

**A culturally-focused life cycle sustainability assessment:  
Analysis of forestry value chain options with Māori land owners**

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in

Life Cycle Management

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## Abstract

The purpose of this research was to 1) explore the potential for the more distinctive representation of Māori culture in Life Cycle Sustainability Assessment (LCSA), and 2) understand the relationship between culturally-focused LCSA and the Māori decision-making process. These two interrelated aspects were investigated through participatory engagement with three members of the Ngāti Porou iwi (tribe), and through collaborative development of three forestry LCSA scenarios (radiata pine, rimu, and mānuka).

Aligning with principles of kaupapa Māori research, a participatory LCSA methodology approach was created which encapsulated five phases: 1) understand Ngāti Porou aspirations and concerns, 2) co-develop options for forestry scenarios, 3) co-develop and select LCSA indicators (including a cultural indicator), 4) LCSA indicator data collection and modelling, and 5) communication of results. The methodology utilised a mixed methods approach as Stage 1, 2, 3, and 5 are predominantly qualitative while Stage 4 is predominantly quantitative.

Culture was represented in the participatory LCSA in two ways. Firstly, a bespoke cultural indicator (Cultural Indicator Matrix) was co-developed to distinctly include culture within LCSA. The Cultural Indicator Matrix was based on and adapted an existing cultural decision-making framework (i.e. the Mauri Model) in order to ensure its capability to represent both Ngāti Porou aspirations and the forestry value chains explored in this research. The Cultural Indicator Matrix was completed by each participant and subjectively measured the impact they perceived each forestry process or product had upon a range of Ngāti Porou aspirations. Secondly, a participatory research approach was utilised that itself made the LCSA process more culturally-focused. The participatory approach relied on active engagement with the research participants throughout the LCSA study, primarily with the utilisation of semi-structured interviews. Such collaborative participatory engagement with the research participants allowed for their cultural input, preferences, and knowledge at each stage of the LCSA process.

This research has yielded several original and meaningful results:

1. The Cultural Indicator Matrix is a new culturally-focused mechanism which can be used to support the Māori decision-making process. The participants viewed

the Cultural Indicator Matrix as an effective method for gathering community impressions of how potential forestry life cycle processes could impact upon their cultural aspirations.

2. The participants felt the participatory LCSA aspect was crucially important; the open and consistent communication between themselves and the LCSA practitioner provided them with more control, access to information, understanding of the LCSA process, and enhanced their acceptance of the final results. They considered that the results of the culturally-focused LCSA gave them “validation” and “direction”, and justified their interests in pursuing forestry options for their land.
3. The participatory LCSA process led to the identification of a need to formally include a Cultural Compliance process with the LCSA. The Cultural Compliance process is comprised of six cultural components occurring throughout the forestry life cycle. Recognition of these components helps to ensure that appropriate and necessary cultural considerations are taken into account during relevant forestry life cycle processes. It is unlikely that this insight would have been reached if not for the participatory engagement focus of this LCSA research.
4. The development and analysis of three forestry scenarios using a range of sustainability indicators generated distinctive datasets on the life cycles of radiata pine, rimu, and mānuka. As the rimu and mānuka scenarios are particularly underrepresented in forestry-life cycle literature, this research has provided a contribution to knowledge regarding these two forestry options.

For the first time, indigenous culture has been represented alongside economic, social, and environmental impacts in LCSA. This comprehensive presentation of results facilitates the decision-making process by providing the decision maker(s) with information about the “big picture”, thus supporting educated and informed decisions. Furthermore, a culturally-focused LCSA approach helps to ensure that culture is not lost during the decision-making process, but rather is an active component. Finally, of critical importance, both the culturally-focused LCSA process and associated results will further enable the recognition cultural groups, including their values and aspirations. The explicit acknowledgement of culture in LCSA will engender more awareness and protection for culture, lessen the isolation and marginalisation of culture, and empower cultural groups to develop and pursue brave choices.

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## Abbreviations and acronyms

ABM	Agent Based Modelling
ALCA	Attributional Life Cycle Assessment
CIA	Cultural Impact Assessment
CHI	Cultural Health Index
CLCA	Consequential Life Cycle Assessment
DSTD	Dutch Sustainable Technology Development programme
EIA	Environmental Impact Assessment
E-LCA	Environmental-Life Cycle Assessment
ETS	Emissions Trading Scheme
FDB	Feller-Delimer-Buncher
GIS	Geographic Information Systems
GWP	Global Warming Potential
ISO	International Organisation for Standardisation
L1, L2, L3	Large branch logs
LCC	Life Cycle Costing
LCSA	Life Cycle Sustainability Assessment
NPS-FM	National Policy Statement for Freshwater Management
NPV	Net Present Value
PP	Pia Pohatu
S1, S2	Structural logs
SED	Small end diameter
SIA	Social Impact Assessment
S-LCA	Social-Life Cycle Assessment
TEK	Traditional environmental knowledge
TP	Tina Porou
TW	Tui Warmenhoven
UNESCO	United Nations Educational, Scientific and Cultural Organisation

## Māori/English Glossary

<i>Māori word</i>	<b>English word</b>
<i>Aotearoa</i>	New Zealand
<i>Awa</i>	River
<i>Hapū</i>	Sub-tribe(s)
<i>Heke</i>	Descend, fall
<i>Hui</i>	Meeting
<i>Iwi</i>	Tribe(s)
<i>Kai</i>	Food
<i>Kāinga</i>	Home
<i>Kaitiaki</i>	Guardian, minder, steward
<i>Kaitiakitanga</i>	Guardianship, stewardship (often used regarding the environment)
<i>Karakia</i>	Prayer, blessing
<i>Kaumātua</i>	Elders
<i>Kaupapa Māori</i>	Māori ideology - a philosophical doctrine, incorporating the knowledge, skills, attitudes and values of Māori society
<i>Ki uta ki ta</i>	Mountain-to-the-sea holistic philosophy
<i>Kōiwi</i>	Bones
<i>Kōrero</i>	Discussion, stories
<i>Mahinga kai</i>	Traditional resource harvesting
<i>Mana</i>	Spiritual power and authority, control
<i>Manaakitanga</i>	Kindness, generosity, support
<i>Mana motuhake</i>	Autonomy, self-government, self-determination, independence
<i>Mana whenua</i>	Power from the land, territorial rights
<i>Marae</i>	Courtyard where formal greetings and discussions occur
<i>Mātauranga</i>	Knowledge, wisdom, understanding
<i>Mate</i>	Dead, ailing, unwell, diseased
<i>Maunga</i>	Mountain
<i>Mauri</i>	Binding life force between all living and non-living things
<i>Mihi</i>	Greetings
<i>Noho</i>	Stay, remain

<i>Ora</i>	Alive, well, safe, healthy, healed, vitality
<i>Pākeke</i>	Adults
<i>Papatūānuku</i>	Earth mother and wife of Sky father (Rangi-nui), all life originates from them
<i>Patu</i>	Weapons
<i>Piki</i>	Climb, ascend
<i>Rākau whenua</i>	Trees of the land
<i>Rangi-nui</i>	Sky father and husband of Earth mother (Papatūānuku), all life originates from them
<i>Rongoā</i>	Māori traditional medicine, remedy, cure, treatment
<i>Taiao</i>	Natural world, environment, Earth
<i>Tangata whenua</i>	People of the land, indigenous people
<i>Taonga</i>	Treasure, anything prized or of value including culturally and socially
<i>Te reo Māori</i>	Māori language
<i>Tikanga</i>	Protocol, procedure, custom, practice
<i>Tū</i>	To be raised
<i>Urupā</i>	Burial grounds
<i>Waka</i>	Canoe, vehicle
<i>Wāhi tapu</i>	Sacred place or site
<i>Wairuatanga</i>	Spirituality
<i>Wai taonga</i>	Waters that are treasured
<i>Wānanga</i>	Traditional learning and knowledge, Māori tertiary institution
<i>Weka</i>	Endemic (woodhen) bird
<i>Whakaaro</i>	To think, plan, understanding, idea
<i>Whakakau</i>	Gradually appear, rise
<i>Whakamana taiata</i>	Importance of treating everybody with respect and ensure that they are empowered
<i>Whakapapa</i>	Genealogy, lineage, descent
<i>Whakataukī</i>	Māori proverb
<i>Whānau</i>	Family
<i>Whānaukatanga</i>	Māori kinship and togetherness

# Chapter 1

## 1. Introduction

The internationally recognised and standardised methodology of Environmental Life Cycle Assessment (LCA) focuses on the environmental “cradle to grave” impacts associated with a product or service. In order to encompass a greater range of interests, including economic and social aspects, the methodology has been broadened into an expanded, more holistic methodology named Life Cycle Sustainability Assessment (LCSA). LCSA is inclusive of LCA, Life Cycle Costing (LCC), and Social-LCA (S-LCA).

S-LCA, as both an individual methodology and when embedded within LCSA, measures and assesses impacts in various stakeholder categories: worker, consumer, local community, society, and value chain actors (UNEP & SETAC, 2009). However, despite the presence of a comprehensive collection of stakeholder categories and sub-categories, most S-LCA studies do not include the full range of social indicators available in S-LCA, and thus generally do not represent a significant breadth of social impacts (Ramirez, Petti, Haberland, & Ugaya, 2014). Cultural indicators, for example, although present in S-LCA sub-categories are fairly limited and are not compulsory; performing an S-LCA, therefore, does not guarantee the inclusion of cultural values. Indeed, in research and decision-making processes more generally, culture<sup>1</sup> is often under-recognised (Alonso & Medici, 2012).

Walker (2015) suggests that the term “sustainability” should be progressed to embrace a fourth pillar – one with more qualitative, value-based information that will aid the transition from a system focussed on knowledge (what we *can do*) to a system focussed on wisdom (what we *should do*); such a transition may offer a “broader perspective of reality” (p. 182). Indeed, many planning and policy makers recognise culture as a significant and meaningful component of “sustainability” (e.g. Axelsson et al., 2013;

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<sup>1</sup> For the purposes of this research and the results discussed in this paper, the following definition of ‘culture’ was used as defined by Anderson and Gale (1992, p. 3): *A dynamic mix of symbols, beliefs, languages and practices that people create, not a fixed thing or entity governing humans.* The definition of culture is discussed more fully in Chapter 2, Section 2.1.1.

Hawkes, 2001). Furthermore, the UNESCO Sector for Culture (2001) recommends the integration of culture and a cultural approach (holistic, participatory, dynamic) throughout the project cycle of a sustainable development strategy; repositioning culture at the core of development strategies will help to ensure constructive, balanced interactions between cultures and development projects. As such, there may be occasions where it is desirable for culture to be more distinctly evident in LCSA studies as doing so will allow for more adequate assessment of the effects on – and of – culture when reviewing the impacts associated with a product or service. Such occasions may include (but are not limited to) if an indigenous cultural group is a key stakeholder in the LCSA study, or if the country within which the LCSA study is carried out has an active presence of unique cultural groups. The potential benefits of representing culture within LCSA include a more comprehensive decision-support tool which appropriately accounts for cultural values, greater resonance of LCSA results with stakeholders, and an assessment technique which may help to protect the rich diversity of cultures found in communities across the world. Thus, there is an opportunity for culture to be integrated into the emerging LCSA technique.

Māori are the indigenous people of Aotearoa (New Zealand). Although there are current and ongoing threats to Māori culture, Māori remain resilient due in part to their entrepreneurial and innovative capabilities, and cultural values (Davies, Lattimore, & Ikin, 2005). Cultural values are particularly influential regarding Māori aspirations as well as are the foundational reasoning behind decision making (Montes de Oca Munguia, Harmsworth, Young, & Dymond, 2009).

The sustainable development and management of Māori land and resources is a significant priority for Māori. Forestry and its socio-economic benefits in particular have often been of high interest to Māori thus demonstrating forestry's potential to meet key objectives and aspirations of Māori landowners (Fairweather et al., 2001). New Zealand forestry is largely comprised of exotic planted forests (predominantly containing radiata pine (*Pinus radiata* D. Don)) and protected nature reserves of indigenous tree species. However, various drivers are currently increasing the focus on sustainable forest management and alternative options to radiata pine, with Māori forest owners showing a particular interest in indigenous species.

Therefore, there is a lack of culturally-focused sustainability assessment tools, a lack of distinct cultural representation in the LCSA methodology, a lack of progressive and participatory sustainable forestry measures in New Zealand, a lack of utilising a full life cycle perspective in forestry, and a lack of sustainable forestry options for Māori landowners. The purpose of this PhD research was to confront these shortcomings and explore the potential to represent culture and cultural values alongside the existing environmental, social, and economic impacts assessed in LCSA.

This study therefore addressed the following research questions:

- 1. How can Māori culture be represented in LCSA studies involving forestry value chain options?**
- 2. What are the relative benefits and disadvantages of using LCSA in Māori forestry value chain decision-making situations?**

Collaborative research was undertaken with three members of a Māori tribe (Ngāti Porou) who are involved with decision making regarding Māori land. The LCSA study itself was undertaken with the active involvement of these three Ngāti Porou members to identify relevant impacts associated with potential forestry options for Ngāti Porou land. The research actively utilised participatory engagement techniques such as semi-structured interviews, a questionnaire, and frequent consultation with the case study participants.

Māori are one of the largest forest land owners in New Zealand (Te Puni Kōkiri, 2015) yet their recognition and understanding of the variety of forestry options remain fairly limited, and the availability of such information in an easily comprehensible format is largely missing (Te Puni Kōkiri, 2011). To address this knowledge gap, potential forestry life cycle scenarios were co-developed, and risks and trade-offs were evaluated through the consideration of environmental, social, economic, and cultural indicators.

Representing Māori culture and cultural values within this LCSA research involved 1) co-creating a bespoke cultural indicator to integrate into the collection of existing LCSA indicators, and 2) adapting the LCSA process itself to be more accommodating to active participation and guidance from culturally-focused end users. The integration of

indigenous cultural values within the LCSA tool and process is the first of its kind. This research also contributed to the limited number of studies regarding the use of LCSA both as a decision-making tool and process, and as a technique to determine sustainable forestry practices and products.

## 1.1. Thesis structure and content

This dissertation is comprised of four main sections: 1) foundational introductory information, 2) the participatory LCSA journey, 3) culturally-focused LCSA results and related discussion, and 4) major findings and conclusions (see Figure 1).

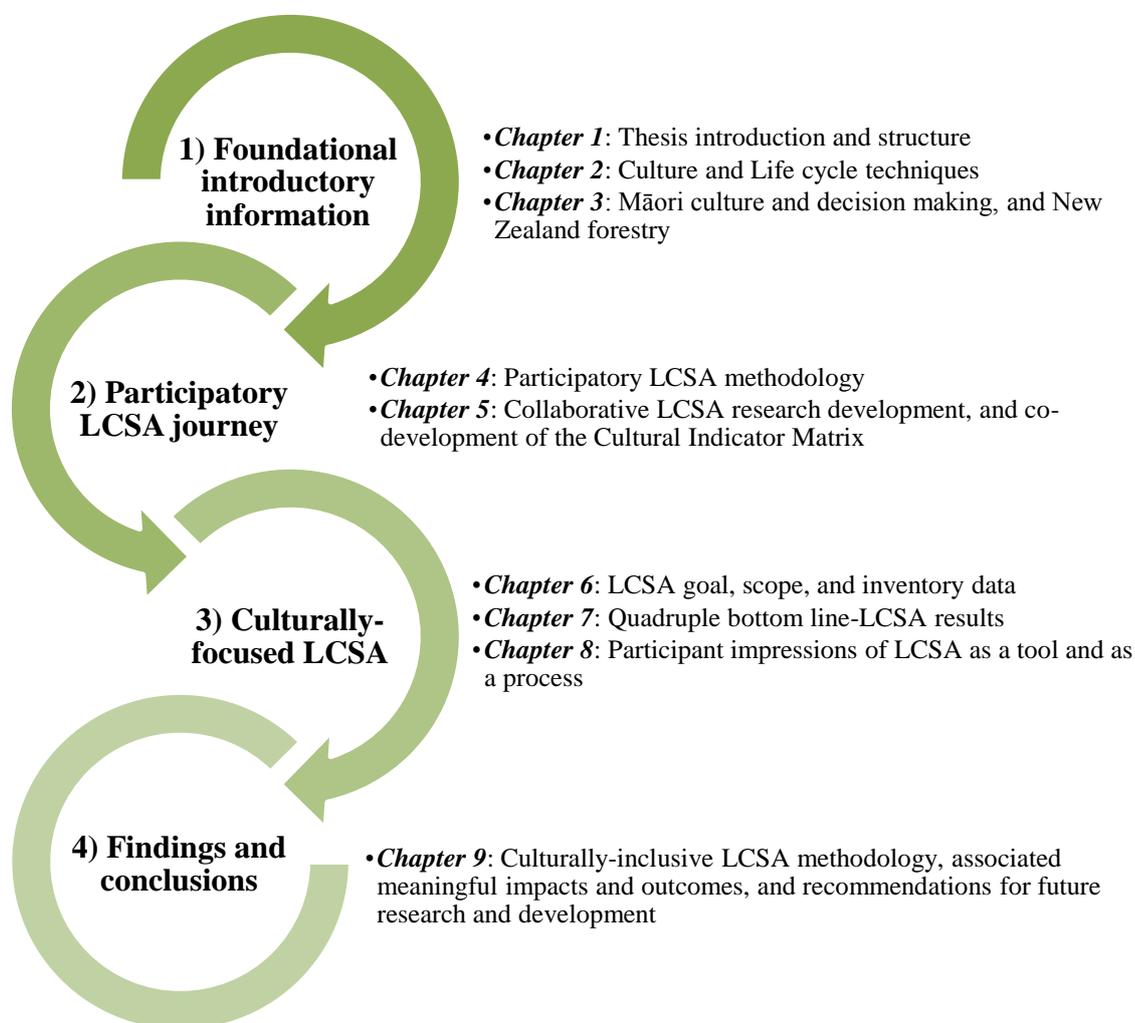


Figure 1. Thesis structure and content.

## Section 1: Foundational introductory information

The introductory chapters present background information regarding culture, the life cycle technique, forestry, and Māori history, culture, and decision making. Chapter 1 presents an introduction to the thesis, and outlines its structure and content. Chapter 2 discusses the representation of culture in decision support processes and tools, critiques the presence of culture in the life cycle techniques (LCA, S-LCA, and LCSA), and examines the potential for representing culture more distinctly in LCSA. Chapter 3 provides a brief introduction to Māori history and culture, and highlights how Māori decision making is often strongly influenced by cultural traditions and aspirations. The Māori decision-making process aims to find solutions that address a range of needs – not just economic ones. Thus Māori decision making processes align with the endeavour of creating a culturally-focused LCSA tool and process.

Chapter 3 also presents background information on forestry trends in New Zealand, the potential for increased recognition of sustainable forestry practices in New Zealand, and how forestry represents a major asset base of the current Māori economy.

## **Section 2: Participatory LCSA journey**

The participatory LCSA journey is comprised of two chapters. These chapters discuss the development and initial outcomes associated with the participatory LCSA methodology including the process of aligning the use of LCSA within the Ngāti Porou decision-making context, engaging with a culturally distinct community (Chapter 4), understanding cultural aspirations, co-development of the LCSA goal, scope, and research objectives, and co-development of a cultural indicator (i.e. the Cultural Indicator Matrix) (Chapter 5).

## **Section 3: Culturally-focused LCSA**

The culturally-focused LCSA section is comprised of three chapters. These chapters outline the goal, scope and inventory data used in the LCSA (Chapter 6), present the culturally-focused LCSA results (Chapter 7), review the participants' impressions of the culturally-focused LCSA as both a tool and a process, and assess its usefulness in Māori (Ngāti Porou) decision making (Chapter 8).

## **Section 4: Findings and conclusions**

Finally, findings and conclusions are presented and discussed in Chapter 9. This chapter details the culturally-focused LCSA methodology that resulted from the research, and highlights the significance of such a methodology in the field of life cycle research and in culturally-based decision making processes. It includes further recommendations for future research.

## **Chapter 2**

### **2. Literature review of culture in the context of LCSA**

#### **2.1. Culture**

There is increasing recognition of the need to protect and nurture culture and cultural values, especially throughout the decision-making process. Yet, to what extent are culture and cultural values recognised, and how do decision support tools represent and protect culture and cultural values?

This chapter considers the role of culturally-focused research, and how culture and cultural values may be recognised. This is important in order to better understand current limitations and challenges as well as benefits and successes of research inclusive of culture. In addition, this chapter explores the importance of culture in decision making, and how culture is currently represented in the LCSA methodology. Finally, recommendations are made regarding the potential for recognising culture more distinctly in LCSA.

##### **2.1.1. Definition of culture**

There are a variety of interpretations and perspectives on the meaning of “culture” (see Table 1). This variety demonstrates the globally important role of culture and its ability to contribute to multiple areas of research.

Culture is inherently complex due to its distinctly dynamic nature as demonstrated by a broad range of definitions and uses. Culture is recognised in a variety of fields from business to climate change, landscape management to sustainable development, and indigenous knowledge to ecosystem valuation. The purpose of cultural recognition in these fields varies as well – cultural recognition may aid the decision making process, enhance the potential to identify and protect culture (e.g. language, knowledge, locations, and artefacts), and assist with focused sustainable development.

Generally, culture is defined as an emergent grouping of beliefs, knowledge, practices, values, ideas, language, and worldviews within a social group; each of these elements affects the social group's on-going attitudes and behaviour. However, culture is not bound to a given geographical location or fixed in time. Indeed, culture is often thought of as an inter-generational concept. It is therefore perhaps not unexpected that there are challenges when attempting to represent culture within environmental management and planning (Satterfield, Gregory, Klain, Roberts, & Chan, 2013).

For the purposes of the discussion in this dissertation, the general definition of “culture” is used as defined by Anderson and Gale (1992):

*A dynamic mix of symbols, beliefs, languages and practices that people create, not a fixed thing or entity governing humans. (p. 3)*

Table 1. Definitions for and type of research using the term “culture”.

Source	Terminology	Definition	Type of research
Anderson and Gale (1992, p. 3)	Culture	“A dynamic mix of symbols, beliefs, languages and practices that people create, not a fixed thing or entity governing humans” (cited in Head, Trigger, & Mulcock, 2005)	Cultural geography
Llobera (2003, pp. 7-9)	Culture	“The totality of a people’s way of life, the whole complex of distinctive spiritual, material, intellectual and emotional features through which a society lives and reproduces itself.” (cited in Kuruppu, 2009)	Climate change adaptation
Hofstede (1980, p. 21)	Culture	“The collective programming of the mind which distinguishes the members of one human group from another.”; “includes systems of values, and values are among the building blocks of culture”	Work-related values
Lindsay (2005, p. 1)	Culture	“Culture influences attitudes and behaviour, varies within and across nations and within and across ethnicities, and is strongly embedded in Indigenous communities.”	Indigenous entrepreneurial attitudes
Cochrane (2006, p. 320)	Cultural capital	“Cultural capital, being the aptitude or inclination of a group or society to behave in a certain way, underlies human and social capital and describes the potential of a group or society”; “It includes elements such as socio-political institutions, values and needs, social preferences, environmental ethics and traditional ecological knowledge in a society”	Sustainable development
Millennium Ecosystem Assessment (2005, p. 40)	Cultural ecosystem services	“Non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences” (cited in Schaich, Bieling, & Plieninger, 2010).	Cultural landscape research
King (2000, p. 7)	Cultural resource	“Any resource (i.e., thing that is useful for something) that is of a cultural character. Examples are social institutions, historic places, artefacts, and documents.”	Environmental Impact Assessment
Chan, Satterfield, and Goldstein (2012, p. 9)	Cultural services	“Ecosystems’ contributions to the non-material benefits (e.g., capabilities and experiences) that arise from human–ecosystem relationships”	Ecosystem services
Billgren and Holmén (2008, p. 554)	Cultural theory	“Concerned with people’s values, ideas and worldviews” (cited in Thompson, Ellis, & Wildavsky, 1990); people are strongly influenced by their social relations	Natural resource management

Burger (2011, p. 137)	Eco-cultural attributes	“Cultural resources which derive from, and indeed require, intact and unspoiled natural ecosystems or settings for their cultural value”	Valuation of ecological resources
Groenfeldt (2003, pp. 919-920)	Indigenous cultural values	Indigenous: “minority cultural groups...that have a historic relationship to a particular territory and a marginalized relationship to the nation-state”; Cultural: “the system of values, beliefs, and ideas that social groups make use of in experiencing the world in mutually meaningful ways”; Values: “the guiding principles of a social group”	Cultural development
Howden (2001, pp. 60-62)	Indigenous knowledge	“A living system of information management which has its roots in ancient traditions. It relates to culture and artistic expression and to physical survival and environmental management. It controls individual behaviour, as it does community conduct.”; “Indigenous knowledge systems are better understood as practical, personal and contextual units which cannot be detached from an individual, their community, or the environment (both physical and spiritual). (cited in Davis, 2006)	Native land entitlements
UNESCO (2003, p. 2)	Intangible cultural heritage	“the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity.”	Cultural diversity and sustainable development
Stephenson and Moller (2009, p. 139)	Traditional Environmental Knowledge	“A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and the environment” (cited in Berkes, 2008)	Cross-cultural environmental research and management
Harris and Harper (1997, p. 793)	Tribal values	“Individual and collective well-being is derived from membership in a healthy community with access to ancestral lands and heritage resources, and from the ability to satisfy the personal responsibility to participate in traditional community activities and to help maintain the spiritual quality of a site, resource, or area”	Subsistence exposure scenarios for tribal communities

### **2.1.2. Culture and values**

As referenced earlier in the definition by Hofstede (1980), “values are the building blocks of culture”, and indeed there are numerous references which highlight the relationship between values and culture (p. 25). In their work on the effect of cultural values on economic development, Granato, Inglehart, and Leblang (1996) noted that promoting the value of economic achievement in a given society affected that society’s motivation which in turn affected the rate of economic growth. Furthermore, Inglehart and Baker (2000) argue that understanding a society’s beliefs, values, and worldviews may enable one to predict the direction and rate of cultural change. In social psychological theory, both values and cultural norms play a large role in how people respond to and perceive fairness as well as how they manage uncertainty (van den Bos, Poortvliet, Maas, Miedema, & van den Ham, 2005). Essentially, changes in values may cause a cultural shift in social attitudes and behaviours in such areas as the equality of women, morality, desired traits for children to display, and tolerance of foreigners (Schwartz, 2006). Thus values are inextricably linked with culture.

The notion of “value” is arguably just as ambiguous as “culture”. It is used to refer to something of significance, worth or importance, and the value attached to this “something” can vary between geographical location, scales (individual, community, regional, national), religions, political parties, and cultures. Frequently, value is ascribed to tangible, discrete objects. For instance, indigenous values are sometimes associated with the presence of a traditional resource, sacred building or meaningful site (e.g. burial ground) which, when assessed or accounted for, is ultimately similar to the process of listing or categorising archaeological sites (English, 2002; Jackson, 2006; King, 2000). Yet values can also be intangible, attached to something that cannot be directly measured such as a landscape or being able to perform a traditional activity.

Schwartz (1999) defines values as, “conceptions of the desirable that guide the way social actors (e.g. organisational leaders, policy-makers, individual persons) select actions, evaluate people and events, and explain their actions and evaluations”; they are the “vocabulary of socially approved goals” which can be used to motivate, justify, communicate, inspire, or condemn actions (pp. 24-25). In short, values are the “guiding

principles in life”. Cultural values, Schwartz continues, can then be considered to represent specific societal norms, both implicitly and explicitly, and therefore focusing on such values directly is an efficient way of describing and representing cultures (Schwartz, 2006).

Overall, then, there is some consensus that assessing cultures by using a value-based framework<sup>2</sup> is effective in deciphering and interpreting cultures (Javidan, House, Dorfman, Hanges, & De Luque, 2006; Leung et al., 2005). But the “tightness of culture on the relationship of values and behaviour has yet to be explored systemically” (Roccas & Sagiv, 2010, p. 35). It can be concluded that significant work still remains for the fair representation and assessment of intangible, holistic, and aesthetic elements such as cultural values (Burger et al., 2008; Daily et al., 2009; Venn & Quiggin, 2007).

### **2.1.3. Recognition of culture**

Culture diversity and its protection is increasingly recognised as evidenced by the number of national and international policy documents and agreements that are specifically concerned with culture such as:

- UNESCO (1972) (United Nations Educational, Scientific and Cultural Organisation) Resolution and Recommendation on the Studies and Development of Culture,
- UNESCO (2001) Universal Declaration on Cultural Diversity,
- UNESCO (2003) Convention for the Safeguarding of the Intangible Cultural Heritage,
- United Nations (2007) Declaration on the Rights of Indigenous Peoples,
- UNESCO (2013) Declaration on Placing Culture at the Heart of Sustainable Development Policies, and

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<sup>2</sup> A value-based framework is an approach which assumes a distinct relationship between values and culture, and subsequently between culture and behaviour (Javidan et al. 2006). Scrimgeour and Iremonger (2004) argue that creating a value-based framework (including identifying culture-specific values, criteria, objectives, and attributes) is useful for developing a values hierarchy which can then be used when deciding between alternatives. Assessing culture using a value-based framework has been applied in such fields as international business development (Leung, Bhagat, Buchan, Erez, & Gibson, 2005), organisational ethics (Sanchez, Gomez, & Wated, 2008), participative decision making (Sagie & Aycan, 2003), and governance and leadership (Bao, Wang, Larsen, & Morgan, 2013)

- UNESCO (2014) Declaration on Culture, Creativity, and Sustainable Development.

Environmental beliefs, ethics, and values often differ between cultures (Cochrane, 2006). The process of developing solutions to environmental issues, therefore, should not be universal but instead should take into account the unique cultural beliefs of a given area, ranging from local to national levels depending on the relevance of the issue. Indeed, one could argue that culture is integrally tied into the notion of environmental sustainability (UNESCO, 2009) given that human beings (and the societies within which they exist) have a relationship with the natural environment that transcends biophysical definitions. The World Commission on Culture and Development (1995) states:

*It has become clear also that any approach that deals only with biophysical exchanges between societies and the environment is incomplete. The notion of sustainability raises the question of how nature itself is conceived and consequently of the cultural values that condition a society's relationship to nature. Important variants in attitudes to ecological sustainability demonstrate the need for a culturally diversified approach to issues of culture, environment and development, as well as for an analysis of mechanisms that perpetuate views or actions beneficial or harmful to the environment. (p.38)*

Many studies have highlighted the importance of recognising cultural values, aspirations, or other considerations (albeit each with a varied definition of “culture”) within activities such as:

- planning and management of landscapes (e.g. Stephenson, 2008; Tengberg et al., 2012),
- community development (e.g. Lane, 2006),
- conservation initiatives (e.g. Daily et al., 2009),
- ecosystem management (e.g. Burger et al., 2008),
- local and national policy making (e.g. Berke, Ericksen, Crawford, & Dixon, 2002),
- entrepreneurial attitude models (e.g. Lindsay, 2005), and

- resource management (e.g. Ross & Pickering, 2002).

Furthermore, culture is considered by some (e.g. Hawkes, 2001; Nurse, 2006; Saastamoinen, 2005; UNESCO, 2001) to be the fourth pillar of sustainability alongside economic, social, and environmental considerations in what is often described as the “quadruple bottom line”. There is a growing recognition of the quadruple bottom line within research topics such as sustainable societies (e.g. Ellyard, 2008), community and environmental health (e.g. Luckman, 2006), farming systems (e.g. Cooper, 2011), and indigenous economic development (e.g. Scrimgeour & Iremonger, 2004).

Within sustainable development, Dessein, Soini, Fairclough, and Horlings (2015) argue that culture plays three critically important roles: 1) culture *in* sustainable development (as the fourth pillar of sustainability in a supporting and self-promoting role), 2) culture *for* sustainable development (as a more influential component that mediates and balances the three existing pillars of sustainability), and 3) culture *as* sustainable development (as an essential foundation for coordinating and guiding the process of attaining sustainable development).

#### **2.1.4. Assessment of culture in land use and resource management activities**

There is debate concerning how best to represent culture and the impacts on culture arising from different land use and resource management activities (Harris & Harper, 1997). Some have argued that it is important to qualitatively assess and illustrate the extent of these impacts (e.g. MacLean, 1996). Others believe it is necessary to quantify the impacts so as to make them more readily comparable with other quantitative impact categories (e.g. pollution, employment) (National Research Council, 1994).

Recent work to assess culture within, for example, the valuation of ecosystem services (e.g. Martín-López, Gómez-Baggethun, Lomas, & Montes, 2009) has largely been focused on translating culture into economic figures since doing so may allow the quantification of the relative value of different ecosystem functions. Such quantification of ecosystem functions may allow for the consideration and inclusion of associated non-

market benefits (e.g. biodiversity or flood prevention) during resource management and development of related policy. Alternatively, Chan, Satterfield, et al. (2012) argue that to value cultures entirely in economic terms “cannot reflect the full extent of their differences from other ecosystem services”, and risks the unintended interpretation that different cultures can be bought or sold (p. 9). Although the authors do not have a solution to overcome this issue, they do stress that reducing the value of culture to representation in economic terms is a simplification that hides culture’s complex interconnectedness with other environmental, social, and economic services.

There are a few examples of tools specifically designed to assess only cultural values but this may result in the isolation of culture, forcing it to be considered separately during decision-making. Examples include the use of an agent-based model to represent Māori cultural values (Montes de Oca Munguia et al., 2009), development of a cultural entrepreneurial attitude model (Lindsay, 2005), mapping and quantifying cultural services (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013), and the creation of a landscape-based cultural values model (Stephenson, 2008).

However, Alonso and Medici (2012) emphasise that the lack of assessment tools that specifically include cultural aspects alongside environmental, economic and social aspects directly contributes to the marginalisation of culture, particularly regarding development policies. The authors argue that tools or methodologies are needed to adequately assess the effects on - and of - culture.

### **2.1.5. Examples of cultural assessment for New Zealand land use and resource management**

Social Impact Assessment (SIA) is often regarded as complementary to Environmental Impact Assessment. An SIA provides a more “human” context to impact assessment and involves “analysing, monitoring and managing the social consequences of development” (Vanclay, 2003, p. 6). However, although SIAs tend to evaluate and engage a range of socio-cultural factors, indigenous cultural values in particular are often stifled by Western-dominated initiatives and policies (Groenfeldt, 2003). As a result there are various decision makers who wish to see cultural values and implications articulated

separately in order to facilitate their distinct consideration. Therefore, Cultural Impact Assessment (CIA) has begun to emerge as a potential solution which can be used to provide culture-specific impact information.

The recognition of Māori cultural interests (especially mātauranga Māori and Māori participation in science (MSI, 2013)) has been increasing over the last few decades, and, in particular, since the enactment of the *Resource Management Act 1991* (New Zealand Government, 1991). The *Resource Management Act 1991* established a framework for recognising and integrating Māori traditions (e.g. kaitiakitanga (environmental guardianship or stewardship)), opinions, and concerns into the decision-making process regarding resource management.

In response to the challenge of understanding and conveying Māori values in resource management, the Cultural Health Index (CHI) was developed by Tipa and Teirney (2003) and based on earlier stream indicator work by Tipa (1999). As a basis for developing cultural indicators, the CHI used five fundamental cultural values of the Ngāi Tahu tribe (values that are also represented in many other Māori tribes): “[1] mauri (spiritual life force), [2] mahinga kai (traditional resource harvesting), [3] kaitiakitanga (guardianship obligation), [4] ki uta ki tai (mountains-to-the-sea holistic philosophy), and [5] wai taonga (waters that are treasured)” (Townsend, Tipa, Teirney, & Niyogi, 2004, p. 184). Then relevant indicators were created to assist Māori in the process of monitoring stream and river health including: river shape; fish are safe to eat; uses of the river; presence of traditional food species; sound of water flow, and riparian vegetation. The indicators were recorded on a scoring scale of 1 (poor) to 5 (excellent). The authors concluded that by using the CHI Māori would become self-sufficient in being able to identify issues, determine incremental changes in their environment, and also recognise restorative actions which may be needed to counteract such changes. It was recognised that the CHI required further validation (Tipa & Teirney, 2003), and subsequent validation successfully demonstrated its potential for use by any iwi in any river environment (Tipa & Teirney, 2006).

Young, Harmsworth, Walker, and James (2008) provide an example of further validation of the CHI. The authors adapted the CHI and applied it throughout the Motueka and Riwaka catchments in order to explore cross-cultural perspectives within integrated

catchment management. The study was designed to utilise both the CHI and scientific monitoring techniques in order to compare results from the approaches, and, in doing so, identify if any differences in the respective results were apparent. Certain fundamental differences exist between cultural indicators (being largely qualitative, subjective, and based on observations) and scientific indicators (being largely quantitative, objective, and based on tested techniques). However, the study demonstrated that despite these differences the results were generally well correlated (i.e. both monitoring techniques identified similar environmental issues) and the overall monitoring approaches involved were complementary; in other words, where the cultural approach was weak the scientific approach was strong, and vice versa. As expected, there were some issues in attaining unbiased scores for the cultural indicators as the results could, for instance, be influenced by the recorder's personal subjective memory of the river site in the past rather than relying only on current objective and impartial observations. Yet the overall result was a seemingly positive one: utilising both scientific and cultural monitoring techniques (and related indicators) side by side allowed for (i) more representation and articulation of different perspectives and values, and (ii) greater cross-cultural interaction and communication creating the enhanced potential to prevent or resolve resource conflicts (particularly on indigenous lands).

