Managing risk and uncertainty through adaptive forest management

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Figure 1: Pruned pine plantation in Northland to reduce climate-related risks of disease and fire

Abstract

Despite advances in science and technology contributing to the progress of humankind, the presence of known, unknown and uncertain risk remains an important societal challenge. Modern-day decision-making is already complex. Furthering our understanding of the significant uncertainties related to climate change, market fluctuations and changing demand for products and services can only benefit society going forward.

This paper outlines areas of research currently being undertaken as part of the Resilient Forest Programme (funded by Scion's Strategic Science Investment Fund and the Forest Growers Levy Trust) to better understand the sources of risk and uncertainty influencing returns from plantation forests. The aim is to provide insight into approaches and tools, including adaptive management options that can be used to eliminate risk and mitigate risk outcomes.

The objective of the research is to provide the forest industry with a better understanding of the permutations of risk, and to simulate the use of adaptive management pathways to achieve sector resilience under ever-changing climatic-environmental and socio-economic uncertainty.

Introduction

Despite rapid advances in science and technology across many fields important to the progress of humankind the presence of known, unknown and especially uncertain risks remains an important societal challenge. This is particularly true in terms of uncertainties associated with the climate drivers of environmental change, market demand for products and services, and societal response to these and other changes. Moreover, these risks and their interactions can potentially create large-scale disruptions that can affect enterprises and their economic, social and environmental outcomes.

The COVID-19 pandemic is a prime example of how both local and global situations can change dramatically in very short timeframes (Snow et al., 2021), creating short and long-term disruptions at varying levels and scales across the forestry value chain. What has transpired since this initial disruption was not predicted at the time and we have gone on to see widespread impacts on labour markets, global supply chains and emerging inflationary pressures in the major economies of the world. Many countries, including New Zealand, have also recently declared 'climate emergencies' and embarked on ambitious journeys to transform economies toward zero-carbon emission targets (NZPC, 2018). Traditional methods of risk management, especially in the face of risk emulating across jurisdictional and environmental boundaries, are becoming increasingly ineffective (Adams et al., 2021).

In the forestry sector, there is uncertainty about how planted forests will evolve in response to the emerging socio-economic and climate-environmental risk (Keenan, 2015; Watt et al., 2019). The availability of scientific information about climate change, and the capacity for society to adapt and mitigate this risk, varies across New Zealand. Issues such as climate change, although with high political priority, are also affected by considerable uncertainty or deep uncertainty (Hörl et al., 2020). Deep uncertainty is when decision-makers cannot collectively decide on the model that relates actions to consequences (Stanton & Roelich, 2021), and how to value the desirability of the alternative outcomes (Walker et al., 2013).

How do forest managers and consultants cope with deep uncertainty about climate change in addition to numerous market and environmental uncertainties? At the same time, how do forest managers and consultants address the challenge to provide more transparency, participation and accountability as demanded by the public?

Fear of blame arising in the aftermath of mismanagement and underperformance can be inhibiting on decision-makers. On the other hand, different societal groups may hold partial, different or conflicting understandings of the risks concerned (Jansen et al., 2019), which contributes further uncertainty over appropriate courses of action. Relying only on hard science and ignoring public sentiment (i.e. their perceptions and values) may lead to local protests (Lidskog & Löfmarck, 2015). This can threaten a business or industries' licence to operate and lead to political impetus for regulatory change.

Plantation forestry as practised in New Zealand is a good example of how many primary industries throughout the world have focused production on selected species that consistently deliver uniform products to meet consumer demand. Although it has been recognised for many years that this approach has many risks associated with it (Sweet & Burdon, 1983), it has not stopped continued re-investment in large-scale radiata pine plantations in what could be seen as a strength in numbers strategy (Sweet & Burdon, 1983). So despite a focus on advancing the science and technology used in forest management, the fundamental risks to plantation forestry, particularly those posed by climate change (Watt et al., 2019), still remain against the backdrop of increasing uncertainty (not just over climate change but also about widespread social and economic disruption).

