively agreed principles as well as constitutes a type of agreement is a forest policy.

For example, the Food and Agriculture Organisation of the United Nations (2018) defines "forest policy" as:

> A negotiated agreement between government and stakeholders … on the orientations and principles of actions they adopt, in harmony with national socioeconomic and environmental policies, to guide and determine decisions on the sustainable use and conservation of forest and tree resources for the benefit of society.

Weber and Rohracher (2012) add that an articulated collective policy is crucial as the basis for the direction- and priority-setting needed to achieve transformative change. It is important to note that a forest policy can be in the form of strategies (Germany), frameworks (Canada), laws (Sweden), national forest programmes (Sweden, Finland), or a combination of these. While several forest strategies and laws exist in New Zealand, there is no single, commonly accepted document that articulates a shared, long-term vision for the industry. For example, the Forests Act specifically guides administration of forests, while Fit for a Better World (2020a) is a broad strategy and lacks specificity for forestry and innovation.

Given that interviewees and industry representatives like NZIF support the notion of a national forest policy, this thesis recommends that governance actors renew efforts to negotiate an inclusive forest policy that supports the many roles of New Zealand's forests and breaks the siloed approaches to forest management. There are several existing documents that can support this negotiation. For example, NZIF proposed a national forest policy and presented it to the then Minister of Forests, Shane Jones, in 2018 (New Zealand Institute of Forestry, 2018). In addition, MPI has produced Fit for a Better World (2020a) and the Te Taiao framework in The Natural World and Our People Are Healthy (2020). Taken together, these two MPI documents set out a "vision and strategic direction" for all New Zealand primary industries and three core principles that guide this strategy. These principles are founded in the Māori concept of Te Taiao, "a deep relationship of respect and reciprocity with the natural world" (Howard et al., 2020; Ministry for Primary Industries, 2020a).

One way to develop a forest policy for New Zealand could be a stepwise refinement of NZIF's policy draft alongside existing work such as MPI's Fit for a Better World programme (https://www.fitforabetterworld.org.nz/), the Forestry and Wood Processing Industry Transformation Plan (ITP) (2022a), and the extensive research by the Whai Rawa Research Programme to inform a Māori economic development strategy (Ellis, 2021). For example, the policy draft could be harmonised with the vision, strategy, and guiding principles set out in these documents. Next, the draft forest policy

and ITP could be publicised, and public feedback gathered to identify the most important issues. Once priority areas for the short-, medium-, and long-term have been identified, the ITP could be progressed accordingly while a formal forest policy is developed. Germany took a similar stepwise approach in negotiating their forest policy, circulating a draft strategy for feedback and engaging in numerous subsequent forums to refine the document and gain consensus (Weber, 2018). The process will likely be resource intensive as hui (gatherings) and regional meetings will be needed, as well as good virtual access, to ensure inclusion of Māori and SMFOs throughout this process. It is important to acknowledge and describe the diverse modes of Māori economies and ensure that any interventions fit with Māori forms of business, enabling the creation of resilient Māori organisations (Ellis, 2021).

According to the Food and Agriculture Organisation of the United Nations (2010), a forest policy could mitigate the FIS problems summarised in Table 8 in several ways. Firstly, the process of bringing together stakeholders with diverse interests to negotiate an agreement is extremely valuable for developing leaders for collaboration and building a soft institution of collaboration and joint ownership of the policy. This sense of joint ownership and mutual acceptance of the new forest policy among FIS stakeholders is crucial to successful implementation (Food and Agriculture Organisation of the United Nations, 2010). For instance, Weber (2018) describes how Germany's "most outstanding example of a substantive National Forest Programme" came to a "standstill" due to lack of acceptance from NGOs and other actors. Furthermore, shared ownership of any initiatives will help to balance the existing soft institution of actor autonomy that has previously hindered collaborative efforts in New Zealand.

Secondly, a national forest policy can guide the planning and operations of all FIS actors (Food and Agriculture Organisation of the United Nations, 2010). For example, the policy could articulate an overarching vision for all New Zealand forestry actors, with short-, medium-, and long-term supporting goals. Finland's National Forest Strategy (2019), for instance, has a vision to grow welfare, and has three main goals centred around competitiveness; renewal and diversification of forest-based businesses; and active, diversified, and sustainable use of forest resources. A national New Zealand forest policy would be forestry-centric and support forest-related areas of larger national policies and initiatives such as MPI's primary sector roadmap in Fit for a Better World (2020a). It could provide guidance on research, innovation, and mātauranga Māori, which are currently listed under "Other opportunities" in the Fit for a Better World (2020a) roadmap. This would offer researchers and other FIS actors direction while maintaining alignment with other primary sectors, enabling planning of short-, medium-, and long-term

work programs. This, in turn, would help address the systemic problems of researchers being hindered by lack of direction and the lack of a collective strategy for the forestry industry. The policy could also outline priority research areas and examples of successes, as in Canada's Forest Service Strategic Framework (2019).