Tipa and Nelson (2008) also developed a Cultural Opportunity Mapping and Assessment framework which was divided into six steps: “initiating the project, defining and validating the association of Māori with the resource (in their case freshwater), cultural opportunity mapping, critical review to focus the investigation of key issues, cultural opportunity assessment, and analysis and participation in planning and decision-making” (p.319). Many of the steps were achieved through using methods such as meetings with tribal members, focus groups, and semi-structured interviews. The use of the framework to assist the management of resources showed great promise in clearly identifying priorities (e.g. restoration) that could help realise Māori aspirations for their land. A limitation, however, was the inconsistent availability of cultural knowledge.

Enhancing the visibility of Māori cultural values within assessment techniques is progressing in other aspects of natural resource management, such as landscape management. An early example is that of Morgan (2004) who produced a Mauri Model (“mauri” meaning the binding and inter-related life force between all living and non-

living things) which is designed to measure impacts on the mauri of (a) the family (economic), (b) community (social), (c) hapū/sub-tribe (cultural), and (d) ecosystem (environment). The Mauri Model identifies (using independent weighting by Māori users) whether a resource management option is affecting each of the four previously mentioned aspects positively, negatively, or neither. The overall score is an aggregated collection of qualitative impressions of potential impacts associated with a proposed resource management option, and does not utilise scientific measurement techniques. Therefore, when considering management options, the Mauri Model measures the impacts (destroyed, diminishing, neutral, enhancing, or restored) on Māori cultural values. However, this methodology has yet to be robustly tested.

Stephenson (2008) developed a Cultural Values Model so as to provide a framework for uniting the often fragmented landscape values in New Zealand, in order to provide greater insight into the relationship between landscapes and cultural sustainability. Although this model helps one to understand cultural values related to a landscape, it does not necessarily provide qualitative or quantitative impacts associated with changes to the landscape.

Montes de Oca Munguia et al. (2009) attempted to create a land use and land change impact assessment tool as they recognised that cultural values can be difficult to situate alongside socio-economic and environmental goals in land use management. Montes de Oca Munguia et al. (2009) argue that a methodology is lacking which is readily able to represent economic, social, environmental, and cultural data related to land use (current or proposed). The authors present a potential tool to fill this need which involves combining agent-based modelling (ABM; an “agent” is a simulated set of behavioural rules for an individual) with spatial mapping software (Geographic Information Systems (GIS)) to produce alternative land use scenarios. However, the proposed model is still under development and has not yet produced peer-reviewed results.

Regardless of the progress demonstrated in these examples, there is still very little research and application of decision-support tools that integrate cultural aspects alongside environmental, social, and economic aspects. This suggests that there is still an obvious need to develop a comprehensive methodology or tool which can support Māori decision-making on alternative land management options.

## **2.2. Life Cycle Sustainability Assessment (LCSA) methodology**

Section 2.2 introduces the fundamental concepts associated with the three components of LCSA recognised to date: Environmental Life Cycle Assessment (Section 2.2.1), Life Cycle Costing (Section 2.2.2), and Social Life Cycle Assessment (Section 2.2.3). When combined, the three techniques create the structure for Life Cycle Sustainability Assessment (LCSA) which is presented in Section 2.2.4. In addition, two common life cycle methodological approaches (attributional and consequential) used to support decision-making processes are reviewed and discussed in Section 2.2.5.

### **2.2.1. Environmental Life Cycle Assessment (LCA)**

Environmental Life Cycle Assessment (hereafter “LCA”) is a tool that supports the decision-making process (within both the public and private sectors) by providing environmental impact information (e.g. climate change, acidification, eutrophication) (Basson & Petrie, 2007; ISO, 2006b). LCA is often described as the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO, 2006b) from the extraction raw materials through to its final disposal, or, in other words, from the “cradle” to the “grave” (Baumann & Tillman, 2004). The results of LCA provide the opportunity to evaluate and compare trade-offs, to explore “what if” scenarios<sup>3</sup>, and to make balanced and informed decisions both in the short- and long-term (Galeano, 1997; Owens, 1999). Although LCA is commonly used to assess products it can also be used to assess services, such as waste management (e.g. Finnveden, 1999b).

The publication of the *Code of Practice* in 1993 was the foundation of formalising standard LCA procedures. The subsequent International Organisation of Standardisation (ISO) published a series of methodological standards from 1997 to 2000: ISO 14040 (Principles and framework), ISO 14041 (Goal and scope definition and inventory analysis), ISO 14042 (Life cycle impact assessment), and ISO 14043 (Life cycle

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<sup>3</sup> A scenario “can be used to build a vision, negative or positive, and can also help to identify the actions necessary for such a vision to occur” (Mitchell, 2002, p. 57).

interpretation). These four ISO standards were updated and replaced in 2006 (ISO, 2006b, 2006c). Other related ISO publications include standards on environmental labelling and declarations (ISO, 2006a) and data documentation formats (ISO/TS, 2002).

The basic LCA methodology comprise of four main stages: 1) goal and scope definition, 2) inventory analysis (including indicator development and data collection), 3) impact assessment, and 4) interpretation (including classification, characterisation and weighting). The interpretation phase, however, may occur during each of the preceding life cycle phases (see Figure 2). A functional unit is used to describe and quantify the impacts associated with the product or service being studied (e.g. one m<sup>3</sup> radiata pine house framing) (Weidema, Wenzel, Petersen, & Hansen, 2004).

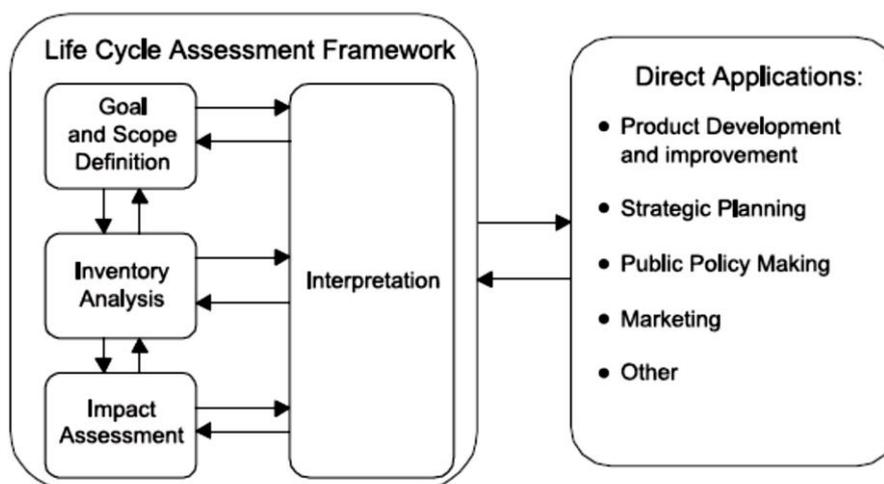


Figure 2. The UNEP/SETAC (2009) list of recommended stakeholder categories and sub-categories to be reviewed within an S-LCA (ISO, 2006b; Rebitzer et al., 2004).

LCAs have been used to support decision making during activities such as product design (e.g. Norris, 2001), policy making (e.g. Tukker, 2000b), eco-labelling (e.g. Cowell, Fairman, & Lofstedt, 2002), and land use strategy development (e.g. Lindeijer, 2000). In the case documented by Norris (2001), the LCA process helped companies re-evaluate investment decisions by broadening the decision scope to incorporate typically ignored factors such as indirect and intangible aspects (e.g. corporate image). Furthermore, the LCA process helped to stimulate thinking and dynamic discussions between company groups which generated insights, and ultimately led to better decisions.

Fuller, Allen, and Glaser (1996) describe LCA as “holistic in nature” and relate it to Barry Commoner’s (1971) first two laws of ecology: “Everything is connected to everything else” (p. 29) and “Everything must go somewhere” (p. 36). Historically, LCAs encompass only the environmental aspect of a product or service’s life cycle; the economic and social elements are only considered relevant as a basis for weighting (Baumann & Tillman, 2004). Yet there is an increasing interest in expanding LCA to account for the missing economic and social components in order to more fully represent the concepts of sustainability and sustainable development. Therefore, the future of LCA is becoming more elaborate with the inclusion of social and economic dimensions as well as multiple models into one comprehensive framework (Hellweg & i Canals, 2014).

### **2.2.2. Life Cycle Costing (LCC)**

LCC (or “environmental LCC”) is effectively the economic equivalent of LCA, and, although it has not yet achieved international standardisation, best practice guidelines have been developed (Ciroth, Hunkeler, & Lichtenvort, 2008; Simões, Costa Pinto, & Bernardo, 2012; Swarr et al., 2011). Klöpffer and Giroth (2011) define LCC as being completely compatible with LCA whilst allowing for the assessment of micro-economic costs associated with product systems. This assessment is relevant for the product suppliers, producers, users, and/or final disposer (Simões et al., 2012), and is especially useful when undertaking product comparisons.

Several studies have sought to integrate LCA with economic indicators (e.g. Carlsson Reich, 2005; Deng, Wu, & Shao, 2013; Heijungs, Settanni, & Guinée, 2013; Norris, 2001; Shapiro, 2001; Simões, Pinto, Simoes, & Bernardo, 2013). For instance, Deng et al. (2013) proposed to divide LCC into two components: environment-related LCC (e.g. raw material cost, fuel cost) and non-environment-related LCC (e.g. overheads cost, product design cost). The environment-related LCC is associated with the same factors that exist in LCA thus enabling their integration. Deng et al. (2013) note that aligning LCA and LCC can help decision makers justify the environmental and economic costs of, for example, choosing to improve product design.

### **2.2.3. Social Life Cycle Assessment (S-LCA)**

Although there is the socially-related impact category of ‘human health’ within an LCA, it typically refers to those environmental impacts which directly affect the quality of human life (e.g. toxicological impacts) (Dreyer, Hauschild, & Schierbeck, 2006). Social aspects were first taken into account alongside LCA in 1996 with the publication of Social and Environmental Life Cycle Assessment (SELCA) (O’Brien, Doig, & Clift, 1996), and in 1998 when Hauschild and Wenzel (1998) included such health impacts as worker injuries into the LCA process.

S-LCA is methodological approach that “aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle” (UNEP & SETAC, 2009, p. 37). Social impacts are also referred to as “social considerations”, “social conditions”, “social values”, “social effects”, “social sustainability” or “social aspects”. The measurement of social impacts occurs through the use of sub-category indicators such as working hours, fair salary, health and safety, cultural heritage, corruption, and supplier relationships. S-LCA guidelines were published in 2009 by the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) (UNEP & SETAC, 2009) and align with the ISO standard for LCA (ISO, 2006c).

The S-LCA methodology has been elaborated over the last twenty years so that it can be used for “increasing knowledge, informing choices, and promoting improvement of social conditions in product life cycles” (Benoît et al., 2010, p. 158). However, S-LCA methodologies remain largely underdeveloped with no agreed approach and require further refinement (Clift, 2014; Martínez-Blanco et al., 2014; Muthu, 2015). A number of challenges remain including:

- There is still no methodological consensus of how to incorporate, calculate and compare social effects of various products (Fan, Wu, Chen, & Apul, 2015; Martínez-Blanco et al., 2014),
- There is no methodological consensus on how to determine what constitutes a socially important process, system boundary, or weighting criteria (Benoît et al., 2010; Chhipi-Shrestha, Hewage, & Sadiq, 2014),

- There is a lack of modelling tools and social impact data (Benoît-Norris, 2014; Jørgensen, 2013; Lehmann, Zschieschang, Traverso, Finkbeiner, & Schebek, 2013), and
- The impacts on society and people may be sensitive to variation and interpretation, and are complex to consistently measure (due in particular to their qualitative characteristics) (Jørgensen, Le Bocq, Nazarkina, & Hauschild, 2008).

However, S-LCAs are still able to provide useful and meaningful results. Nemarumane and Mbohwa (2015) performed an S-LCA case study which evaluated the South African sugar industry (growers and millers). The sub-category indicators assessed were health and safety, gender equality, and wages. The results of the S-LCA highlighted several societal impacts such as lack of wage rises, gender discrimination, and worker exposure to unsafe dust particles. Therefore, the S-LCA process may help to achieve a greater understanding of how the development of a given product: affects social well-being; helps to assess trade-offs between social and environmental impacts; and can provide insight into the socio-political infrastructure across regions.

#### **2.2.4. Structure of LCSA methodology**

The potential to include additional sustainability aspects in LCA has been recognised for a long time (e.g. Andersson, Eide, Lundqvist, & Mattsson, 1998), yet it remains an emerging assessment concept. Extension to encompass the full range of sustainability issues has been progressed more recently through the technique of LCSA.

LCSA measures the environmental, social, and economic impacts associated with product systems (Capitano, Traverso, Rizzo, & Finkbeiner, 2011; Ciroth et al., 2011; Finkbeiner, Schau, Lehmann, & Traverso, 2010; Guinée et al., 2011; Heijungs, Huppel, & Guinée, 2010; Hu, Kleijn, Bozhilova-Kisheva, & Di Maio, 2013; Klöpffer, 2008; Moriizumi, Matsui, & Hondo, 2010; Traverso, Asdrubali, Francia, & Finkbeiner, 2012; Zamagni, 2012; Zamagni et al., 2009; Zhou, Jiang, & Qin, 2007). According to Ciroth et al. (2011), LCSA is considered to be the future of LCA as it has greater potential to represent a variety of impacts beyond the conventional focus in LCA on environmental impacts. The combination of LCA with LCC and S-LCA to form LCSA has begun to gain momentum

in the scientific world with LCSA studies on, for example, marble products (Capitano et al., 2011), photovoltaic modules (Traverso, Asdrubali, et al., 2012), waste management of used cooking oil (Vinyes, Oliver-Solà, Ugaya, Rieradevall, & Gasol, 2013), and concrete recycling (Hu et al., 2013). Furthermore, the *International Journal of Life Cycle Assessment* recently published a special issue entitled, “Life Cycle Sustainability Assessment: From LCA to LCSA”, indicating that there is growing interest in the LCSA field.

Ciroth et al. (2011, p. 3) highlight the benefits of utilising and applying an LCSA methodology including its potential to:

- Organise and structure detailed datasets of environmental, social and economic information,
- Highlight the positive and negative trade-offs between products, life cycle processes, and sustainability indicators,
- Help corporations and producers to take account of the full range of impacts associated with their products and services,
- Identify “hot spots” (i.e. areas of significant impact within the life cycle) and allow for their improvement,
- Support decision-makers’ ability to choose sustainable products and technologies, and
- Supply data and inform product labelling programmes.

### **2.2.5. Attributional and Consequential methodological approaches**

There are two dominant methodological approaches when performing an LCA: attributional and consequential. An attributional-LCA (ALCA) is focused on measuring (or accounting for) environmental impacts associated to a product system and its physical relationships (Earles & Halog, 2011). ALCA generally uses average data within each unit process throughout the life cycle of a product (Poeschl, Ward, & Owende, 2012), and can be considered to contribute knowledge into a “static technosphere” (European Commission, 2010). Rehl, Lansche, and Müller (2012) highlight ALCA terms such as

“accounting, average, book-keeping, descriptive, non-marginal or retrospective” (p. 3767).

A consequential-LCA (CLCA) is essentially a “convergence of LCA and economic modelling methods” (Earles & Halog, 2011, p. 445) which seeks to explore and depict the theoretical impacts anticipated as a consequence of a decision about a product system. CLCAs often must assess and include the effects on markets (supply and demand) resulting from changes in the product system, thus providing knowledge relevant to a “dynamic technosphere” (European Commission, 2010). Rehl et al. (2012) identify CLCA terms such as “change-oriented, market-based, marginal or prospective” (p. 3767).

Determining which approach (attributional, consequential, or both) to use often occurs at the start of the life cycle research; not to do so may “result in the wrong method being applied, a mixture of the two approaches within a single assessment, or misinterpretation of results” (Brander, Tipper, Hutchison, & Davis, 2009, p. 1). Indeed the use of an attributional or consequential approach will undoubtedly influence various LCA attributes including the determination of system boundaries and allocation procedures, as well as the definition of the functional unit (Finnveden et al., 2009; Rebitzer et al., 2004; Tillman, 2000). However, it is still often the case that many LCAs do not clearly classify the decision-context (European Commission, 2010), and thus do not adequately state their involvement with either an attributional or consequential approach.

### **2.2.5.1. Attributional and Consequential debate in LCSA**

In the LCA research community, attributional and consequential approaches have been thoroughly discussed and debated over many years. However, as LCSA may still be considered an emerging technique, the discussion and debate regarding the application of attributional and consequential methods is limited. Bachmann state that an attributional LCSA “focuses on all sustainability-relevant flows of the considered life cycle and its subsystems” while a consequential LCSA “covers direct or indirect changes resulting from substitutional effects” (p. 1700). LCA, LCC, and S-LCA (as the primary components of LCSA) follow the same ISO 14040 (2006b) standards and framework regarding goal and scope definition, inventory analysis, impact assessment, and

interpretation (Bachmann). Therefore, it may be assumed that the consequential and attributional methodologies (and their purported appropriate applications) are equally relevant in LCSA (inclusive of LCA, LCC, and S-LCA) as they are in LCA alone.

There is some mention of attributional and consequential issues within LCC and S-LCA. For example, Wood and Hertwich (2012) reviewed the use of LCC within LCSA and state that since “LCC does not consider any dynamic effects of behavioural or price relationships, it is a method that is limited to the attributional setting. Methods drawing on rebound effects, equilibrium analysis and the like are required to address consequential questions” (p. 10). The authors suggest that a consequential approach will require “indicators of economic impact that apply to multiple stakeholders and the dynamic relationships between them, and that these indicators should be able to address long-term economic sustainability and not just short-term economic cost” (Wood & Hertwich, 2012, p. 11).

Regarding S-LCAs, to date they “have mainly been conducted using attributional modelling, but as practices evolve, consequential S-LCA is likely to develop (e.g. to inform technology choices--biofuels are a good example)” (UNEP & SETAC, 2009, p. 56). Ekvall (2011) discussed the development of “oppression” and “freedom” indicators and their application in attributional S-LCA since “they give information on to what extent the product and, hence, its buyer is associated with undemocratic or otherwise undesirable political systems” (p. 2). However, there are some (e.g. Zamagni, Amerighi, & Buttol, 2011) who argue that the distinction between consequential and attributional is “neither relevant nor pertinent” in S-LCA (p. 597).

Indeed, Suh and Yang (2014) question why there must always be such a hard distinction between consequential and attributional approaches in LCA, and that to assert that one method is always superior to the other may be considered “naïve and mechanistic” (p. 1180). The authors argue that “in reality, the LCA space is more a continuous spectrum, rather than a dichotomy, between idealized CLCA and ALCA” (Suh & Yang, 2014, p. 1181).

Many researchers consider that both attributional and consequential LCAs have a role in decision making and learning processes (Ekvall, Tillman, & Molander, 2005). Rehl et al.

(2012) consider both ALCA and CLCA to be vulnerable to instability issues regarding assumptions and parameters, and suggest that both would benefit from the use of sensitivity and scenario analyses. Furthermore, both approaches have been identified as being appropriate methods for modelling past, current, or future systems (Ekvall et al., 2005; Finnveden et al., 2009), and both are suitable for comparisons between product/service systems (Baumann & Tillman, 2004).

Guinée et al. (2011) argue that there is still much research needed to advance and clarify criteria related to attributional and consequential approaches in LCAs (as well as in LCSAs (Guinée & Heijungs, 2011)), with particular attention to the complexity and uncertainty associated with timeframes and scenario-based modelling. It is clear that there are many areas where future research can be focused to minimise the errors and ambiguity associated with the results from ALCAs and CLCAs, and the data that drive these methodologies.

### **2.3. Culture and values in LCA, S-LCA, and LCSA**

This section reviews if – and how – culture and values are represented in LCA, S-LCA, and LCSA.

The literature review highlighted few studies which recognise the role of values in LCC. For example, two studies explicitly emphasised the use of values when selecting a discount rate (Gluch & Baumann, 2004) and when determining a weighting system (Carlsson Reich, 2005). Other LCC studies use the term “subjective judgement” or “expert judgement” and stress its importance when creating a thoughtful design process (e.g. Christensen, Sparks, & Kostuk, 2005), when selecting and interpreting data (e.g. Korpi & Ala-Risku, 2008), and when undertaking risk assessment (e.g. Senthil Kumaran, Ong, Tan, & Nee, 2001). However, based on the literature review findings, it may be argued that the recognition of value in LCC mirrors the recognition of value in LCA (i.e. the use of value-based judgements when, for instance, making decisions or interpreting the data). For this reason, the discussion of culture and values in LCA (Section 2.3.1) is assumed to be representative of culture and values in LCC.

A review of the LCA literature suggests that there are two categories of approaches to inclusion of culture, and its constituent values, in LCA. One category of approaches focuses on recognising and allowing values to shape the process of undertaking an LCA study (Cowell, 1998); generally this takes the form of explicitly soliciting the values of stakeholders at the goal and scope definition phase of LCA, and/or choosing impact assessment methods that are consistent with these values. The other category of approaches focuses on identifying and assessing additional impact categories (such as unique landscapes) and/or dimensions of environmental impacts (uncertainty of results, ability to manage impacts, etc.) whose degree of significance is generally recognised as being value-based. Examples are given in Section 2.3.1.

It may be argued that these two categories of approaches to include culture will also be applicable to S-LCA (Section 2.3.2) and LCSA (Section 2.3.3).

### **2.3.1. Culture and values in LCA**

The role of values in the process of undertaking LCA studies has been recognised in relation to: defining the problem, goal, and scope; the selection of impact category indicators; the optional weighting element at impact assessment; and interpretation of results (Bare & Gloria, 2008; Bras-Klapwijk, 1998; Hauschild, 2005; Hertwich & Hammitt, 2001; Schmidt & Sullivan, 2002; Tukker, 2000a). Indeed, the ISO 14044 standard (ISO, 2006c) uses the term “value choices” 15 times in conjunction with: scope of the standard (Section 1), scope of the study (Section 4.2.3.1), classification and characterisation (Section 4.4.2.2.2, 4.4.2.2.3, 4.4.2.4), weighting (Section 4.4.3.1, 4.4.3.4.1, 4.4.3.4.2), ranking of impact categories (Section 4.4.3.3), comparative assertions (Section 4.4.5), interpretation (Section 4.5.2.3), and third-party reporting (Section 5.2, 5.3.2). Moreover, the values and worldviews of stakeholders can affect whether or not LCA is chosen as an analytical tool to support the decision-making process (Finnveden et al., 2003).

Regarding the problem, goal and scope definition, and choice to use LCA in a decision-making process, Ehrenfeld (1997) and Heiskanen (1999, 2000, 2002) highlight the role of life cycle thinking and/or LCA in “constructing problems in a distinctive way”

(Heiskanen, 2002, p. 434). And Coelho and McLaren (2013) show how the scope for three out of six LCA studies in different manufacturing companies changed during the process of undertaking the LCA studies – with a significant influence on the LCA results and associated implications for the decision situation. This suggests that the choices made at goal and scope definition can be important when the LCA results are used to support decision-making. Arguably values have an important – if largely unrecognised - role to play in influencing these choices about inclusion of different processes on the basis that they are judged as more or less relevant to the decision situation.

The selection of impact category indicators obviously determines which types of environmental impacts are represented in LCA results. ISO 14044 is not specific about which impact category indicators are to be included in an LCA study but requires that “the selection of impact categories, category indicators and characterization models shall be both justified and consistent with the goal and scope of the LCA. The selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration” (ISO, 2006, Section 4.4.2.2.1). Elghali, Cowell, Begg, and Clift (2006) and Elghali, Clift, Begg, and McLaren (2008) discuss how an LCA study was combined with decision conferencing to support a United Kingdom local authority decision about road maintenance; they highlight how additional environmental impact categories relevant to local people but not normally included in LCA (such as noise and visual amenity) were identified through this process. However, they recognised that “a natural tension exists between the need to standardise information requirements for completeness in assessment and the needs of a particular local decision context, since in the former case the information required for the decision process may not be generated while in the latter there is a possibility that important data may be overlooked” (Elghali et al., 2006, p. 37). It is clear that choice of impact categories in an LCA study utilises value-based judgements about the relevance of different types of environmental impacts.

Weighting is recognised as being the element in an LCA study that “combines scientific results with value judgements” and “serves as a base for the interpretation of results” (Walz, Herrchen, Keller, & Stahl, 1996, p. 193). During weighting, values (including ethics, morals, worldviews, and ideology) are recognised not only in the chosen weights but also in the chosen weighting method itself (Finnveden, 1997). Bengtsson and Steen

(2000) describe the weighting process as a “value-laden expression of relative severity” (p. 102). For example, a weighting method can be developed to account for the values of future generations (such as by using discounting techniques (Hellweg, Hofstetter, & Hungerbuhler, 2003; Udo de Haes, 2000)), or those in a precautionary society may wish to apply a greater weight to LCA impact assessment results that have a high degree of uncertainty (Tukker, 2002a; Werner, 2005). Furthermore, Finnveden (1999a) notes that “if robust results are wanted, it can be important to use several methods and sets of weighting factors to examine the sensitivity of the results to different values and worldviews” (p. 35). Miettinen and Hämäläinen (1997) argue that there is no set of weights which can accurately reflect stakeholder values in all situations since “they neither depend on the preferences of the actual decision makers nor on the attribute ranges that the product alternatives define” (p. 293); weights and the weighting method should be chosen specifically for the LCA study at hand.

Interpretation of LCA results is explicitly recognised as requiring consideration of value choices made at goal and scope definition (ISO, 2006c, Sections 4.5.2.3). However, the format in which LCA results are reported may also influence interpretation. A small number of studies have explicitly explored use of different formats for the communication of LCA results (e.g. Dahlbo et al., 2013; Molina-Murillo & Smith, 2009; Nissinen et al., 2007). Another group of studies have experimented with “actor LCA,” focusing on presenting the results of LCA studies in ways that represent the potential for different stakeholders (or “actors”) to realise potential improvement options at different stages along the product life cycle (e.g. Berlin, Sonesson, & Tillman, 2008; Brunklaus, Thormark, & Baumann, 2010; Löfgren, Tillman, & Rinde, 2011). The values of the LCA practitioner may influence the choice of presentation format and whether, for example, uncertainties and/or ranges of data are presented on impact assessment graphs, and which processes are aggregated together (e.g. whether transportation processes are subsumed within the other life cycle stages of a product system or separately represented on impact assessment graphs).

Turning to culture, its recognition in the LCA literature is quite limited. One example is that of Hofstetter, Baumgartner, and Scholz (2000) who, with the statement that all stages of an LCA should integrate subjective elements, suggest that a “valuesphere” be added within LCA which would represent the views of the decision-maker. The authors utilise

cultural theory to apply three perspectives of social decision-making: (a) hierarchy – “nature is tolerant”, (b) individualism – “nature is benign”, and (c) egalitarianism – “nature is fragile”. These three perspectives were also used in the LCA-based Ecoindicator’99 methodology (Goedkoop & Spriensma, 1999) and are used in the ReCiPe method (Goedkoop et al., 2013). Accounting for differences in cultural perspectives will, in theory, help to “establish the seriousness” of environmental impacts (Baumann & Tillman, 2004) and the “importance of damages” (Mettier & Hofstetter, 2004), communicate and emphasise LCA results in a way which is most appropriate or effective for a given decision maker, and, overall, create a more robust decision support system. De Schryver, Brakkee, Goedkoop, and Huijbregts (2009) also applied cultural theory in their research on refining global warming characterisation factors, and concluded that different cultural perspectives will significantly alter the relative importance of various impact indicators.

Another example of culture being recognised in LCA is seen in the work of Weidema and Lindeijer (2001). This research aimed to contribute to the development of “missing” LCA elements that included “cultural values”. The authors interpreted cultural values in a context of “unique landscapes and unique archaeological sites”. It is this uniqueness, the authors argued, which inhibits cultural values from being a general indicator, and therefore they must be considered on a case-by-case basis. Nevertheless, the authors developed a general indicator to account for the disruption of “unknown archaeological sites” by relating the factors of disturbed soil depth, area, and probability of site occurrence.

### **2.3.2. Culture and values in S-LCA**

An S-LCA assesses social and socio-economic impacts (which positively or negatively affect stakeholders) throughout the life cycle of a product. Social impacts occur when product or system changes create effects which in turn produce phenomena; these phenomena can be experienced by and influence people thus leading to social impacts (Macombe, Leskinen, Feschet, & Antikainen, 2013; Vanclay, 2002). UNEP and SETAC (2009) describe the aim of S-LCA as being to “help stakeholders to effectively and

efficiently engage to improve social and socio-economic conditions of production and consumption” (p. 5).

Though there are various examples of S-LCA methodologies, for the most part they aim to mirror the LCA procedure comprising goal and scope definition, inventory analysis, impact assessment, and interpretation (Arcese, Lucchetti, & Merli, 2013; Benoît et al., 2010; Hunkeler, 2006; Jørgensen, Finkbeiner, Jørgensen, & Hauschild, 2010; Jørgensen et al., 2008). Furthermore, although some aspects vary, an S-LCA generally follows the ISO 14044 framework (UNEP & SETAC, 2009). Therefore, it can be postulated that the discussion in Section 2.3.1 related to LCA is also largely applicable to S-LCA.

The categories, sub-categories, and inventory indicators proposed for S-LCA have been developed primarily in relation to international initiatives, frameworks, and conventions promoting and protecting social wellbeing. Table 2 highlights the stakeholder categories and sub-categories developed for use in S-LCA which, to some extent, represent culture and cultural impacts (e.g. the sub-category of “Cultural heritage”). Despite the representation of culture being evident, in particular, throughout the category of “Local community”, most S-LCA studies have a tendency to only use indicators that are similar to those used in environmental LCA (Guinée, 2016; Hutchins & Sutherland, 2008). For example, in their critical review on the development of the Social Life Cycle Impact Assessment (S-LCIA) method, Chhipi-Shrestha et al. (2014) highlighted that the S-LCA case studies reviewed used the Environmental Life Cycle Impact Assessment (E-LCIA) database for the S-LCIA process, and that linking the two created a bridge between E-LCA and S-LCA. However, Chhipi-Shrestha et al. (2014, p. 591) further state that “only a few social impacts such as health impact and employment are assessed by this method”. Regarding the issue of which S-LCA indicators to use, Dreyer et al. (2006, p. 96) published a framework for S-LCIA that advocates using an “obligatory set of impact categories” based on the Universal Declaration of Human Rights because “there are some social impacts which are relevant to address for all companies”. Indeed, Ramirez et al. (2014, p. 1516) state that “failure to take into account any one of the [impact] subcategories is an issue”. Therefore, although these researchers have recommended that S-LCAs utilise a specific set of impact categories, it is evident that most S-LCA studies do not follow this guidance.

Table 2. The UNEP/SETAC (2009) list of recommended stakeholder categories and sub-categories to be used in an S-LCA (Benoît et al., 2010).

STAKEHOLDER CATEGORIES	SUB-CATEGORIES
Worker	Freedom of association and collective bargaining
	Child labour
	Fair salary
	Working hours
	Forced labour
	Equal opportunities/discrimination
	Health and safety
Consumer	Social benefits/social security
	Health and safety
	Feedback mechanism
	Consumer privacy
	Transparency
	End of life responsibility
	Access to material resources
Local community	Access to immaterial resources
	Delocalisation and migration
	Cultural heritage
	Safe and healthy living conditions
	Respect of indigenous rights
	Community engagement
	Local employment
Society	Secure living conditions
	Public commitments to sustainability issues
	Contribution to economic development
	Prevention and mitigation of armed conflicts
	Technology development
	Corruption
	Value chain actors (not including consumers)
Promoting social responsibility	
Supplier relationships	
Respect of intellectual property rights	

In addition, culture is acknowledged as influencing “what is conceived as damaging or beneficial for the human dignity and well-being in a society” (Dreyer et al., 2006, p. 94). Thus, from the topics in Table 2, the extent to which child labour is accepted, corruption is resisted, or indigenous rights are respected within a society is largely affected by that society’s culture. For instance, in their evaluation of different S-LCA impact assessment methods, Parent, Cucuzzella, and Revéret (2010) note that the use of a child labour indicator may raise uncertainties as to whether the child labour is a “cultural feature of the community” or “a company choice”. These cultural perceptions, unique to a given society, must be considered within S-LCA in order for the subsequent results to be relevant and meaningful to the society involved (Dreyer et al., 2006; Hauschild, Dreyer, & Jørgensen, 2008).

### **2.3.3. Culture and values in LCSA**

As mentioned in Section 2.1.3, recognition of culture as a fourth pillar of sustainability (alongside economic, social, and environmental aspects) is gaining momentum, and is often referred to as the “quadruple bottom line”. New Zealand, in particular, has been one of the first countries in the world to adopt and promote the application of a quadruple bottom line throughout governmental activities. Until the 1970s, indigenous Māori were largely excluded from government planning (Dalziel, Matunga, & Saunders, 2006). In 1991 the *Resource Management Act* was created which references the Treaty of Waitangi (the original signed agreement between Māori and the British settlers), and thus strongly advocates the recognition and respect of Māori culture in resource management decision making. Legislation introduced in 2003 required “councils to plan and work on the basis of the “quadruple bottom line” approach and undertake quadruple bottom line reporting – considering social, economic, environmental and cultural impacts” (Spiller & Lake, 2003, p. 15). Dalziel et al. (2006), discussing local government legislation, state that each of the four components of sustainability are strongly linked and mutually dependent; it is essential not to neglect a particular component, nor to consider any of them in isolation. And Montes de Oca Munguia et al. (2009), in the context of representing Māori cultural values in land use management, argue that a methodology is lacking which is readily able to illustrate economic, social, environmental, and cultural data related to land use (current or proposed).

Since values are at the heart of multiple-objective decisions, including values (such as those associated with culture) within LCA may then lead to it becoming a more robust decision support tool (Hofstetter et al., 2000). Indeed LCAs guided by the values and worldviews of the decision maker(s) may lead to clear-cut and focused decision situations (Heiskanen, 2000; Werner & Scholz, 2002). One may argue that these arguments would also apply to LCSA.

Cultural aspects are not readily evident within current LCSA methodology but may be found in a limited number of impact sub-categories (e.g. Cultural heritage) in S-LCA (Benoît et al., 2010); since there is no one group of recommended impact sub-categories, the representation of cultural impacts in the final LCSA results is not guaranteed. Instead, representation of culture depends on the goal and scope of the study at hand as well as the context of the study's geographical and cultural settings (Hauschild et al., 2008; Zamagni et al., 2011). Therefore, an S-LCA may not always be considered to have accounted for culture in its process and/or results. In fact, the inclusion or recognition of culture (and/or changes in culture) within LCSAs is virtually non-existent apart from rare exceptions such as Ketola and Salmi (2010). The authors conducted a holistic LCSA, including culture, which compared different biofuels. They performed semi-structured interviews with a variety of decision makers in order to identify their perspectives regarding environmental, social, cultural, and economic impacts associated with different types of biofuels. The cultural results related to, for instance, biodiesels indicates that many stakeholders felt there would be a loss of cultural landscapes during the growing stage of the crop used to produce biodiesel. The results from the interviews were represented qualitatively rather than quantitatively i.e. they did not present discrete cultural indicators but instead discussed cultural aspects identified during the interviews.

The under-representation of culture in LCSA may be unsurprising given that LCSA is still in its relative infancy. But there is great interest in developing comprehensive, streamlined methodologies and tools which are able to assess the whole picture (rather than focusing on just one aspect) (Hellweg & i Canals, 2014; Valdivia et al., 2012).

## **2.4. Recognising culture in LCA, S-LCA, and LCSA**

This section identifies and discusses the relationship between culture and the life cycle techniques of LCA, S-LCA, and LCSA. The benefits and challenges of recognising culture in LCA, S-LCA, and LCSA are highlighted (Sections 2.4.1 and 2.4.2), and the argument is made that in some cases the distinct representation of culture in LCSA is needed (Sections 2.4.3 and 2.4.4).

### **2.4.1. Benefits**

People are often intimately connected with their culture, and this connection can influence one's way of life, sense of identity (individually and as part of a larger group), and level of engagement in social processes (Stephenson, 2008; Thrift & Whatmore, 2004). To this effect, Article 13 of UNESCO's Convention on the Protection and Promotion of the Diversity of Cultural Expressions states that "parties shall endeavour to integrate culture in their development policies at all levels for the creation of conditions conducive to sustainable development" (UNESCO, 2005, p. 8). This process of integrating culture into policy can be beneficial as sustainable development which recognises culture is more likely to be successful, especially regarding the public's acceptance of proposed development initiatives (Macnaghten & Jacobs, 1997). Indeed, developmental change that is *not* embedded in the values and knowledge of a community may be like "trying to walk through a locked door after throwing away the key" (Gould, 2001, p. 69).

In order for modern societies to protect the cultural values of indigenous communities, in particular, Groenfeldt (2003) argues that the global community must: support local indigenous participation in resource management and development planning; embrace indigenous spiritual practices and worldviews within environmental conservation; recognise and protect indigenous rights to land and water resources; and, respect indigenous identity as it is the cornerstone of the cultural values of indigenous communities.

The representation of culture in LCA through, for example, recognising and allowing values to shape the process of undertaking an LCA study and/or through identification of

additional indicators may provide an appropriate platform with which to address Groenfeldt's recommendations. Structuring an LCA study to be consistent with the values of the intended audience will ensure the LCA results are in an appropriate context (Bengtsson & Steen, 2000). However, failure to transparently reflect values during the LCA process may lead to a collapse in meaningful communication, discussion, and justification of the LCA results (Bras-Klapwijk, 1998; Finnveden, 1997; Steen, 2006), and even hinder the broader societal acceptance and trust associated with the LCA results (Freidberg, 2015).