The New Zealand Productivity Commission (NZPC) made it clear in their 2018 report that forests are crucial in this country's fight against climate change (NZPC, 2018). The view that more forests are needed to support a transition towards the 2050 target of zero emissions was reiterated by the Climate Change Commission in 2021 (NZP, 2021). Since these aspirational statements were published, there has been much debate about where the investment required to plant these trees is going to come from. What types of forests should be planted and where? More importantly, how does the forest sector minimise risk and maximise opportunity in the face of climate change? Will disease risk go up? How will communities be impacted?

Polarising debates have emerged about natives versus exotics and the impacts of large-scale afforestation, as suggested by the Climate Change Commission (NZP, 2021; FOA, 2021). These debates and additional concerns around market concentration risk, labour shortages, industry safety records and the focus on responsible investment highlight how quickly and widely public and political pressure can build on the forestry sector. Clearly, sector resilience relies on anticipating and managing emerging risks and incorporating risk awareness as foundational thinking in decision-making.

The identification of risk requires careful consideration. Some risks are readily identified where the causality and effects can be understood. In contrast, the cause and effects of transboundary and socio-economic risk is harder to trace and understand and therefore harder to assess and manage.

Figure 2 illustrates how risk can be transmitted from often rare and unpredictable events, creating a ripple effect impacting countries, sectors, enterprises, consumer preferences, disrupting supply chains and invoking market volatility. Geopolitical dynamics, coupled with the tendency to enact self-interest policies, amplify these risks and the spread of potential outcomes.

For systematic risk, using historical data to develop future risk profiles is problematic as the future can be