Thirdly, a national forest policy can communicate important messages to FIS actors and the broader public. Examples of such messages are the longer time horizons needed for effective forestry management, areas expected to experience disruptive changes, and how forestry relates to wider domestic and international policy. A shared, consistent understanding of forestry timescales is important for shaping public and investor expectations of investment timeframes, which can be significantly longer than for other primary sector investments.

A national forest policy can also provide certainty to guide decisions on emerging issues, "particularly those where quick, difficult or controversial decisions must be made" (Food and Agriculture Organisation of the United Nations, 2010). It is important that the national forest policy provide long term certainty about government priorities, climate change action, and broader resource management policy direction, because if actors each pursue their diverse interests and change course frequently, longer-term objectives such as socioeconomic and environmental wellbeing are unlikely to be attained (Food and Agriculture Organisation of the United Nations, 2010). In this way, a forest policy would provide a stable policy environment conducive to sustainability initiatives.

Lastly, the FAO (2010) assert that a national forest policy provides "excellent guidance for developing more coherent institutional frameworks and policy instruments" including forest-related legislation. This function of a national forest policy could then directly support governance actors in revising laws that are currently perceived as too stringent and help shape a cohesive and inclusive FIS.

Importantly, a New Zealand national forest policy could not work in isolation, but should be compatible with policy processes at a global and at subnational level (Food and Agriculture Organisation of the United Nations, 2018). The national forest policy would need to provide for binding commitments such as those under the Treaty of Waitangi and legislation like the Resource Management Act and the Forests Act. For example, Natural Resources Canada (2019) states international, national, and local goals in their 2019 Canadian Forest Service Strategic Framework. A forest policy that provided similar guidance for

New Zealand's FIS actors would address the lack of strategic direction currently hindering researchers, as researchers and other actors would have clarity on the long-term vision for the forestry industry.

It is crucial that new policy instruments are sensitive to New Zealand's sociocultural context and environment. For this reason, a national forest policy needs to be formulated in partnership with Māori in the spirit of Treaty partnership (Ministry of Business Innovation and Employment, 2020). According to Harmsworth and Awatere (2013), the most effective models and processes for including Māori in decision-making are based on the Treaty of Waitangi, as shown in Figure 4 below. Several key elements of this framework can help resolve FIS problems related to a lack of strategy. For example, this framework provides for a structure where management of forest resources is a shared responsibility between government and Māori (Harmsworth & Awatere, 2013), which is essential to successful forest policy implementation (Food and Agriculture Organisation of the United Nations, 2010). Adoption of policy planning and decision-making processes that emphasise shared responsibility between government, Māori, and other stakeholders would contribute to mitigation of the lack of collective strategy for the forestry industry. This framework would also enable FIS governance actors draw on the "dual paradigms" of mātauranga Māori and Western knowledge, facilitating creation of legislation that better aligned with Māori values and aspirations for their forests. Such a framework would support development of an integrated, Treaty-based partnership with Māori and align with recommendations from a CRI review by an independent Panel (Ministry of Business Innovation and Employment, 2020).

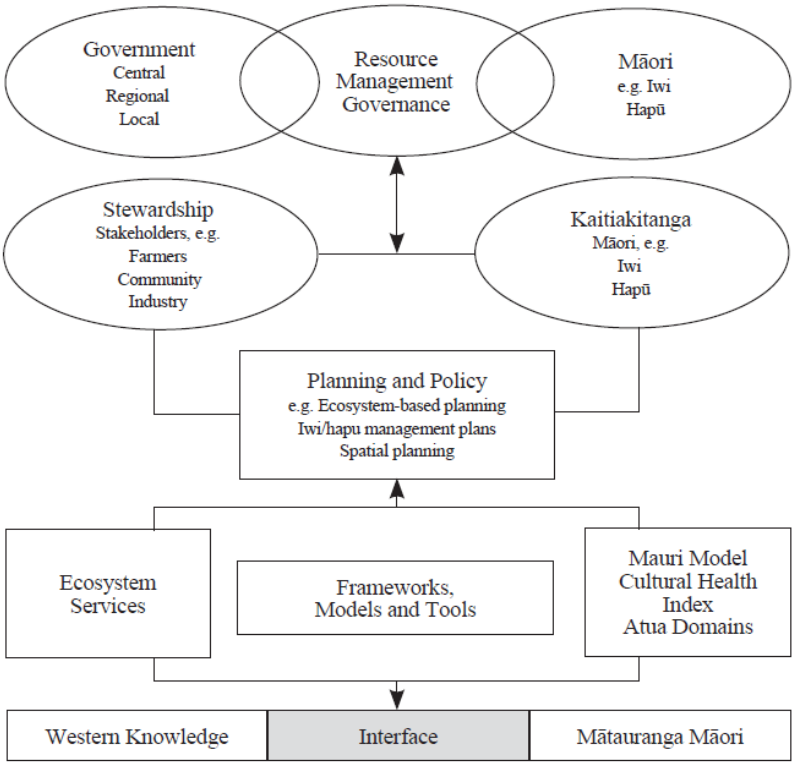

Figure 3 A planning framework based on Treaty of Waitangi principles that could be used in developing a New Zealand forest policy (from Harmsworth and Awatere (2013)).