Whilst cultural considerations in LCSA have rarely been incorporated, the potential exists to do so. Indeed, Jeswani, Azapagic, Schepelmann, and Ritthoff (2010) state that “broadening LCA towards social, cultural and economic aspects would move LCA from environmental towards sustainability assessments” thereby creating “an opportunity to increase the significance of LCA in political spheres beyond environmental policy” (p. 124). Furthermore, Allenby, Allen, and Davidson (2007) argue that the whole of industrial ecology, the discipline in which LCSA sits, should encourage continued expansion of LCSA to include cultural considerations as it represents an “important opportunity”.

### **2.4.2. Challenges**

It is important to note that cultural values and knowledge are neither static (Jacobs & Mulvihill, 1995; UNESCO, 2009) nor homogenous; there is no single perspective, interpretation, definition, or value system that can summarise an entire culture indefinitely (Hardy & Patterson, 2012). Just as economies and ecological habitats change over time, so may certain cultural values thus implying the need for their periodic assessment and reconsideration within decision-making processes. In order to cope with dynamic cultural elements, efforts should be focused on developing frameworks to represent culture that can adapt to their subtle nuances, reflecting how these change in different contexts. Perhaps successful frameworks could be created by conceptualising culture in more detail (e.g. from socio-economic-political drivers of change) (Leung et al., 2005). In the context of international business development, Leung et al. (2005) suggest systematically characterising the complexity of cultures in a way which allows

for the identification of when and how the effects of cultural considerations may impact the decision-making process. These effects can then be integrated into business models and theories.

Inclusion of specific cultural indicators in S-LCA and LCSA studies, in particular, requires extensive data collection and analysis across a range of aspects. Some aspects may be numerical and other aspects may be more narrative (as is often the case with cultural data). LCSA research, therefore, may require use of a mixture of both quantitative and qualitative methods (i.e. mixed methods research).

The data collection process is often the area with the most limitations. These limitations may be due to data being restricted, uncertain, unavailable, inaccurate, unreliable, etc. Collecting generally less discrete and tangible cultural data may also prove difficult. Some researchers (e.g. Chan, Satterfield, et al., 2012; Keeney & Gregory, 2005; Tipa & Teirney, 2003) have handled this challenge by creating a community-constructed metric or scale (e.g. 1-5) which translates qualitative data into numerical scores. Also, Chan, Guerry, et al. (2012) developed an engagement framework which can be used to integrate culture into ecosystem services research and decision making. Furthermore, some researchers have advocated a requirement for site-specific data and others have asserted that general, published statistics are adequate (Jørgensen et al., 2008). Ultimately the decision between site-specific and more general data is highly dependent on how much time and resources are available for the data collection phase, since collection of site-specific data will undoubtedly require a significant amount more effort.

A key challenge is the collection and representation of any qualitative (social or cultural) information which may not be suitable to represent in the format of a functional unit (Arcese et al., 2013; Klöpffer, 2008). If this is the case, then proportional weighting may be used to transform the qualitative results into a format which allows them to be summarised per functional unit (Benoît et al., 2010).

Yet, Espeland (2001) cautions that when recognising culture it is important to not only account for what people value (e.g. land) and how much they value it (e.g. on a scale of 1-10), but to understand the process of *how* they value it. When we convert their values

into new, often numerical, configurations we may inadvertently be “threatening their integrity as social beings” (p. 1845).

The “value” of culture can be diversely defined depending both on stakeholders (i.e. their specific cultural background) and on scale (e.g. a sacred site may have more cultural significance to a stakeholder at a local scale than at a global one) (Head et al., 2005; Hein, Van Koppen, De Groot, & Van Ierland, 2006). Decision-making in general is, of course, a complex process not least because of the typically large number of stakeholder aspirations, goals, and objectives which must be considered in order to make a balanced decision (Finkbeiner, 2010). Hein et al. (2006), for example, examined how stakeholders valued ecosystem services of the De Wieden wetland in The Netherlands at various scales. The results indicated that local stakeholders are more likely to value the enhanced fishing benefits while national stakeholders will more highly value the potential for increased biodiversity. However, the authors acknowledge that it is challenging to understand how intricate spatial associations within landscapes and ecosystems affect and are affected by a particular action such as flood prevention measures.

One possible way to account for this diversity of cultures is to engage with stakeholders (including members of relevant communities). Thus, participatory techniques may be used in order to, for example, enhance the underlying LCSA framework and/or indicators. Extensive stakeholder participation is uncommon in the process of undertaking LCA and LCSA studies. Yet an LCA undertaken using participatory techniques may lead to more balanced and socially-accepted results (Tukker, 2002b). An LCSA process, especially one that is inclusive of both social and cultural aspects, has the potential to have much more stakeholder involvement during, for instance, the data collection or inventory phase. Indeed, in their review of cultural ecosystem service indicators, Hernández-Morcillo, Plieninger, and Bieling (2013) note that utilising participatory mapping tools can greatly increase the quality and visibility of intangible cultural attributes, thereby allowing for more informed decision making in regional landscape planning. Valdivia et al. (2012) suggest that future LCSA studies should create subsequent guidance on how stakeholder engagement was utilised throughout the process of undertaking the study.

### **2.4.3. Social versus cultural indicators**

But why distinguish between the social and cultural dimensions in sustainability? It is true that social and cultural aspects are not entirely separate; social and cultural traits do not evolve independently from one another (Weinstein, 2005). However, there are differences between social and cultural aspects. In anthropology, for example, Barrett (2009) notes that the term “cultural” embraces beliefs and values while the term “social” refers to social structures (institutions, roles, etc.).

Social and cultural indicators also demonstrate some distinct differences. Table 3 illustrates how the labelling of “social” or “cultural” indicators differs amongst various policies, guidelines, or other research documents. Some indicators, such as “language”, tend to be considered cultural whilst others, such as “health”, are thought of in a social context. Although there is some overlap (e.g. the “education” indicator), one may argue that there is still enough difference between social and cultural indicators to justify representing them separately within an assessment methodology such as LCSA. However, it is worth stressing the importance of focusing efforts across all relevant fields of study to achieve more consensus and consistency between the use of social and cultural indicators. Only when this is done can the meaningful progression of these indicators be realised.

Table 3. Labelling of indicators as either “social” or “cultural” as demonstrated by various policies, guidelines, and other research studies.

	Health	Political participation	Safety	Housing	Skills	Social connectedness	Employment	Recreation & tourism	Education	Language	Autonomy	Media communication	Artistic creation	Protection of culture & places
Arctic social indicators (Nordic Council of Ministers, 2010)	■							■	■	■	■			
Investing in cultural diversity (UNESCO, 2009)									■	■		■	■	
New Zealand Sustainable Development (Department of Prime Minister and Cabinet, 2003)	■	■	■	■	■	■	■			■				■
Cultural Indicators: Views from Africa Task Force (UNESCO, 2010)									■	■	■			
Sustainable Management of Temperate & Boreal Forests (The Montréal Process, 2009)							■	■						■
Indicators for Aboriginal forestry (Saint-Arnaud, Asselin, Dube, Croteau, & Paptie, 2009)							■				■			■
Māori sustainable economic development (Scrimgeour & Iremonger, 2004)	■			■			■		■	■		■	■	■
European System of Social Indicators (Noll, 2002)	■	■						■	■			■		
Social indicators (OECD, 2011)	■	■						■	■					
Sustainability indicators for community tourism (Choi & Sirakaya, 2006)	■		■		■	■	■	■	■	■				■
Sustainable development indicators for mining (Azapagic, 2004)	■		■		■	■	■		■					■
ISO 26000 Social responsibility (ISO, 2010)	■	■	■		■	■	■		■					■
Guidelines on S-LCA of products (UNEP & SETAC, 2009)	■		■	■			■							■
<b>KEY</b>	<b>Social indicator</b>		<b>Cultural indicator</b>											

#### **2.4.4. The representation of culture in LCSA**

In recent years there has been increased recognition of the need for a more holistic and comprehensive extension of the environmentally-focused LCA methodology (e.g. Hellweg & i Canals, 2014). Indeed, Heiskanen (2001) argues that “the exclusion of non-quantifiable and non-environmental issues from LCA” does not generally correspond with how ordinary people (i.e. non-LCA professionals) see this type of assessment (p. 43). Instead she recommends anchoring LCA in the culture and worldviews of decision-makers, both on personal and organisational levels, arguing that doing so may facilitate the interpretation, endorsement, and uptake of LCA (Heiskanen, 2000).

The inclusion of non-environmental issues in LCA has been pursued through two categories of approaches: (a) focusing on recognising and allowing values to shape the process of undertaking a study and/or (b) identifying additional impact categories and/or dimensions of environmental impacts that can be represented at the impact assessment and interpretation phases of a study. The more recent emphasis upon development of S-LCA and LCSA provides an opportunity to explicitly recognise culture and/or cultural values in these sustainability assessment techniques alongside LCA. Other environmental assessment studies have suggested that this may be possible. For example, concerning the first category of approaches (allowing values to shape the process of undertaking a study), an example is Stevenson (1996) who developed an approach for including the indigenous knowledge and values of a First Nation tribe in Canada in Environmental Impact Assessment (EIA). Stevenson argues that it is beneficial to recognise and incorporate indigenous knowledge and values into all stages of an EIA, thereby enhancing the potential for EIAs to become more holistic. Concerning the second category of approaches (development of additional impact categories), an example is Axelsson et al. (2013) who attempted to map cultural sustainability in the context of land use planning in Sweden. Their cultural indicators included “cultural landscape” (in number of active farmers per km<sup>2</sup>) and “cultural heritage” (in number of historical remains per km<sup>2</sup>).

Thus future research should focus on opportunities for development of (a) a culturally-focused LCSA process, and (b) additional cultural indicators and/or dimensions of

existing LCSA indicators that represent cultural values. Attention should also be given to whether inclusion of culture in LCSA is more appropriate for some decision situations than others e.g. public policymaking, decisions involving alternative uses of land. The challenges to be explored in representing culture within LCSA include: recognising when “culture” should be distinguished from “social”; culture’s dynamic nature; the data collection process; and the diversity of cultures between stakeholders and at different scales from community through to nation.

## **2.5. Conclusions**

It is clear that different cultures are valued for their inherent importance and distinct worldviews, and indeed there are a few examples of tools designed to help assess and protect culture. However, there is a lack of assessment tools that distinctly place cultural aspects alongside environmental, economic, and social aspects; this may lead to the marginalisation of culture.

The emerging LCSA technique currently represents environmental (LCA), economic, (LCC), and social (S-LCA) considerations. Culture is represented to a certain extent in S-LCA through sub-indicators yet these sub-indicators are not mandatory when performing an S-LCA. Therefore, undertaking an S-LCA does not guarantee the assessment or representation of culture.

In some cases it may be useful or even necessary for culture to be more upfront and apparent within LCSA; doing so will allow for more adequate assessment of the effects on – and of – culture when reviewing the impacts associated with a product or service. Thus, there is an opportunity for culture to be integrated into the emerging LCSA technique.

Presenting decision makers with information about economic, social, environmental and cultural aspects will allow them to simultaneously consider a range of impacts associated with a given process or product, not just impacts associated with one or two aspects. The potential benefits of representing culture within LCSA include a more comprehensive decision-support tool which appropriately accounts for cultural values, greater resonance

of LCSA results with stakeholders, and an assessment technique which may help to protect the rich diversity of cultures found in communities across the world.

## **Chapter 3**

### **3. Contextual background for the participatory LCSA research**

In Chapter 2 it was acknowledged that culture and cultural values are often underrepresented in decision-making processes, and the potential for recognising culture more explicitly in LCSA was highlighted. In this chapter, a more focused literature review is presented which aims to provide foundational insights into two further aspects that play critical roles throughout the PhD research: Māori culture and forestry options.

The topics covered in this chapter include fundamental Māori cultural traditions, aspirations (Section 3.1), and interest in forestry and forestry options (Section 3.2). In addition, forestry in a New Zealand context is presented, and important forestry concepts and processes are identified (Section 3.3).

#### **3.1. Māori: Tangata whenua**

This section describes fundamental aspects of Māori culture that have particular relevance to this participatory research such as Māori cultural values and the connection of Māori to the land (Section 3.1.1). This section also discusses the importance of recognising Māori aspirations during the decision-making process (Section 3.1.2), the essential components of Māori decision making (Section 3.1.3), and key considerations when engaging with Māori (Section 3.1.4). These topics represented three of the most significant elements of this participatory research; this type of research will not succeed without adequate recognition and respect of Māori aspirations, decision making, and engagement tikanga (protocol).

##### **3.1.1. Māori history, culture, and traditions**

Māori are the indigenous people of Aotearoa (New Zealand) (Hodges, 1994). Māori history extends over 1,000 years to when their ancestors arrived from northern islands in the Pacific (Patterson, 2006), and includes an intimate association with specific

geographical territories. Relatively recent history involved colonisation by the British that has led to significant discrimination and marginalisation of Māori people and culture (McGavock, M., & McCreanor, 2012; Walker, 1990).

Threats to Māori culture and identity remain present (Moeke-Pickering, 1996). Yet, Māori have rebounded in recent years demonstrating an extraordinary sense of entrepreneurialism and innovation, while ultimately proving to be an extremely resilient people (Davies et al., 2005; Jones, 2000; Ritchie & Ritchie, 1978).

According to the New Zealand census (2013), over 668,000 people were identified as being of Māori descent while 598,000 people (nearly 15% of New Zealand's population, or one in seven) identified themselves with one or more Māori iwi (tribe) (Statistics New Zealand, 2013). Māori are highly urbanised and the Māori worldview is a mix of old and modern views, with a range of cultural practices (Harmsworth, 2011). There is no one perspective as indeed the name “Māori” represents a composition of discrete groups, iwi and hapū (sub-tribe), each with their own unique yet sometimes similar viewpoints (Roberts, Norman, Minhinnick, Wihongi, & Kirkwood, 1995).

In the Māori worldview, there is a distinct genealogical relationship (known as whakapapa) between the natural world (animate and inanimate alike) and people as all are descendants of Ranginui (sky father) and Papatūānuku (earth mother). Thus, Māori have a strong spiritual and physical connection to the land (Cheung, 2008; Mead, 2003; Simon, 2003; Te Rito, 2007). A Māori understanding of the world based on whakapapa includes the personification of nature and each of its components, therefore resulting in an interconnectedness analogous to that of a family (Marsden & Henare, 1992).

At the core of the natural world (i.e. elements, species and phenomena) and its sustained existence is mauri, the “essential life-force, the power and distinctiveness” which is present in everything from humans and animals to forests and rivers. Mauri can be decreased or damaged as well as ameliorated or reinforced (New Zealand Conservation Authority, 1997). Mauri is an important concept that was used in the co-development of the bespoke cultural indicator (i.e. the Cultural Indicator Matrix) as part of the participatory LCSA research (see Section 5.4.1).

### **3.1.2. Aspirations**

In relation to the environment, Māori aspirations as well as the reasoning behind decision-making are heavily influenced by Māori cultural values (Harmsworth, 1997; Loomis, 2003; Montes de Oca Munguia et al., 2009). The importance of recognising cultural values and aspirations is widely emphasised as both informing and influencing decisions regarding, for example, resource management (Tipa & Nelson, 2008), indigenous species (Wright, Nugent, & Parata, 1995), business development (Best & Love, 2010; Durie, 2003), and sustainability monitoring (Jollands & Harmsworth, 2007).

The Hui Whakapumau (1994), Te Oru Rangahau (1998), and the Hui Taumata (2005) conferences outlined several aspirations for ongoing Māori development in various areas including: social equality, cultural well-being, economic growth, and enhanced self-regulation (Davies et al., 2005; Henare, 2000). Indeed, there is great interest amongst Māori land owners in managing their land in accordance with their cultural values and aspirations, but also a sense that existing barriers (e.g. limited available information about the land, its potential, and diverse opportunities) often prevent balanced land management from being fully realised (Te Puni Kōkiri, 2011). To achieve these aspirations, it was noted in Hui Ōhanga (1999) and Hui Taumata (2005) that changes are needed in a diverse range of areas including: improved management practices; changes to commercial legislation; increased education; and pursuit of dynamic joint ventures (Davies et al., 2005). Thus, there is a need for a methodology or tool that can address barriers and facilitate the fulfilment of Māori aspirations whilst being rooted in Māori values.

### **3.1.3. Decision-making process**

Decisions are made by judging a situation, evaluating the choices, and applying values to ultimately select the best solution (although what constitutes the “best solution” is subjective to the decision-maker). All decisions happen within a specific cultural context, however, the importance of culture is often neglected (Wrisberg, Udo de Haes, Triebswetter, Eder, & Clift, 2002). Wrisberg et al. (2002) define the cultural context of a decision process as “the way that criteria are established which then are used to assess the quality of the decision” (p. 24).

Māori may be considered to utilise a “systems thinking” approach when developing opinions, assessing options, and making decisions (Beall, 2012; Scrimgeour & Iremonger, 2004). A system is often understood as a collection of things which, when combined, produce a connected group of elements that interact with each other (Maani & Cavana, 2009). Describing the world as a set of systems and subsystems helps us to organise and group entities, thereby reducing complexity. Systems thinking is the process of “understanding change and complexity through the study of dynamic cause and effect over time” (Maani & Cavana, 2009, p. 7). During the process of systems thinking, Māori may use mātauranga Māori (traditional knowledge) since it is: closely connected with social and cultural identity and values; comprehensive and inclusive of all natural processes and species (and their associated cultural, spiritual and historical information); focused on societal benefits; and passionate about the long-term adaptive progression of local and regional environments and communities (New Zealand Conservation Authority, 1997). Mātauranga Māori is considered to be one of the most pivotal ways to achieve long-term, sustainable environmental management in New Zealand since it looks beyond economic growth and focuses on the “intrinsic value and integrity of the ecosystem” (Voyde & Morgan, 2012; Wehi, 2009). Indeed, mātauranga Māori is considered to be a tool for organising information and reflecting on the ethics of knowledge, as well as understanding how knowledge can best inform Māori (Mead, 2003).

Furthermore, in relation to mātauranga Māori, mātauranga taiao (environmental knowledge) represents the collective information and beliefs which have evolved and adapted over time, thus representing generations of Māori experiences (King, Goff, & Skipper, 2007). Such traditional environmental knowledge (TEK) is a valuable addition to decision making regarding land and resource management, sustainability assessment, environmental monitoring, mitigating natural hazards, and gathering of biological and other data (Brodnig & Mayer-Schonberger, 2000; Huntington, 2000; King et al., 2007; Stevenson, 1996; Voyde & Morgan, 2012). The importance of TEK has also been acknowledged in national (e.g. Assembly of First Nations and Inuit Circumpolar Conference, 1991; Ministry for the Environment, 2000) and global reports (Brundtland, 1987; United Nations, 1993b), but there is an overriding issue of it being underutilised and unmaintained.

### **3.1.4. Engagement with Māori**

Throughout the decades, a sizeable amount has been written about Māori history, culture, traditions, and other related subjects. The bulk of the research has been carried out by non-Māori (typically of European descent). Many early researchers of Māori culture, such as Augustus Hamilton, used aggressive and violating techniques to attain knowledge including the exploitation of Māori chiefs, theft of artefacts, and collection of human remains (Jahnke & Taiapa, 2003, p. 40). There is an increasing awareness amongst Māori that they fulfil the role of the “guinea pig” within academic research, research which often only defines problems rather than solutions (Jahnke & Taiapa, 2003, p. 39; Stokes, 1985). To counteract this exploitative research, researchers have asserted that Māori-based research should clearly benefit the community and be undertaken with sensitivity, respect, and transparency (Jahnke & Taiapa, 2003; Pipi et al., 2004; Te Awekotuku, 1991; Walker, 1995).

There has been much work surrounding the process of developing robust and functional guidelines for Māori engagement. For example, Landcare Research, a governmental Crown Research Institute, has outlined several ways to develop and maintain a relationship with Māori iwi such as: adhere to and respect cultural or political protocols; understand and empathise with Māori issues; have a personal interest rather than be merely research focused; keep regular contact with iwi (e.g. networking, face-to-face visits); demonstrate a sense of long-term commitment and a willingness to help (Landcare Research, 2012). Several others (e.g. Cram, 2001; Mead, 1997; Smith, 1999) have also defined similar guidelines to facilitate Māori engagement and stress the importance of looking and listening, forming a reciprocal and collaborative research approach, and ensuring informed consent. In particular, Bruges and Smith (2009) stress that any process should address Māori’s “diverse, complex social, economic, or environmental issues”, and be an “iterative process of negotiation” (p. 218). Indeed, kaupapa Māori research, a foundational Māori ideology increasingly used in research approaches, embodies all of the aforementioned characteristics.

Kaupapa Māori is a term that describes “traditional Māori ways of doing, being, and thinking, encapsulated in a Māori worldview” and, by extension, kaupapa Māori research

“embraces traditional beliefs and ethics, while incorporating contemporary resistance strategies that embody the drive for tino rangatiratanga (self-determination and empowerment) for Maori people” (Henry & Pene, 2001, pp. 235-236). Kaupapa Māori research, therefore, exemplifies the phrase “for Māori, by Māori, with Māori” (Smith, 1997), and has strategically reoriented social science research practices towards meeting the needs and aspirations of Māori communities (Ahuriri-Driscoll et al., 2011).

Indigenous communities across the world are increasingly being recognised for their right to participate in decision-making due to their unique traditional and cultural views of land and resource use (e.g. United Nations, 1993b), and Māori are no exception. Environmental researchers (e.g. Jollands & Harmsworth, 2007; Maynard, 1998) highlight the importance of engaging with Māori early on in decision-making processes, allocating appropriate resources (e.g. funding), being open to cross-cultural interaction, and embracing varying perspectives. Henwood and Henwood (2011) recommend that “the starting point for long-term sustainable environmental action is collaboration and cooperation among multiple community and agency stakeholders” (p. 226). Similarly, carbon farming work on Māori land by Funk and Kerr (2007) advises the use of a participatory approach in order to ensure a culturally sensitive project.

In his review of Māori perspectives, Harmsworth (2011) identified three core capital areas which need to be strengthened in order to progress Māori involvement and contribution to science and innovation within New Zealand:

1. Cultural capital (e.g. Māori language, values, knowledge)
2. Human, social and technological capital (e.g. Māori professional and personal networks, community interaction, scientists)
3. Physical and economic capital (e.g. Māori assets and economy, scientific resources)

Each of these capital dimensions should also be aligned with Māori ambitions, goals, and priorities in order to “untap” Māori potential.

Furthermore, key aspects regarding sustainable Māori development and engagement include the importance of: creating a holistic framework (including wide ranging consultation and involvement); empowerment through member involvement;

strengthening of Māori pride and identity; and using Māori values and expectations to guide strategic development decisions (Loomis, 2003; Loomis, 2000).

## **3.2. Māori connection to the land and to forestry**

### **3.2.1. Kaitiakitanga**

Māori are tangata whenua (people of the land) and have a symbiotic relationship with the natural world (Henwood & Henwood, 2011; Marsden & Henare, 1992; Mead, 2003), believing that if you nurture the land it will nurture you. Māori and the natural world are often inextricably linked as the well-being of the former is dependent on the health of the latter (Mead, 2003). Therefore, conservation and sustainability are fundamental concepts within the Māori culture and worldview, the foundation of which is the traditional practice of “kaitiakitanga”.

Roberts et al. (1995) define kaitiakitanga as an implication of guardianship and protection of the mauri (life force) of all taonga (treasured land, people, and resources). Although descriptions and expressions of kaitiakitanga may vary between iwi and hapū, it often signifies a distinct connection between people and the environment (Boulton, Hudson, Ahuriri-Driscoll, & Stewart, 2014; Crengle, 1993; Harmsworth, 2011; Kawharu, 2000; Roberts et al., 1995). Furthermore, two pivotal environmental planning statutes (*Resource Management Act 1991* and *Fisheries Act 1996*) give specific recognition to kaitiakitanga; this incorporation is viewed as a significant achievement for Māori environmental values (Jones, 2000). Kaitiakitanga has also been documented as being integral in protecting and enhancing New Zealand’s biodiversity (Morad & Jay, 2000), wetland ecosystems (Forster, 2012), sustainable forestry (Asher, 2003), cultural well-being (Dalziel et al., 2006), and even business enterprises (Bargh, 2012; Spiller, Pio, Erakovic, & Henare, 2011).

### **3.2.2. Forestry and resource management on Māori land**

The development and management of Māori land and resources are not necessarily progressed through a formal compartmentalised set of processes with only economic

profit as a priority. Kaitiakitanga prioritises the use of comprehensive environmental management approaches which balance cultural, social and environmental values with financial investments and gain (Loomis, 2003). Yet, Māori land use is complicated by the fact that any given site may hold a range of values: from tourism to ancestral resting places to culturally valuable craft-making material (Jones, 2000).

New Zealand's Business and Economic Research Limited group has estimated Māori assets and associated economy to be valued at nearly \$37 billion in 2010; much of this value is dominated by farming, forestry, fisheries, and other land and resource-based activities (Nana, 2012). However, it is also recognised that there are several challenges that contribute to the Māori decision-making process regarding assets such as small and fragmented land holdings, vague authoritative processes, lack of decision implementation strategies, and restrictive ownership legislation (Nana, 2012).

Māori own a significant amount of forested land<sup>4</sup>: 520,000 hectares of exotic forest land (30% of New Zealand's exotic forest land), and 600,000 of indigenous forests (Holt & Bennett, 2014). Much of planted (exotic) forested land was previously managed by the New Zealand Forest Service<sup>5</sup>, yet when this government agency was comprehensively restructured in 1987 to controversially favour corporatisation and privatisation of public assets many of the harvesting rights to the planted forested lands had been sold to private, mostly foreign companies (Walker, Cocklin, & Le Heron, 2000). The lease agreements with the private companies were often regarding forests on Māori ancestral land, and did little, if anything, to include and respect Māori cultural considerations – a devastating act since the leases effectively alienated Māori from their right to access and manage their own lands. However, the amount of Māori forested land is set to rise due to two main factors: 1) the expiration of the privately-held lease agreements (thus returning the rights of the land back to Māori), and 2) the Waitangi Tribunal<sup>6</sup> and future land claim

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<sup>4</sup> Māori land refers to “land that has not been alienated from Māori tribal ownership following colonisation” (Rotarangi, 2012, p. 1679)

<sup>5</sup> Established in 1919, the New Zealand Forest Service was responsible for managing the forestry, conservation, and recreational aspects of New Zealand's state-owned forests. At the time, the New Zealand government was concerned about the rapid rate of deforestation due to the progression of a pastoral economy and predominantly pursued the intensive planting of the non-native radiata pine to re-establish forests whilst providing economic and social benefits.

<sup>6</sup> Resulting from the *Treaty of Waitangi Act* 1975, the Waitangi Tribunal is a government-led court which reviews and settles claims made by Māori regarding the unlawful dispossession of their ancestral lands and resources (Bourassa & Strong, 2002). Over 700 claims have been made with still many requiring settlement.

settlements. As a result, Māori will have more direct control of their forest land and are looking at a range of future options rather than simply replanting with radiata pine.

Forestry and its socio-economic benefits in particular have often been of high interest to Māori. For example, the East Coast Forestry Project<sup>7</sup> (ECFP) was a government grant scheme for commercial forestry which aimed primarily to ameliorate the erosion-prone lands of the eastern region of New Zealand's North Island (Cocklin & Wall, 1997). Of all the iwi in the region, Ngāti Porou held the majority of land in the area and therefore was the most involved in the ECFP. Ngāti Porou identified benefits which could arise from their involvement with the ECFP such as long-term economic growth, employment opportunities, and erosion control, but perhaps most importantly, spiritual and cultural survival (Cocklin & Wall, 1997).

Forestry is multifaceted, and can represent an array of benefits (or hindrances) to a variety of stakeholders. To begin to understand the views of Māori landowners regarding planted forestry on their ancestral land, recent social engagement work was undertaken in the central North Island region. Rotarangi (2012) demonstrated that the Māori participants in the study were unanimously supportive of forestry on their lands, and were particularly in favour of sustainable forest management options (in addition to radiata pine forestry) which could protect their cultural practices as well as provide environmental benefits. Although forestry as a land use was fully accepted, the land management structure in the area was generally viewed to be restrictive (e.g. long-term land lease agreements). To ease any frustrations, Rotarangi (2012) identified four key areas to help improve forest management for Māori-owned land: (1) increase the flow of information; (2) create more opportunities for secondary businesses to run alongside forestry (e.g. growing ginseng); (3) enhance community identity and pride relating to the forest; and (4) reinstate the traditional names to the forest through signage of roads and landmarks.

In addition, several others have highlighted how forestry can meet key objectives and aspirations of Māori landowners (e.g. Fairweather et al., 2001; Groome, 1994; Parore, 1983). The Māori business perspective tends to differ from 'traditional' Western business models as Māori (owners, stakeholders, beneficiaries) often attach greater importance to

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<sup>7</sup> The East Coast Forestry Project rebranded in 2014 and changed its name to the Erosion Control Funding Programme.

other non-market outcomes besides financial gains such as environmental, social and cultural benefits (Best & Love, 2010; Funk, 2009). Therefore, to many Māori, the economic value of forestry may be quite different from its total value; Best and Love (2010) suggest that this difference is largely due to the value that Māori place on preserving, protecting, and enhancing their culture and cultural values.

The New Zealand government is committed to sustainable management and the “quadruple bottom line” (social, economic, environmental, and cultural well-being) approach, as seen within both the *Resource Management Act 1991* and the *Local Government Act 2002*. The quadruple bottom line focus is also prevalent in Māori business governance and resource management (Phillips, Woods, & Lythberg, 2014). This therefore supports the focus in this PhD research on performing a quadruple bottom line LCSA study on forestry options for Māori landowners.

### **3.3. Forestry and forest management**

This section summarises the current state of forestry and forest management in New Zealand (Section 3.3.1), and discusses what is meant by sustainable forest management - including the importance of active stakeholder engagement (Section 3.3.2). In addition, the fundamental life cycle processes involved in a forestry value chain are reviewed (Section 3.3.3). It is concluded that there is potential for New Zealand forestry to progressively pursue more sustainable and participatory measures (Section 3.3.4).

#### **3.3.1. Forestry in New Zealand**

New Zealand has substantial areas of indigenous forests (6.8 million hectares and 26% of land area) and also planted exotic forests (1.77 million hectares (net stocked) and 7% of land area) (Ministry for Primary Industries, 2015a). The indigenous forests contain various native species such as rimu and mānuka, while the planted forests are predominantly (87%) radiata pine (Ministry for Primary Industries, 2015a). Furthermore, indigenous forests exist on both public and private lands, and small amounts of timber can be harvested on private lands (in accordance with requirements from *The Forests Act 1949*).

Both indigenous and planted forests provides distinct benefits; plantations are generally managed to maximise economic returns while nature reserves provide the majority of forest-based biodiversity and recreation. Although, multiple-use forestry (i.e. managing forested lands to achieve a variety of objectives) is not a common practice in New Zealand (Maclaren, 1996) there are some examples where planted forests have been instigated for intentions in addition to economic gain such as erosion control, land rehabilitation, carbon sequestration, and improvement of water and soil quality (Ministry of Agriculture and Forestry, 2011; Rhodes & Stephens, 2014). The associated additional benefits of planted forests (albeit arguably unintentional) include habitat creation for a variety of biodiversity species (Borkin & Parsons, 2010; Yao et al., 2014), the potential for recreation (Dhakal, Yao, Turner, & Barnard, 2012), and other societal benefits (e.g. employment, paid hunting, food gathering) (Dyck, 2003)

However, various drivers such as the Montreal Process (Ministry for Primary Industries, 2015b) and certification (e.g. Forest Stewardship Council, Programme for the Endorsement of Forest Certification) are increasing the focus on sustainable forest-management practices (Rhodes & Stephens, 2014). Certification in particular requires the forest owner/operator to demonstrate that their forest management is economically viable, environmentally appropriate and socially beneficial. Having this accreditation (presumably) helps New Zealand forest products compete in key markets where customers are concerned about the sustainability of products they purchase. Furthermore, a study by Fairweather and Hock (2004) identified a growing interest amongst New Zealand foresters in sustainable forest management and alternative species in addition to radiata pine. Māori own over 1.1 million hectares of forested land (Holt & Bennett, 2014) and show particular interest in indigenous species. Yet, movements to adopt alternative management techniques and/or species can be hampered by the success of current practices (Kennedy, Dombeck, & Koch, 1998).

Radiata pine comprises 87% of New Zealand's planted forest area (Ministry for Primary Industries, 2015a), and contributes in excess of 90% of the annual volume harvested. The harvested logs can be manufactured into a wide range of products: structural and appearance lumber, packaging lumber, plywood, laminated veneer lumber (LVL), medium-density fibreboard (MDF), particle board and a variety of pulp and paper

products. New Zealand exports substantial quantities of sawlogs annually (16.5 million m<sup>3</sup> in 2014 – from a total cut of 30.235 million m<sup>3</sup>). Nearly all (99.9%) of these logs originate from planted forests (as opposed to natural forests) (NZFOA, 2011), and approximately 54% are unprocessed. Wood exports already comprise New Zealand's third largest export industry after dairy and meat/wool (NZFOA, 2014) but there is potential to further develop and enhance New Zealand's forestry industry by processing more sawlogs in the country instead of focussing on their export in raw form.

The New Zealand forestry sector may, therefore, benefit from exploring a range of other forestry options (and associated resultant products) in addition to the well-established radiata pine industry. Such diversification of forestry (including species and also management techniques) and wood-product manufacturing has the potential to enrich, broaden, and strengthen the New Zealand forestry sector.

### **3.3.2. Forest management and sustainability**

There are a myriad of ways in which a forest can be managed as well as for a variety of objectives. Forest management can be broadly defined as a “set of rules and techniques that people devise to maintain forested land in a desired condition, including the processes through which the rules and techniques are adapted to deal with changing circumstances” (Rietbergen, 2001, p. 2). Essentially, forest management is the process of deciding what to do with a forest whilst considering the socio-economic implications of doing so and the forest's capabilities (or limitations) (FAO, 1994).

Forestry has four distinctly different traits to other land uses: 1) forests can provide a multitude of other benefits besides a designated volume of timber; 2) a forest's lengthy growing phase requires adaptation to a frequently changing market as well as the consideration of delayed returns; 3) a variety of products can be made out of a single tree; and, 4) forestry can occur on a land which is remote, mountainous, and inaccessible which has implications for the employees needed for maintenance and harvesting (Osmaston, 1968). Therefore, forest management must be flexible and adaptable.

Various types of forest management have been explored and developed so that specific objectives could be achieved. Management can be classified in a variety of ways according (but not limited) to desired stand structure (e.g. even-aged, uneven-aged) or eventual harvesting technique (e.g. clearcut, small patch removal, seed-tree retention) (Mitchell & Beese, 2002). Duncker, Spiecker, and Tojic (2007), for example, organise forest management into five distinct alternatives which sit along a gradient of management intensity. The alternatives, ranging from least intensive to most intensive, are: forest nature reserve, close-to-nature (aka – continuous cover forestry), combined objective, intensive even-aged and short-rotation forestry.

Historically it was often thought that forest sustainability was the efficient act of balancing the rate of timber harvesting with forest growth. However, forest use and management has generally evolved from focusing on timber production to ensuring that the central focus is on forest ecosystems and their associated processes are being managed sustainably (FAO, 1994; Kennedy et al., 1998; United Nations, 1993a). Sustainability is often considered a long-term, trans-generational concept involving a degree of uncertainty, and the holistic integration of economic viability, ecological wellbeing, and social responsibility (Ikerd, 1997; Kant & Berry, 2005; Kennedy et al., 1998). Forest-specific sustainability is defined as the “capacity of forests, ranging from stands to eco-regions, to maintain their health, productivity, diversity, and overall integrity, in the long run, in the context of human activity and use” (Helms, 1998; Oliver & Deal, 2007, p. 144).

Thus, sustainable forest management can be perceived as based upon a set of comprehensive values. The pillars of sustainability (social, environmental, economic, and cultural) can also be seen as underpinned by scientific, recreational, aesthetic, wildlife, biotic, natural history, spiritual values (Rolston & Coufal, 1991). Overall, sustainable forest management requires that timber production occurs within a context of maintaining the health and integrity of the surrounding forest ecosystem (both at local and landscape levels) and other non-timber values (Lindenmayer, Margules, & Botkin, 2001).

As forest management becomes more inclusive of societal needs and demands, the importance of engaging with stakeholders (e.g. decision-makers, landowners, politicians,

community members, timber industry) has been increasingly recognised (Rotarangi & Thorp, 2009). Particularly at a local level, this type of management, often called “participatory forestry”, has demonstrated the potential to incorporate the intimate knowledge and objectives of local participants into the forest management strategies (Salam, Noguchi, & Koike, 2005).

Armitage et al. (2008) argue that resource management, including that of forestry, is in need of reinvention. With competing, conflicting, and complex social values and expectations, adaptive co-management may encourage active communication and collaboration between stakeholder groups. Moreover, there is a significant amount of evidence which shows that involving stakeholders may help to generate more valuable and robust decisions during the process of environmental management (Reed, 2008). However, Reed (2008) advises that contributions from stakeholders should be sought early and often during the decision-making processes, and to ensure key objectives of such engagement are clear from the outset.