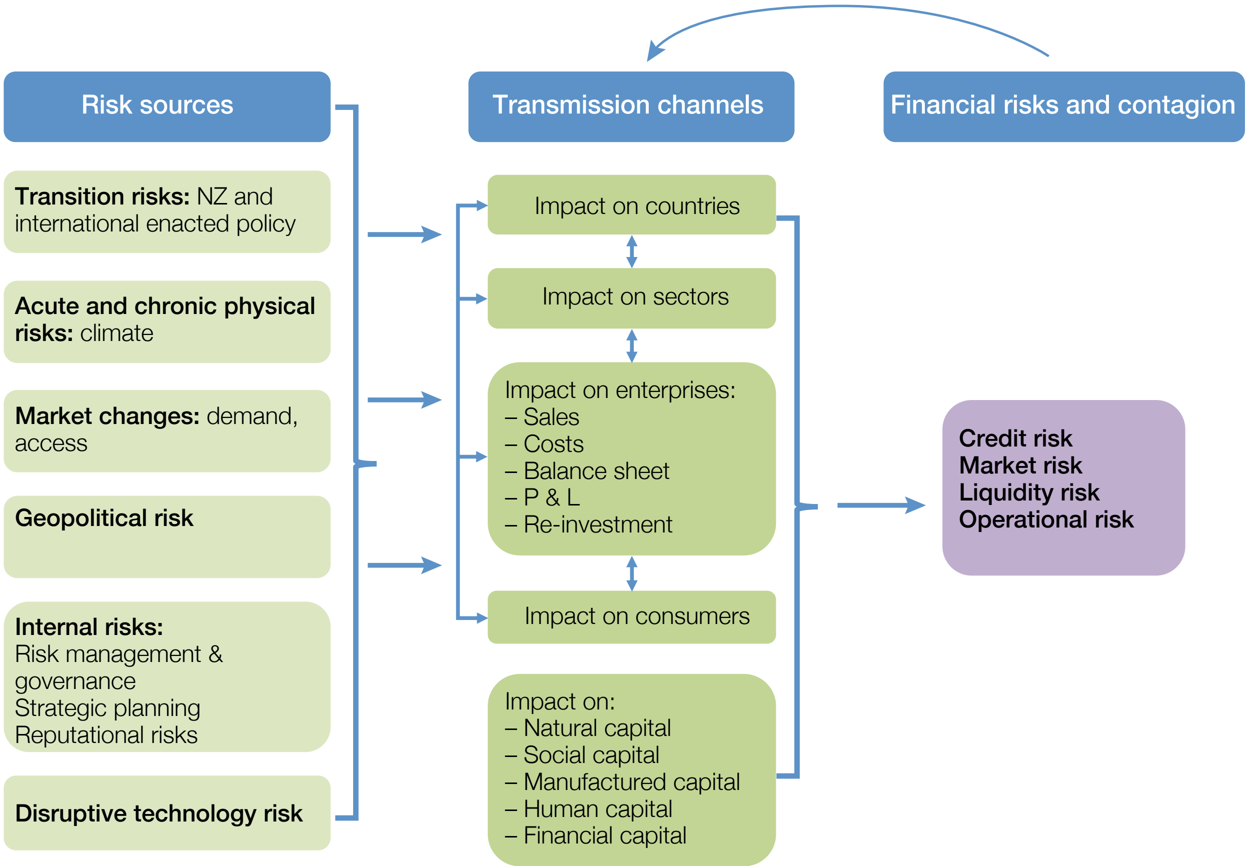

Figure 2: Sources and pathways of interacting systematic risk impacting enterprise resilience. Source: Based on Bolton et al., 2020; Bank for International Settlements, 2021

very different from the past, which reduces the ability to use historical data to predict event occurrence probabilities. For example, climate change and the transition to a zero-carbon emissions economy is new and without precedent, as is the impact of the Russian war in the Ukraine and the European/US response. Therefore, new methods and processes are required based on various potential future scenarios that enable effective enterprise risk management, especially in understanding sources of risk and uncertainty and adaptive responses.

Key sources of risk and uncertainty and ways to address them

So where will monocultures sit in the future? The same risks will still exist with forest owners vulnerable to numerous socio-economic, biological and climatic externalities which threaten their long-term resilience. What has changed since Sweet and Burdon's analysis? Climate change is upon us and there are now concerns around market concentration and what that means as global geopolitical tensions rise. There is also growing public sentiment against the major plantation species in New Zealand, with a widespread preference for planting natives to meet climate-related afforestation goals.

To respond, a resilient and sustainable forestry sector requires a decision-making framework that integrates productivity and risk across a range of dimensions (economic, social, environmental and temporal), representing the long business cycles of forestry.

The forestry sector currently earns more than $6 billion dollars in export revenues and is a major contributor to GDP. As of 2018, MPI reported that 40% of New Zealand's forestry products were exported to China. New Zealand land and forest asset values are substantial (close to $60 billion) so the protection of these assets and expected future growth is critical, particularly in an uncertain future, both biophysical and in relation to climate-motivated legislation and consumer preferences.

Three major uncertainties faced by the forestry sector are:

1. Market and enterprise risks

Market risk may arise from changes affecting supply and demand, market access restrictions, changes in interest rates, natural disasters and geopolitical events, including recessions or from policy implementation. Examples include COVID-19-related port constraints in China, tariffs (e.g. Australian wine exports), import bans (e.g. Australian log exports to China), China's wood self-sufficiency policy, phytosanitary barriers (e.g. Indian log export restrictions), potential changes in Russia's (post-sanctions) wood export policy, changes in wood demand

Table 1: Appraisal methodologies and tools for addressing complex interacting risks and associated uncertainty