The Treaty-based framework in Figure 3 extends to broader community and shared values, and emphasises finding common ground, "a space where the ideals of stewardship can work alongside the principle of kaitiakitanga" (Harmsworth & Awatere, 2013). According to Harmsworth and Awatere (2013), kaitiakitanga entails active protection and care for a resource, such as guardianship and sustainability practices, so that the resource can continue providing benefit. Adopting a Treaty-based framework that places kaitiakitanga alongside stewardship in the policy process could shift decision-making norms away from a strong focus on the current forestry model and expectations of short-term rewards from forestry to a greater interest in alternative and sustainable forestry practices with multigenerational benefits. A Treaty-based framework would also enable holistic, landscape-level approaches for forest management, which are consistent with Māori values (Harmsworth & Awatere, 2013) and recommendations for New Zealand's climate change strategy made by the Parliamentary Commissioner for the Environment (2019) and the Climate Change Commission (2021).

It is crucial that the process of articulating a shared future vision incorporates participatory processes and supporting scientific evidence (Weber & Rohracher, 2012). Instruments for defining "corridors" of acceptable development paths could include education and recognition, coordination mechanisms,

regulations and standards, demonstration projects, and funding for key research and infrastructure (Weber & Rohracher, 2012; Wieczorek & Hekkert, 2012). It is essential to include te ao Māori, Māori values, and Māori ways of working in the process of creating an authentic shared vision for New Zealand forestry, considering the importance of forests to Māori culture, identity, wellbeing, and livelihoods.

In addition to being participatory, a good forest policy is compromise-based, cross-sectoral, long-term, adaptable, evidence-based (Food and Agriculture Organisation of the United Nations, 2018). In this context, a forest policy for New Zealand could be a pivotal instrument for creating a cross-sectoral vision and multi-directional partnership under the Treaty of Waitangi, provide for expression of Māori values, and guide the transformation of the forestry industry. Such a policy could therefore directly or indirectly address the root causes of many of the FIS problems shown in Table 8.

In summary, a national forest policy would describe a shared, overarching vision and outline goals that promote a sustainable, innovative, and accessible forestry industry. This policy would communicate to all New Zealanders how the forestry industry will develop in alignment with other primary sectors, conservation efforts, evolving socioeconomic and cultural aspirations, broader national direction and regulations, and international commitments. It would also highlight priority research areas, including mātauranga Māori, and offer examples of what success might look like. Finally, it would provide guidance for decisionmakers at all levels, enabling multigenerational, landscape-level resource management and fuller Treaty partnership in forest governance.

5.2 Limited interaction between FIS actors

The second key challenge identified is limited interaction between SMFOs, CFOs and other FIS actors. This affects all three focal FIS functions as well as the "Guidance of the search" function (Table 8). Note that low connection between actors is also considered a "key underlying challenge" for New Zealand's RSI system (Ministry of Business Innovation and Employment, 2019).

Interview data suggest that the main factors that limit collaborative interaction between SMFOs, CFOs, and other FIS actors include different motivations for growing forests and limited leadership for strategic collaboration. For example, interviewee motivations for planting forests varied from personal enjoyment and curiosity to conservation interests and secondary income. As mentioned in Section 5.1, there is a lack of strategic leadership, which in turn affects actor motivation for collaboration (Emerson et al., 2011).

These findings are consistent with the results of the Forest Sector Study by Ministry of Agriculture and Forestry (2009), suggesting little has changed in the past 12 years. Other studies have suggested that because SMFOs are an increasingly important source of timber, such collaboration problems among small forest growers pose a risk to New Zealand's forest supply chain (Wang & Radics, 2021).

The systemic problem of low interaction identified in this study is in stark contrast to the cooperation that was "the hallmark of the New Zealand forestry sector" up until the 1980s (Ministry of Agriculture and Forestry, 2009). This cooperative nature has, in part, been lost through "diverse ownership", a shift to short term corporate strategies, and increased industry fragmentation (Ministry of Agriculture and Forestry, 2009).

Wieczorek and Hekkert (2012) suggest that cooperative grants, joint research projects, or bridging instruments like centres of excellence could be deployed to stimulate interactions in the FIS (Table 8). The newly launched Timber Design Centre (the Centre) (https://www.timberdesigncentre.co.nz/) is potentially one such bridging instrument that could provide a platform for joint research involving SMFOs, CFOs, and other FIS actors. The Centre is an initiative between Te Uru Rākau – New Zealand Forest Service and a consortium comprising Scion (a Crown Research Institute), the Wood Processors and Manufacturers Association, New Zealand Timber Design Society and BRANZ (Ministry for Primary Industries, 2022d). The Centre will be an industry advisory service for building designers to promote and facilitate use of timber in non-residential buildings (Ministry for Primary Industries, 2022d). The Centre's core services are likely to include information development and dissemination; technical advice and assistance to help better connect FIS actors; and workshops, webinars, and field trips (Timber Design Centre, 2022).