Therefore, successful integration of forest management and stakeholder participation may lead to a positive and influential partnership, one which is mutually beneficial as knowledge is transferred between both parties to overcome limitations and identify optimal solutions. Such an integration aligns well with the Māori engagement guidelines discussed earlier in Section 3.1.4.

### **3.3.3. Forestry life cycle processes**

The forestry life cycle is comprised of a series of processes from “cradle” (e.g. forest growth) to “grave” (e.g. burning of wood fuel). Lindner et al. (2010) describe forestry life cycles as “value-adding production processes by which forest resources are converted into products and services” (p. 2198). The forestry life cycle (see Figure 3) depicts the flow of resources and their transition from a raw material into a product or service.

The forestry life cycle begins with the growth and cultivation of a forest. This phase may involve preparation of the site for planting, establishment of seed or seedlings, tending such as weeding and pest control, and thinning of the forest stand (i.e. the removal of

poorly formed trees to allow room for the best trees to further develop (Maclaren, 1993). Depending on the tree species and the overall forest management intentions, the forest growth stage may last a few years, a few decades, or even a few centuries.

The next phase is the harvesting or felling of trees. This is a critical stage for optimising the value from each log and, as Maclaren (1993) states, represents a “golden opportunity to waste money, if incorrect practices are adopted” (p. 96). Harvesting often requires a high level of expertise to ensure that all associated operations occur efficiently and effectively, thereby maximising log value, minimising costs, waste and damage to the tree, and complying with environmental and safety standards. Harvesting can be done with a single operator and a chainsaw or a team of operators and mechanised harvesters.

Once the tree has been felled then it must be extracted from the harvesting site. In many intensive forestry operations extraction typically occurs using a skidder (a purpose-built machine which lifts the logs on one end and drags them out of the forest), or a cable hauler (a logging system that pulls the logs out along a cable which is attached to a tower). The skidder is most commonly used on flat terrain whilst a cable hauler is used on steep gradients where machines are unable to operate. Other extraction techniques range from a traditional horse-drawn method to use of a helicopter to air-lift the log out. The logs are extracted to a skid/landing site where the whole logs are loaded to a logging truck which transports the logs to an appropriate processing plant such as a sawmill.

The next phases include the primary processing and, if needed, secondary processing (i.e. manufacturing) stage. The primary processing phase typically occurs at a sawmill and is any processing that uses logs as its main feedstock. Therefore, it also includes pulp and paper, medium density fibreboard, laminated veneer lumber and plywood. The secondary processing stage is where the sawn timber from the primary processing stage can be further utilised and manufactured into a product such as furniture.

New Zealand exports approximately half of all the sawlogs it produces (13.8 million m<sup>3</sup> annually (NZFOA, 2011)). This significant exportation of unprocessed logs represents a great opportunity to examine the full life cycle of forestry; doing so will help to better understand the potential for further developing the log processing industry and for capturing the added value that is gained during processing.

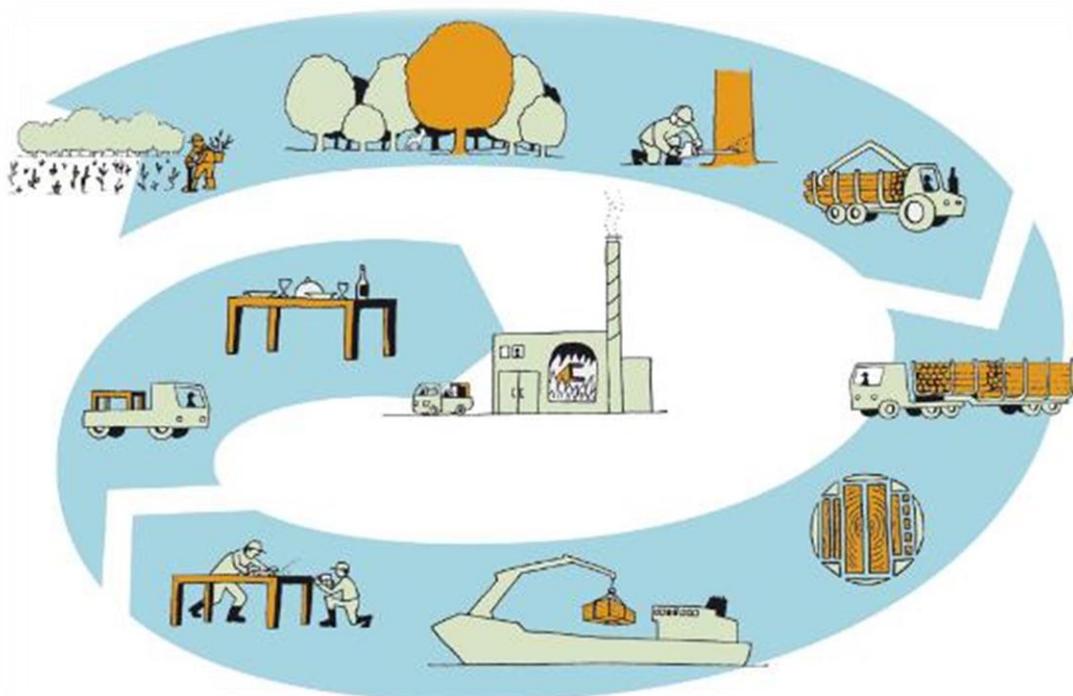


Figure 3. Forestry life cycle with forest management occurring during the beginning stages of forest growth and harvesting (Lindner et al., 2010).

### 3.4. Conclusions

As decision makers, Māori are often strongly influenced by their cultural traditions and aspirations. Their decision making process, therefore, may be considered holistic as many Māori seek solutions that meet a range of needs – not just economic ones. Certainly the quadruple bottom line focus (environmental, economic, social, and cultural) is relatively common throughout Māori business and resource management.

Forestry represents a major asset base of the current Māori economy inclusive of a sizable amount of radiata pine forestry. However, many Māori landowners indicate a desire to pursue and maintain sustainable forestry options on their land, in particular, forestry of indigenous species. Information associated with the development and implementation of such forestry options must align and meet the comprehensive aspirational needs of Māori landowners.

Forestry in New Zealand is predominantly intensive radiata pine forestry or native forest reserves; there is significant potential to diversify forestry options regarding species, forest management, and forest products. Indeed, sustainable and multiple-use forestry is gaining recognition.

The main findings and knowledge gaps of the literature review presented in Chapters 2 and 3 include the identification of the lack of culturally-focused sustainability assessment tools, the lack of distinct cultural representation in the LCSA methodology, the lack of progressive and participatory sustainable forestry measures in New Zealand, the lack of utilising a full life cycle perspective in forestry, and the lack of sustainable forestry options for Māori landowners. Therefore, this PhD research aimed to address these aspects by exploring if: (1) culture can be distinctly represented in LCSA, and (2) if the resultant culturally-focused LCSA can be used to meet holistic Māori decision making needs during the pursuit of sustainable forestry options for their land.

## **Chapter 4**

### **4. Methodology**

Resulting from the detailed literature review on culture, LCSA (and its components), the Māori worldview, and forestry, the overall theoretical framework for this PhD research is based on the following four key tenets:

1. The recognition and inclusion of culture within sustainability assessment methodologies is generally lacking worldwide. Yet a comprehensive assessment process addressing the quadruple bottom line (environmental, social, economic, and cultural) could be beneficial in the decision-making process. This process may be of use for Māori land owners as they strive to make educated and balanced land management decisions which also account for their values and aspirations.
2. LCSA is an emerging methodology which currently represents environmental, social, and economic impacts associated with the life cycle of a product or service. Whilst cultural considerations in LCSA have rarely been incorporated (e.g. Ketola & Salmi, 2010) and indigenous culture has never been distinctly represented, the potential exists to do so. Furthermore, LCSA is likely to be a suitable decision making tool to use in Māori decision-making processes because both LCSA and Māori culture adopt a holistic and comprehensive viewpoint; focus on sustainability and sustainable development; engage a long-term systems thinking approach; and consciously apply values within decisions and decision-making.
3. The forestry value chain in New Zealand is largely limited to the intensive production of radiata pine which is often then exported as raw logs. However, there is more potential to diversify forest management practices and to extend the value chain into log processing and product creation. These opportunities should be explored in order to encourage long-term sustainability of the New Zealand forestry sector, and LCSA provides a mechanism for facilitating this exploration.
4. Māori land owners are in a position to consider such diversification of the forestry value chain. Yet, the information sought by Māori to make decisions regarding their land and communities often needs to be inclusive of more than just economic considerations. Indeed, Māori are holistic decision makers and require

information encompassing the quadruple bottom line of economic, social, environmental, and cultural aspects. LCSA may be a suitable platform for providing this information.

A theoretical framework and supporting methodology were developed for the PhD research based on the findings noted above. Two fundamental characteristics of this research were utilisation of participatory and mixed methods approaches. This chapter provides an overview of the reasoning and the methods that were employed in the research.

This participatory LCSA research involved close collaboration with three members of the Ngāti Porou iwi (tribe) from the Waiapu catchment (in the eastern region of New Zealand's North Island). This chapter presents the foundational components of the participatory LCSA (Section 4.3), reviews the aspirations of the Ngāti Porou participants (4.3.1), and discusses the qualitative interview process (Section 4.4).

#### **4.1. Theoretical framework of research**

This section presents the outline and justification for the theoretical framework used in the research as well as the underlying research paradigms.

To use terms highlighted by Guinée (2016) in his recent review on current LCSA research trends, the research aims of this dissertation sought to 1) “broaden” the scope of LCSA impacts by distinctly representing culture, and 2) “deepen” the research approach by utilising participatory techniques throughout the LCSA process. The participatory aspect itself was based on a methodological approach developed by the Dutch Sustainable Technology Development (DSTD) programme (Weaver, Jansen, van Grootveld, van Spiegel, & Vergragt, 2000) which focuses on the integration of goals, values, and aspirations when attempting to achieve a desired future. The DSTD methodology suggests that focusing on the future desired state (i.e. goals and aspirations) of the stakeholders during the initial stages of research will help to minimise the “loss of creativity resulting from being bound mentally in the possibilities of the present” (Jansen, 2003, p. 243). In addition, addressing goals and aspirations in research is particularly

useful for assessments with a long-term horizon, e.g. forestry (Bras-Klapwijk, 2003). The steps of the DSTD methodology include identifying the problem, developing potential alternative solutions, using models to assess each alternative, comparing and ranking the results, and, finally, communication of the results. Each of the steps and the process as a whole are both iterative and interactive. The methodology also stresses the importance of recognising culture as well as involving stakeholders; doing so is viewed as essential to generate and maintain support of the research and to facilitate uptake of the results.

The synergies between the DSTD programme methodology and the aims of this participatory LCSA research are numerous (e.g. focus on culture, involvement of stakeholders, and achieving long-term aspirations). Therefore, the methodology was only slightly adapted for use in this participatory LCSA research (see Figure 4). Indeed, adaptation of an existing and tested methodology for use in this dissertation also provides added rigour and robustness. The resulting adapted methodological approach reflects an LCSA process that was “deepened” to incorporate the participatory aspects of the DSTD methodology. It is worth noting, however, that the fundamental structure of the LCSA process (i.e. goal and scope definition, inventory analysis, impact assessment, and interpretation) remained unchanged. Furthermore, the stages outlined in Figure 4 directly align with the LCSA process: the first, second, and third stages align with the “goal and scope definition” phase; the fourth stage aligns with the “inventory analysis” and “impact assessment” phases; and the fifth stage aligns with the “interpretation” phase.

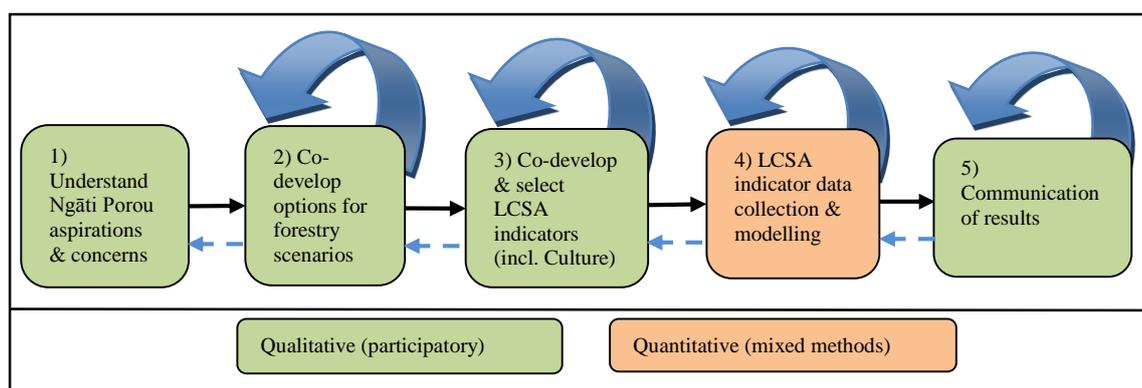


Figure 4. Adapted methodological approach to be used during PhD case study. Arrows above and between boxes indicate an iterative process. Stages 1, 2, 3, and 5 are predominantly qualitative (using participatory techniques) whilst Stage 4 is predominantly quantitative (using mixed methods techniques). Stages 1, 2, and 3 align

*with the “goal and scope definition” phase; Stage 4 aligns with the “inventory analysis” and “impact assessment” phases; and Stage 5 aligns with the “interpretation” phase.*

The methodological approach outlined in Figure 4 encompasses five main stages. The first stage of understanding Ngāti Porou’s goals, aspirations, and concerns helped to articulate and develop their long-term visions (these are presented in Section 5.1.2). Such contextual knowledge of Ngāti Porou’s ambitions was essential to ensure that the LCSA research aligned with the ultimate aspirations of the iwi. The second stage was to collaboratively co-develop (with the participants) options for forestry scenarios they felt may help to achieve their aspirations. The third stage was to co-develop and select indicators for use in the LCSA research. To represent culture distinctly in LCSA involved the creation of a bespoke cultural indicator; this process relied once again on collaboration and involvement from the Ngāti Porou participants. In addition, the third stage of the methodology is where the first research question was answered (i.e. how can Māori culture be represented in LCSA studies involving forestry value chains options). The fourth stage focused on data collection and modelling to achieve the LCSA results for each of the forestry scenarios. This was the only stage that was predominantly quantitative, and where the mixed methods approach (discussed in Section 4.2.2) became more evident. The final stage (Stage 5) was centred on discussing, reviewing, and communicating the final LCSA results. This stage was critical for understanding how the LCSA results may potentially be utilised in Ngāti Porou’s decision-making process and to what effect. Therefore, the fifth stage answered the second research question (i.e. what are the relative benefits and disadvantages of using LCSA in Māori decision-making situations).

## **4.2. Research paradigms**

Research paradigms aid the search for knowledge. There is no single method or “one size fits all” approach to attaining information about the world and its inhabitants. A number of paradigms have been developed which assist those seeking information in how they identify, gather, and interpret data. The following discussion reviews and critiques various paradigms to ascertain the best approach for answering the research questions of this dissertation.

Perhaps the two most prevalent paradigms are that of a positivist approach and a constructivist approach (the latter is also referred to as “interpretive”). Positivism has prevailed throughout centuries of scientific pursuit where there was a prized convenience in assuming that natural phenomena could be broken down into distinct pieces suitable for examination. Indeed, using a positivist approach, the complex building blocks of the natural world could be objectively dismantled; thus one could then understand and use the underlying persistence in their relationships to confidently create plans with predictable outcomes (Khakee, 2003; Wheatley, 1992). Relying of empirical- and analytic-based knowledge (i.e. the objective reporting of experimental observations and measurements), a positivist approach will typically disengage a given experiment or study from contextual elements such as social or historical factors (Kruger & Sturtevant, 2003; Williams & Slife, 1995). Based on the laws of “harmonious patterns or regularity” seen in nature, the positivist approach assumes a degree of similar regularity exists within social experiences; the same scientific principles used to discover natural cause-and-effect” phenomena can be used to discover social phenomena (Reza, 2007).

Yet, the shortcomings of the positivist approach (particularly when used in social research) have been recognised in numerous studies (e.g. Breu & Peppard, 2001; Deetz, 1996; Reason & Bradbury, 2001). Some critics (e.g. Reza, 2007) argue that the prescriptive disposition of positivism can not only obstruct scientific progress but cause its destruction it as well. The research process has subsequently grown from developing knowledge based on observation to also recognise the value of obtaining knowledge based on experiences (both of the “researcher” and the “subject”); the latter paradigm is commonly known as the constructivist approach (see Table 4).

*Table 4. The differences between positivism research (empirical and analytic) and constructivism research (interpretive) (Kruger & Sturtevant, 2003, p. 26).*

	Positivism	Constructivism
Inquiry aim	Explanation: - Prediction and control - Generalisability - Representativeness	Understanding: - Improved relationships - Partnerships - Particularity
Quality criteria	- Internal and external validity - Reliability - Objectivity, research assumed “value free”	- Clarification - Generation of discourse and inquiry - Recognition of values

<b>Approach</b>	<b>Reductionist:</b> - Fragmenting and static - Focus on things - Decontextualising - Separation of theory from practice	<b>Holistic:</b> - Dynamic - Focus on relations - Recognises multiple realities - Theory and action inform each other
<b>Role of researcher, knowledge</b>	- Researchers discovers and verifies truth - Privileges knowledge of researcher	- Researchers facilitates participation in construction of knowledge - Participants as researchers, researcher as participant
<b>Types of knowledge</b>	- Knowledge based on empirical-analytic scientific model - Instrumental - Verified hypotheses	- Local, indigenous, traditional, and other forms of knowledge are valued along with scientific knowledge
<b>Communication styles</b>	Competitive, independent, exclusive	Collaborative, cooperative, inclusive
<b>Outcomes</b>	- Product oriented -Subordinates common knowledge - Disenfranchises people - Depreciates experiential, common-sense knowledge	- Process oriented - Recognises legitimacy of local knowledge - Empowers people to action - Creates knowledge accountable and responsible to ordinary people affected by it

### 4.2.1. Participatory approach

Related to the constructivist approach is the participatory research approach (Heron & Reason, 1997). Participatory research focuses on uniting the researcher and the subject as co-researchers so that knowledge and other outcomes derived from research can be achieved in a cooperative and mutually meaningful manner. Reason (1998) states that the foundation of the participatory approach is built on viewing the world as a “living whole” from which no one person can exist in isolation. Therefore, researchers are not distinctly separate from that which they wish to research. By using a participatory approach, researchers and their subjects co-create knowledge (Breu & Peppard, 2001; Reason, 1998). Knowledge can be based on direct or indirect (e.g. stories, metaphors) experience, theoretical concepts, and practical skills and capabilities (Heron & Reason, 1997). Although this approach is not new, the use of participatory methods in natural and social sciences (especially in Western cultures) has steadily become more established and commonplace.

Methodologies for participatory research differ between studies and can be applied using varying degrees of inclusiveness. Nevertheless, Pretty (1995, p. 1253) identified six common principles utilised during participatory research:

1. A defined methodology and systematic learning process,
2. Multiple perspectives,
3. Group learning process,
4. Context specific,
5. Facilitating experts and stakeholders, and
6. Leading to sustained action.

Participatory research (and its related technique of “participatory action research”) maintains a constructivist and interpretive-based focus not only on processes but also on the involvement of people (Kruger & Sturtevant, 2003). There is a focus on integrating action with knowing, and subjectivity with objectivity (Heron & Reason, 1997). Key terminology often found within this research paradigm include: collaboration, empowerment, motivation, open, exploration, cyclical, meaningful, education, well-being, interaction, holistic, and community accountability. The latter term of “community accountability” acts as one of the fundamental concepts of participatory research, and depends on: (i) open and free participation in identifying problems, goals, and concerns on behalf of those making or affected by decisions; (ii) creating comprehensible knowledge through collaboration between researchers and the local group; and, (iii) local people are active participants instead of passive objects in a study (Chesler, 1991; Gaventa, 1993; Kruger & Sturtevant, 2003; Maguire, 1987; Reza, 2007). It is seen as an essential element of participatory (and action-oriented) research that “the people who are to benefit from the research should participate in the research process” (Park, 1999, p. 142).

Despite certain challenges (e.g. potential for researcher to lose objectivity or credibility), the benefits of participatory research are well documented. In particular, it has been noted as pivotal in gaining both greater understanding of social phenomena and social acceptance in strategic decision making such as within resource management (Kruger & Sturtevant, 2003). Furthermore, the participatory research approach may also facilitate the development of trust between researchers and social actors or group members. It is

therefore entirely justifiable that the participatory research approach may be considered most appropriate when engaging with and designing research outcomes for communities.

However, it is important to align such participatory and collaborative research techniques with kaupapa Māori. First mentioned in Section 3.1.4, kaupapa Māori research is a critical theory, anti-positivist approach that “has provided a focus through which Māori people, as communities of the researched and as new communities of the researchers, have been able to engage in a dialogue about setting new directions for the priorities, policies, and practices of research for, by, and with Māori” (Smith, 1999, pp. 297-298). The application of kaupapa Māori research (and its embodied ethics and cultural considerations) is a participatory way of knowing that “privileges sharing, subjectivity, personal knowledge, and the specialised knowledges of oppressed groups” (Denzin & Lincoln, 2008, p. 14). Through kaupapa Māori, moral, ethical, and respectful research can exist and flourish.

#### **4.2.2. Mixed methods research**

Typically research is based on either quantitative or qualitative techniques, and many have strongly argued for their distinct separation and use. However, as political, educational, and stakeholder agendas have changed so too must the process of undertaking research. Trends such as these suggest a need for greater convergence of quantitative and qualitative techniques (Brannen, 2005) in order to “facilitate communication, to promote collaboration, and to provide superior research” (Johnson & Onwuegbuzie, 2004, p. 15); this convergence is termed “mixed methods research”.

Teddlie and Tashakkori (2008) define quantitative methods as “the techniques associated with the gathering, analysis, interpretation, and presentation of *numerical* information”, and qualitative methods as “the techniques associated with the gathering, analysis, interpretation, and presentation of *narrative* information” (pp. 5-6). One may choose to unite the two techniques depending on two contexts in the research process: (1) the context of enquiry (i.e. the type of questions being asked during the research design phase), and (2) the context of justification (i.e. how knowledge and belief are used to assess and interpret data) (Brannen, 2005). A mixed methods approach may be warranted

when the line of enquiry becomes more complex and the justification for converging quantitative and qualitative techniques to analyse data becomes greater. However, the context or logic of justification does not predetermine what research methodology should be used (Johnson & Onwuegbuzie, 2004; Onwuegbuzie & Teddlie, 2003).

Although there are many definitions of mixed methods research, for the purposes of this research the following definition will be used as defined by Johnson, Onwuegbuzie, and Turner (2007):

*Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (p.123)*

The use of mixed methods research is advocated especially within social and behavioural studies (Tashakkori & Teddlie, 1998, 2002; Teddlie & Tashakkori, 2008). Collecting data with a mixed methods approach may lead to a more holistic and complete understanding of results (Brannen, 2005) which may not have been achieved if either quantitative and qualitative methods had been used in isolation (Robins & Ware, 2008). It is mixed methods' holistic nature which makes it more culturally inclusive, since culture involves “collective, shared, and collaboratively constructed processes” (Moghaddam, Walker, & Harre, 2003, p. 113).

While quantitative techniques are considered to be objective-focused and qualitative techniques to be subjective-focused, mixed methods research has been associated with pragmatism. Creswell and Plano Clark (2011) define pragmatism as focusing “on the consequences of research, on the primary importance of the questions asked rather than the methods, and on the use of multiple methods of data collection to inform the problems under study (p. 41). The usefulness of associating pragmatism with the mixed methods approach is that it provides a common ground between quantitative and qualitative techniques; it is practical and actively seeks to achieve robust results; and it allows

researchers to select and mix methodologies to fulfil research objectives (Johnson & Onwuegbuzie, 2004).

Many authors support the use of mixed methods noting the similarities between quantitative and qualitative approaches. The objective of mixed methods research is not to eradicate the individual quantitative or qualitative techniques but instead to utilise their respective strengths to minimise their respective weaknesses (Johnson & Onwuegbuzie, 2004).

Even though mixed methods is thought of under a pragmatic paradigm, researchers may use multiple paradigms in their research so long as they explicitly state they are doing so (Creswell & Plano Clark, 2011). Therefore, as described in section 4.2.1, this PhD research will utilise both the participatory approach (i.e. empowerment and issue oriented, collaborative) and the pragmatic paradigm (i.e. focused on consequences of actions, real-world practice oriented).

The mixed method design which is most suited to this PhD research is that of “transformative design”. A transformative design is most suited to research wishing to progress the needs and aspirations of “underrepresented or marginalised populations” where the researcher is “sensitive to the needs of the population being studied, and recommending specific changes as a result of the research to improve social justice for the population under study” (Creswell & Plano Clark, 2011, p. 96). Transformative design is change-oriented and aims to empower individuals and/or communities by helping to facilitate positive change and action. Participatory research is often a fundamental component of the transformative design with stakeholder playing an active role in progressing the research. In addition, transformative design has been applied in such research fields as education (e.g. Li, 2002), infrastructure development (e.g. Van Gent et al., 2011), and health care (e.g. Stewart, Makwarimba, Barnfather, Letourneau, & Neufeld, 2008). Li (2002) identified that the interactive process of transformative design helped to solidify the collaborative spirit of engagement with participants, design visions and goals, enhance participatory relationships, and enable enlightened design thinking.

In order to most appropriately fulfil the objectives of the participants, transformative design may also utilise a variety of mixed method approaches and is not associated with

any one particular methodology. The mixed method approach which is most suited to this PhD research is an “embedded” approach. An embedded approach is considered appropriate because the LCA process (and by extension, the LCSA process) is a quantitative method, and, as a result, qualitative measures will be embedded into the quantitative LCSA process. Therefore, an embedded approach allows the researcher to combine the collection and assessment of quantitative and qualitative data within a conventional qualitative or quantitative framework (such as with LCA) (Creswell & Plano Clark, 2011).

### **4.3. Foundational components of the participatory LCSA research project**

Participatory engagement of LCSA stakeholders or end-users throughout the process of undertaking an LCSA study appears to be relatively uncommon and underdeveloped (Sala, Farioli, & Zamagni, 2012a, 2012b). Utilising a participatory approach within life cycle methodologies may lead to a number of benefits such as conscious recognition of the “plurality of stakeholder interests” and encouraging more interdisciplinary dialogue (Mathe, 2014). Indeed, “participation of stakeholders” is seen as a crucial criterion for sustainability assessment methodologies (e.g. LCSA), and the importance of this aspect has been acknowledged within LCSA frameworks (Guinée et al., 2011; Klöpffer & Renner, 2008). Limited utilisation of participatory approaches can be seen in E-LCA (e.g. Bras-Klapwijk, 2003; Elghali et al., 2006) and S-LCA (e.g. De Luca, Iofrida, Strano, Falcone, & Gulisano, 2015; Mathe, 2014), but there is no consensus about stakeholder involvement throughout the process of undertaking life cycle-based studies.

Although this participatory LCSA research project followed the methodological approach outlined in Figure 4, there was an important process prior to the initiation of the research which involved building rapport and relationships with the participants. This LCSA research relied on continuous and active engagement with three participants of Ngāti Porou descent: Tina Porou (T.P.), Pia Pohatu (P.P.), and Tui Warmenhoven (T.W.); the participants have chosen and given approval to be identified by name in this dissertation. Scion (New Zealand Forest Research Institute), one of the key funders of this research, has had extensive previous collaborations with these three participants (Scion, 2012;

Warmenhoven et al., 2014). Utilising guidance from the Māori-related collaborative research model by Harmsworth (2001), I, too, was able to build upon Scion’s successful affiliation to forge my own personal and professional relationship with T.P., P.P., and T.W..

The process of building trust and cooperation was progressed throughout the first year of the PhD research. I prioritised the actions of listening, observing, and learning: listening to their concerns and aspirations, observing their decision making process and passion for progress, and learning about their culture through visiting their community and completion of Māori language courses at Te Wānanga o Aotearoa in Rotorua. Learning some Māori language was especially important as it is culturally traditional and appropriate to offer a mihi (greetings) in Māori before meetings and presentations begin. Furthermore, as the project outline and objectives (i.e. the research questions) were developed and refined, I consciously focused on ensuring that these were in line with the needs and visions of the participants.

#### **4.3.1. Participants’ aspirations for the LCSA research project**

The participants themselves shared the same desire for the LCSA research project: to explore potential forestry options (and subsequent forest-related products) for their land whilst recognising their cultural aspirations and preferences. The Waiapu catchment (i.e. the LCSA research location; see Figure 5) is rapidly eroding and has significant potential for forestry (Scion, 2012); indeed the non-native radiata pine has been vigorously planted throughout the catchment. However, although the non-native radiata pine does provide some benefits such as employment, overall it is not considered by many in the catchment to be a “culturally appropriate” tree species (Int-9-TP). The participants therefore were interested in pursuing viable alternative forestry options including varying the tree species and the forest management style. In addition, although Ngāti Porou own the land they often have little interaction with the remainder of the forestry life cycle and generally do not have a hand in product development, production, or marketing. A clear objective of this research was to allow for greater consideration of the potential benefits and impacts of timber product creation.



the local people. Maintaining integrity and respect throughout the research process in turn created a high level of trust between myself and T.P., P.P., and T.W..

#### **4.4. Qualitative interviews**

This section describes the aspects of performing the qualitative interviews including a description of the participants, the structure of the interview process, and how the subsequent interview data was analysed and interpreted.

##### **4.4.1. LCSA participants**

As described in Section 4.3, three Ngāti Porou participants were recruited for involvement in this LCSA research project. These participants were selected for involvement due to the fact that they were working (at the time when I was beginning the PhD research) with Scion on building community resilience in the Waiapu catchment (Warmenhoven et al., 2014). They were approached by the manager of the aforementioned project and myself to gauge their interest in working on a tangent project (i.e. this LCSA research). They were enthusiastic and supportive of the proposed LCSA research and committed themselves to being the participants. An open call for participants from the wider Ngāti Porou community was not made as this LCSA research was considered too complex to involve many participants.

Each of the three participants are seen as leaders in their iwi and their community. Each are dynamic visionaries who are actively striving towards achieving measurable, on-the-ground progress for their land and people. And each have a variety of professional and personal strengths and distinctions which provided this research with invaluable expertise.

Tina Porou has a Master of Social Science, a Post Graduate Diploma in Māori and Pacific Island Development, and a Bachelor of Social Sciences (Double Major in Geography and Māori Development). She is a Trustee of Toitu Ngāti Porou and Pahitua Farm Trust, Director of Lake Taupō Forest Trust, and is a member of the Crown's Waste Advisory

Board and FSC Forest Certification: Māori Chamber. Her research specialities include Māori resource planning and management, and commercial development.

Pia Pohatu has a Bachelor of Resource & Environmental Planning and is currently obtaining her Masters in Indigenous Studies. She is a Trustee of Te Rohenga Tipuna o Hikurangi Trust (Hapū Cluster), a member of Te Aitanga A Mate Customary Fisheries Management Committee, Trustee and Secretary to Committee of Management (Proprietors of Pahiitaua & Other Blocks Incorporated and Akuaku A10 Inc.), Treasurer and Researcher of Kariaka Pa Committee (Ruatorea), and Treasurer and Finance Administrator Te Kōhanga Reo o Whakarua (Ruatorea). Her research specialities include mātauranga-informed, participatory research with/in Māori communities (whānau, hapū and iwi) promoting environmental and social restoration and well-being, leadership and benefit sharing.

Tui Warmenhoven has a Bachelor of Law LLB and is the Environmental Commissioner of the Making Good Decisions Foundation Programme as well as the Project Coordinator for the Uepohatu Education Strategy. She is a Trustee of Radio Ngāti Porou, a member of the Joint Governance Group (TRONPnui, Gisborne District Council, MPI) Waiapu Restoration Programme, a Director of Te Runanganui o Ngāti Porou, and the Ngāti Porou Co-representative of the Freshwater Advisory Group for the Gisborne District Council. Her research specialities include mātauranga Māori and sustainable development, collaborative research (between science and mātauranga), natural resource advocacy, and community development and capacity building.

#### **4.4.2. Interview process**

The purpose of the interviews was two-fold: 1) to educate me, the researcher, on the participants' views, opinions, assumptions, and understandings of the research topics, and 2) to provide a platform upon which the participatory LCSA engagement and co-development of LCSA results could occur. As noted in the methodology framework (Figure 4) four of the five stages involve and rely on participative engagement and input from the three participants. Thus, the LCSA research project could not have succeeded without the use of interviews.

A series of nine qualitative interviews took place over a period of approximately 18 months. There was no strategic reason for using a time span of 18 months; this was the amount of time needed to cover the five stages of the methodology while accommodating the busy schedules of the participants.

It was initially envisioned to hold group interviews however, due to scheduling conflicts, it was rarely possible to undertake interviews where all three participants were present. At first, this seemed like it might have a negative effect on the quality of the interviews and the information subsequently attained. However, I found that having the opportunity to occasionally hold interviews with one participant at a time was beneficial in that it allowed for in-depth discussion. Of course, interviews where two or more participants were involved were also very useful as the associated discussion often provoked further thought, opinions, and learning opportunities.

This research actively utilised participatory engagement techniques such as semi-structured interviews, a questionnaire, and frequent consultation with case study participants to develop and guide the research. The participants were involved at every step of the LCSA process, giving their impressions, recommendations, refinements, guidance, and approval. However, it was recognised by both the researcher (myself) and the participants that this was a two-way process, and that sometimes there would be a difference between the needs of the researcher (related to development of this PhD research) and the priorities of the participants. In these situations, the different priorities had to be transparently discussed and a way forward reached by consensus. For example, during the discussion and selection of environmental indicators to include in the LCSA research, the participants readily identified “erosion prevention” as an indicator of great interest. However, it is only applicable in the land preparation and forest growth phases of the life cycle. Therefore, for the purposes of the LCSA research which was focused on using a life cycle perspective, the participants were encouraged to select an indicator that spanned the entire life cycle of the forestry products; this resulted in selection of “climate change” as the environmental indicator. This indicator was not of high interest to the participants but was accepted by them as a compromise to meet the research priorities of the PhD researcher (myself).

Each interview was semi-structured and based around a few key open- and close-ended questions from which discussion was encouraged to organically flow. I made concerted effort not to lead the participants towards any one answer but to offer guidance and further information if they asked for it. See Appendix A for a compilation of interview questions.

To complete the methodological stages of co-developing forestry scenarios (Stage 2) and selecting and co-developing LCSA indicators (Stage 3), it was found to be beneficial to utilise visual aids (e.g. pictures, diagrams, PowerPoint presentations). For example, when reviewing potential forest management options it was useful to have pictures on hand so that the participants could better visualise the aesthetic difference between “intensive” management and “continuous cover” management.

There were nine significant interviews and several informal discussions that occurred throughout the case study. See Table 5 for more interview details. The table provides details on the number of interviews and who was involved in each, the coding for each interview which is used throughout the thesis, the subject discussed, and the methodological stage with which interview aligned. The order and flow of the subjects discussed directly align with the methodology outlined in Figure 4 (Section 4.1).

*Table 5. Summary of interview discussions, participants involved, and methodology stage(s) with which they aligned.*

	<b>Reference</b>	<b>Participant(s)</b>	<b>Subjects discussed</b>	<b>Stage(s) of Methodology</b>
Interview 1	Int-1-TP.PP.TW	Tina (in person), Pia and Tui (via Skype)	Previous research, Ngāti Porou aspirations, Ngāti Porou decision making	1
Interview 2a	Int-2a-TP.TW	Tina (in person), Tui (via Skype)	Forest management, tree species, timber products	2
Interview 2b	Int-2b-PP	Pia (via Skype)	Forest management, tree species, timber products	2
Interview 3a	Int-3a-TW.PP	Tui and Pia (via Skype)	Forestry-related aspirations and preferences	1, 2

Interview 3b	Int-3b-TP	Tina (in person)	Forestry-related aspirations and preferences	1, 2
Interview 4a	Int-4a-PP	Pia (via phone)	Forestry life cycle scenarios	2
Interview 4b	Int-4b-TW	Tui (via Skype)	Forestry life cycle scenarios	2
Interview 4c	Int-4c-TP	Tina (via phone)	Forestry life cycle scenarios	2
Interview 5a	Int-5a-TW.PP	Tui and Pia (via Skype)	Life cycle indicators and Cultural Indicator Matrix	3
Interview 5b	Int-5b-TP	Tina (via phone)	Life cycle indicators and Cultural Indicator Matrix	3
Interview 6	Int-6-TP	Tina (via phone)	Cultural Compliance process	3
Interview 7a	Int-7a-TP.TW	Tina (in person) and Tui (via phone)	Cultural Compliance process and Cultural Indicator Matrix	3
Interview 7b	Int-7b-PP	Pia (via phone)	Cultural Compliance process and Cultural Indicator Matrix	3
Interview 8a	Int-8a-TW	Tui (via Skype)	Review and refinement of the Cultural Indicator Matrix	3, 5
Interview 8b	Int-8b-PP	Pia (via phone)	Review and refinement of the Cultural Indicator Matrix	3, 5
Interview 8c	Int-8c-TP	Tina (via phone)	Review and refinement of the Cultural Indicator Matrix	3, 5
Interview 9a	Int-9a-TW.PP	Tui and Pia (in person)	Review and discussion of LCSA results	5
Interview 9b	Int-9b-TP	Tina (in person)	Review and discussion of LCSA results	5

### **4.4.3. Analysis of interview data**

The interviews were transcribed by the PhD researcher (myself); this ensured confidentiality whilst meeting the ethical considerations outlined in Section 4.5. Analysis of the interviews was done through “coding” – the process of “organising the material into chunks or segments of text in order to develop a general meaning of each segment” (Creswell, 2009, p. 227). During reviews of interview transcripts, dominant and reoccurring subjects were identified and ascribed a suitable and meaningful code. Codes were devised partly around the content of the questions asked and partly around the answers provided. For example, given that the PhD research is focused on forestry options, it was obvious that “forestry” would be a suitable code; yet, discussion arising from forestry-related questions often created justification for unforeseen codes such as “vision and willingness” and “future forestry needs”. Appendix B provides a complete list of codes used. To minimise researcher bias, a thematic overview of the codes used was informally reviewed by a third party (PhD supervisor, Dr Margaret Forster) who evaluated the codes for consistency and purpose.