Methodology	Short description
Productivity and impact models	Models that predict a range of different parameters, such as productivity (e.g. trees, horticulture, grassland); river flow, groundwater, pest and disease occurrence and establishment, fire, wind, extreme events
Soft Systems methodology	A framework for dealing with multi-stakeholder and 'ill-defined' problems based on the premise that 'human and organisational factors cannot be separated from problem-solving and decision-making'
Causal loop diagrams	Causal loop diagrams identify key variables in a system and indicate the causal relationships
System Dynamics (SD)	A methodology for simulating complex systems to observe and test their dynamic behaviour. SD can be viewed as quantifying casual loops
Input-output modelling	Input-output model estimates economic impacts and traces financial flows
Bayesian Belief Networks (BBNs)	BBN is a group decision-making tool based on probability theory. The main aim of this network is to understand the concept of causality relations (Maani, 2013)
Agent-Based Models (ABMs)	ABM models focus on 'agent' behaviours and how that affects land use (amongst other) decisions. ABMs are used for the extrapolation of trends, the evaluation of scenarios and the prediction of a future state, and are particularly useful for scenario development and policy decisions
Computable general equilibrium models	General equilibrium models help quantify the wider economic repercussions from changes in economic systems, or as a consequence of policy changes. Quantitatively represent and trace through the consequences of inter-linkages between economic sectors and thus the effects from one sector on all others (UNFCCC, 2009)
Value-at-Risk (VAR)	VAR is a financial metric to estimate the risk of investments. VAR measures how much investments might lose (with a given probability), given normal market conditions, in a set time period in response to some probabilistic driver
Catastrophe models	Catastrophe models simulate potential catastrophic events and quantify the amount of loss due to the events
Multi-criteria Analysis	A qualitative-based approach, where end-users rank options based on a range of different criteria
Portfolio Analysis (PA)	Fundamental to PA is that diversification is a significant risk management response. Therefore, PA attempts to identify the best portfolios according to their performance concerning economic efficiency and risk
Integrated Assessment Models (IAMs)	IAMs are made up of modules representing the climate, biosphere, energy and economy. The outputs of IAMs are simulations based on assumptions, historical data and scenario designs. IAMs are widely used in assessing various greenhouse gas mitigation policies and climate impacts
Real Options Analysis (ROA)	ROA is a robust decision-making tool that incorporates the uncertainty and the value of flexibility into decision-making when appraising policy options. ROA extends the principles of cost-benefit analysis to allow for learning based on an uncertain underlying parameter (Wreford et al., 2020)

Source: Dunningham et al., 2021

in China (e.g. house/apartment construction), shipping costs and availability, and the export of beetle-infested wood from Europe, impacting supply and demand elasticity and log prices.

Market risk impacts cascade to business entities in the form of increased market volatility, affecting profitability, return on investment, asset valuations, liquidity, access to capital and credit and, for public companies, market capitalisation.

For investment portfolio managers, forest sector investment exposure is considered a useful diversifier of traditional investment portfolios due to its low or negative return correlations with traditional stocks and bonds (Busby et al., 2020).

For the forest sector investor, within sector diversification of market risk remains an important risk mitigation strategy. The preferred diversification strategy is dependent on the attributes of the entities' existing forestry investment portfolio but may include:

- Investing in different countries, regions and locations, including the size and distribution of investment properties *(spatial)*
- Establishing different ages and maturity of blocks or forest stands, and harvest schedules *(temporal)*
- Silvicultural regime diversification, producing different log products from a range of tree species to supply a range of markets *(product diversification)*
- The supply of non-timber products such as carbon sequestration, fibre for bioenergy and vertical integration with wood processing *(market and end-product diversification)*
- Co-investment with investors across the supply chain and distribution market *(supply-chain protection)*
- Providing ESG services and outcomes for investors *(Environment, Social and Governance)*
- Reducing environmental risk by improving the quality of the land portfolio and operations *(environmental risk diversification)*.

While some forest entities already practice aspects of portfolio diversification, the full range of adding forestry and its ecosystem service values to an institutional portfolio remains under-utilised for improving risk efficiency and long-term financial performance. Despite portfolio diversification reducing investment risk, the potential downside of this approach is that it can be time-consuming, requires specialist expertise, diminishes a management focus and may increase transaction costs. For large portfolios, scenario modelling may assist to match portfolio risk with the investor's appetite for risk.