Considering that these proposed core services align well with SMFO and CFO needs and interaction preferences, the Centre could therefore consider designing its services to encourage more SMFO and CFO participation. For example, SMFOs and CFOs could embark on joint research projects with researchers, processors, building designers, and marketing agencies with an aim to create a local and international supply chain for niche products. It would also benefit the Centre to actively engage more industry bodies not currently included in the partner list. For instance, NZFFA, Tane's Tree Trust, and New Zealand Dryland Forest Initiative (NZDFI) hold extensive knowledge of specialty native and exotic timbers and have access to a network of growers who can supply specialty timber to the industry.

According to a study by Mancheva (2018) on Swedish forest owner collaboration for resource management, factors like trusted informants and leadership can spur collaboration at a local level. Enabling industry collective actors like NZFFA, NZIF, and Tane's Tree Trust to represent SMFO and CFO interests at national-level consensus development engagements could help interaction problems between FIS actors, foster partnerships, and promote creation of a shared vision for forestry. They already facilitate knowledge development and dissemination for SMFOs and are considered trusted informants. In addition, these organisations have structures that clearly identify leaders and are often in strategic positions to advocate for SMFO and CFO needs. These leaders could champion public-private partnerships and influence decision-making to help alleviate various infrastructure problems.

It is not clear, however, if existing collectives like the NZFFA are able to adequately represent Māori and CFO needs and aspirations. From a verbal inquiry to MPI, there is no large-scale collective to represent or facilitate interaction for Māori forest owners in the FIS (personal communication, February 2022). Māori representation is vital to accommodate the diversity of Māori sociocultural and economic interests. It is therefore important for governance actors to address this gap and ensure that Māori and CFOs are represented in decision-making processes. MPI's Fit for a Better World (Ministry for Primary Industries, 2020a) strategy provides good examples of cross-industry and multi-actor interaction. It could therefore be a useful guide for developing interdependent, mutually beneficial relationships between highly autonomous FIS actors.

For implementation of any activities to increase interaction between FIS actors, governance actors could draw upon the Department of Conservation's experience and attend regular iwi meetings with an agenda item instead of organising special technical huis (Wilson et al., 2007). These governance actors could be policy writers, decision makers, and industry liaisons. Wilson et al. (2007) add that some key factors that support establishment of working relationships with Māori are: support from local rangatira (leaders) who had the community's trust; relationship-based interactions (rather than transactional ones); regular kanohi ki te kanohi (face-to-face) meetings; maintaining clear goals and a permanent core group of individuals to manage relationships throughout the lifetime of the project; and communicating progress effectively to all partners including Māori and local government. The recommendation for rangatira or local champions was echoed by researchers like Awatere et al. (2018) and Kirk et al. (2022).

While the recommendation for a national forest policy in Section 5.1 was primarily intended to address the lack of strategic direction, the process of creating a forest policy for New Zealand would also support efforts to resolve problems related to interaction. For instance, forest policy negotiations would constitute consensus building, which is a systemic instrument for interaction problems (Wieczorek & Hekkert, 2012) and would necessarily require increased interaction between actors. These negotiations therefore directly facilitate communication, coordination, and collaboration between actors (Food and Agriculture Organisation of the United Nations, 2010), thereby helping to mitigate interaction-related problems.

5.3 Infrastructure problems hindering SMFO and CFO participation

As outlined in Chapter 4, several infrastructure-related problems hinder actor participation in knowledge development, dissemination, and resource mobilisation. For example, SMFOs and CFOs have difficulty navigating the existing funding mechanisms and meeting current co-funding requirements. There is also limited financial and knowledge infrastructure and capacity for knowledge holders to disseminate forestry and wider supply chain information to the wider public, including SMFOs and CFOs.

Several barriers related to infrastructure could be addressed by adopting a national forest policy. According to the FAO (2010), a national forest policy can provide a basis for strengthening technical assistance and cooperation. Developing a national forest policy as recommended in Section 5.1 would set expectations around which focal issues are likely to guide funding criteria. With well-understood expectations, funding mechanisms could then be more accessible, encouraging broader public participation in the FIS. In this way, the national forest policy would mitigate knowledge and financial infrastructure barriers for SMFO and CFO participation in knowledge development.

Interview data revealed various infrastructure-related problems for the focal FIS functions, ranging from prohibitive co-funding requirements and short funding cycles to difficulties accessing and using existing knowledge. This thesis recommends creating a resource mobilisation and prioritisation process that enables development of infrastructure that facilitates broad participation in knowledge development and dissemination, for industry as well as SMFOs and CFOs. This suggestion echoes MBIE's (2020) recommendation that the Ministry for the Environment, Ministry for Primary Industries, Department of

Conservation, CRIs and Māori co-design and implement a process for prioritising and funding CRI research for government. It could be helpful to draw on learnings from collaborative governance when designing knowledge and financial infrastructure as a number of scholars argued that such approaches to collaborative governance can help to overcome "stubborn conflicts" where existing governance and consultation systems struggle to achieve the desired outcomes (Eppel, 2013; Kirk et al., 2022; Salmon, 2012). It would also be useful to consider criteria for inclusive development in any infrastructure initiatives (Caverley et al., 2020).