The transcripts were then uploaded to QSR International’s NVivo 10 qualitative software analysis programme where the codes and associated coded material were highlighted. Further electronic analysis was made using the “query”, “explore”, and “view” functionalities of NVivo which allowed for easy identification of the leading themes arising from interviews. The use of NVivo can help to “improve the rigour of analysis” by allowing the researcher to verify their own impressions and interpretations of the data (Basit, 2003; Welsh, 2002). Analysis led to identification of the following dominant themes: forestry, decision making, mānuka, indicators (including “cultural indicator” and “cultural compliance”), forest management, and aspirations. Identification of dominant themes is an effective and practical way of checking that the qualitative data are addressing the research questions.

## **4.5. Ethical principles and conduct**

This PhD research engaged with three Māori (Ngāti Porou) participants, and actively sought their opinions, feelings, impressions, and insight into their aspirations for the

wellbeing of their land and community. This research ensured a sensitive and respectful approach by:

- Emphasising participatory engagement throughout the LCSA process.
- Co-developing forestry strategies and associated (social, cultural, economic, and environmental) indicators with the three Ngāti Porou stakeholders.
- Clear and mutual understanding of potential end uses, storage, and publication of cultural information.
- Prior to beginning research, attaining understanding and approval from the three Ngāti Porou participants that all research data will be used in my doctorate and that publications will be made.
- Before publication, the participants were consulted for their comments and feedback. Where relevant, the participants were also invited to be co-authors on journal publications.
- Before any presentations were made regarding the research, the case study participants were sent the presentations for their review and approval.
- Transcription of all audio recordings was done by me, the researcher, to ensure confidentiality of the discussions.
- Any cultural data will be given to Ngāti Porou after the project is completed.

Furthermore, the project received approval on September 16, 2013 from Massey University Human Ethics Committee (MUHEC): Southern B (Application – 13/58). See Appendix C for a copy of the MUHEC application approval letter. The MUHEC is based on foundational ethical principles of “respect for persons, minimisation of harm to participants, researchers, institutions and groups, informed and voluntary consent, respect for privacy and confidentiality, the avoidance of unnecessary deception, avoidance of conflict of interest, social and cultural sensitivity to the age, gender, culture, religion, social class of the participants, and justice” (Massey University, 2015, p. 4). Therefore, by receiving MUHEC approval, the objectives and processes of this research were consistent with the Massey University code of ethical conduct.

## **4.6. Conclusions**

The methodological framework outlined in this chapter focused on culture, involvement of participants, and recognising long-term aspirations of participants, and creating pathways towards achieving them. The resultant methodology includes five iterative and interactive stages: understanding Ngāti Porou aspirations and concerns (Stage 1), co-develop options for forestry scenarios (Stage 2), co-develop and select LCSA indicators, including culture (Stage 3), undertake LCSA indicator data collection and modelling (Stage 4), and communicate the LCSA results (Stage 5). Furthermore, the methodology incorporated participatory (qualitative) and mixed method (quantitative and qualitative) research approaches.

The methodology emphasises the active involvement of participants, and participation was achieved through a series of collaborative, semi-structured interviews. The interview process used a number of open- and close-ended questions which were designed to aid the organic flow of discussion. The results of the interviews directly supported the progression of the participatory LCSA research, and helped to ensure that all subsequent LCSA results are meaningful and useful to the participants.

## Chapter 5

### 5. Ngā takahanga waewae tuatahi – the first steps

This chapter describes the first three stages of the LCSA research (as outlined in Figure 4) and subsequent results. This involved developing an understanding of Ngāti Porou aspirations and concerns (Stage 1), collaboratively developing options for forestry scenarios (Stage 2), and development and selection of the LCSA indicators, including a cultural indicator (Stage 3).

A main focus of the research was co-development of a cultural indicator to sit alongside the other LCSA-based sustainability indicators (environmental, economic, and social). This methodology is presented in Section 5.4.1.

#### 5.1. Stage 1: Te iho o Ngāti Porou – the heart of Ngāti Porou

As the three participants involved with this LCSA research were of Ngāti Porou descent, it was important to understand the more recent historical events as well as current drivers of change within the region. A brief discussion of historical trends in the Ngāti Porou region is presented in Section 5.1.1 and such insights may be useful when interpreting Ngāti Porou aspirations. The aspirations of Ngāti Porou (Section 5.1.2) were defined and discussed, and their significant influence in decision making was highlighted. The decision-making process of Ngāti Porou was also reviewed (Section 5.1.3) in order to ascertain where and how this LCSA research could align with Ngāti Porou decision making and help fulfil Ngāti Porou aspirations.

##### 5.1.1. History and Background

Ko Hikurangi te maunga

Hikurangi is the mountain

Ko Waiapu te awa

Waiapu is the river

Ko Ngāti Porou te iwi.

Ngāti Porou is the tribe.

The Ngāti Porou iwi is a collective of hapū (sub-tribe) within the east cape of the North Island, a geographic range from Potikirua to Te Toka a Taiau (Figure 6), and have been settled in this area for several centuries (Harmsworth, Warmenhoven, Pohatu, & Page, 2002). Prior to 1840, the Waiapu catchment alone had at least an 80% coverage of natural forests; however, pastoral farming (initiated by European settlers and encouraged through government incentives) led to the clear-felling and drastic decline of natural forests – a loss of nearly 70% (approximately 121,000 hectares) between 1840 and 2002 (Scion, 2012).



Figure 6. The geographic range of Ngāti Porou iwi from Potikirua to Te Toka a Taiau (reproduced from Reedy, 2012).

The result of such rapid and extensive deforestation of native forests coupled with unstable underlying geology and frequent severe storm events has caused the Waiapu region to erode at a devastating rate (over 90% of the land is currently experiencing some

form of erosion effect) (Scion, 2012). As many people in the Ngāti Porou region derived their livelihoods from the land (e.g. agriculture, sheep or cattle herding, forestry), such widespread erosion has significantly impacted upon the Ngāti Porou people forcing many to relocate to find jobs; indeed nearly 83% of those claiming Ngāti Porou descent live outside of the region (Reedy, 2015). Furthermore, “the issue of land erosion in itself is a form of land alienation” (TP) (Int-2a-TP.TW) creating another barrier between the people and their land. Thus, over time the cultural and social connectedness of Ngāti Porou has been diminished yet there is a clear recognition amongst iwi members that restoration of the land will in turn restore the mana whenua of Ngāti Porou.

Various afforestation efforts have taken place since the 1960s in an attempt to not only stem erosion rates but also to generate employment and income from resulting timber sales of afforested areas. As a result, government-approved initiatives principally encouraged planting significant amounts of non-native radiata pine. However, extensive coverage of Ngāti Porou land with an exotic species such as radiata pine conflicts with fundamental aspirations of the tangata whenua in the Waiapu catchment.

### **5.1.2. Aspirations**

The aspirations of Ngāti Porou have been researched and articulated in reports undertaken by Harmsworth et al. (2002), Scion (2012), and Warmenhoven et al. (2014). Numerous face-to-face interviews and Ngāti Porou wananga were undertaken with pākeke (adults) and kaumatua (elders) of the Ngāti Porou community, and subsequently created “explicit and implicit themes drawn from the interviews, wananga (traditional learning), kōrero (discussion, stories), writings and traditions” to form a robust representation of iwi values, visions, and aspirations (Harmsworth et al., 2002, p. 23).

As an initial step, this research reviewed and confirmed the relevancy of 10 Ngāti Porou aspirations published within the Scion (2012) report: 1) Strong identity – whakapapa; 2) Ngāti Poroutanga; 3) Employment and wealth creation (economic); 4) Te Reo and tikanga; 5) Whānau; 6) Mana Motuhake; 7) Connectedness; 8) Mātauranga ; 9) Clean environment; and 10) Infrastructure (p.199). Although the aspirations had been defined in other reports it was recognised that these aspirations can “mean different things to

different people at different times” (TP) (Int-1-TP.PP.TW). Therefore, for the purposes of this research, each of the aspirations were defined by the participants as shown in Table 6. It is worth highlighting that the definitions of these terms align with leading authorities in the area of Māori language and meaning (e.g. Marsden, 2003; Mead, 2003).

Table 6. Ngāti Porou aspirations and associated definitions.

Aspiration	Meaning
1) Whakapapa	Family Tree, genealogy, and orderly sequence
2) Ngāti Poroutanga	Culture, language and identity; what it means to be Ngāti Porou; to identify with and whakapapa to Ngāti Porou; contributing to Ngāti Porou and being a person or group from the descent line of the eponymous ancestor Porourangi and his wife Hamoterangi.
3) Employment	Work, occupation; livelihoods underpinned by the cultural, social and economic aspirations of the people.
4) Te reo me ōna tikanga	Te reo Māori; the Māori language and associated values, customs and practices.
5) Whānau/Hapū	Multi-generational family units; hapū share an identified geographical area that includes lands, waters, forests, marine and foreshore, air and subterranean and an identified male and female eponymous ancestor.
6) Mana Motuhake	Autonomy, authority, leadership; wairuatanga (spirituality); “mana” means spiritual power and authority since authority is a spiritual gift delegated by the Gods, man always remains the agent or channel – never the source of mana.
7) Connectedness	Reversing the disconnect between “ <i>Ahi kaa, hau kāinga</i> ” (those that live at home, keeping the home fires burning, occupation of ancestral lands) and “ <i>Ra waho</i> ” (those who live outside of the tribal area); contribution to the hapū, iwi and whenua; closely connected to whakapapa; maintaining the responsibility toward your whānau, hapū, and iwi and receiving benefits as a member of those entities.
8) Mātauranga	Knowledge and understanding.

<p>9) Healthy Ecosystems</p>	<p>Conserving biodiversity (the variety of life on Earth) is essential in order to sustain healthy ecosystems (dynamic complexes of plants, animals, micro-organisms and their non-living environment) of which humans are an integral part; biodiversity and healthy ecosystems underpin human health through innumerable goods and services they provide such as: the provision of food, water, fibres, energy and medicines; the production of oxygen and purification of air and water; the regulation of climate, by storing carbon and controlling local rainfall; the moderation of weather extremes (such as. floods and droughts) and their impacts; the regulation of disease-carrying organisms and decomposing of waste and detoxifying of pollution; the cycling of nutrients to support soil fertility and the pollination of crops and plants, and control of pests; and the provision of models to understand and address health issues; Biodiversity also provides cultural, aesthetic, spiritual, recreational and educational benefits, which are important for physical and mental health.</p>
<p>10) Infrastructure</p>	<p>The basic, underlying framework or features of a system or organization; the governance, management and systems required to enable cultural aspirations objectives and outcomes to take effect in way that supports social, cultural and economic wellbeing.</p>

During the first interview with the participants we reviewed and discussed the 10 aforementioned aspirations. It was further recognised that Ngāti Porou aspirations are not singularly focused; the aspirations are inclusive of environmental, economic, social, and cultural visions. Importantly, it was highlighted that none of the aspirations sit in isolation.

*It goes back to the list of aspirations but really if you think of them in a list it's really one-dimensional, and to realise that there're relationships between each one that makes it a fuller experiential way of living and way of wanting to live (PP) (Int-1-TP.PP.TW).*

*A key assumption is that those aspirations...just how interconnected and multi-dimensional especially the Māori ones are. Like kaitiakitanga, mana motuhake, te reo and tikanga are very intricately linked to mātauranga (TW) (Int-5a-TW.PP).*

This multi-dimensionality was particularly visible when participants discussed the land and what it provides. Land is Papatūānuku (the earth mother), providing life, food, energy, material for shelter and livelihoods, resources for rongoā (medicine), and an enduring landscape for all Māori whakapapa. Therefore, decision making regarding the land is not a trivial nor a simple process.

The interconnecting aspirations are seen as both an ‘implementation plan’ and as a way to “measure success” of any given endeavour or activity (PP, TW) (Int-1-TP.PP.TW). However, critical to achieving and enhancing these aspirations is “vision and willingness” (TP) (Int-1-TP.PP.TW).

*Without vision and without looking forward to see that things can be done nothing will be done. And without willingness we spend all of time talking about strategy and the fight and we spend more time on the fight to get to the table that when we get to the table we’ve got nothing to say...my strategy is finding the vision and willingness to achieve the aspirations that we’ve been talking about for so long (TP) (Int-1-TP.PP.TW).*

Whereas vision and willingness were seen as the two key elements for achieving aspirations, three particular barriers were identified to achieving these aspirations: capability, governance, and access to capital (TP) (Int-2a-TP.TW). Mention of these three barriers arose in various contexts such as in understanding the drivers behind people’s land use choices (TP) (Int-2a-TP.TW), lack of implementation strategies and “follow through” for ideas (TP) (Int-2a-TP.TW), and addressing the challenges in planning for and utilising East Coast Forestry Project grant money (TW) (Int-2a-TP.TW).

There was some discussion in the interviews of adding an 11<sup>th</sup> aspiration to the previous 10, the aspiration of “leadership” – leadership that is fair, democratic, organic, and not loud or boastful (Int-1-TP.PP.TW). Someone who is a leader is also a champion of Ngāti

Porou visions and aspirations, but must be “of the people” (i.e. Ngāti Porou iwi) (TP) (Int-2a-TP.TW).

*So sometimes that’s what it takes, it takes people with guts, people with energy, people with charisma, like-minded, working together, making something happen for the rest of us to say, “hey, look how they made that happen”. We can do that, too. And that’s what we need in a place like this because we’re isolated, low socio-economic factors etc etc...that’s what we need (TW) (Int-2a-TP.TW).*

However, it was finally agreed that the aspiration of “leadership” was embedded within each of the other 10 aspirations and, in particular, embedded within “mana motuhake” (Int-5b-TP).

### **5.1.3. Decision making process**

The importance and influence of decision making within Ngāti Porou was a reoccurring theme throughout nearly all of the interviews. The decision making process in Ngāti Porou is ideally done by consensus (TP) (Int-1-TP.PP.TW). Decision-making practises emulate the whakataukī (proverb) “whakamana taiata” which emphasises treating everybody with respect and encourages empowerment (PP) (Int-1-TP.PP.TW).

*It’s not just the outcome you’re trying to achieve, it’s the process and keeping everyone involved in the process empowered (PP) (Int-1-TP.PP.TW).*

An example of the decision-making process within Ngāti Porou was made by Tina Porou who told a kōrero (story) of recent steps taken within the iwi to ameliorate the lack of housing in the Waiapu catchment:

*We’re working to build some houses, communally-owned houses. So we have about 700 beneficiaries but we go out and talk to everybody, we present to everybody, we decide on any decisions through a vote of those people who come to the hui but we’ve an executive who will carry out those decisions. It’s a collaborative process of what we want. And then we will send out letters to all of those 700 people and*

*unless we get somebody who's totally against it we will just carry on. And if we do get someone who's totally against it then we will work with them to see what their issues are, can we fix it in a certain way. So it's really collaborative but those things take a long time; for us we've spent the last six months on this particular issue and getting a decision (TP) (Int-1-TP.PP.TW).*

The initial identification and confirmation of the housing issue happened at an annual general meeting, where a small number of members formed into a “committee” to focus efforts on finding a solution. This committee met with members of the community thus highlighting the importance of face-to-face discussion conversation and participation. The committee developed and investigated potential solutions, and essentially made “decisions about options” (TP) (Int-1-TP.PP.TW). The most viable options were presented to the whānau and the final decision was made by the rūnanga (tribal council) leaders. This process can be generalised as shown in Figure 7.



Figure 7. The decision making process of Ngāti Porou.

Regarding the housing kōrero, identification and refinement of potential solutions required significant research and gathering of information. There was a feeling in the committee that they had to “muddle through” the process of finding solutions, relying on their own tenacity, diligence, and professional and personal contacts.

And yet the participants identified that there is no consistently used decision-making model or process in Ngāti Porou; if “integrity is lacking or if the intention is for political points” then the resulting decision may not be representative of the iwi collective and their aspirations (PP) (Int-1-TP.PP.TW). The participants also recognised that decisions are sometimes made without access to or acknowledgement of all relevant information. It was here that the participants felt this LCSA research could be most useful – to help

them to “reconfigure” how they make decisions (Int-2b-PP), and to acknowledge the full range of benefits and impacts relevant to a decision (environmental, social, economic, and cultural) (Int-2a-TP.TW; Int-3b-TP).

*We as land owners we might think, “oh, that’s a good idea”, but we don’t know enough about it to do the proper analysis: the cost-benefit, the trade-offs, moving to another land use, or whatever. So those things are making our decision making more robust - those sorts of full scenario case studies where things are more fully worked out. Then we can make the best decisions with the right information (PP) (Int-1-TP.PP.TW).*

*We just want to know the options. It’s more than being feasible, the option has to be... enduring and the option has to be consistent with the values that we live every day but also has to create benefit. So those are kind of the key things that you view your decisions through, and the benefit has to be collective not individual (TP) (Int-1-TP.PP.TW).*

*We’re always given a dollar value for the pine, you’re going to get “x” amount every year, or at 25 years you’re going to get \$350,000 and that’s all we see. We don’t see everything else that we lose because it doesn’t have a dollar value: culture, cultural values, even ecological values... For some reason we always go back to the dollar, to the value of the dollar in terms of our decision making (TW) (Int-3a-TW.PP).*

*I guess for me the more work such as yours that is being done is going to shed more light on that which we just don’t know. (TW) (Int-3a-TW.PP).*

The participants felt that more collaboratively gained information would enhance their opportunities to make more informed decisions, and more informed decisions (with the influence of tikanga) would trigger meaningful opportunities – all of which further help to achieve their iwi aspirations. However, it is important to reiterate that these aspirations are not necessarily focused solely on economic gain; it is essential that decisions are multi-dimensional and are beneficial for both the land and the people, where long-term reconnection and relationships are a priority. The significance of multi-dimensional

decision making and the effects if it does not happen were highlighted during several interviews.

*I think that a lot of us here in our community see to be successful is to make a big profit and make big dividends. If that's your definition of success then that's how you're going to make decisions and manage land and all of these other [aspirations]...they'll just stay the same or get worse (Int-2b-PP).*

*Our people have got a lot of learning to do because all their decisions have been made on basis of economics and that's why I think we've suffered so much for so long (TW) (Int-2a-TP.TW).*

*We want all of that value to be included in decisions rather than what's going to make us the most profit but disconnect us, terrorise our land (Int-4a-PP).*

*I think our people want to have an economic return, they want to be reducing erosion, they want to retain their land, they are keen to choose an option that is environmentally sustainable and meet the needs of our cultural aspirations (Int-3b-TP).*

*So while [culture is] a part of us we're actually not that good at making decisions that embrace or integrate those things into those decisions. We actually use other people's decision-making processes and models and we need to step up and use, incorporate these in...it's making these things integral to the decisions we make is where the real power is I feel. To me it'll make the decision making more robust, not just one track profit-oriented or one track jobs-oriented, the complexity is that it is multi-dimensional but our decision making has to get more multi-dimensional as well (Int-4a-PP).*

It was recognised that decision making did not have to always be a simple process; consideration should be made of the opportunities foregone as a result of making a particular decision (Int-2b-PP; Int-3b-TP). This concept of “opportunity cost” is revisited in more detail in Appendix F.

## 5.2. Stage 2: Co-development of forestry scenarios

In Stage 2 of the research, participants articulated their visions for the future of forestry in their catchment including consideration of alternative forestry scenarios that could be explored within the LCSA research.

The interviews were designed to guide the participants through consideration of alternative species (native and exotic) to the commonly planted radiata pine, various types of forest management (based on the work of Duncker et al. (2007)), harvesting of native species, and production of timber products. To aid discussion, I presented the participants with pictures and background information (e.g. environmental needs, time before harvest, potential economic and cultural value) of various tree species and types of forest management. The pictures and information helped to stimulate dialogue around forestry options, life cycle thinking, and long-term land use decisions. The participants were invited to vocalise their visions for the future of forestry in their catchment, and to work towards defining alternative forestry scenarios to explore within the LCSA research.

Forestry was seen as one of the main land use options in the Waiapu catchment. This was primarily due to the rapidly eroding land which could be protected if trees are planted, but also forestry is able to provide some economic, social, and environmental benefits (Int-2a-TP.TW; Int-3b-TP). However, direct cultural benefits (from radiata pine forestry) were generally viewed by the participants as being minimal, if any.

*We don't have many options for land use. We are far from market. We have highly erosion-prone land which means the land can't sustain many cattle crops so doing beef and dairy is probably worse for our whenua than doing sheep. ...Forestry has always been seen as a return on land that is marginal. I know that if many could clear and go back to farming they'd probably do that...certainly people want to live off the land. But there aren't that many land use options for us – forestry is really the only option (TP) (Int-2a-TP.TW).*

*Forestry is still out of the available land options the one that will currently provide an income (TP) (Int-2a-TP.TW).*

There was a consensus amongst the participants that diversification in forestry should be actively pursued – both in terms of species planted and forest management. This was seen as a necessity in order to more fully realise their aspirations but also as a way to prepare for increased biotic and abiotic threats (TW) (Int-2a-TP.TW).

*[Forests] left to regenerate we prefer, or I prefer that it's native and it's really for that purpose of being a forest, not necessarily harvesting it. Not into Pinus radiata (Int-2b-PP).*

*So it is about having the information to determine what are the best land uses for like what we're doing now, what are the best land uses and then making those choices. And forestry and pine will always be a factor in those choices. But currently it's the only solution (Int-3b-TP).*

*In order to continue to grow trees and continue to have that connection it's going to have to be across a range of species. I'm not convinced that pine is the only way (TP) (Int-2a-TP.TW).*

*We've got to step up and actually have 5 or 6 things going on the land all at the same time to get the benefits from it (Int-4a-PP).*

Diversification was also mentioned in the context of “staggered” investments and distribution of benefits (Int-3b-TP). For example, it was acknowledged that an increase of forestry of slow growing native species would generate benefits over several decades or even centuries. A shift to such long-term forestry would be difficult for land owners to adopt. However, if native forestry is simultaneously pursued in addition to radiata pine forestry (which provides benefits on a more short-term scale) then these two forestry options would create a staggered approach of managing operating costs as well as receiving benefits.

The participants were also focused on the quest for capturing more of the value chain (Int-2a-TP-TW; Int-2b-PP; Int-3a-TW-PP; Int-3b-TP). There is great potential for more of the value chain processes (e.g. processing and manufacturing) to be controlled and performed

by Ngāti Porou; as such, it was appropriate to include processes beyond the forest in each scenario. The process for choosing products for further consideration involved acknowledging the aspirations of the participants and then deliberating on what products were viewed as currently feasibly achievable (i.e. did not require significant infrastructural investment or skill sets) and that would help meet one or more aspirations. For example, the aspiration of “infrastructure” includes generating more affordable housing within the case study catchment; thus, for the radiata pine scenario, the product of house framing was chosen. The “complete” value chain analysis topic is discussed in more detail in Chapter 6.

*What we need to do is we need to ensure that more of the product is staying with us. We need to be more innovative than what we're doing. Because all we're doing is allowing that the trees are growing on our land. You get planting, thinning, and harvesting jobs, and then it's gone. We need to be able to get more value than that* (TW) (Int-2a-TP.TW).

The perceived benefits of developing the processing and manufacturing capability in the catchment are numerous and include: increased local employment, development of roading and other infrastructure, enhanced connectedness and reinvigoration of communities, and general prosperous effects on whānaugatanga (Māori kinship) and manaakitanga (kindness, generosity) (Int-3b-TP; Int-4c-TP).

The assumed baseline was taken as one hectare of unmanaged, unutilised land in the Waiapu catchment. The participants decided on three potential forestry-based options for this land: intensive management of radiata pine, continuous cover forestry management of rimu (*Dacrydium cupressinum* Lamb.), and intensive management of mānuka (*Leptospermum scoparium* J.R.Forst. & G.Forst. (Myrtaceae)). As mentioned above, it was envisioned that these three options could be realised in parallel throughout the catchment under a “cooperative”-type setting (Int-4b-TW; Int-4c-TP); the forestry cooperative could not only stagger the benefits and costs but also ensure that no one land owner assumed all of the risk of pursuing a less common forestry option (i.e. the rimu or mānuka options).

*Going forward we have to be smarter and make brave choices* (Int-3b-TP).

### 5.2.1. Radiata pine

Radiata pine is grown in all regions of New Zealand from North Cape to Bluff and generally enjoys robust health across a range of soil types and climates, although wood quality does decline the further south in latitude the species is planted. The justification for including plantation forestry of radiata pine is that it is a current and productive land use in the catchment. It was acknowledged by the participants as providing some benefits including economic gains, jobs (albeit “labouring jobs”), and erosion control during forest growth (Int-1-TP.PP.TW; Int-4c-TP).

*Radiata pine is our [status quo] so we already have blocks here and so even if we take steps to move away from it we still have to manage what is here (Int-4a-PP).*

This is not to say that the participants felt that all radiata pine must be immediately eradicated. It was thought that transitioning pine into a less dominant “subset of forestry” was a suitable forestry strategy, one that could lead to more “shared outcomes” and objectives (Int-4c-TP).

There was an emphasis amongst the participants that harvested trees, especially native trees, should ideally be fulfilling a purpose or a need of some urgency to the people in the catchment; housing and housing materials is in great demand by Ngāti Porou and therefore the participants decided that the products created from a harvested radiata pine tree should aim to meet this demand, where possible. Therefore, the primary product focus chosen by the participants for the radiata pine scenario was for housing purposes – pine framing.

*Housing or shelter or components of housing would be very valuable to us because they're what our people need. The basic necessities of life will always be of primary value to us. So if products could meet those things either in the short-term, the regular-term, or the long-term, to me it's not about terms it is more about those needs that will always be paramount to us – anything else is nearly secondary (PP) (Int-3a-TW.PP)*

*If some pine trees getting cut down actually build houses for the people of that land then that is better, that's a good reason for forestry (Int-2b-PP).*

### **5.2.2. Rimu**

A fundamental Māori principle is to live in harmony with nature and the natural world as a dynamic, contiguous entity. In Māori history trees would be selectively harvested to, for example, build kāinga (homes) or waka (canoes); the emphasis though was on always striving to find a balance between human and environmental needs. In terms of forestry and forest management, the principles and objectives of continuous cover forestry were seen to be in alignment with the Māori worldview of harmonious, multi-generational relationship with nature (Int-3a-TW-PP; Int-3b-TP). This is consistent with findings published in Warmenhoven et al. (2014).

*I think there'll always be a place for pine but I hope over coming generations that this generation has the foresight to respect the long-term native species and the benefits are being reaped by our grandchildren, and that needs to happen sooner rather than later (TP) (Int-3b-TP).*

The pursuit of planting more native species was seen to fulfil several aspirations, and in particular that of “Te reo me ōna tikanga”, “Mātauranga”, “Connectedness” (Int-3a-TW-PP; Int-4b-TW; Int-4c-TP; Int-5b-TP). Native species are essentially a living embodiment of traditional knowledge and associated practices (e.g. rongoā or medicinal uses). As such, growing more native species is viewed as an essential element towards reconnecting Ngāti Porou and reawakening the cultural practices of their ancestors (Int-4b-TW).

The native rimu tree was chosen as it has always been present in the catchment. Rimu grows throughout the country from sea level to 700-800 metres elevation, and was once prevalent in lowland forested areas (Norton, Herbert, & Beveridge, 1988). After European settlement, rimu was a mainstay of New Zealand saw-milling and the lumber was used in framing, cladding (weather boards), interior joinery and furniture (Clifton,

1990; James & Norton, 2002). Logging of rimu from state-owned forests continued into the early 1980s but has largely stopped due to concerns over the reducing area of natural forest and the environmental impacts of the harvesting. Very small volumes of native timber are now produced annually (30,000 m<sup>3</sup> per annum) which is predominantly used in high-value furniture. There are only small areas of rimu on private land forest managed for timber under Government legislation. In comparison to radiata pine, natural forests of rimu stands grow slowly and, therefore, the wood is more expensive. Other natives of interest but not assessed in this research due to time constraints included Totara (*Podocarpus totara* G.Benn.), Beech (red (*Fuscospora fusca* Hook.f.), silver (*Lophozonia menziesii* Hook.f.), and black (*Fuscospora solandri* Hook.f.)), Kānuka (*Kunzea ericoides* A.Rich.), Kahikatea (*Dacrycarpus dacrydioides* A.Rich.), and Kawakawa (*Piper excelsum* G.Forst.).

*Natives species are my priority, absolutely. I prefer indigenous because they're ours and we relate to them* (TP) (Int-2a-TP.TW).

*Any native tree is a good tree* (Int-2b-PP).

*It's endemic, mana whenua like us, or rakau whenua like us* (PP) (Int-1-TP.PP.TW).

Pesticides and herbicide usage as the use of chemicals is “fundamentally a cultural no-no” (Int-3b-TP), and was spoken of as being “abhorrent to every living thing” (TW) (Int-3a-TW-PP). Therefore, every attempt was made to exclude chemical usage in the rimu scenario. In addition, to protect the vulnerable soils during harvesting, selective logging via helicopter was chosen as a suitable method for extracting the limited amounts of harvested rimu (Int-4c-TP).

*I prefer our native trees first. I don't know much about it but I would be interested in sustainable harvesting of them but again for building homes or rebuilding our marae or things like that or for medicines* (Int-2b-PP).

*We're bound by the Forestry Accord to do a process...so continuous cover forestry would be the only option for us for the natives* (TP) (Int-2a-TP.TW).

*People would prefer to have natives as well as long as it was bringing the same amount of employment and opportunity as pine is at the moment (Int-4c-TP).*

The primary product focus chosen by the participants for the rimu scenario was also for housing purposes – rimu heartwood flooring. For over 50 years, rimu has dominated New Zealand’s domestic indigenous furniture industry, and is highly preferred for domestic furniture applications (Donnelly, 2011). Admittedly, however, high-end rimu heartwood flooring may be too expensive for many people in the catchment. Yet, the rimu tree is a high-value timber and as such its value may, in some ways, justify the harvesting process. It was felt that native trees should never be harvested for trivial or inconsequential purposes.

*I was always taken by the example with the Native Americans and in Canada as well about their continuous cover forest methods, and the sheer scale of those things to allow them to grow. Those are the key reasons why it allows them to grow native species, it’s much less invasive on the environment but the product it produces is high-value which justifies the method (Int-3b-TP).*

*The high-value hardwood so Kauri, rimu, Totara...those are much longer rotation species but I think that if we’re processing them correctly that the outcomes of those will justify the harvesting and forest management methods (Int-3b-TP).*

The potential for the flooring to be recycled into a secondary product once the rimu flooring had completed its life cycle in the house was discussed. There was a great amount of support for this process as it fits well with the Māori worldview of minimal waste of a “precious” resource (Int-4c-TP), a multi-generational focus, and provides a “cascade flow-on effect” from the original rimu product (Int-4a-PP). The resulting recycled product was randomly chosen and was assumed to be a rimu table purely for demonstrating the effects of pursuing a secondary product in the rimu value chain.

### **5.2.3. Mānuka**

The native species mānuka is one of most abundant woody species in New Zealand due to its environmentally-tolerant nature (Derraik, 2008). Although treated as a weed for many decades by European settlers, mānuka is currently undergoing a rapid resurgence in New Zealand with widespread recognition, nationally and internationally, of its many uses such as for: slope stability and erosion prevention (Bergin, Kimberley, & Marden, 1995; Watson & O'Loughlin, 1985); anti-bacterial purposes (Perry et al., 1997); helping in the remediation of polluted land (Craw, Rufaut, Haffert, & Paterson, 2007); promotion of biodiversity by acting as a nectar and pollen food source (Department of Conservation, 2014); and use in Māori cultural practices (e.g. rongoā (Māori traditional medicine), weapons) (Maddocks-Jennings, Wilkinson, Shillington, & Cavanagh, 2005; Patel, 1994).

*Number one it's a nursery, it provides a nursery for the native forest to naturally revert. Number two it stems erosion. Number three it improves soil quality as a tree. Number four the products...beautiful shelter, great for shelter belts, it provides habitat for the weka, birds like Piwaiwaka, other insects and no doubt other birds. It's endemic to this area. In terms of what it provides, well it provides food in the way of honey. It provides medicine, the pharmaceuticals, you know of a very high standard. It provides fuel, very good, it's the most popular wood I would say in the country to burn. (TW, Int-1-TP.PP.TW; TW, Int-2a-TP.TW; TW, Int-3a-TW.PP; Int-4b-TW).*

*We look at mānuka like it's a weed but really it's one of our trees. It's in this space where my whakaaro, my ideas and that come out (Int-2b-PP).*

Mānuka's medicinal (anti-bacterial, anti-fungal, anti-viral) properties (Porter & Wilkins, 1998) are proving lucrative in particular for the mānuka honey and mānuka essential oil markets (Derraik, 2008). The Gisborne and East Cape regions (within which the Waiapu catchment sits) are very well located for mānuka as it not only grows naturally there but the regions produce mānuka with the most potent (and therefore the most valuable) medicinal qualities (Douglas et al., 2004).

The discussion about mānuka as a forestry option was focused more on the product side of the value chain, instead of on the forest growth side as with radiata pine and rimu. The participants deliberated on whether the assessment should be on mānuka honey or

mānuka essential oil as a potential product. The ultimate choice to review mānuka essential oil was made in light of the sheer volume of current and past research on mānuka honey; thus the participants saw this as an opportunity to instigate research of mānuka essential oil and subsequently increase their knowledge in an otherwise unfamiliar product area. Furthermore, the production and ultimate consumption of mānuka essential oil was seen as more “accessible” for Ngāti Porou people, especially “cost-wise” (Int-4a-PP).

*I can see more of us being involved in the process if we go the oil way somehow, which is what’s informed me around choosing oil (Int-4a-PP).*

*Essential oils I think are an untapped opportunity for Ngāti Porou...there are some mass uses for essential oils that aren’t just around the medicinal. I think we’re under-subscribed to it (Int-4c-TP).*

With mānuka essential oil chosen as the preferred product, we then worked “upstream” (i.e. the initial processes of the mānuka value chain) to determine what kind of forest management would be required to maintain a highly-producing and efficient mānuka forest estate. It was recognised that for a mānuka forest estate to be able to consistently produce a high volume of branches for the distillation process, it would have to rely on fairly intensive forestry measure including the use of mechanised trimming and harvesting (Int-4c-TP; Int-5b-TP). The latter operation of harvesting introduced the potential again for cultural conflict around cutting down a native species. Yet, this act was seen as less serious if the mānuka stand were to be replanted (Int-4a-PP).

### **5.3. Stage 3: Identification of economic, social, and environmental indicators**

As with the development of the forestry scenarios, I provided the participants with some guidance around example environmental, social, and economic indicators (the cultural indicator is discussed in Section 5.4). The guidance was a list of range of potential indicators, and from this list the participants could debate, revise, dismiss, or add indicators. The initial list of indicators was an amalgamation of LCSA midpoint impact

categories and indicators used in forestry life cycle research (EFORWOOD, 2007; Lindner et al., 2012). The list of indicators was not an all-encompassing list but rather focussed on presenting a range of “high-level” indicators using fairly general terminology (e.g. “water quality” instead of “eutrophication”) in order to stimulate further discussion. It was considered useful to at least have something from which they could begin forming their opinions and preferences on indicators.

### 5.3.1. Economic indicator

Demonstrating the economic costs and values of each forestry scenario was deemed as a necessity by the participants. In particular, it was agreed that it would take substantial effort to convince land owners and Trust organisations that there are other viable alternatives to radiata pine forestry; the most effective way to do this would be to show the economic potential of the other forestry scenarios. Therefore, the two selected economic indicators were total costs and potential profit.

*I think too for me you've got to get the economic value. So all of them we know have a high cultural value, the [native trees] we've identified, but for me it's to make sure that there's an economic value off those (TP) (Int-2a-TP.TW).*

*You would have to clearly show the business case for an alternate species and that would have to include maintenance, harvesting, management, you would have to be able to show all of that. I think if it was a smaller trust or incorporation that are already earning nothing off the land then those decisions are much easier because it won't be about economics, it's a bonus. But for our larger organisations they're going to have to see why you would swap from pine to an alternate species (TP) (Int-2a-TP.TW).*

However, in the eyes of the participants the pursuit of forestry in general is not necessarily focused on generating the greatest profit when it may come at the expense of other aspirations.

*The profit doesn't have to be huge if it can provide employment, safe employment. Even if it broke even, the main thing is that we've provided work and income and a livelihood. As long as it can cover itself, connects us to our land, supports livelihoods, it's a winner (Int-4a-PP).*

Other economic indicators identified as a priority or being of interest (but not included in this LCSA research due to time constraints) include “resource and material use” (Int-4a-PP) and “investment in Research and Development” (Int-4c-TP).