Enterprise Risk Management (ERM) is another approach developed in response to the siloed approach to risk management that has led to business failures (Wolf, 2008). ERM is a systematic and integrated approach to managing entity-wide risks. It focuses on the drivers of potential risk and how they may impact the strategic plan, organisational mission or a specific operation, hence integrating risk assessment and management across organisational 'silos' (Beasley, n.d.; Malik & Holt, 2013).

ERM embeds risk into business functions of strategy, governance, culture, information, communication and reporting. It incorporates sophisticated risk identification, risk analysis and evaluation, risk treatment, review and revision (OECD, 2021). For example, strategic planning is supported by forecasting a range of scenarios and evaluating their impacts on the achievement of the strategy. Scenarios employ a range of quantitative models, such as integrated assessment models, input-output models, system dynamics and agent-based models (see Table 1).

Underpinning ERM is a range of tools that inform decision-makers on impacts, enabling effective risk management across a range of risk dimensions. Within the primary sector, this can improve the awareness of impacts on: natural capital productivity, resilience and survival (e.g. on trees and animals); economic resilience at the business, regional, national and international level (e.g. GDP, employment); and on other capitals, such as infrastructure, human, cultural, social and intellectual (Ivory & Brooks, 2018).

Using models and tools that identify, measure and analyse risk and responses leads to more informed decision-making. This results in risk reduction and a correspondent increase in resilience. The range of tools adopted by practitioners of ERM to address complex interacting risks and uncertainty is set out in Table 1.

2. Public acceptance and social licence to operate

Public acceptance and social licence to operate (SLO) represents a risk and opportunity related to the preferences and values of society relative to an entity's commercial, environmental and social activities. SLO is a condition through which businesses (and sectors) have local and wider public support to undertake their activities. It can be threatened or revoked when the expectations and values of communities are undermined by inappropriate business and sector activities and outcomes. SLO is dependent on assumed norms and values. When such norms and values change (because of unexpected events) or are threatened (through exposure to new information) the social acceptability of previously accepted practices can come under scrutiny (Edwards & Lacey, 2014).

Despite the growing capacity to engage local communities in forestry development (Hall, 2019), the experience of Tolaga Bay and influence on public perceptions of forestry had struck deep into the rationales of forestry development (Raymond & Bawdin, 2019). The potential for shifts in perception and rationale, from afforestation for erosion control purposes to aversion for steep country plantation forestry, can upturn the SLO (Raymond, 2015).