However, Brower (2016) cautions that collaborative governance can create systems in which "those not invited into the collaborative deliberation do not count". This potential issue warrants consideration as SMFOs and CFOs are already poorly represented in decision-making at the national level. There is also a risk that incumbent actors may wield more power in negotiations than other actors, and that development for economic gain will be favoured over other forest uses and values (Brower, 2016; Echeverria, 2000; Schuckman, 2001). In addition, the resource prioritisation process needs to accommodate criticism or objections in a constructive manner to maintain legitimacy (Kirk et al., 2022).

Other infrastructure-related systemic barriers identified in Chapter 4 are related to a body of forestry knowledge that is scattered across multiple organisations, not easily accessible by the public for free, and is at risk of being lost due to storage and management issues. These problems potentially limit the ability of SMFOs and CFOs to incorporate practical adaptation strategies into business models and decision-making processes, including methods 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).

Several systemic instruments could support consolidation of scattered information sources, such as a well-publicised and accessible knowledge portal, partnerships for knowledge exchange, a national data repository, and ongoing information needs monitoring. A public forestry knowledge portal already exists in New Zealand: MPI's Canopy website (https://www.canopy.govt.nz/). It is available in both English and Te Reo Māori, and includes a section dedicated to supporting Māori make decisions for forestry on Māori land. This website contains much of the information interviewees indicated was necessary to support forest owners through all stages of forestry, from planning to harvesting and marketing.

However, despite providing a wealth of relevant content, the Canopy website was not mentioned by any interviewees as a source of knowledge, possibly due to a lack of awareness. There was also limited

information on sustainable practices like mixed age and mixed species planting, selective logging; sustainable harvesting practices like selective or coupe harvesting; and how to market non-log wood products. These stages of forest management were mentioned by SMFO interviewees as important, as many SMFO-owned forests were approaching maturity within the decade. In addition, while there was information on specialty timbers as a link to NZFFA content, it was located under the "Harvest" section. It may be useful to include this link in other sections such as "Plan>Choose the right tree" to better inform users about alternative timber species early in the planning process.

Considering the low use of Canopy and the preference for participatory knowledge exchange methods revealed in interviews, it would be fruitful to develop partnerships between SMFOs, CFOs, and other FIS actors for knowledge exchange and to promote the existing Canopy knowledge portal. Such partnerships are required to enable FIS actors to effectively use existing information, evidenced by the low awareness of the well-resourced Canopy website. For example, TUR and Scion could support translation of more research into accessible language and media on the Canopy website. In addition, TUR, DOC, Scion, NZFFA, and other industry bodies could actively encourage use of the website via field days or targeted engagement. For example, when NZFFA holds field days, speakers could refer attendees to Canopy in addition to the NZFFA website. To facilitate uptake of the Canopy resources, MPI may need to hold more regular workshops with industry bodies, virtually and in person, to demonstrate learning and management tools and available on Canopy that can support new and existing forest owners.

Knowledge exchange partnerships should also include international partners that have inclusive FIS and forest sustainability organisations. For instance, MPI could organise knowledge exchanges with trade partners like Canada to share information on sustainable forestry, forest-based innovation, and learnings from indigenous forest growers. As an example, Sweden sent a delegation to Canada to learn about Canada's FIS, successes, and challenges (Theander, 2016). More active international knowledge exchange could increase exposure of FIS actors, SMFOs, and CFOs to novel forest practices from other countries. This exposure is useful because it may help FIS actors, including SMFOs and CFOs, conceptualise a collective forestry model that is both appropriate for the New Zealand context and in line with Treaty partnership.

Aside from increasing public awareness and use of existing knowledge portals, a central knowledge repository for long-term storage is needed to mitigate the risk of knowledge loss. While websites hosted by government agencies and industry bodies provide a suite of information, there is no central repository for forestry knowledge in New Zealand. This knowledge repository would be the storage hub for resources like research articles, data sets, reports, citizen science contributions, and mātauranga Māori. Importantly, digital storage and public access for mātauranga Māori via this repository will need consideration and consultation with Māori to ensure data sovereignty is protected (Walter et al., 2020).

Given MPI's role as the main regulatory agency for forests, and TUR's role as an extension service provider, MPI is well-placed to lead the creation of a national forest knowledge repository, in collaboration with other government agencies and FIS. It is important that this repository has consistent and sufficient resources for maintaining the repository, including regular digital and physical infrastructure upgrades, to avoid risks of running on a "shoestring" budget as experienced by other national datasets (Parliamentary Commissioner for the Environment, 2020). Interactive discussions are needed to secure and maintain such financial and political support for a national forestry knowledge repository. These discussions could take place at the forums established for discussion of the national forest policy mentioned earlier.