### **5.3.2. Social indicator**

Employment of Ngāti Porou people is a significant aspiration for the catchment as well as for the entire Gisborne/East Coast region (Fairweather et al., 2001). According to the New Zealand 2006 census, the Gisborne region has the highest unemployment rate in the country (7.2% in the region compared to 5.1% overall in New Zealand). Indeed, Ngāti Porou employment is also connected to the “Mana motuhake” aspiration (see Table 6) in that an increase in jobs occupied by Ngāti Porou workers will enhance the independent capability of the region.

*But the other large forestry companies on the east coast, there's a lot of about the fact that people come in and take our jobs. There's always, “Why are the trucking operators from outside? Why aren't all our people working to be big companies and we're not and it's our land?” All of those discussions are important in any decision because they've all got to be working on their own land but they either lack the capability or the capital (Int-3b-TP).*

Therefore, employment was chosen as a suitable “social” indicator of great interest to the participants (Int-4a-PP); the indicator unit is reported in “hours” per process. It is worth noting that “local employment” was preferred over the more general “employment” indicator (Int-4a-PP; Int-5a-TW.PP; Int-7a-TP.TW); certainly, employment generated from forestry scenarios that may be filled by local Ngāti Porou members was valued more highly than employment filled by non-Ngāti Porou (PP) (Int-5a-TW.PP). However, since

this was a theoretical LCSA research exercise, it was impossible to say how much of the forestry scenarios' employment needs could be met by local Ngāti Porou in practice.

Other social indicators identified as a priority or being of interest (but not included in this LCSA research due to time constraints) include “health and safety” (Int-4a-PP; Int-4c-TP), “household income” (Int-4c-TP), and “availability of rongoā” (Int-4b-TW).

### **5.3.3. Environmental indicator**

As Māori are kaitiaki (guardians, stewards) of the land and associated ecosystems, there was much passionate discussion around potential environmental indicators – erosion prevention being one of the frequently suggested indicators (Int-4a-PP).

Despite “erosion prevention” being an indicator of great interest to the participants, it is only applicable in the land preparation and forest growth phases of the life cycle. For the purposes of demonstrating “cradle-to-grave” sustainability assessment of one hectare of unmanaged land, I encouraged the participants to select an indicator that was able to span the entire life cycle of the forestry options. This was one of the few times during the interviews where I actively introduced and discussed viable indicators and did so for the primary reason that the participants were, to some extent, unaware of the broad range of life cycle indicators from which they could choose.

The selected environmental indicators were greenhouse gas (GHG) emissions and carbon sequestration/storage. These indicators were not necessarily of high interest to the participants but use of this indicator enabled environmental assessment along the product life cycle for a globally-relevant impact. Other environmental indicators identified as a priority or being of interest (but not included in this LCSA research due to time constraints) include “water quality and quantity” (Int-4c-TP), “biodiversity” (Int-4c-TP), and “waste” (TW) (Int-3a-TW.PP).

## **5.4. Stage 3: Identification of cultural indicators**

To recognise Ngāti Porou culture within LCSA, it was deliberated and decided during the fifth interview to develop a cultural indicator. The cultural indicator (when placed alongside the other environmental, social, and economic indicators) would provide a distinct representation of impacts on Ngāti Porou aspirations. The participants felt that such a qualitative representation would be a powerful addition (and perhaps also an improvement) to their decision making process.

*The essence of what we do and what we choose must be inherent in our culture* (TW) (Int-2a-TP.TW).

*It's that vicious circle which is why we have to show them how to make their decisions better, which comes back to what you're doing in your research is being able to plug in all of the measures of success, giving a rating to those, so that the measures of success are relative to the community that are using the decision making model* (TP) (Int-2a-TP.TW).

The process of creating a cultural indicator for use within the LCSA methodology is detailed in Section 5.4.1. In addition, the Cultural Compliance process (a concept that emerged during the interviews) is presented in Section 5.4.2.

### **5.4.1. Cultural Indicator Matrix**

The LCSA researcher (myself) performed a detailed literature review on methods of integrating culture into decision making processes, both within New Zealand and abroad. A potentially suitable approach was identified (the Mauri Model by Morgan (2004)), and, during the sixth interview, was brought to the attention of participants for their consideration and approval. The deliberation process was facilitated by the fact that the participants were already familiar with the Mauri Model and its creator, and could more clearly and easily envision how to modify the model to be more relevant within this case study research.

The Cultural Indicator Matrix is based on the work of Morgan (2004) who developed the Mauri Model (“mauri” being the binding life force between all living and non-living

things, and “without it there is nothing” (Int-5a-TW.PP)). The Mauri Model is a decision-making framework which relies on the subjective judgement of the users to decide the impact that an activity, process, or product has on the mauri of four interdependent dimensions of wellbeing: whānau (economic), community (social), hapū (cultural), and taiao/ecosystem (environmental) (see Figure 8). The Mauri Model can be used to evaluate an activity, process, or product from past, current, or even future situations, and can be useful when “stakeholder relationships are adversarial and problems have significant inherent complexity” (Morgan, Sardelic, & Waretini, 2012, p. 3). The Mauri Model has been published and used in previous research (e.g. Platia 2012; Khan 2012; Peacock 2011).

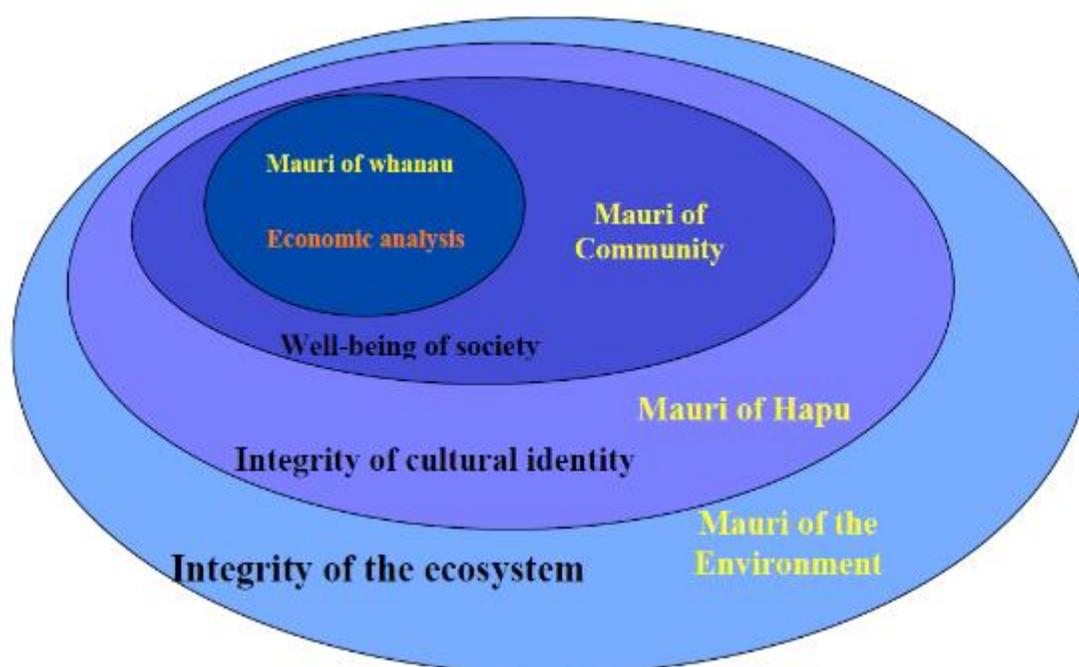


Figure 8. A visualisation of the interdependent dimensions of wellbeing used in the Mauri Model (Morgan, 2004).

T.W. and P.P. generally approved of the Mauri Model whilst T.P. felt it unrealistically took a complex, all-encompassing cultural subject and forced it into a measurable format (Int-4c-TP). However, T.P. conceded that: 1) there was currently no better alternative, 2) the framework within the Mauri Model is reasonable, and 3) the Mauri Model has been published and used in research. Thus T.P. gave her support to adapting the Mauri Model to be suitable for our purposes within this research (Int-4c-TP).

The Mauri Model scale is used to subjectively record an impact (positive or negative) upon mauri and ranges from -2 to +2. The scale range is defined as follows: +2 Restored (mauri ora/tu), +1 Enhancing (mauri piki), 0 Neutral (mauri whakakau), -1 Diminishing (mauri heke), and -2 Destroyed (mauri mate/noho) (Morgan et al., 2012).

The mauri impact scale and the meanings associated with the numbers (from -2 to +2) were reviewed by the participants. In some cases the terminology and definitions were changed to be of more meaning to the group. For example, for the mauri score of +2, the previous use of the “restored” description was seen as an inference to a status of final completion or full restoration in a “past tense”; yet, the mauri of any aspiration will never be “finished” or “completed”. The word “flourishing” was suggested instead and indicates a continuous and prosperous state (Int-5a-TW.PP). Figure 9 depicts the final version of the mauri impact scale, as refined by the participants.

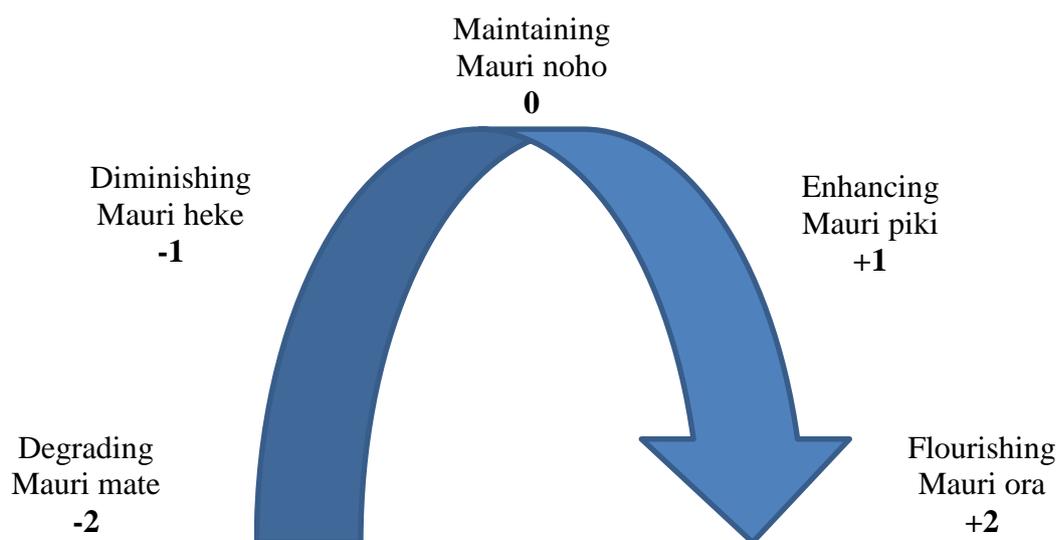


Figure 9. The refined version of the mauri impact scale that is used in the Cultural Indicator Matrix (Morgan et al., 2012).

A useful aspect of the Mauri Model is that it allows for users to assess the impacts of a process upon mauri at any time, and as often as necessary. Using the Mauri Model to perform multiple assessments over time would enhance the understanding and acknowledgement of a process’ effect upon mauri (Int-4a-PP).

The Mauri Model framework was adapted to be more suitable and meaningful to Ngāti Porou and their identified aspirations. Of the original 10 aspirations (see Table 6) it was decided to condense these into 7 aspirations: 1) Ngāti Poroutanga (including Whakapapa, Te Reo, tikanga), 2) Employment, 3) Whānau and Connectedness, 4) Mana Motuhake, 5) Mātauranga, 6) Infrastructure, and 7) Kaitiakitanga and Healthy ecosystems (Int-5a-TW.PP; Int-5b-TP). Condensing the aspirations made the resulting matrix easier to use and interpret, without losing a great amount of aspirational detail. Indeed, all of the original 10 aspirations are represented in the condensed list since related aspirations were grouped together (e.g. Kaitiakitanga and Healthy ecosystems).

The Cultural Indicator Matrix template below (see Figure 10) is a visual representation of the aforementioned refinements. The simple matrix framework exists in Microsoft Excel, a programme that I confirmed that each of the participants had access to; it is generally important to confirm participant access to software, computers, or other infrastructure so as to ensure that no one is prevented from fully participating in the research process. The seven condensed Ngāti Porou aspirations are along the top row of the matrix while every main life cycle process from each forestry scenario are along the far left column. Each participant was sent the Excel file and asked to individually complete the Cultural Indicator Matrix for the baseline of unmanaged forest and each of the combined forestry scenarios i.e. provide their personal evaluation (impression, score) on the impact they perceived that process had on each aspiration. The full Cultural Indicator Matrix had one tab with an introduction to the process and definitions of both the aspirations and forestry processes, and three following tabs – one for each forestry scenario (radiata pine, rimu, and mānuka) (see Appendix D).

	1. Ngāti Poroutanga (including Whakapapa, Te Roa, tikanga)	2. Employment	3. Whānau & Connectedness	4. Mana Motuhake	5. Mātauranga	6. Infrastructure	7. Kaitiakianga & Healthy ecosystems
Pine processes							
Nursery							
Site prep							
Planting							
Tending							
Thinning (to waste)							
Felling (clear-felling)							
Extraction							
Skid site							
Landing construction							
Roading							
Roading - maintenance							
Timber transport (44t logging truck)							
Sawmill							
Housing construction							
Consumer/use of house							
House deconstruction							
Burning (end of life)							
Cultural compliance (throughout chain)							
Freight transport (throughout chain)							
	Scoring value	English meaning	Māori meaning				
	2	Flourishing	Mauri ora				
	1	Enhancing	Mauri piki				
	0	Maintaining	Mauri noho				
	-1	Diminishing	Mauri heke				
	-2	Degrading	Mauri mate				

Figure 10. The final version of the Cultural Indicator Matrix as developed and refined by the participants. The seven (condensed) Ngāti Porou aspirations are along the top row, and the process of each forestry scenario (pictured here is for radiata pine) is along the left column. Using the mauri impact scale (bottom left), the user subjectively scores the impact they perceive each forestry process has on each aspiration.

Initial calculation requires a consolidation of participant scores. This process entails summing the scores from the participants for each cell in the matrix, and then dividing by the number of participants involved (in this case, three).

Once consolidation of participant scores has been made, interpretation of the Cultural Indicator Matrix scores involves summing and averaging the scores in three ways. First, sum the scores per process and divide by the number of aspirations (in this case study, seven aspirations) to produce one overall score per process. Second, sum the scores per aspiration and divide by the number of processes (in the case of Figure 11, nineteen processes) to produce one overall score per aspiration. And third, sum the scores within the entire matrix and divide by the total number of cells (in the case of Figure 11, 133 cells) to produce one overall score inclusive of the whole life cycle-value chain and all cultural aspirations. The mauri impact scale (Figure 9) is used to further translate the scores. In addition, averaging the matrix scores in this way allows for comparison

between scenarios. Weighting of the aspirations, if desired, can be applied during this step.

The resulting figures therefore enable interpretation and assessment of the perceived impacts that the participants felt 1) an individual process has upon the cultural aspirations, 2) a life cycle-value chain has upon each individual cultural aspiration, and 3) the entire life cycle-value chain has upon the entire range of cultural aspirations. The results of the Cultural Indicator Matrices can be seen in Appendix E, and are reviewed and discussed alongside the other LCSA indicators (economic, social, and environmental) in Chapter 7.

	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems	TOTAL
<b>Pine processes -COMBINED ANSWERS</b>								
Nursery	0.00	0.67	0.33	0.33	0.33	0.67	0.00	0.33
Site prep	-0.33	0.67	-0.33	0.00	0.00	0.33	-0.33	0.00
Planting	-0.33	0.67	-0.33	0.33	0.00	0.33	-0.33	0.05
Tending	-0.33	0.67	0.33	0.00	0.00	0.33	0.00	0.14
Thinning (to waste)	-0.33	0.67	0.33	0.00	0.00	0.00	-0.67	0.00
Felling (clear felling)	-0.67	0.67	-0.33	-0.67	-0.67	0.00	-1.33	-0.43
Extraction	-0.33	0.33	0.00	0.00	0.00	0.00	-1.00	-0.14
Skid site	-0.33	0.33	0.00	0.00	0.00	0.33	-1.00	-0.10
Landing construction	-0.33	0.33	0.00	0.00	0.00	0.67	-1.00	-0.05
Roading	-0.33	0.33	0.00	0.00	0.00	0.67	-1.00	-0.05
Roading - maintenance	-0.33	0.33	0.00	0.00	0.00	0.67	-0.67	0.00
Timber transport (44t logging truck)	-0.33	0.67	0.00	0.00	-0.33	0.00	-1.00	-0.14
Sawmill	-0.33	1.33	0.00	-0.33	0.33	0.67	-0.67	0.14
Housing construction	0.00	1.00	0.33	0.00	0.33	1.33	0.00	0.43
Consumer/use of house	0.33	0.67	0.33	0.00	0.33	1.00	0.00	0.38
House deconstruction	0.00	0.33	0.00	0.00	0.00	0.00	-0.33	0.00
End of life	-0.33	0.33	0.00	-0.33	0.00	0.00	-0.67	-0.14
Cultural compliance (throughout chain)	-0.33	0.33	0.00	0.00	0.00	0.00	-0.33	-0.05
Freight transport (throughout chain)	-0.67	0.67	0.00	0.00	0.00	0.00	-0.33	-0.05
<b>TOTAL</b>	<b>-0.28</b>	<b>0.58</b>	<b>0.04</b>	<b>-0.04</b>	<b>0.02</b>	<b>0.37</b>	<b>-0.56</b>	<b>0.02</b>

Figure 11. An example of a completed Cultural Indicator Matrix with consolidated scores from all participants for one scenario. Interpretation of consolidated answers occurs through summing and averaging scores per process (as seen in the right-most column), per aspiration (as seen in the bottom-most row), and for the entire matrix (as seen in the bottom-right cell in yellow). Use of the impact scale (Figure 9) indicates that this example achieved an overall score of 0.02 or ‘maintaining’/‘mauri noho’.

A final important step of the Cultural Indicator Matrix is to present and collaboratively discuss (and refine, if need be) the final LCSA results with the user group(s) or community. The results of this step are presented and discussed in Chapter 8.

## 5.4.2. Cultural Compliance process

An important outcome of utilising collaborative participatory engagement throughout the LCSA process (instead of using LCSA only as a tool to generate results) was achieved during the fifth interview with T.P. In this interview she introduced the concept of ‘cultural compliance’ (after realising its absence from our previous interviews) and advocated for its inclusion as a process within appropriate areas of the life cycle. As part of her role as a Trustee of Lake Taupo Forest Trust, T.P. has extensive professional knowledge of the necessary elements required to meaningfully satisfy “cultural compliance” throughout each forestry life cycle.

*So you can see you have “cultural compliance” inputs which would be project planning, cultural practices, cultural maintenance which are consistent with our world view...we’re looking after the whakapapa of the tree (Int-5b-TP).*

*For example, before we harvest we make sure that we have a karakia, we deal with assessing the general wahi tapu in the area, we have processes and procedures in place to ensure that there is a procedure if there are archaeological finds, and all of that has to be part of the value chain (Int-5b-TP).*

The inclusion of the Cultural Compliance process will enhance the transparency and recognition of cultural factors in the life cycle. Thus, the Cultural Compliance process may further enable decision makers (Māori and non-Māori alike) to have more robust and open discussions regarding culture and cultural needs. Additionally, this process will ultimately increase credibility, traceability value, and strength to a Māori-“telling the story”-brand of resulting forestry products (Int-5b-TP; Int-7a-TP.TW).

*There are costs attributed to cultural compliance definitely. We maintain cultural sites...but what is missing in the Lake Taupo Forest Trust is that we don’t commercialise that input at the other end. There’s no clear value from that to the consumer whereas I think cultural compliance is actually adding value to the end products. Which is why I think we need to articulate that and see it as a real input into the value chain (Int-5b-TP).*

*At the end it is really around branding. If we're going to be selling native trees it makes sense to be branding the story and the traceability of that product. And that needs to be discussed right through the value chain because it's actually a value added to have a tangata whenua brand (Int-5b-TP).*

Furthermore, recognition and inclusion of the Cultural Compliance process throughout the life cycle would act as a base of standardised and transparent evidence with which to prove observance of culturally-related regulations (e.g. the Resource Management Act, Forest Stewardship Council certification) as well as to the shareholders themselves (Int-5b-TP; Int-7a-TP.TW; Int-7b-PP).

There are six main components of the Cultural Compliance process (see Table 7) as defined by T.P., and refined by P.P. and T.W.: 1) Wahi tapu, 2) Cultural monitor, 3) Cultural Health and Safety, 4) Marketing (of a Māori brand), 5) Kaitiakitanga (annual), and 6) Benefits to owners. It is important to note, however, that this Cultural Compliance process is a “tiny component of the wider cultural value” as Māori culture is much broader and all-encompassing than just the six elements listed above (TP) (Int-7a-TP.TW).

*Table 7. Components of the Cultural Compliance process.*

Component	Definition	Where in the life cycle it occurs
<b>Wahi tapu</b>	Identification of culturally sacred places (e.g. urupā (burial grounds)) and areas with native vegetation that is retained for traditional kai and rongoā; protection (e.g. fencing, removal of exotic trees) and monitoring of wahi tapu areas; includes capital expenses such as a GPS and mapping software.	Ground preparation, planting, harvesting
<b>Cultural monitor</b>	Esteemed and “culturally competent” individual of the iwi (pākeke) to oversee work, ensure recovered artefacts (e.g. patu (weapons) or kōiwi (bones)) follow cultural and archaeological protocols	Ground preparation, planting, harvesting

<b>Cultural Health and Safety</b>	Includes performing karakia (blessings) of the land, new forestry crews, and clearing the area of spirits; understanding and recognition of wahi tapu areas by those working in the forest; includes kai to share between whānau and contractors after a karakia	Ground preparation, harvesting
<b>Marketing (of a Māori brand)</b>	Specific marketing and branding of the Māori story behind the taonga (treasure) that is the tree sustainably grown on Māori land; enhance the added value opportunity of commercial “indigeneity”; increase the traceability of a product; recognising the value of Māori culture	Harvesting, timber/material processing, product disposal
<b>Kaitiakitanga (annual)</b>	Carrying out responsibilities as kaitiaki (stewards) to care for the land over the long-term; environmental and biodiversity protection and conservation (even if at the expense of economic benefit); includes development and fulfilment of an environmental management plan	Ground preparation, planting, harvesting
<b>Benefits to owners</b>	Distribution of economic returns to land owners; ensuring open access and connection to forested land for hunting and gathering of firewood, food, rongoā; includes administration of hunting permit system and delivery of firewood to tribal elders; provision of non-dividend benefits (e.g. student scholarships)	Harvesting

The “cultural health and safety” component was strongly supported by T.W. and P.P., and P.P. offered the following kōrero (story) to help guide the understanding of how significant this component is:

*I’ve heard a number of guys here who’ll be planting a number of different sites but there might be one or two specific even pinpoint areas within the block that they will have a spiritual experience. So either they will physically not be able to perform their jobs or they’ll get sick or they’ll just know that “I’m not going to go*

*there”. It’s like a cultural OSH, these karakia over the sites and such...in a sense to outsiders this might seem random. There’s a cultural safety, and that might actually scare some people, but if our people are the labour force we should be doing these things to protect them (Int-7b-PP).*

Overall, the inclusion of the Cultural Compliance process does not generally exist within forestry companies – only within Māori forestry companies will you expect to find this type of non-commercial focus (TP) (Int-7a-TP.TW). It is therefore of great meaning and importance that this aspect has been included in the LCSA scenarios.

The figures and assumptions associated with Cultural Compliance are presented in Appendix F, and the participants’ impressions of recognising Cultural Compliance within their decision making is reviewed in Section 8.2.

## **5.5. Conclusions**

The participatory LCSA research focus led to a number of important results. Not only did the definition of the forestry scenarios take place in a collaborative manner but so did the selection and development of sustainability indicators. Such collaborative scenario and impact assessment development was both meaningful and useful to the participants of the LCSA results.

The Cultural Indicator Matrix signifies a substantial advancement in the endeavour of distinctly representing culture within LCSA. Indeed, the creation of this bespoke cultural indicator to include within the LCSA technique essentially provides an answer to the first PhD research question: How can Māori culture be represented in LCSA studies involving forestry value chains options?

The Cultural Compliance process was also a direct result associated with the participatory nature of this research. Cultural Compliance adds a degree of cultural accountability in a more transparent manner thus strengthening the viability and credibility of a culturally-focused LCSA framework.

## **Chapter 6**

### **6. LCSA study: Goal and Scope, and Inventory Analysis**

This chapter describes the goal and scope for the LCSA study (Section 6.1) and the data collected and models developed at Inventory Analysis (Section 6.2). This LCSA research utilised participatory engagement and qualitative interviews (Sections 4.3 and 4.4) to co-develop and define the LCSA scenarios (Section 5.2) and indicators (Sections 5.3 and 5.4).

#### **6.1. Goal and Scope definition**

##### **6.1.1. Goal of study**

As the main context for this LCSA study was research on how to represent Māori culture in LCSA studies involving forestry value chains, and on the relative benefits and disadvantages of using LCSA in Māori decision-making situations, assessment of a comprehensive set of sustainability indicators was not a high priority. Instead, it was decided to focus on one or two sustainability indicators from each of the sustainability “pillars” i.e. the environmental, economic, social and cultural dimensions of sustainability.

The goal of the LCSA study was therefore defined as being to assess selected sustainability impacts associated with three forestry scenarios: intensive radiata pine, continuous cover rimu, and production-scale mānuka (described in more detail in Sections 5.2.1, 5.2.2, and 5.2.3 respectively). These three scenarios were deliberated upon and decided by the participants with the acknowledgement that 1) radiata pine is currently present in the Waiapu region and so represents the “status quo” forestry option, 2) rimu is a native species which encapsulates the potential to plant and manage native species with long-term, inter-generational considerations, and 3) mānuka is another native species but one with the ability to provide short-term financial gain.

The process of undertaking the LCSA study relied on consistent and active engagement with three Ngāti Porou participants (see Section 4.4.1 for further background on the participants). The primary decision-context for this research was the participants' desire to consider and evaluate viable forestry scenarios in a concurrent manner in order to understand their relative sustainability impacts; they were not aiming to compare the scenarios to determine or choose which might be “best”. Instead, the participants wanted to understand how to combine and implement each of the forestry scenarios in order to achieve a staggered distribution of benefits and impacts over a long-term scale (i.e. to ensure that benefits and other impacts do not occur all at once).

For this study, it was decided to use an attributional – rather than consequential – LCSA modelling approach for the study.

Ekvall and Weidema (2004) state that consequential LCAs (CLCA) are commonly utilised to gain information on the “consequences of actions” (e.g. buying a product) while attributional LCAs (ALCA) provide information regarding “environmentally relevant physical flows to and from a life cycle and its subsystems” (p. 161). As the participants were interested in the information associated with the different forestry scenarios, and not the consequences of each scenario, it was therefore decided to use an attributional LCA modelling approach. More discussion on these modelling approaches can be found in Sections 2.2.5 and 2.2.5.1, including the arguable overlap in benefits and applications of ALCA and CLCA, as well as the assertion that there is no one superior approach.

### **6.1.2. Functional unit**

The LCSA was performed using two perspectives: land-use and product. The land-use perspective was defined as being from cradle (i.e. nursery) to point of harvest. For the product perspective, one product within each respective forestry scenario was pursued. Thus, the system boundaries were extended based on a single product relevant to each scenario; this extension allowed the demonstration of a full “cradle-to-grave” assessment. Ideally more products would have been analysed but due to time constraints only one product per forestry scenario was investigated.

The land-use perspective functional unit was selected to be “use of 1 hectare of unmanaged land”. This was regarded as the most appropriate functional unit given that the case study participants (and intended audience of the LCSA results) are most familiar and engaged with land-based activities, and so a “hectare” is an easily understandable unit with which to communicate the results.

For the product perspective, the selected products were house framing from radiata pine, flooring from rimu, and essential oil from mānuka. Thus, the functional units for the product perspective were 1 m<sup>3</sup> radiata pine framing, 1 m<sup>3</sup> rimu heartwood flooring, and 9,712 mānuka essential oil-filled 10mL bottles (i.e. 5% of the total essential oil produced per hectare of mānuka). The functional unit for mānuka was based on the knowledge that approximately 5% of the total essential oil produced is packaged into 10mL bottles; the remainder of the essential oil is used in other products (e.g. beauty and health care products).

### **6.1.3. System boundaries**

The baseline for the study was un-forested, unmanaged land (Figure 12). In addition, three forestry scenarios were modelled:

- i. Radiata pine, involving production forestry procedures including intensive ground preparation and clearfelling. The selected product was framing used in house construction (Figure 13).
- ii. Rimu, involving continuous cover forestry procedures including minimal chemical use and select group felling. The selected product was heartwood flooring used in home finishings. Following the life span of the rimu flooring, the subsequent secondary selected product was a rimu table made of recycled rimu flooring (Figure 14).
- iii. Mānuka (for essential oil production), involving intensive forest plantation operations and a substantial amount of seedlings planted. The selected product was 9,712 bottles of mānuka essential oil (i.e. 5% of the total oil produced per hectare) (Figure 15).

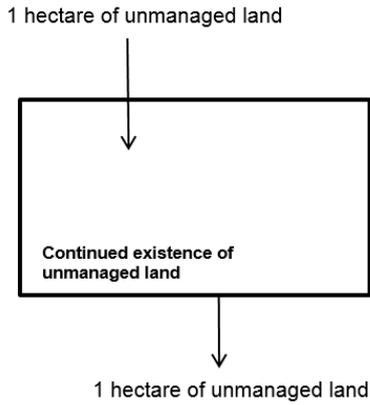


Figure 12. Baseline scenario (attributional) for forestry in New Zealand: one hectare of unmanaged land with natural regeneration and growth of grass and scrub. This land is suitable for forestry but is currently unutilised.

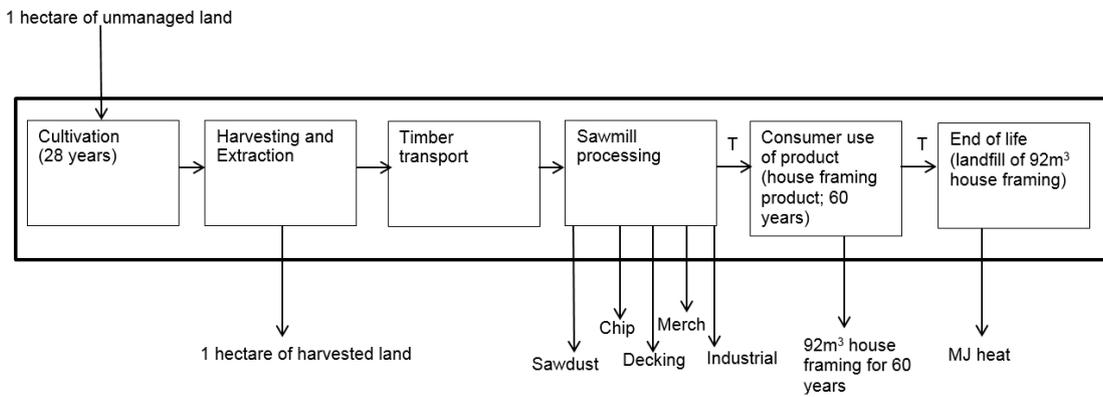


Figure 13. Radiata pine scenario (attributional): Radiata pine planted using intensive management techniques and clearfelled after 28 years.<sup>8</sup> (T indicates freight transport)

<sup>8</sup> ‘Merch’ refers to non-structural products (e.g. parts of fence, palings, boards) and ‘Industrial’ refers to pallets, crates, etc.

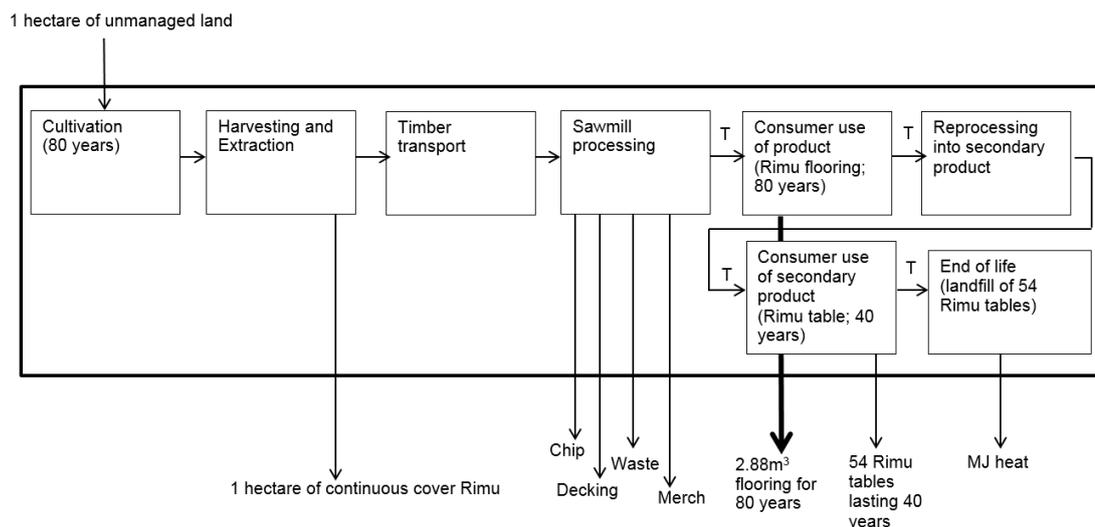


Figure 14. Rimu native forestry scenario (attributional): Rimu is planted using continuous cover forestry management and has small group fellings after 80 years (10% per hectare at year 80, and 10% every decade thereafter). The timber is transported to a portable sawmill where it is processed into high-end products such as heartwood flooring. After the consumer use of the rimu heartwood flooring, it is reprocessed into a secondary product such as a rimu table. (T indicates freight transport)

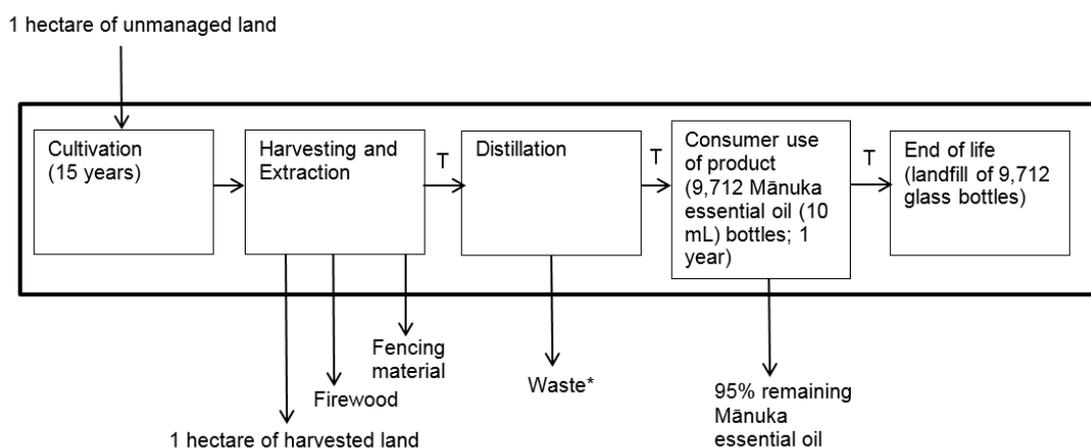


Figure 15. Mānuka forestry scenario (attributional): Mānuka is planted using intensive short rotation forestry management and has several cuttings of branches before the entire tree is cut and replaced at 15 years. The branches are distilled and the resulting oil is packaged and consumed. \*Distillation produces steamed branch matter that may be considered waste yet is also viable mulch material which could be sold as a co-product. (T indicates freight transport)

The diagrams in the solid-outline boxes in Figures 12-15 show the main activities assessed in the LCSA

#### **6.1.4. Data Sources and Data Quality**

Where possible, current and site-specific (i.e. Waiapu catchment) primary data was sourced from industry experts. Other data sources include modelled data, publications, reports, and the v3.1 Ecoinvent database. Appendix F presents the data used, the sources, date when data was attained or published, assumptions made (if any), and potential data quality issues (if any). The majority of the data are representative of values from 2014 and 2015.

#### **6.1.5. Impact Assessment**

As presented in Sections 5.3 and 5.4, the midpoint indicators were collaboratively selected by the participants and guided by myself, the LCSA practitioner. The chosen economic indicators were “cost” and “profit” (Section 5.3.1), the social indicator was “employment” (Section 5.3.2), the environmental indicators were ‘GHG emissions’ and “carbon sequestration/storage” (Section 5.3.3), and the cultural indicator was the “Cultural Indicator Matrix”, a bespoke development derived from this LCSA research (Section 5.4.1).

In order to calculate profit it was necessary to define ownership structures within each scenario. The life cycle-value chains were assumed to be owned and operated by one “entity” (i.e. the participants and the Ngāti Porou iwi), and were inclusive of the nursery through to entry at the sawmill gate (radiata pine, rimu) and through the distillation process (mānuka). This assumption is based on the participants’ desire to own and operate as much of the life cycle-value chain as possible; the proposed processes from each scenario to be defined under one entity represent a viable, albeit ambitious, segment of the life cycle-value chains which could potentially be owned and operated by Ngāti Porou. The remainder of the life cycle-value chain processes (e.g. sawmilling, house construction, mānuka oil packaging) are assumed to be operated by external entities. However, output materials from certain processes (e.g. seedlings output from the nursery)

are input materials into other processes (e.g. seedlings output used as planting input). With internal material flow occurring under one owner/operator entity, the dominant implication is that profit does not transpire until the final process controlled by said entity (i.e. transport (radiata pine, rimu) and distillation (mānuka)).