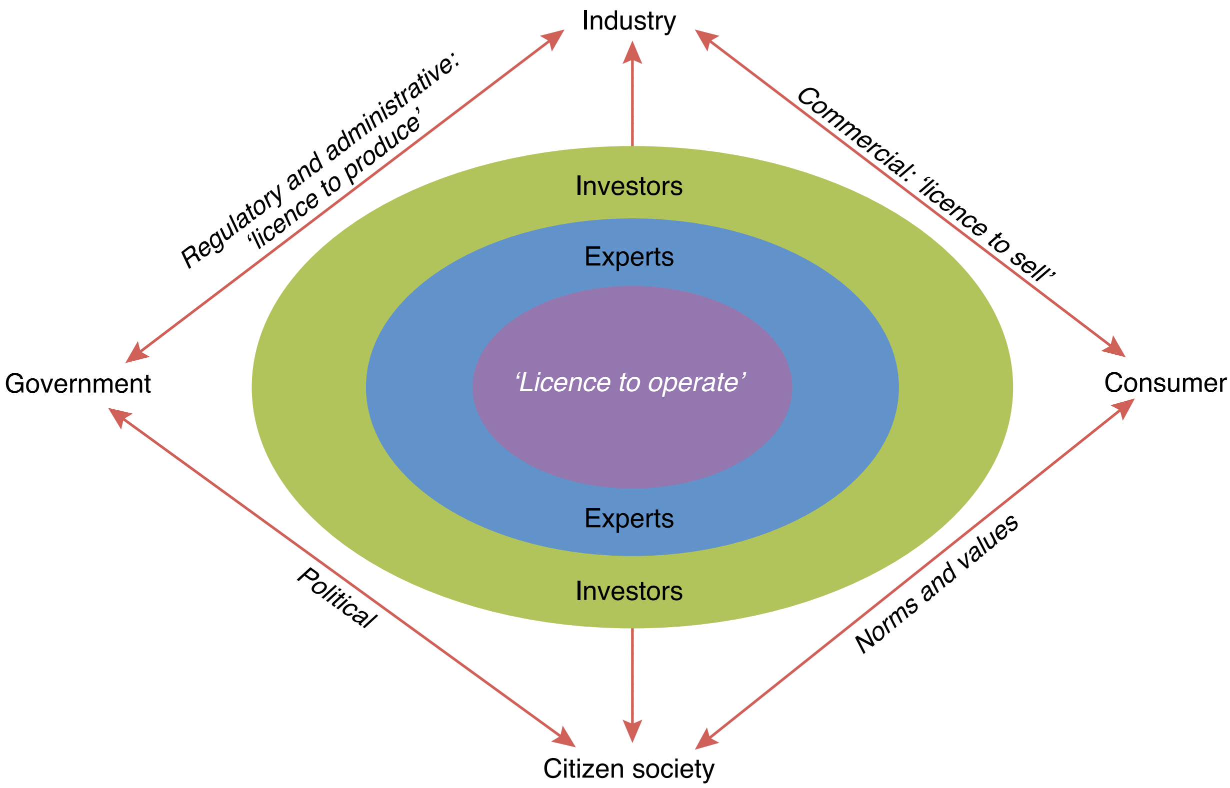

Figure 3: Adaptation of Casimir and Dutilh's (2003) structural interactions between participants involved in sustainable development

Dutilh (2005) noted that governments have a responsibility to inform communities and the public of hazards related to business operations and provide the technical mechanisms (legislation and regulation) to mitigate these risks. The interaction between government, industry, society and the consumer in shaping the norms and values and the SLO is set out in Figure 3, with key influences from experts and investors who circle between these entities.

Companies will undoubtedly benefit from a greater awareness of the diversity of concerns within local communities and the wider public, and how forestry operations intersect with those concerns. Understanding how different segments of society perceive the forestry sector and their expectations for the management of forestry risk is necessary to ensure expectations can be addressed and the SLO maintained.

For example, some people may measure forestry performance based on the affordability of local wood products or the quality of jobs provided. Others may be concerned about responsibilities for managing risks, such as wildfire, erosion and slips or pests and diseases. As values change with new knowledge, and the challenges of responding to dynamic and unfolding events from climate change to COVID-19 increase, a more considered approach to SLO for the forestry sector will be needed.

3. Adaptive forest management and decision-making

Predicting the future impacts of our changing climate is a major source of uncertainty, as the magnitude and speed of change are constantly being updated and reinterpreted (IPCC, 2014). Because of this, the beliefs, expectations and responses of decision-makers also change.

For forest sector decision-makers and managers this raises several questions: how well do individuals adapt and respond to new knowledge, how do they form and change their perceptions, or update their decision-making behaviour, and how do their decisions affect the resilience of the plantation forests?