Aside from knowledge infrastructure barriers, financial barriers hinder SMFO and CFO participation in knowledge development and dissemination. For example, project grant co-funding requirements can be up to 50%, and this sum is not easily available to most SMFOs and CFOs. Likewise, the cost of engaging a professional forestry adviser can be prohibitive to SMFOs and CFOs. Two systemic instruments could be employed to better understand the nature of these barriers and how best to resolve them (Table 8). Firstly, analysing and aligning universities' areas of expertise with industry priorities would enable the forestry industry (including SMFOs and CFOs) to leverage the role of universities as international knowledge development and dissemination platforms OECD (2022). Further targeted surveys of a broad range of industry actors would improve understanding of the problems for SMFOs and CFOs and inform approaches to encourage greater collaboration between actors in forest-related knowledge development and dissemination. Secondly, options for removing or mitigating those barriers could be explored. These options might be different, lower-cost ways of knowledge dissemination such as via video call or group sessions. Co-funding requirements could be met by matching SMFOs and CFOs with domestic or international partners with similar interests or motivations to support the research. It is also crucial that

any infrastructure for knowledge development, dissemination, and resource mobilisation is regularly reviewed to ensure it remains effective and fit for purpose. For instance, MBIE conducted a review of New Zealand's science system and found numerous issues that negatively impacted resource use efficiency and prevented Māori from participating as full Treaty partners in research (Ministry of Business Innovation and Employment, 2019).

Although the FIS functions of developing entrepreneurial activity and market formation are outside the scope of this study, creating spaces to develop, trial and market novel forest products could indirectly motivate SMFO and CFO actors and other actors outside the FIS to participate in knowledge development, dissemination, and resource mobilisation, as new and niche products or methods may involve cross-sectoral collaboration. This may create supply chains and pathways to new markets and potential for economic gains for SMFOs and CFOs.

In conclusion, many of the problems identified in this study overlap with those previously noted by MAF (2009). These include an absence of "strategic thinkers" in the FIS, the importance of interactive learning between actors, the negative effects of funding volatility, the need for a long time horizon in forestry management, and the presence of barriers to cooperation. These findings highlight that the problems identified by MAF (2009) continue to impede innovation in NZ's forestry sector. Beyond that, the complexities of these problems pose challenges that will require innovative policy interventions, policy instruments, infrastructure, and practices, such as those discussed in this section.

6 Conclusion

It is clear that current forestry practices and systems are insufficient for maximising forest values for New Zealanders. These values encompass economic opportunity, environmental quality, biodiversity, climate resilience, indigenous knowledge, and sociocultural wellbeing. This study has shed light on the challenges to designing and implementing forest policy instruments that provide multiple benefits to New Zealand's people, environment, and economy, while safeguarding forest and ecosystem resources for the future.

The study revealed that, for the three focal FIS functions of knowledge development, dissemination, and resource mobilisation, systemic problems identified by interviewees were consistent with those mentioned in published documents. New Zealand's FIS can be broadly characterised as being fragmented, with little collective strategy or direction, and having a strong focus on existing systems and practices. Study data also showed that FIS actors are disconnected from each other. Overall, knowledge and financial infrastructure is not adequately resourced and, in its current configuration, unable to fully support the diverse aspirations of New Zealand's forest owners.

The study showed a growing need for practical sustainability knowledge and a broad understanding that forests are of central importance for human survival and wellbeing, climate change resilience, ecosystem service provision, and biodiversity. There is also an expectation that New Zealand's forest values and management system will reflect Māori values and aspirations. For example, while many FIS interactions are transactional, there is keen desire across stakeholder groups to move towards more relationship-based connections.

The structural-functional analysis undertaken in this research identified key challenges for knowledge development, dissemination, and resource mobilisation, as well as potential systemic instruments that could help address them and support uptake of more sustainable practices. Below is a summary of recommendations on potential systemic instruments to facilitate more innovative, sustainable, and culturally appropriate forest practices in New Zealand:

- Negotiating a national forest policy that is sensitive to New Zealand's sociocultural context and environment

- Leveraging the new Timber Design Centre as a bridging instrument to promote more collaborative efforts between SMFOs, CFOs, and other FIS actors
- Enabling industry collective actors like NZFFA, NZIF, and Tane's Tree Trust to better represent SMFO and CFO interests at national-level consensus development engagements
- Establishing and maintaining relationships with Māori, supported by local rangatira (leaders)
- Creating a resource mobilisation and prioritisation process that enables development of infrastructure that facilitates broad participation in knowledge development and dissemination
- Developing and publicising an accessible knowledge portal
- Improving multi-party partnerships for knowledge exchange
- Creating and maintaining a national data repository
- Monitoring ongoing information needs for the industry and broader stakeholder groups

The analysis also revealed that these problems are interrelated, affecting the focal functions, as well as other FIS functions beyond the scope of the study. This interlinking between FIS elements and functions possibly warrants fuller exploration to enable holistic solution design.

The results of this study point to several measures for better embedding SMFO and CFO interests in national-level strategies for advancing forestry research, the Māori economy, rural economic development, and climate change initiatives. For example, the MBIE report *Te Pae Kahurangi* presents a review of CRIs and research actors, and outlines problems consistent with many of those identified by interviewees in this study. Effective solutions to CRI problems outlined by MBIE should therefore consider effects on SMFOs, CFOs, and Māori, and maximise their capacity to contribute to the forestry industry. This approach is important because Māori are the New Zealand government's Treaty partners and there is increasing domestic and international attention on the indigenous people-policy interface.