Furthermore, for each product perspective study, profit is only reported for those processes which add value to the product detailed within each scenario. For example, the deconstruction process in the radiata pine scenario does not incur a profit as the wood sourced as a result is considered a waste and is subsequently delivered to the landfill. The deconstruction process in the rimu scenario, however, does incur a profit as the wood sourced as a result is considered a commodity as it is recycled and used in the following refurbished timber furniture process.

Weighting of the different indicator results was not included in the LCSA. The participants considered it to be “inconsistent” with the Māori worldview and inherent “holistic framework” (Int-5b-TP), as highlighted in this comment:

*With my sustainability hat on, I have to say no. They all have to be given the same emphasis because we may have very strong tikanga and Te Reo but our environmental or healthy ecosystems are not good. Or really strongly connected whānau but no one has a job. For me I don't think we can weight them against each other (Int-5b-TP).*

However, one of the participants considered that there could be a role for a reflexive weighting step when analysing the scenarios in future research regarding decision-making processes:

*We probably would require a weighting but I would also say that the aspirations might stay the same but the weighting might change depending on what phase you were in. So, say if you've got nothing and you want to start taking up one of these industries it might pan out that they are all critical or the economic ones might be more critical. But once you're established the weighting might change so that we can look at the other aspects (PP) (Int-5a-TW.PP).*

## **6.2. Life cycle inventory analysis**

This section describes the data used in modelling the baseline and the three scenarios (radiata pine, rimu, and mānuka), and the main assumptions. For further, more detailed data see Appendix F.

### **6.2.1. Baseline scenario**

The baseline is defined as unmanaged, un-forested land covered in wild grasses and shrubs. The land is assumed to be flat, suitable for forestry, and not marginal (i.e. “land that in its current use gives a poor economic return, and has the potential for improved returns” (Payn, 2010, p. 4). Since the land is unmanaged and unutilised, there are no associated activities and therefore there is no cost, profit, employment, or relevant changes in greenhouse gas emissions associated with the land. However, carbon is sequestered in the grasses and shrubs, and the land has cultural value.

### **6.2.2. Radiata pine scenario**

Radiata pine forestry is the most common type of forestry in New Zealand and as such it represents the “status quo” option. The rotation length used in the radiata pine scenario is 28 years.

The processes modelled in the radiata pine life cycle are shown in Figure 13 and described below; the associated data are in Appendix F.

- Nursery

Radiata pine seedlings are produced in a nursery and take 12 months to grow from a seed to seedlings ready for planting. Nurseries primarily use fungicides and pesticides, electricity for heating in the greenhouse, and diesel for operating the tractors on-site. The number of radiata pine seedlings required for one hectare of land is 833 seedlings (P. Hall, personal communication, August 18, 2014).

- Site preparation

Site preparation involves spraying the land to kill existing vegetation, and mechanical preparation of the soil. In this scenario, it was assumed that fertiliser was not required.

The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 63,800 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (BSI, 2011b).

As per the PAS 2050 (BSI, 2011a) guidelines, the total GHG emissions from land use change were evenly distributed over 20 years (5% per year).

- Planting

The planting process includes only the labour cost of planting 833 stems per hectare. The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not included as an additional cost during the planting process.

- Tending

The tending process involves the management, protection, and maintenance of the forest throughout its growth. Tending includes weed control (aka – “releasing”), tree disease control (for the two dominant diseases of Red Needle Cast (*Phytophthora pluvialis* (Reeser, Sutton, & Hansen, 2013)) and Dothistroma needle blight (*Dothistroma septosporum* (Dorog.) M. Morelet)) via helicopter spraying, tree inventory assessment (i.e. determining the value of the standing forest), and the annual activities of forest management, rates (land tax) and fire insurance, fence and track maintenance, and animal (pest) control.

The tending activities include the processes of construction of in-forest roading and landing sites (i.e. cleared areas where felled trees are processed and prepared for transport). These activities occur towards the end of the forest growth cycle at year 26 in

preparation for harvesting activities. Roading external to the forest was excluded as it was assumed that no additional infrastructure was required.

- Thinning (to waste)

The thinning process is assumed to reduce the total number of planted stems per hectare from 833 to 450 at year 10. The thinnings are left on-site to decompose.

- Clear felling (i.e. complete harvesting of a site)

The clear felling process involves the cutting of the entire forest stand. Felling occurs at year 28 and the total standing volume at the time of felling is estimated at 760.5 m<sup>3</sup> per hectare<sup>9</sup> (MacLaren & Knowles, 2005).

- Extraction

The extraction process involves removing the felled stems from the site and depositing them at the landing site for further handling. It is estimated that 11% of the original total standing volume (760.5 m<sup>3</sup> per hectare) is left on-site during extraction and landing site operations (P. Hall, personal communication, 15 March, 2014). This non-merchantable volume amounts to a volume loss of approximately 84 m<sup>3</sup> per hectare. Non-merchantable wood is below a merchantable size, has exceedingly poor form or is damaged when the trees are felled. In addition to this material, biomass in the form of stumps, branches, and foliage is left on site after harvest.

- Landing site operations

Landing site operations primarily include log making (i.e. cutting the stems into pre-determined log lengths) and loading (i.e. placing the logs onto the logging trucks for timber transport). It is estimated that 4% of the original volume deposited at the landing site (676.84 m<sup>3</sup>) is left on-site, i.e. 27.07 m<sup>3</sup> is left at the landing site (P. Hall, personal communication, 15 March, 2014). This loss of volume is attributed to the log making process and any stem breakage that may occur during handling.

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<sup>9</sup> 1 m<sup>3</sup> is assumed to be harvested softwood under bark.

- Timber transport

The logs are transported to a sawmill. The volume transported per hectare is 650 m<sup>3</sup> (i.e. the remaining volume after harvesting and landing site operations). Although a given radiata pine stem consists of both sawlog and pulp wood, it is assumed that all of the wood is transferred to the same sawmill. Subsequent processing of the logs in the sawmill yard is excluded from the assessment due to its anticipated insignificant contribution to the indicator results.

- Sawmill

The sawmill process is modelled to account for the production of framing product for residential housing purposes. Specifically, the framing product is defined as “SG8” where “SG” denotes “stress grade” and is used in areas of high weight load such as roof trusses and load bearing walls. SG8 is the most valuable type of framing product.

The sawmill figures are based on the output of a large sawmill with a volume intake of 350,000 m<sup>3</sup> per year. The proportion of each log that is suitable for framing timber can be seen in Figure 16. Of the sawlog material, approximately 14% will be suitable for framing (Jack, Hall, Goodison, & Barry, 2013). Therefore, of the original 650 m<sup>3</sup> per hectare delivered to the sawmill, 92 m<sup>3</sup> per hectare will be processed into framing product.

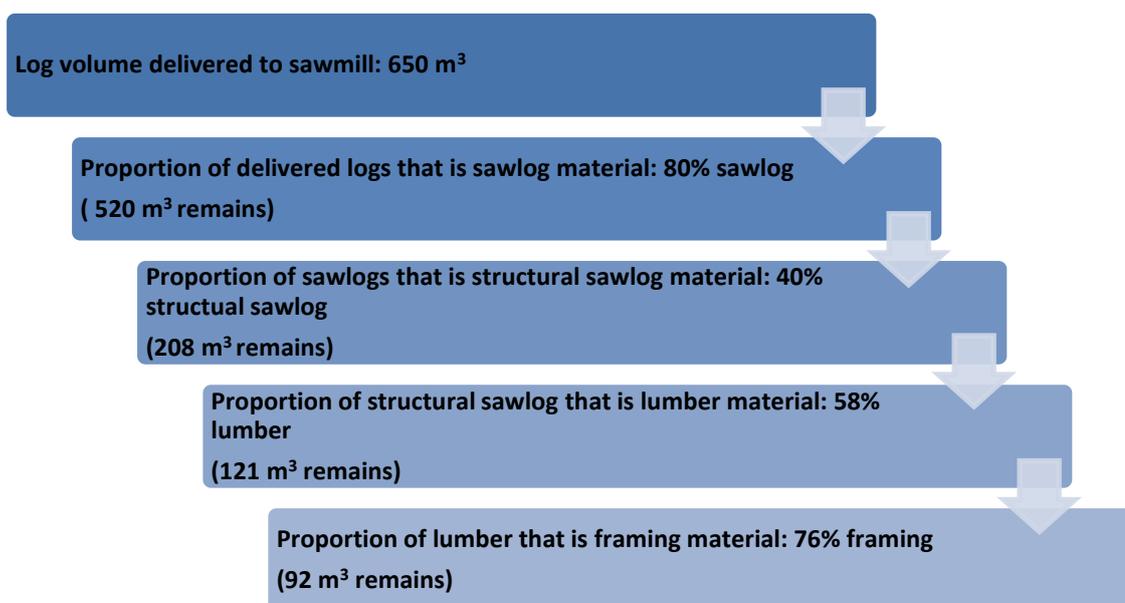


Figure 16. Representation of the proportion of radiata pine wood supply moving through different processing activities to production of framing material.

- House construction

The house construction process is based on a large home production business (e.g. Stonewood in New Zealand) that has a significant intake of wood, and therefore could buy direct from sawmill. This assumption therefore circumvents the need to include a retail operation process to sell the sawn timber. Waste generation is assumed to be 10% during the construction process (i.e. 9.2 m<sup>3</sup> of radiata pine construction waste). Furthermore, as this is a theoretical “what if” LCSA scenario, it was assumed that minimal transport was needed to travel from the sawmill to the house construction site, and thus this transport was excluded from the assessment due to its anticipated insignificant contribution to the indicator results.

A generic, “exemplar” house (BRANZ, 2010; Love & Szalay, 2007; Willson, 2002) was chosen to represent the “house construction” process, and contains 195 m<sup>2</sup> of floor area. Given the timber framing component of the house is estimated to weigh 10,367.8 kg (or 4.69% of the total house weight) (McDevitt & Allison, 2012) and the density of oven dried wood with a 16% moisture content is 450 kg/m<sup>3</sup> (Sandilands & Nebel, 2010b), there is approximately 23 m<sup>3</sup> of framing product in the exemplar house. Accounting for 10% construction waste generation, 82.8 m<sup>3</sup> is used in house construction – this is enough framing product to complete approximately four houses (assuming 23 m<sup>3</sup> of framing product is needed per house).

- House deconstruction

Costs and figures for house deconstruction are based on an industry quotation (J. Davy, personal communication, January 12, 2015) which states an average house deconstruction cost of \$16,000. With the framing component of the house accounting for 4.69% of the total house weight then it may be estimated that framing deconstruction costs \$750, or \$32.60/m<sup>3</sup> (based on a total of 23m<sup>3</sup> of framing).

- Landfill (end-of-life)

The end-of-life process for the radiata pine house framing is comprised of wood waste from both the construction and deconstruction processes – a total of 92 m<sup>3</sup> (i.e. the amount of framing material arising from one hectare of radiata pine forest). The wood waste is

to be disposed of in a landfill as this is the most dominant form of wood waste disposal (Nielsen & Gifford, 2001; Sandilands & Nebel, 2010a). Current landfill costs are \$251 per tonne of commercial waste (Gisborne District Council, 2015). With the density of radiata pine framing waste after 60 years of consumer use being 420kg per m<sup>3</sup> (New Zealand Institute of Forestry, 2005), then 1 m<sup>3</sup> is equivalent to 0.42 tonne of waste. Therefore, the cost for one m<sup>3</sup> of radiata pine wood waste is \$105.42.

As per the PAS 2050 guidelines regarding the landfill process (Annex B.1.2), calculations were made to determine the weighted average impact of “delayed release” landfill emissions (BSI, 2008). The landfill emissions also include the use of diesel for landfill operations.

*Table 8. Summary of inventory data used for the radiata pine scenario.*

<b>Radiata pine processes</b>	<b>Unit of analysis</b>	<b>Total costs (NZ\$)</b>	<b>Employment (hours)</b>	<b>Profit (NZ\$)</b>	<b>GHG (kgCO<sub>2</sub>eq)</b>
<b>Nursery</b>	seedling	0.70	0.02	-	0.02
<b>Aerial spray</b>	hectare	155.00	0.058	-	24.23
<b>Mechanical preparation</b>	hectare	28.49	0.19	-	11.48
<b>Opportunity cost (annual)</b>	hectare	1040.00	0.000	-	-
<b>Planting</b>	hectare	323.94	8.10	-	111,650
<b>Release (years 1, 2, and 3)</b>	hectare (for 1 spray)	230.00	0.06	-	23.08
<b>Forest management (annual)</b>	hectare	48.00	2.00	-	-
<b>Rates &amp; Fire insurance (annual)</b>	hectare	17.00	0.00	-	-
<b>Fences &amp; track maintenance (annual)</b>	hectare	6.00	0.15	-	-
<b>Animal control (annual cost)</b>	hectare	2.00	0.05	-	-
<b>Red needle cast spray (3 sprays - year 2, year 7, year 12)</b>	hectare (for 1 spray)	64.13	0.02	-	8.53

<b>Dothistroma spray (3 sprays - year 2, year 7, year 12)</b>	hectare (for 1 spray)	42.75	0.014	-	6.10
<b>Inventory</b>	hectare	20.00	0.500	-	-
<b>Thinning (to waste)</b>	hectare	320.00	7.60	-	17.34
<b>Landing construction</b>	hectare	1500.00	7.67	-	690.00
<b>Roading (new)</b>	hectare	2643.00	6.33	-	466.90
<b>Felling</b>	m <sup>3</sup> felled tree	5.65	0.012	-	1.20
<b>Extraction</b>	m <sup>3</sup> felled tree	6.52	0.024	-	2.54
<b>Landing site - log making</b>	m <sup>3</sup> felled tree	4.76	0.072	-	1.34
<b>Landing site - loading</b>	m <sup>3</sup> felled tree	4.61	0.036	-	1.69
<b>Timber transport (44t logging truck)</b>	m <sup>3</sup> felled tree	19.74	0.12	2.19	14.30
<b>Sawmill (framing product)</b>	m <sup>3</sup> framing product	264.00	1.06	116.00	30.00
<b>Housing construction (framing product)</b>	m <sup>3</sup> framing product	693.00	3.50	41.58	9.50
<b>House deconstruction (framing product)</b>	m <sup>3</sup> framing product	32.60	0.54	-	2.99
<b>Landfill (end of life)</b>	m <sup>3</sup> framing product	105.42	0.43	21.08	18.79

### 6.2.3. Rimu scenario

Forestry using a native species was of great interest to the participant group. However, the intensive harvesting (i.e. clearfelling) of a planted native species is generally not culturally favourable. Therefore, this rimu scenario utilised a continuous cover forestry management technique where only 10% of each hectare was selectively felled at any given time in order to preserve the native forestry ecosystem whilst concurrently attaining economic, social, and cultural services. It was assumed that the first selective felling of rimu occurred at year 80.

The processes modelled in the rimu life cycle are shown in Figure 14 and described below; the associated data are in Appendix F.

- Nursery

Rimu seedlings are produced in a nursery and take 12 months to grow from a seed to seedlings ready for planting. Nurseries primarily use fungicides and pesticides, electricity for heating in the greenhouse, and diesel for operating the tractors on-site. The number of rimu seedlings required for one hectare of land is 1,100 seedlings (G. Steward, personal communication, November 19, 2014).

- Site preparation

In the rimu scenario, the site preparation process was assumed to utilise minimal intensive techniques. Thus, rimu site preparation involved initially hand spraying the land with an herbicide to desiccate the existing grasses and shrubs. Mechanical preparation of the soil was avoided in favour of the less mechanically intensive (albeit more labour intensive) process of “screefing” (i.e. “removal of the surface vegetation with a spade or grubber to expose the soil” (Douglas, Dodd, & Power, 2007, p. 146). In this scenario, it was assumed that fertiliser was not required.

The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 63,800 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (BSI, 2011b).

As per the PAS 2050 (BSI, 2011a) guidelines, the total GHG emissions from land use change were evenly distributed over 20 years (5% per year).

- Planting

The planting process includes only the labour cost of planting 1,100 stems per hectare. The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not also included during the planting process.

- Tending

The tending process involves the management, protection, and maintenance of the forest throughout its growth. Rimu tending was assumed to include weed control (via hand weeding), tree inventory assessment (i.e. determining the value of the standing forest), and the annual activities of forest management, rates (land tax) and fire insurance, fence and track maintenance, and animal (pest) control.

The tending activities included the processes of construction of in-forest roading and landing sites (i.e. cleared areas where felled trees are processed and prepared for transport). These activities occur before the first selective harvesting process at year 78 in preparation for harvesting activities. Roading external to the forest was excluded as it was assumed that no additional infrastructure was required.

- Form pruning

The form pruning process ensures that each tree grows with a single, straight stem and removes any steep-angled branches which may impact upon timber quality as the tree matures. Form pruning occurs three times during the initial growth phase of planted rimu: at year 8 to remove steep-angled branches and double leaders (i.e. one tree growing two stems), and at years 18 and 28 to raise branch height (G. Steward, personal communication, November 19, 2014).

- Selective felling

The selective felling process involves the partial harvesting of a rimu stand (i.e. 10% per hectare, and 10% per hectare every decade thereafter). With the total standing volume at the time of felling estimated at 920 m<sup>3</sup> per hectare <sup>10</sup> (G. Steward, personal communication, November 19, 2014), 92 m<sup>3</sup> was selectively felled at year 80. Selective felling involves three activities: surveying the stand before felling and marking the trees

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<sup>10</sup> 1 m<sup>3</sup> is assumed to be harvested softwood under bark.

to be felled, felling the marked trees with a chainsaw, and cutting the felled trees into suitable logs for subsequent helicopter removal.

- Extraction

The extraction process involves removing the felled stems (via helicopter) from the site and depositing them at the landing site for further handling. A proportion of the original felled volume (92 m<sup>3</sup> per hectare) is left on-site and may include material from the stumps, tree tops, and branches. It is assumed that there is less wastage with rimu harvesting than with radiata pine due to the extra care that would be taken during the felling process; minimisation of wastage increases the recoverable volume of each tree and thus increases the attainable value from each tree. It is estimated that 9% (approximately 9 m<sup>3</sup>) of the total standing volume is woody material left on-site as non-merchantable material; therefore, the amount of m<sup>3</sup> actually handled during extraction and deposited at the landing site is 83 m<sup>3</sup>. Non-merchantable material is below a merchantable size, has exceedingly poor form or is damaged when the trees are felled. In addition to this material, biomass in the form of stumps, branches, and foliage is left on site after harvest.

- Landing site operations

It is estimated that 4% of the original volume deposited at the landing site (83 m<sup>3</sup>) is left on-site, thus amounting to 3 m<sup>3</sup> left at the landing site (P. Hall, personal communication, 15 March, 2014). This loss of volume is attributed to the log making process and any stem breakage that may occur during handling. All loading-related costs and figures are based on those of radiata pine as there is little anticipated difference between loading radiata pine and loading rimu.

- Timber transport

The logs are transported to a sawmill. The volume transported per hectare is 80 m<sup>3</sup> (i.e. the remaining volume after harvesting and landing site operations). Although a given rimu stem consists of both sawlog and pulp wood, it is assumed that all of the wood is transferred to the same sawmill. Subsequent processing of the logs in the sawmill yard is excluded from the assessment due to its anticipated insignificant contribution to the indicator results.

- Sawmill

The sawmill process is modelled to account for the production of rimu residential flooring. Specifically, the flooring product is defined as “rimu heartwood flooring – dressing A grade”.

The sawmill figures are based on the output of a small, semi-portable sawmill with a volume intake of 15,000 m<sup>3</sup> per year (P. Hall, personal communication, May 15, 2014). Although the output of a small sawmill is lower, it has the distinct benefit of being able to allocate greater time on timber recovery; a higher rate of timber recovery leads to a greater value attained per tree. Recovery rates (i.e. how much sawlog material can be cut from each tree) are based on those of radiata pine but adjusted to account for greater time given to processing and subsequent rise in accuracy and optimisation.

There is no timber quality data for planted rimu that is harvested at 80 years. As such, extrapolations from current fieldwork regarding planted rimu estimate that 4% of each log is suitable for heartwood flooring timber (G. Steward, personal communication, November 19, 2014). Therefore, of the original 80 m<sup>3</sup> per hectare delivered to the sawmill, only 3.2 m<sup>3</sup> per hectare will be processed into rimu flooring product.

- House construction

The house construction process is based on a large home production business (e.g. Stonewood in New Zealand) that has a significant intake of wood, and therefore could buy direct from sawmill. This assumption therefore circumvents the need to include a retail operation process to sell the sawn timber. Waste generation is assumed to be 10% during the construction process, and so 2.88 m<sup>3</sup> rimu flooring is actually used as flooring in the constructed house. Furthermore, as this is a theoretical “what if” LCSA scenario, it was assumed that minimal transport was needed to travel from the sawmill to the house construction site, and thus this transport was excluded from the assessment due to its anticipated insignificant contribution to the indicator results.

A generic, “exemplar” house (BRANZ, 2010; Love & Szalay, 2007; Willson, 2002) was chosen to represent the “house construction” process, and contains 195 m<sup>2</sup> of total floor

area (including flooring for the loft, garage, etc). However, the area realistically suitable for high-end rimu flooring product in the exemplar house is 147 m<sup>2</sup> (Willson, 2002). Assuming the rimu flooring has a thickness of 19mm (Timspec, 2014), then one m<sup>2</sup> of flooring is equivalent to 0.019 m<sup>3</sup>, and 52.6 m<sup>2</sup> is equivalent to one m<sup>3</sup>. Therefore, the exemplar house requires 2.8 m<sup>3</sup> of rimu flooring product. So, the 2.88 m<sup>3</sup> rimu flooring produced is enough flooring to complete approximately one house.

- House deconstruction

The house deconstruction process occurs after the rimu flooring in the house has been used for 80 years. Costs and figures for house deconstruction are based on the installation times for rimu flooring – it was assumed that it takes 25% of the time to uninstall the 2.8 m<sup>3</sup> of rimu flooring as it does to install it.

- Furniture making

The furniture making process utilises the used rimu flooring and recycles it into a product; for the purposes of this demonstrative exercise, a rimu table was selected as the product using recycled rimu flooring. It is assumed that the process of furniture making incurs 10% waste (Simply Wood representative, personal communication, January 23, 2015); therefore, of the 2.8 m<sup>3</sup> of rimu flooring that was removed from in the exemplar house approximately 2.5 m<sup>3</sup> of recycled rimu wood will exist in the final table product.

The rimu table was assumed to have dimensions of 160cm x 100cm x 2cm. Therefore, if each table requires 0.048 m<sup>3</sup> of wood, then the amount of recycled rimu flooring is enough to create approximately 52 tables.

- Landfill (end-of-life)

The end-of-life process for the rimu heartwood flooring is comprised of wood waste from the construction, deconstruction, and furniture making processes – a total of 3.2 m<sup>3</sup>. The density of rimu wood waste after 120 years of consumer use (80 years as flooring, 40 years as a recycled table) is 490kg per m<sup>3</sup> (New Zealand Institute of Forestry, 2005), and so 1 m<sup>3</sup> is equivalent to 0.49 tonne of waste. As current landfill costs are \$251 per tonne

of commercial waste (Gisborne District Council, 2015), the cost for one m<sup>3</sup> of rimu wood waste is approximately \$123.

As per the PAS 2050 guidelines regarding the landfill process (Annex B.1.2), since the landfill process occurs after the 100-year timeframe the GHG emissions attributed to the decomposition of the wood waste were excluded. Thus, the landfill emissions are associated to the use of diesel for landfill operations.

*Table 9. Summary of inventory data used for the rimu scenario.*

<b>Rimu processes</b>	<b>Unit of analysis</b>	<b>Total costs (NZ\$)</b>	<b>Employment (hours)</b>	<b>Profit (NZ\$)</b>	<b>GHG (kgCO<sub>2</sub>eq)</b>
<b>Nursery</b>	seedling	1.40	0.05	-	0.04
<b>Hand spray</b>	hectare	146.00	3.50	-	4.72
<b>Aerial spray</b>	hectare	155.00	0.058	-	24.23
<b>Screening/mulching</b>	hectare	277.2	7.7	-	111,650
<b>Opportunity cost (annual)</b>	hectare	1,040.00	0.000	-	-
<b>Planting</b>	hectare	718.8	17.97	-	-
<b>Hand weeding year 1 (2x per year)</b>	hectare	1,755.60	48.77	-	-
<b>Hand weeding year 2 (2x per year)</b>	hectare	1,320.00	36.67	-	-
<b>Hand weeding year 3 (2x per year)</b>	hectare	660.00	18.33	-	-
<b>Blanking (replacement) year 1</b>	hectare	33	0.92	-	-
<b>Forest management (annual)</b>	hectare	48.00	2.00	-	-
<b>Rates &amp; Fire insurance (annual)</b>	hectare	17.00	0.00	-	-
<b>Fences &amp; track maintenance (annual)</b>	hectare	6.00	0.15	-	-
<b>Animal control (annual)</b>	hectare	2.00	0.05	-	-

<b>Inventory</b>	hectare	20.00	0.500	-	-
<b>Form pruning - 3x over rotation</b>	hectare	4,845.06	134.59	-	-
<b>Marking</b>	hectare	60.00	2.00	-	-
<b>Landing construction</b>	hectare	285.00	1.46	-	131.10
<b>Roading (new)</b>	hectare	330.38	0.79	-	58.36
<b>Felling</b>	m <sup>3</sup> felled tree	22.00	0.04	-	0.79
<b>Flitching</b>	m <sup>3</sup> felled tree	30.00	0.04	-	0.79
<b>Extraction - helicopter</b>	m <sup>3</sup> felled tree	136.23	0.04	-	45.06
<b>Landing site - loading</b>	m <sup>3</sup> felled tree	26.00	0.036	-	9.52
<b>Timber transport (44t logging truck)</b>	m <sup>3</sup> felled tree	19.74	0.12	2.19	14.30
<b>Sawmill ('boutique')</b>	m <sup>3</sup> flooring product	445.5	0.97	9,285.5	30.09
<b>Housing construction (flooring)</b>	m <sup>3</sup> flooring product	11,916.65	14.31	5,145.85	1.33
<b>House deconstruction</b>	m <sup>3</sup> flooring product	178.91	3.58	1,321.09	-
<b>Furniture making facility</b>	m <sup>3</sup> table product	26,795.71	624.9	4,220.158	-
<b>Landfill (end of life)</b>	m <sup>3</sup> flooring and table products (total)	123.00	0.50	24.60	33.10

#### 6.2.4. Mānuka scenario

The mānuka scenario is another forestry alternative using a native species yet is distinctly different from the rimu scenario in that it is more aligned with intensive production techniques. For this scenario, mānuka is planted, maintained, and harvested for the

purpose of attaining high amounts of foliage material to produce mānuka essential oil. The rotation length used in the mānuka scenario is 15 years.

The processes modelled in the mānuka life cycle are shown in Figure 15 and described below; the associated data are in Appendix F.

- Nursery

Mānuka seedlings are produced in a nursery and take 12 months to grow from a seed to seedlings ready for planting. Nurseries primarily use fungicides and pesticides, electricity for heating the greenhouse, and diesel for operating the tractors on-site. The number of mānuka seedlings required for one hectare of land is 15,000 seedlings (for the initial planting) and, over the 15-year mānuka rotation, approximately 10,000 additional seedlings will be required to replace any dead seedlings (P. Caskey, personal communication, February 2, 2015).

- Site preparation

Site preparation involves spraying the land to kill existing vegetation, and mechanical preparation of the soil. In this case study, it was assumed that fertiliser was required and thus includes an initial soil analysis process and subsequent application of (urea) fertiliser. Irrigation was assumed to not be required.

The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 63,800 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (BSI, 2011b).

As per the PAS 2050 (BSI, 2011a) guidelines, the total GHG emissions from land use change are to be evenly distributed over 20 years (5% per year). However, as mānuka only has a 15-year rotation, 75% of the total GHG emissions were evenly distributed over the full mānuka rotation.

- Planting

The planting process includes only the labour cost of planting the initial 15,000 seedlings per hectare. The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not also included during the planting process.

- Tending

The tending process includes weed control (aka – “releasing”) using herbicides via helicopter, disease control of mānuka blight from the scale insect (*Eriococcus orariensis* Hoy) via hand spray, tree inventory assessment, replacement of dead seedlings (aka – “blanking”), and the annual activities of rates and fire insurance, fence and track maintenance, and animal (pest) control. No in-forest construction for landing sites and roading infrastructure is required for the mānuka scenario.

- Harvesting and transport of branches

Harvesting (or trimming) of each mānuka tree removes two-thirds of the total branch material. Harvesting is done with the simultaneous operation of a forage harvester and a truck with trailer. The forage harvester cuts and immediately deposits material into the trailer. Therefore, the harvesting and transport processes have been combined in this scenario; there is no additional transport process required.

The average amount of branch material trimmed each year is 3 kg per mānuka plant, or 34 tonnes per hectare. The total amount of branch material harvested per hectare per rotation (15 years) is 544 tonnes.

- Distillation

The distillation process involves steam distilling the mānuka branch material to produce mānuka essential oil. Approximately 3.5 kg of essential oil is produced for every tonne of mānuka branch material distilled (P. Caskey, personal communication, February 2, 2015). Therefore, if 544 tonnes of mānuka branch material is produced then 1,904 kg of essential oil is created during the distillation process.

- Packaging (9,712 mānuka essential oil-filled 10mL bottles; 5% of total oil produced)

Of the total amount of mānuka essential oil produced (1,904 kg or, after accounting for density conversions, 1,942,500 mL), it is estimated that 5% is utilised for packaging in 10mL bottles (P. Caskey, personal communication, February 2, 2015). Thus, 5% of the total oil produced 97,125 mL, or 9,712 10mL mānuka essential oil-filled bottles.

- Landfill of empty mānuka essential oil bottle (end of life).

The empty mānuka essential oil glass bottles are assumed to be disposed of in a landfill. Each glass bottle weighs 28 grams, therefore the total amount of glass waste from 9,712 bottles is approximately 272 kg (or 0.272 tonne). As current landfill costs are \$251 per tonne of commercial waste (Gisborne District Council, 2015), the cost for 9,712 10 mL glass bottles is approximately \$68. The landfill emissions also include the use of diesel for landfill operations.

Table 10. Summary of inventory data used for the mānuka scenario.

Manuka processes	Unit of analysis	Total costs (NZ\$)	Employment (hours)	Profit (NZ\$)	GHG (kgCO <sub>2</sub> eq)
Nursery	seedling	1.12	0.04	0.18	0.03
Aerial spray	hectare	140.47	0.06		24.23
Soil analysis and tests	hectare	34.00	0.85		
Fertiliser 1 <sup>st</sup> year	hectare	78.56	0.25		151.74
Fertiliser 2 <sup>nd</sup> year+	hectare	39.28	0.13		75.87
Mechanical preparation	hectare	57.43	0.19		11.48
Opportunity cost (annual)	hectare	1040.00	0.000		
Planting	hectare	5,832.00	145.80		111,650
Planting	seedling	0.39	0.01		

<b>Release (annual)</b>	hectare	210.00	0.06		20.70
<b>Rates &amp; fire insurance (annual)</b>	hectare	17.00	0.00		
<b>Fences &amp; track maintenance (annual)</b>	hectare	6.00	0.15		
<b>Animal control (annual)</b>	hectare	2.00	0.05		
<b>Scale pest control (annual)</b>	hectare	73.00	1.75		
<b>Harvesting and transport</b>	t brush	55.16	1.00	544.84	186.88
<b>Distillation</b>	t brush	913.43	4.00	136.57	44.85
<b>Packaging (5% of total oil produced)</b>	t brush	222.31	0.60	81.14	0.40
<b>Landfill (end of life; 5% of total oil produced)</b>	t brush	0.130	0.0005	0.03	0.3455

### 6.3. Conclusions

This chapter presented the goal and scope, and inventory data that were used in each forestry scenario. The goal of the LCSA study was defined as being to explore and understand selected sustainability impacts associated with three forestry scenarios: intensive radiata pine, continuous cover rimu, and production-scale mānuka.

The radiata pine scenario is based on robust data as the radiata pine forestry processes are well researched and documented. The rimu and mānuka scenarios are based on data mainly sourced from experts currently working in these emerging (and thus less documented) forestry processes. Each of the scenarios use data primarily sourced from 2014-2015.

The details and sources of the primary data are presented in this chapter; for more detailed information see Appendix F.

## Chapter 7

### 7. Life cycle impact assessment and interpretation

This chapter presents and discusses the LCSA indicator results for the baseline and three forestry scenarios (radiata pine, rimu, and mānuka), representing the activities along the life cycle from the cradle (i.e. nursery) to the point of harvest. In addition, one product for each scenario was modelled through subsequent manufacture, distribution, consumer use, and waste management; the products were radiata pine framing, rimu heartwood flooring, and mānuka essential oil-filled 10mL bottles. This extension was undertaken in order to demonstrate a full “cradle-to-grave” assessment using LCSA.

The results for each scenario are presented using two alternative perspectives: the land-use perspective (i.e. cradle-to-point of harvest processes) and the product perspective (i.e. cradle-to-grave processes). The land-use perspective results (Section 7.2) are presented as both “per hectare per rotation” and “per hectare per year”, and the product perspective results (Section 7.3) are presented “per 1 m<sup>3</sup> radiata pine framing”, “per 1 m<sup>3</sup> rimu heartwood flooring”, and “per 9,712 mānuka essential oil-filled 10mL bottles” (note: the number of mānuka essential oil-filled bottles represents 5% of the total essential oil produced). The relevance of each of these perspectives is discussed in Section 7.4.

The indicators presented are: total cost, profit, employment, GHG emissions, carbon sequestered, and the Cultural Indicator Matrix. The development of the Cultural Indicator Matrix was presented in Section 5.4.1, and the full disaggregated results can be found in Appendix E.

As well as presenting the indicator results in table format, showing values per activity in the life cycle, the results are also presented on timelines for each scenario. This timeline presentation format was adopted based on discussions with the participants who wanted to be able to visualise the different timings of costs and benefits, in particular, between the short-rotation radiata pine and the continuous plantation rimu scenario where

activities occur over a lengthy, multi-generational timeline. As the participants commented:

*I think that people will need to be shown clearly that there is an income across the timeline, not just at the end of the timeline. That's probably my biggest challenge (Int-4c-TP).*

*I know we, on our family land, we've spoken about indigenous forests, sustainable harvesting, management and harvesting. We've talked about it but just seeing a timeline on paper actually makes me realise...what we do is sort of by upbringing and by talking and sharing, you know that's how we transfer through the generations our aspirations and what we want, our legacy and all of that. But... we're much lighter on actually backing it up with tools and like I say, this is just your first cut on a timeline, on a plan, but we've actually not even mapped that sort of time frame, we haven't done that yet (Int-4a-PP).*

*And that's where we have a little problem, in fact it's a great problem, everyone wants to realise something for themselves now. And it's a real Western ideology that we've adopted like "get as much as we can now for us now". That's what success, that's what wellbeing is about but it's not real (TW) (Int-2a-TP.TW).*

For the economic indicators, only cost is shown in the land-use perspective timelines as the profit only arises once the harvested timber reaches the sawmill gate (for radiata pine and rimu) and once the distillation process has occurred (for mānuka). The timeline results are presented in Section 7.2.4.2 for the land-use perspective results and in Section 7.3.4.2 for the product perspective results. The overall land-use perspective results are discussed together in Section 7.2.4.1.

Sensitivity analyses were also performed for growing and harvesting radiata pine and rimu on steep land, and using different economic discount rates for each scenario (the results in this chapter reflect a 0% discount rate). The data for the sensitivity analyses are in Appendix G (steep land analysis) and Appendix H (discount rates). The results of the sensitivity analyses are not directly relevant in answering the research questions of this

doctoral research; as such, the results of the sensitivity analyses are not discussed here (see each respective appendix for further discussion).

### 7.1. LCSA results for the Baseline (business-as-usual) scenario

As introduced in Chapter 4 and described in Chapter 6, the baseline scenario (attributional) for forestry in New Zealand is: one hectare of unmanaged land with natural regeneration and growth of grass and scrub. This land is suitable for forestry but is currently unutilised.

The baseline results are presented in Table 11. As the baseline scenario involved unmanaged and unutilised land there was no profit, employment, or GHG associated with it. There was no outright cost of maintaining unmanaged land although if opportunity cost was to be included then the potential annual land rental rate (i.e. the metric used in this research to represent “opportunity cost”) is \$1,040 per hectare per year.

The carbon sequestered on such grassy shrubland was assumed to be 111,650 kgCO<sub>2</sub>eq per hectare (47,850 kgCO<sub>2</sub>eq above-ground (Wakelin & Beets, 2013) and 63,800 kgCO<sub>2</sub>eq in the soil to 30 cm depth (Hewitt et al., 2012)). However, given that there was no change in the carbon sequestered from year to year, this value was excluded as per standard LCA guidelines (BSI, 2011b, p. 11).

The Cultural Indicator Matrix showed a result of 0.67 which is nearing an “enhancing” effect on Ngāti Porou aspirations. In particular, the aspirations of Ngāti Poroutanga, Mātauranga, and Kaitiakitanga/Healthy ecosystems were scored quite highly (between 1.33 and 1.67) by the participants in relation to the baseline of unmanaged land. See Appendix E for a more detailed presentation of the Cultural Indicator Matrix results.