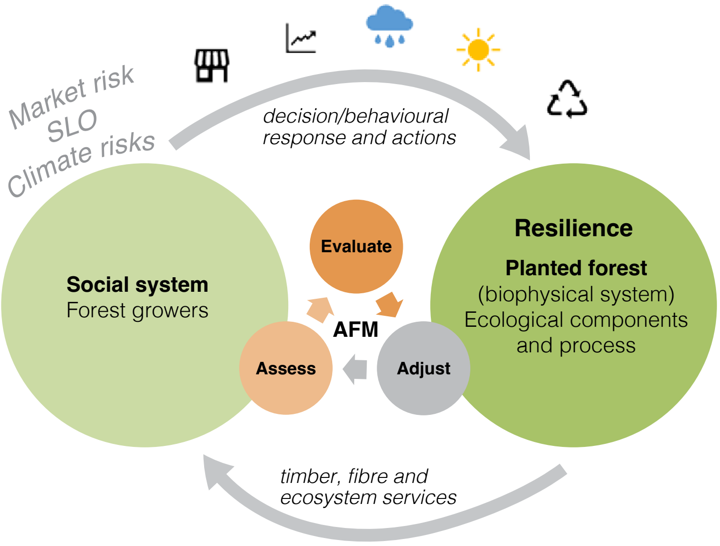

Figure 4: Adaptive forest management based on socio-biophysical drivers

To date, little is known about this subject, especially in the context of New Zealand's plantation forests (Villamor et al., 2022), as well as how behavioural responses to climate change will impact the local and global forestry sector. Answering these questions will require increased integration of social and biophysical systems and the application of adaptive forest management (AFM) (Figure 4).

AFM is not new, and it has been widely advocated in many temperate forest regions as a suitable approach for dealing with uncertainty and complexity about climate change. However, understanding the human dimension of AFM remains limited due to lack of transparency in decision-making, poor stakeholder communication and resistance to cultural change (FC, 2022). Embedding this approach within a socio-biophysical framework will support the risk decision-making pathways of forest owners and managers (Figure 4), as well as providing promising insights into opportunities.

Within this approach, climate risks are anticipated through scenarios, while reflecting insights from risk perceptions and the social amplification of risks (Kasperson et al., 2012). Forest managers assess the potential hazard and calculate the risk to their forests (using the tools mentioned in Table 1). Then, they evaluate this assessment and depending on the risk will respond (e.g. accept the risk, manage the risk and/or diversify the risk impact). The process requires regular re-evaluation of the risk and the response.

Socio-economic pressures, coupled with biophysical impacts, necessitate the implementation of adaptation strategies amongst forest managers to maintain and enhance healthy and resilient forests, as well as overcome threats and take advantage of opportunities. Formulating and implementing adaptation strategies requires both qualitative and quantitative methods. A systemic approach using mixed methods that characterise risk quantitatively and qualitatively has the potential to uncover events still unknown, and not well understood, and provides decision-makers with insights into novel unexpected outcomes.

The direction and extent of climate change remains deeply uncertain. Alternative approaches are needed to deal with this type of uncertainty (Wreford et al., 2021). Developing a more robust (socially accepted and publicly trusted) approach to communication and decision-making may assist in formulating AFM strategies. A recent review conducted by Hörl et al. (2020) suggested that robust communication and decision-making offers a promising approach to identify management strategies that can cope with uncertainties stemming from climate-change-induced deep uncertainty. Robust communication of issues and informed decision-making remains a challenge for the New Zealand forestry sector.

Conclusions

This paper has articulated the problem of deep uncertainty as one that requires innovative risk assessment tools and approaches. Risks confronting the forestry sector are multiple, overlapping and potentially cascading with interacting environment, economic and social consequences. Ultimately, an adaptive management approach is required that recognises the risk and uncertainty posed by evolving *climatic-environmental and socio-economic* factors.

To be effective, the adaptive management approach must recognise that a risk seldom emerges in isolation and that, more commonly, risk will emerge as a confluence of risks that interact and overlap. This requires a more dynamic and adaptive approach to risk assessment and the identification of plausible mitigation pathways. The adoption of innovative risk assessment tools and approaches will aid the robust communication of the issues and informed decision-making.

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