There is a clear need for forest policy instruments that can accommodate multiple objectives and a spectrum of values that shift with constantly evolving social, economic, and environmental needs. The approaches recommended have much in common with those proposed by Wang (2004), which places knowledge as the "centrepiece" for sustainable forest management. The findings are also consistent with the idea of co-development of economic, environment, and social systems articulated by Munda (1997). It is essential that these recommended approaches provide for uniquely New Zealand elements absent in other countries identified as having inclusive FISs, such as the Treaty of Waitangi, a Treaty-based

partnership with Māori, and a legacy of autonomy among forest owners. The recommendations proposed in Chapter 5 are neither easy nor quick – they are iterative, have long time horizons, and will require extensive negotiation and commitment from all interested parties. However, the systemic problems identified ultimately affect all actors in the FIS, so it is imperative that they be addressed.

One limitation of this research was the limited scope. As the study focused on three out of seven Innovation System functions, the holistic analytical power of the chosen framework was reduced. However, analysing the FIS using the using the full framework by Wieczorek and Hekkert (2012) was not feasible due to time and academic program requirements. A fuller analysis of the FIS would provide better understanding of systemic problems that block innovation in forestry, and what instruments could be used to resolve these problems. For example, an expanded analysis scope might show areas where forestry intersects with other industries like agriculture or tourism, or issues across the multiple government agencies that are involved with forests. It could also allow a comparison of New Zealand's Forestry Innovation System with the Agriculture Innovation System (Turner et al., 2016), as the studies employ the same conceptual framework by Wieczorek and Hekkert (2012). Such a comparison would be useful as agriculture and forestry are the main two land-uses in New Zealand, and a comparative analysis of their ISs could reveal areas of shared or divergent challenges, needs, and goals. This knowledge could then inform development of joint cross-sectoral research, efficiencies in resource sharing, or sustainability initiatives.

In conducting this study, it became apparent that there is much yet to be understood where indigenous knowledge, vernacular science, and policy overlap in the FIS. For example, it is unclear how effectively existing systems can promote development of a multi-use, multi-generational forestry model that aligns with international best practice and values like kaitiakitanga and guardianship. A full structural-functional analysis of the FIS could thus reveal barriers to a more competitive and holistic forestry industry. Structural-functional analysis of the FIS could also identify areas where forestry aspirations, for Māori and non-Māori, diverge from (and align with) the status quo, as well as socially and environmentally appropriate policy instruments for addressing these issues. Such analyses would be timely, considering that Māori are Treaty partners and major forestry industry stakeholders, and that forests are central to New Zealand's economy and climate change response. Other scholars and agencies are exploring similar areas in Canada, Australia, and other countries (Caverley et al., 2020; Food and Agriculture Organisation of the United Nations, 2022; Kanowski & Edwards, 2021). New Zealand,

however, offers a rich, singular opportunity to progress forest policy research given the contexts of Treaty partnership, te ao Māori, and mātauranga Māori.

In closing, further exploration and development of forest policy instruments, practices, and forest-related knowledge in close partnership with Māori would be a significant and empowering commitment to Treaty partnership. This could aid resolution of long-standing issues stemming from the fragmented nature of forest knowledge management and encourage formation of pathways towards increased economic and environmental sustainability for New Zealand and forestry communities worldwide.

Appendix 1: Information Sheet

MASSEY UNIVERSITY

Knowledge development, diffusion, and resourcing in New Zealand's forestry innovation system

I would like to invite you to participate in a study exploring knowledge development and diffusion in New Zealand's forestry innovation system. This research is being undertaken as part of my Master's in Environmental Management. My supervisors are Anna Berka and Karen Hytten.

In this study I am investigating the barriers for lifestyle and community-based forest owners in sustainability knowledge development and diffusion in New Zealand, and the associated resource constraints. I am also interested in your thoughts on the "route to market" for forestry innovations such as new wood products. I would like to interview you for approximately 30 minutes to 1 hour between June to September 2021. In this interview, I will ask you about your experience in the forestry sector; your perceptions of how knowledge is developed, diffused, and the resourcing of these activities; and the opportunities and barriers for forestry knowledge development and diffusion in New Zealand.

Why participate?

I hope this study will help to identify potential forestry-related policy strategies and instruments that are: (1) economically and environmentally sustainable; (2) innovative and sensitive to New Zealand sociocultural context and environment. This work will also help identify gaps in New Zealand policy and guide formulation of recommendations to remedy these gaps. I will share my findings with you if you wish.

Your rights as a participant

I guarantee full confidentiality and anonymity to all participants in this study. Your contact details and interview transcript will be kept in a secure environment only accessible to myself and my supervisors. No participants will be identified in any way. Participation in this research is completely voluntary. If you decide to participate, you have the right to:

- Ask any questions about the research at any time
- Decline to answer any question
- Decline to be recorded or to ask for the recorder to be switched off during the interview
- Be provided with a summary of the research findings when the study is concluded
- Withdraw from the study

Please feel free to contact me if you have any questions about the project.

Project contacts

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This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Prof Craig Johnson, Director, Research Ethics, telephone 06 356 9099 x 85271, email humanethics@massey.ac.nz

Appendix 2: Sample Interview Sheet

For this project, I'm interested in what you think is happening and not happening in the forestry sector, in terms of knowledge creation and diffusion. I'm focusing on finding out who does work in the knowledge space, what interesting collaborations exist for developing new ways of working in forestry, and which groups influence direction of research and extension. I'm also interested in hearing what you know about resources that support knowledge creation and diffusion – including financial resources, technical expertise, staff, physical or digital infrastructure. I am interested in your personal perspective. Anything you tell me is in full confidence, shared only between my supervisors and myself.

1. In order to achieve New Zealand's emissions reductions targets, there have been calls for establishment of more native forests, altering ETS to put in place incentives for growing of native trees, better forest management, afforestation on lifestyle properties and farms, enhanced processing of timber for value added products potentially extending to novel forest products and biofuels, and use of thinning for bioenergy. What measures do you think should be prioritised to achieve these goals?

2. What are the more radical innovations being pursued in New Zealand? (Prompt: large departure from existing practices, innovations that potentially create entirely new jobs and industry, and potentially destroy jobs and transform the industry in the longer term?)
    - Could you describe what these innovations do? (i.e., are they technological, social innovations, are they primarily aimed at new products, processes, services?)
    - Who are the main advocates for these innovations?
    - What are the barriers they face?

- *In terms of government support for knowledge development - development of scientific, technological, production, market, and logistics knowledge (*Industry Transformation Plans, Fit for a Better World*) as well as programmes supporting the diffusion of best-practices and low carbon technologies (*Provincial Growth Fund, 1BT*)*
    a. What types of innovation would you say have been a focus point? (Prompt: are they technological, social innovations, are they aimed at new products, processes, services, are they targeted towards existing industry players versus new market players?)
    b. Why have these types of innovation been prioritised?
    c. Do you think there is a balance between supporting existing forestry players and building on existing knowledge and capabilities, versus investing in entirely alternative technologies and practices, often associated with emerging actors? (such as novel forest-based products)?

    d. Are these support mechanisms and the resulting knowledge outputs accessible to small growers and to Māori?

- Do you know of any initiatives that engage with consumers or community organisations in new ways, to create niche domestic demand for novel forest products, or local social/economic co-benefits? E.g., new ways of using existing knowledge (local knowledge and Matauranga Māori), along with new scientific knowledge, new ways of using forests and forest products (F2 & F3)
    a. Who are the main advocates for these types of initiatives?
    b. What are the barriers they face?

c. What resources are available to them?

- In terms of government support for social innovation, be it Māori or civic engagement in afforestation, local capacity building for improved forest management, supporting the creation of local and regional networks and supply chains,
    a. What types of social innovation would you say have been a focus point?
    b. Why do you think have these types of innovation been prioritised?
    c. Do you think there has been adequate support for social innovation relative to the support for technological innovation?

Shared vision/ directionality

1. To what extent is there clarity and consensus across the sector and within government about what the priority measures and policy priorities are?
2. Is there enough consensus brokering and co-ordination across the various parts of the sector?
3. Which agencies are most influential in influencing policy objectives and resource allocation?
4. Is there enough targeted funding for research, development, and demonstration projects to establish corridors of acceptable pathways forward? (What kind of research and demonstration projects are missing?)
5. Are there signposts and channels for growers and co-ops to engage and influence the direction of knowledge creation by these agencies?

Institutional failures

1. To what extent do [MPI, Scion, EECA] create a favourable environment for innovation?
2. Do you think the current regulatory and policy framework presents barriers for investment in new technologies or practices?
3. Are there cultural barriers to innovation, both within government and wider industry?

Capabilities

1. To what extent do producers and processors have the right competencies and resources to know the best course of action to take, to switch to new practices, technologies, and product markets?
2. Where do you think NZ forestry knowledge is lacking? E.g., genetics; planting, silviculture and harvesting techniques; and down the supply chain?

Interaction/network

1. Do you think there is enough interaction and knowledge exchange across the full range of actors to access different knowledge sources (scientific, technical, organizational, institutional, marketing, and managerial knowledge) that are out there and to learn interactively?

Demand articulation

1. In terms of trialling radical innovations (both on the supply side, for example, new products or processing technologies and the demand side) are there niche spaces to learn about domestic consumer preferences to trial products? (Prompt: alternative use of timber in buildings).

Policy co-ordination

1. In terms of policy initiatives seeking to get the sector to engage in innovative practices, products and services, do you think there is enough policy coordination between ministries and implementing agencies?
2. Is there coherence between public sector and industry in terms of the policies and priorities for action?
3. What about coordination between central and regional or local government? (*How do you see us moving towards a place where responsibilities across national, regional, and local authorities and implementing agencies are clear, and co-ordinate effectively to deliver projects on the ground)*

Infrastructure, reflexivity

4. Do you think the sector as a whole reflects on the reasons for success and failure, and on whether it is delivering on long-term social and economic transformation? (Prompt: is there enough monitoring and evaluation, and organisational culture that is geared at critical self-evaluation?)

ENDS

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