Table 11. LCSA results for the Baseline scenario.

Baseline (per ha yr <sup>-1</sup> )	m <sup>3</sup> / ha	Total cost (NZ\$)	Profit (NZ\$)	Employment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	Carbon sequestered (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Unmanaged land	-	-	-	-	-	-	0.67

Opportunity cost	-	1,040	-	-	-	-	-
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## 7.2. LCSA results for the three scenarios using a land-use perspective

### 7.2.1. Scenario 1: Plantation forestry with radiata pine

The radiata pine land-use results are presented in Table 12; the “per ha yr<sup>-1</sup>” results were calculated by dividing the “per ha per rotation” results by 28 i.e. assuming radiata pine is grown in a 28-year rotation.

For the financial costs, after the \$1,040 opportunity cost which was applied every year throughout the 28-year rotation and so adds up to \$29,120, it can be seen that Tending was the costliest activity.

For employment, since the Tending process includes all annual maintenance of the site, this activity also had the highest employment (76.38 hours).

For the two indicators related to climate change, the highest GHG emissions were associated with conversion of the unmanaged grassy shrubland (i.e. the baseline) to forestry, thus incurring a loss of carbon when the existing vegetation was removed and the underlying soil was disturbed (see Section 6.2.2). The second highest GHG emissions were related to the process of aerial spraying of herbicides and pesticides during Tending, in particular, with regards to the use of jet fuel to operate the helicopters. The GHG emissions during Tending were also due to the construction of in-forest roading and landing sites (467 kgCO<sub>2</sub>eq and 690 kgCO<sub>2</sub>eq respectively). For carbon sequestration (weighted average), the Tending stage represented the majority of carbon sequestered over the rotation (i.e. at point of harvest at year 28) (see Section 6.6.2 for further details). This value was high compared with carbon sequestration by radiata pine in other parts of New Zealand; the Gisborne region is one of the most productive areas in New Zealand for radiata pine with wood production of approximately 32 m<sup>3</sup> ha<sup>-1</sup> year<sup>-1</sup> (Palmer et al., 2010).

Finally, the Cultural Indicator Matrix value was highest during the Nursery stage. In part, this was likely to reflect the participants' current efforts to establish a nursery within the Ngāti Porou catchment (K. Te Kani, personal communication, October 8, 2014). However, in general, the Cultural Indicator Matrix values indicated the participants' belief that the radiata pine scenario has a maintaining (mauri noho) effect on their aspirations. This was perhaps due in part to the fact that radiata pine forestry currently exists within the participants' catchment, and they were already familiar with radiata pine's benefits and challenges; thus to further plant radiata pine was seen as neither good nor bad but more along the lines of the "status quo".

Table 12. LCSA land-use perspective results for the radiata pine scenario.

Pine (per ha per rotation)	Total cost (NZ\$)	Profit (NZ\$)	Employ- ment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	Carbon sequest- ered (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	584	-	20.55	19	4 <sup>a</sup>	0.33
Site prep	183	-	0.25	111,686	-	0.00
Planting	324	-	8.10	-	-	0.05
Tending	7,218	-	76.38	1,270	313,934	0.02
Opportunity Cost	29,120	-	-	-	-	-
Thinning	320	-	7.60	17	-	0.00
Pine (per ha yr <sup>-1</sup> )	Total cost (NZ\$)	Profit (NZ\$)	Employ- ment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	Carbon sequest- ered (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	21	-	0.73	0.67	0.14	0.33
Site prep	7	-	0.01	3,989	-	0.00
Planting	12	-	0.29	-	-	0.05
Tending	258	-	2.73	45.36	11,204	0.02
Opportunity Cost	1,040	-	-	-	-	-
Thinning	11	-	0.27	0.62	0.00	0.00

<sup>a</sup> The carbon sequestration values of 4 kgCO<sub>2</sub>eq for the nursery process and 313,934 kgCO<sub>2</sub>eq for the tending process were based on the PAS 2050 (BSI, 2008) specifications for atmospheric carbon take-up, and represented a weighted average for the amount of time that carbon was sequestered from the atmosphere over radiata pine's 28-year rotation. The cumulative amount of carbon sequestered over radiata pine's 28-year rotation was 918,510 kgCO<sub>2</sub>eq.

### **7.2.2. Scenario 2: Continuous Cover Forestry with rimu**

The rimu land-use results are presented in Table 13; the “per ha yr<sup>-1</sup>” results were calculated by dividing the “per ha per rotation” results by 80 i.e. assuming rimu's first harvest in a continuous cover forestry regime is at 80 years. All of rimu's growing costs from years 1-80 were allocated to the first harvest at year 80; this approach was taken to reflect current forestry economic analysis practice whereby forest growing costs (e.g. establishment, planting, tending) are not divided and allocated based on the harvested amount.

For the financial costs, after the \$1,040 opportunity cost which was applied every year throughout the 80-year rotation and so added up to \$83,200, it can be seen that Tending was the costliest activity.

For employment, since the Tending process included all annual maintenance of the site, this activity also had the highest employment rate (283 hours). The Tending process in the rimu scenario relied exclusively on manual labour for activities such as weeding and pruning, whereas the radiata pine and mānuka scenarios used machinery for nearly all Tending activities.

For the two indicators related to climate change, the highest GHG emissions were associated with conversion of the unmanaged grassy shrubland (i.e. the baseline) to forestry, and incurred a loss of carbon when the existing vegetation is removed and the underlying soil is disturbed (see Section 6.2.3). The second highest GHG emissions were during the Tending stage due to the construction of in-forest roading and landing sites (58 kgCO<sub>2</sub>eq and 131 kgCO<sub>2</sub>eq respectively). For carbon sequestration (weighted average), the Tending stage represented the total amount of carbon sequestered over the rotation (i.e. at point of harvest at year 80) (see Section 6.2.3 for further details). The cumulative carbon sequestration rate for rimu (763,000 kgCO<sub>2</sub>eq) was lower than radiata pine (918,510 kgCO<sub>2</sub>eq) as the former is a slower-growing species which therefore sequesters

carbon at a more gradual rate. However, the weighted average of carbon sequestration over the rotation length for radiata pine and rimu indicated that rimu had a higher weighted average carbon sequestration; this is because rimu had a significantly longer rotation than radiata pine, and thus the carbon sequestered by rimu is removed from the atmosphere for a longer time than radiata pine.

Finally, the Cultural Indicator Matrix values for the land-use stages were high, with most nearly reaching the maximum value of “2”. The only exception was the Tending process which had a score of 0.87 (nearing an enhancing (mauri piki) effect). The generally high Cultural Indicator Matrix scores indicated that the participants believed the land-use stages will each have a flourishing (mauri ora) effect on the aspirations of Ngāti Porou. This was most likely attributable to this scenario involving the establishment a native species, application of a continuous cover forestry management style which closely resembles nature and natural occurrences, and minimal usage of chemicals.

Table 13. LCSA land-use perspective results for the rimu scenario.

<b>Rimu</b> (per ha per rotation)	Total cost (NZ\$)	Profit (NZ\$)	Employment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	Carbon sequestered (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	1,618	-	57.75	50	42 <sup>b</sup>	1.95
Site prep	423	-	11.20	111,655	-	1.86
Planting	719	-	17.97	-	-	1.95
Tending	10,381	-	283.43	189	389,837	0.87
Opportunity Cost	83,200	-	-	-	-	-
Pruning	4,845	-	134.60	-	-	1.95
<b>Rimu</b> (per ha yr <sup>-1</sup> )	Total cost (NZ\$)	Profit (NZ\$)	Employment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	Carbon sequestered (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	20.23	-	0.72	0.63	0.53	1.95
Site prep	5.29	-	0.14	1,396	-	1.86
Planting	8.99	-	0.23	-	-	1.95
Tending	129.76	-	3.54	2.37	4,873	1.95

Opportunity Cost	1,040	-	-	-	-	-
Pruning	60.56	-	1.68	-	-	1.95

<sup>b</sup> The carbon sequestration values of 42 kgCO<sub>2</sub>eq for the nursery process and 389,837 kgCO<sub>2</sub>eq for the tending process were based on the PAS 2050 (BSI, 2008) specifications for atmospheric carbon take-up, and represented a weighted average for the amount of time that carbon was sequestered from the atmosphere over rimu's 80-year rotation. The cumulative amount of carbon sequestered over rimu's 80-year rotation was 763,000 kgCO<sub>2</sub>eq.

### 7.2.3. Scenario 3: Intensive production of mānuka

The mānuka land-use results are presented in Table 14; the “per ha yr<sup>-1</sup>” results were calculated by dividing the “per ha per rotation” results by 15 i.e. assuming mānuka is grown in a 15-year rotation.

For the financial costs, despite the \$1,040 opportunity cost which was applied every year throughout the 15-year rotation and so added up to \$15,600, it can be seen that the Nursery was the costliest activity. The high nursery costs were due to the 15,000 stems planted per hectare plus the additional 10,050 stems planted during the Tending process (to replace damaged or dead seedlings). As detailed in Chapter 6, the cost of the seedlings was only accounted for during the Nursery process.

For employment, the Nursery stage also had the highest employment (1,032 hours) with an assumed 0.04 hours required to grow one seedling.

For the two indicators related to climate change, the highest GHG emissions were associated with conversion of the unmanaged grassy shrubland (i.e. the baseline) to forestry, and thus incurred a loss of carbon when the existing vegetation is removed and the underlying soil is disturbed (see Section 6.2.4). The second highest GHG emissions were during the Nursery stage where the intensive production of mānuka seedlings generated 839 kgCO<sub>2</sub>eq. For carbon sequestration (weighted average), the Tending stage represented the total amount of carbon sequestered over the rotation (i.e. at point of harvest at year 15 and excluded carbon associated with annual trimmed material) (see Section 6.2.4 for further details). The calculation of the carbon sequestration value for mānuka required the estimation of the carbon lost due to annual trimming. The estimation of carbon removed in the trimmed portion of branches and leaves from one hectare of

mānuka over the 15-year rotation was approximately 34,320 kgCO<sub>2</sub>eq (Scott et al., 2000); it is important to note, however, that the carbon in the removed trimmed material was not included in the carbon sequestration figure presented in Table 14.

Finally, the Cultural Indicator Matrix values for the land-use stages were all high, between 1.43 and 1.81. This indicated that the participants believed the land-use stages will have an enhancing (mauri piki) effect on the aspirations of Ngāti Porou.

Table 14. LCSA land-use perspective results for the mānuka scenario.

Mānuka (per ha per rotation)	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employ- ment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequest- ered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	28,081	-	1,032	839	6,006 <sup>c</sup>	1.81
Site prep	1,350	-	1	83,925 <sup>d</sup>	-	1.43
Planting	5,832	-	251	-	-	1.52
Tending	9,628	-	156	1,352	90,090	1.43
Opportunity cost	15,600	-	-	-	-	-
Mānuka (per ha yr <sup>-1</sup> )	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employ- ment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequest- ered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Nursery	1,872	-	68.80	55.96	400	1.81
Site prep	90.03	-	0.09	5,595	-	1.43
Planting	388.80	-	16.72	-	-	1.52
Tending	641.84	-	10.38	90.13	6,006	1.43
Opportunity cost	1,040	-	-	-	-	-

<sup>c</sup> The carbon sequestration values of 6,006 kgCO<sub>2</sub>eq for the nursery process and 90,090 kgCO<sub>2</sub>eq for the tending process were based on the PAS 2050 (BSI, 2008) specifications for atmospheric carbon take-up, and represented a weighted average for the amount of time that carbon was sequestered from the atmosphere over mānuka's 15-year rotation. The cumulative amount of carbon sequestered over mānuka's 15-year rotation was 192,192 kgCO<sub>2</sub>eq.

<sup>d</sup> The PAS 2050 (BSI, 2011a) guidelines state that emissions from land use are assumed to be released in equal amounts over 20 years. However, since mānuka's rotation is only 15 years, the GHG emissions attributed to land use change during site preparation was representative of 75% of the total GHG emissions from land use change.

## 7.2.4. Summary of LCSA land-use results

This sub-section presents the LCSA land-use results in three ways: total indicator values related to each forestry scenario (Section 7.2.4.1), the indicator values related to each forestry scenario displayed along a timeline (Section 7.2.4.2), and the Cultural Indicator Matrix results represented per Ngāti Porou aspiration (Section 7.2.4.3). It should be noted that the Cultural Indicator Matrix results are not scaled to the quantities of material utilised or activities undertaken in the forestry scenarios.

### 7.2.4.1. Total indicator values for LCSA land-use results

The results from the land-use perspective are summarised in Table 15 for both the units of “per hectare per rotation” and “per hectare per year per rotation”. For instance, the rimu scenario was shown to be the costliest forestry option on a “rotation” basis but was the least costly on a “yearly” basis. In addition, when excluding opportunity cost, mānuka was the most expensive on a rotational basis while radiata pine was the least expensive; on a yearly basis, mānuka was still the most expensive while rimu was the least expensive. It is important to communicate and interpret the LCSA results using both rotational and yearly formats so that the decision maker can fully appreciate the effects of using different time frames to evaluate each forestry option. The Cultural Indicator Matrix results have also been summarised in this table.

Table 15. LCSA land-use perspective results for each forestry scenario (“per hectare per rotation” and “per hectare per year”).

<b>LCSA land-use perspective results (per hectare per rotation)</b>						
	Cost (NZ\$)	Employment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	C seq. (kgCO <sub>2</sub> eq)	Net climate change impact (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Radiata pine (28-year rotation)	37,749	113	112,992	313,728	112,992	0.10

Rimu (80-year rotation)	101,187	505	111,894	389,880	111,894	1.93
Mānuka (15-year rotation)	60,491	1,440	86,116	96,096	86,116	1.55
<b>LCSA land-use perspective results (per hectare per year)</b>						
	Cost (NZ\$)	Employ- ment (hours)	GHG emissions (kgCO <sub>2</sub> eq)	C seq. (kgCO <sub>2</sub> eq)	Net climate change impact (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Radiata pine	1,348	4	4,035	11,205	4,035	0.10
Rimu	1,264	6	1,399	4,874	1,399	1.93
Mānuka	4,033	96	5,741	6,406	5,741	1.55

#### 7.2.4.2. Timelines of land-use results

Figures 17-19 show the “per hectare per rotation” results for the indicators of each forestry scenario on timelines. The values shown in Figures 17-19 may not directly correlate with those shown in Tables 12-15; this is due to the indicator values being spread across a timeline rather than being grouped under distinct processes.

For the financial costs shown in Figure 17, the variation in costs at year 0 was due to the differences in seedling cost and quantity of seedlings required for each forestry scenario. While the initial planting for the radiata pine scenario required 833 seedlings per hectare and the rimu scenario required 1,100 seedlings per hectare, the mānuka scenario required 15,000 seedlings per hectare. Furthermore, the mānuka scenario aimed to maintain a constant number of trees per hectare and thus required seedlings each year to replace dead or poorly growing seedlings. The effect of such intensive maintenance of trees was apparent in the relatively high yearly cost (approximately \$4,000, after year 0) which was generally triple the yearly costs of radiata pine and rimu.

Unlike, rimu and mānuka, radiata pine’s highest cost occurred before harvesting when roading and landing infrastructure was installed in the forest. The clearfelling and extraction of a substantial volume of timber required an efficient and reliable in-forest roading network, while preparation for transport required large landing sites. Both of these infrastructural requirements were quite costly to install. For the rimu scenario, although some infrastructural costs (roading and landings) were needed before the selective harvesting process, the use of helicopter extraction techniques resulted in significantly less roading requirements than those needed for radiata pine.

All costs shown in the timelines were inclusive of opportunity cost (i.e. \$1,040 per hectare per year). In addition, no profit was recorded during land-use as the profit was initially gained at the sawmill gate (for radiata pine and rimu) or after distillation (for mānuka).

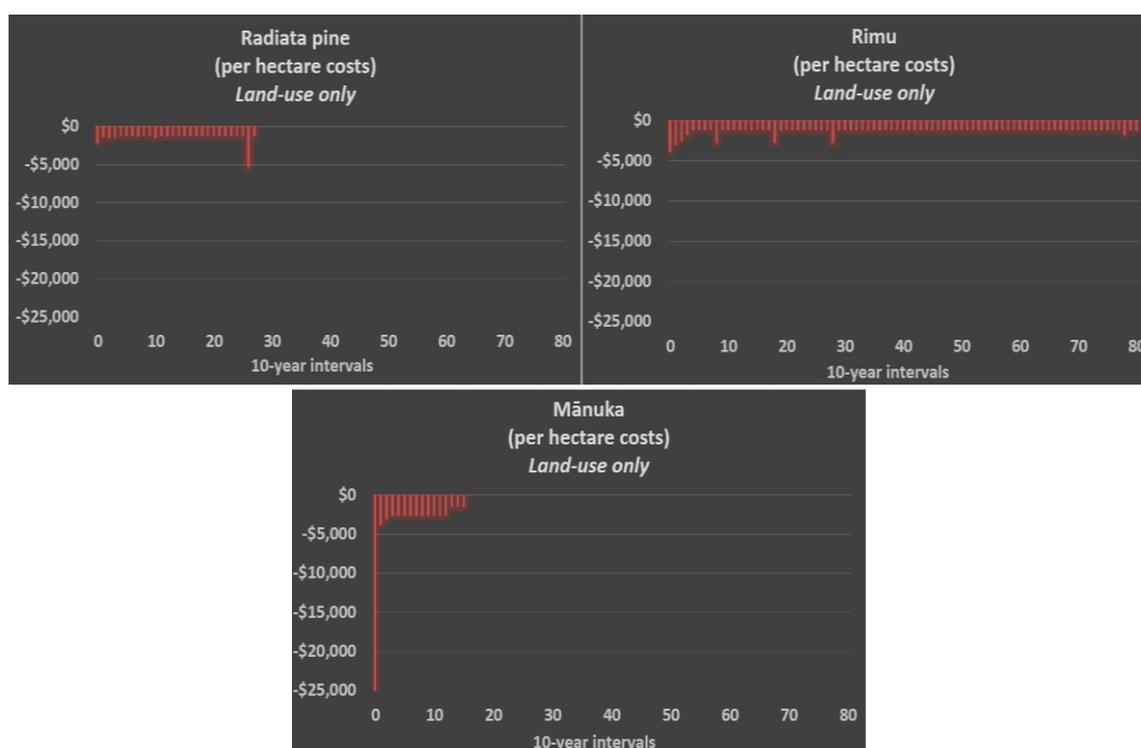


Figure 17. Land-use results for the financial costs associated with each scenario (radiata pine, rimu, and mānuka). The results are indicative of one hectare over one rotation (28 years for radiata pine, 80 years for rimu, and 15 years for mānuka).

For the employment results shown in Figure 18, the highest amount of employment (hours) for all scenarios was generated during the establishment stage (years 0-3). This was due to the intensive amount of activities required during establishment (e.g. nursery,

soil preparation, planting). The radiata pine scenario had the fewest employment hours as this scenario represented an even-aged management regime which focused on the use of mechanised operations instead of manual labour. The use of manual labour in the rimu scenario was evident during the Form pruning stage in years 8, 18, and 28 which showed an increase in employment hours required. The mānuka scenario in particular required a significant amount of employment during the Nursery stage (600 hours to produce the initial 15,000 seedlings planted).

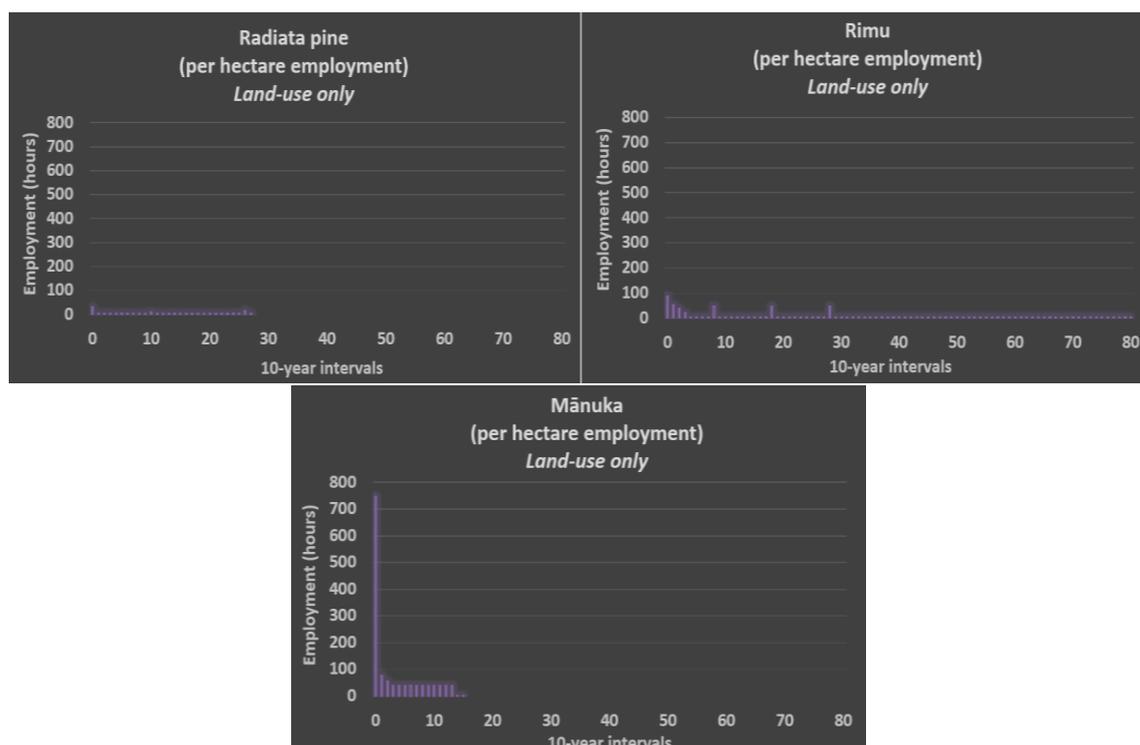


Figure 18. Land-use results for the employment associated with each scenario (radiata pine, rimu, and mānuka). The results are indicative of one hectare over one rotation (28 years for radiata pine, 80 years for rimu, and 15 years for mānuka).

For the GHG emission results shown in Figure 19, each scenario showed a fairly even distribution of GHG emissions. This was largely due to the carbon lost through removal of above-ground carbon and disturbance of underlying soils when converting the land from unmanaged shrubland to forestry. As per the PAS 2050 (BSI, 2011a) guidelines, the emissions arising from land use change are to be evenly distributed over a 20-year period (5% emitted each year). The total GHG emissions from land use change in this research were assumed to be 111,650 kgCO<sub>2</sub>eq, thus amounting to 5,583 kgCO<sub>2</sub>eq emitted each year (up to 20 years). In the case of mānuka, 5,583 kgCO<sub>2</sub>eq was emitted

each year throughout the 15-year rotation. The radiata pine scenario had further GHG emissions due to the use of mechanised operations throughout the rotation (e.g. aerial spraying of herbicides and pesticides). The rimu scenario emphasised the minimal use of machinery and chemicals, and therefore GHG emissions only appeared during rimu’s initial site preparation (which used excavators) while the remainder of the rotation utilised manual labour for all tending processes. The mānuka scenario emitted additional GHG emissions yearly due to the nursery which is annually required to produce replacement seedlings.

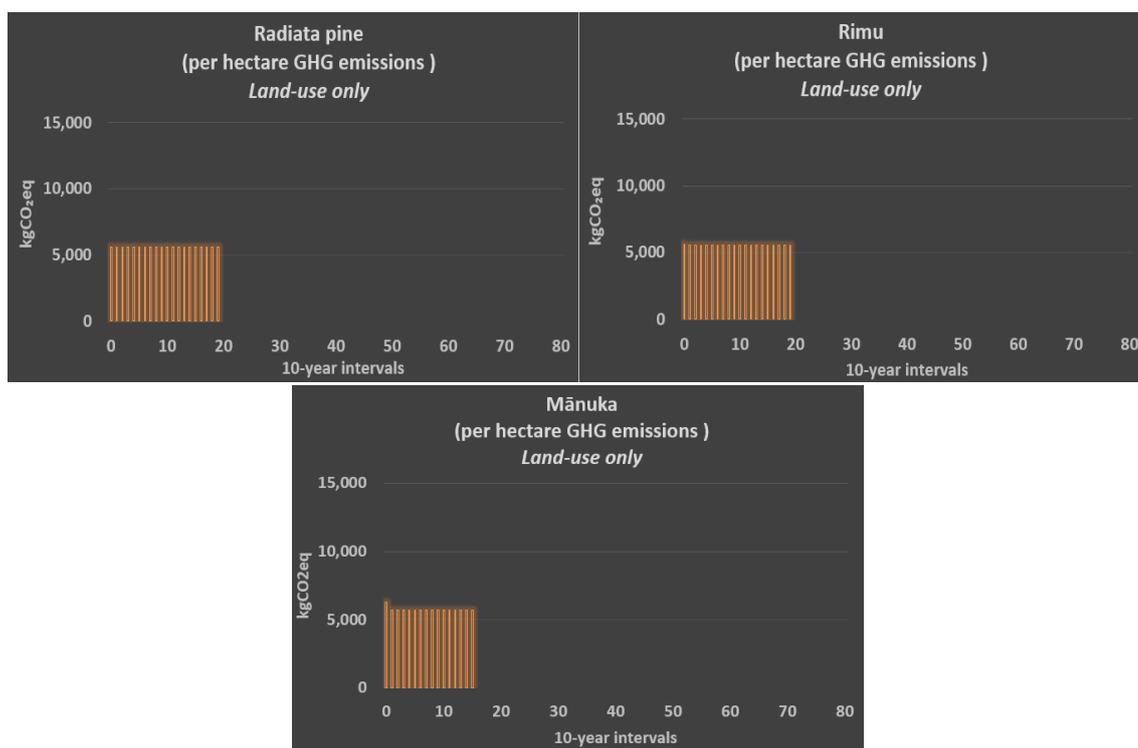


Figure 19. Land-use results for the GHG emissions associated with each scenario (radiata pine, rimu, and mānuka). The results are indicative of one hectare over one rotation (28 years for radiata pine, 80 years for rimu, and 15 years for mānuka).

For the carbon sequestration results shown in Figure 20, the rimu scenario had the highest weighted average carbon sequestration rate followed by radiata pine then mānuka. The carbon sequestration rate for mānuka was at a constant, fixed rate due to the management of the forest stand which included annual trimming of each tree; it was assumed that annual trimming effectively stunted the growth of the trees and therefore the rate of carbon sequestration was not able to increase year on year.

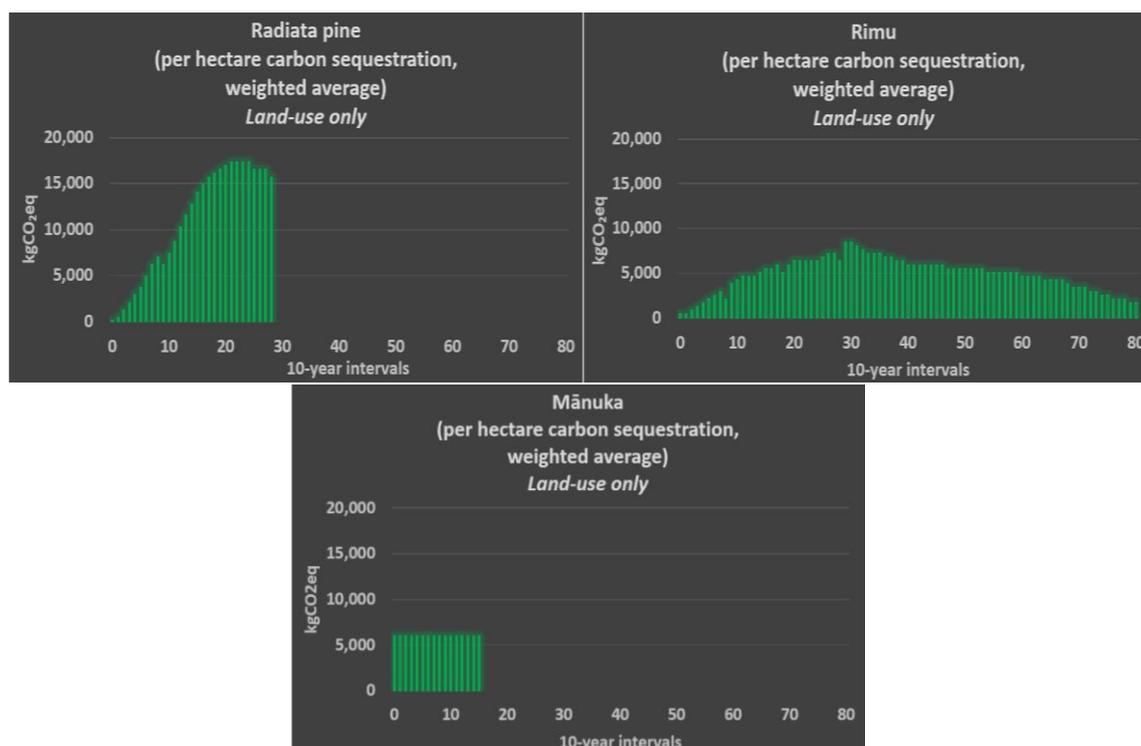


Figure 20. Land-use results for the carbon sequestration associated with each scenario (radiata pine, rimu, and mānuka). The results are indicative of one hectare over one rotation (28 years for radiata pine, 80 years for rimu, and 15 years for mānuka).

For the Cultural Indicator Matrix results shown in Figure 21, the rimu scenario overall received the highest scores followed closely by the mānuka scenario. The radiata pine scenario, however, was generally viewed as having a neutral or maintaining effect (mauri noho) on Ngāti Porou’s aspirations. The Cultural Indicator Matrix results have not been displayed along a timeline as these results do not vary with time. Furthermore, the scores associated with each process cannot be arbitrarily combined to account for several processes occurring in one year (e.g. the processes of Nursery, Site prep, and Planting occur at year 0). In addition, the Cultural Matrix Scores cannot be arbitrarily divided to account for one process that occurs over many years (e.g. the Tending process occurs every year, but not necessarily in equal degrees of intensity).

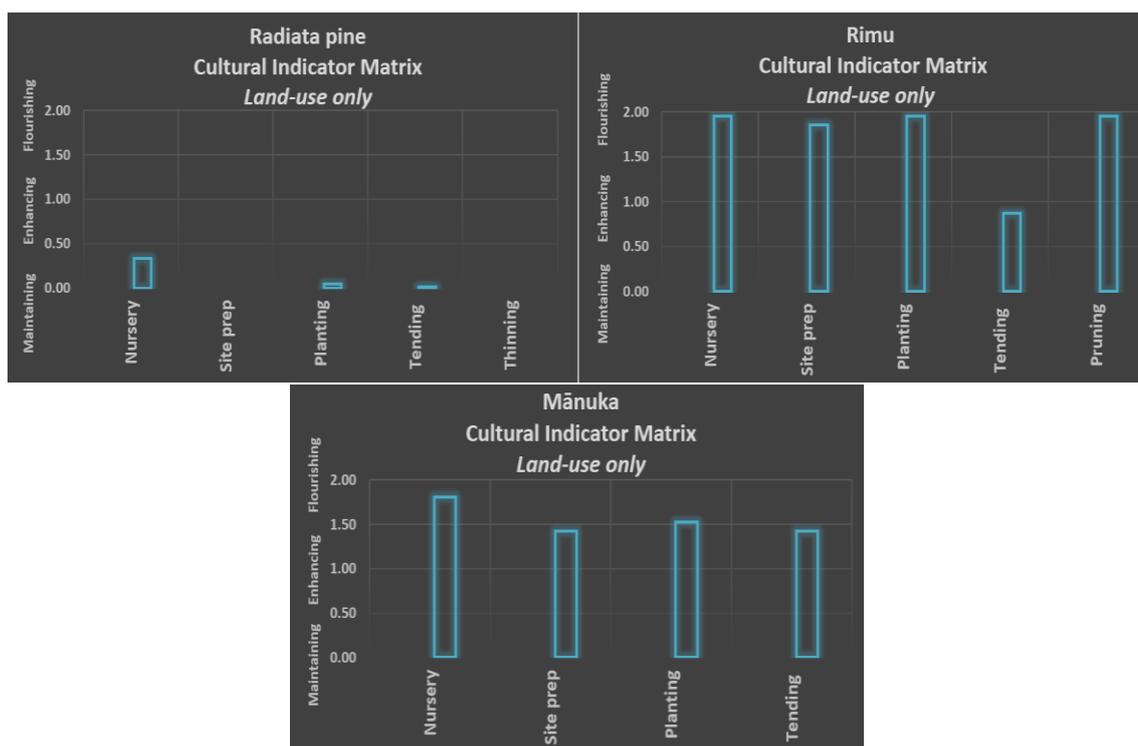


Figure 21. Land-use results for the Cultural Indicator Matrix associated with the processes involved in each scenario (radiata pine, rimu, and mānuka). [Note: the radiata pine scenario’s “Site prep” and “Thinning” processes have no bar in the chart indicating a score of 0].

However, it is important to reiterate that each scenario assumed a land conversion from unmanaged shrubland to forestry which not only incurred more time and expense, but also caused a significant loss of carbon (included in the GHG emission impacts). In subsequent forestry rotations, each of the scenarios would incur less cost and require less employment to clear and prepare the land for forestry planting. Furthermore, future forestry rotations would not have the initial loss of carbon which would have a dramatic effect on the GHG emission results. Regarding the in-forest roads and landing sites, future rotations will only involve maintenance of this infrastructure (not a complete re-installation) and thus will incur much less cost, employment, and GHG emissions. These longer-term effects should also be considered in the context of decisions about long-term, multi-generational forest cover (or forestry land use).

### 7.2.4.3. LCSA land-use results for the Cultural Indicator Matrix per Ngāti Porou aspiration

Figure 22 shows the disaggregated result for each Ngāti Porou aspiration considered in development of the Cultural Indicator Matrix in each forestry scenario. It can be seen that radiata pine was generally viewed by the participants to marginally achieve the aspirations of “Employment” and “Infrastructure” but does little to help fulfil the other aspirations of the iwi. Both the rimu and mānuka scenarios scored highly being viewed as having between an enhancing (mauri piki) and flourishing (mauri ora) effect on the all of the aspirations. The rimu scenario’s highest ratings were for the aspirations of “Employment”, “Mana motuhake”, and “Infrastructure”. The mānuka’s highest ratings were for the aspirations of “Ngāti Poroutanga”, “Employment”, and “Kaitiakitanga & Healthy ecosystems”. Viewing the Cultural Indicator Matrix land-use results in this way allows for the evaluation of how each forestry scenario contributes to the pursuit and fulfilment of each aspiration.

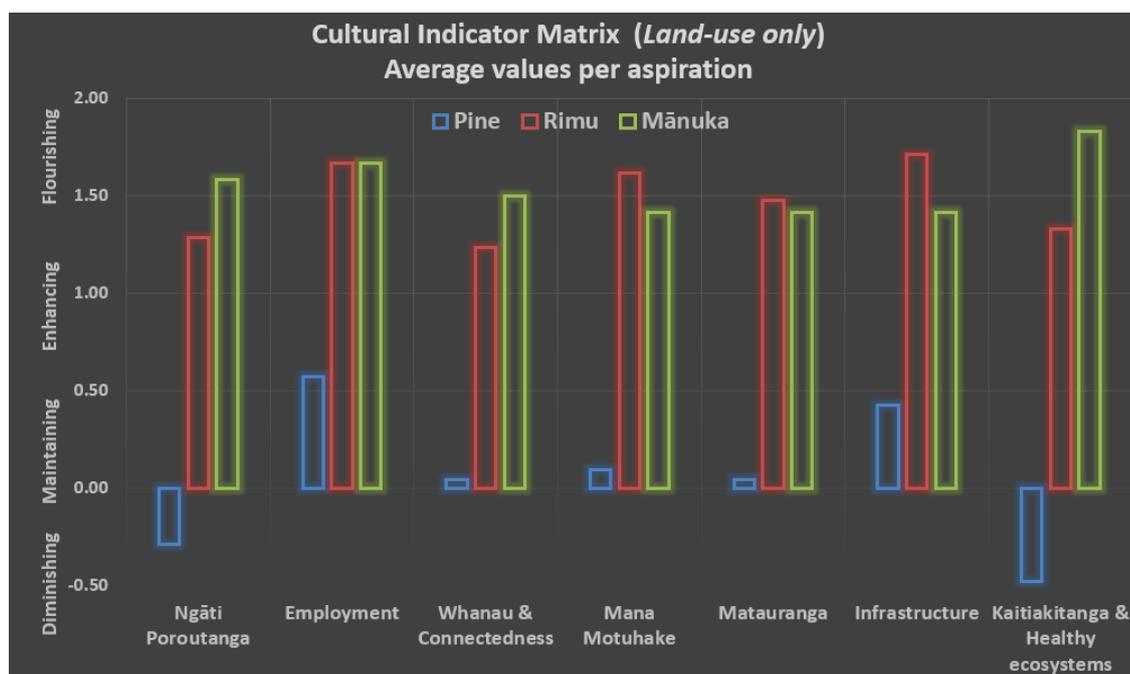


Figure 22. The effect that each forestry scenario land-use has on each Ngāti Porou aspiration. The maximum score is 2 (flourishing/mauri ora effect), the neutral score is 0 (maintaining/mauri noho), and the minimum score is -2 (degrading/mauri mate).

### 7.3. LCSA results using a product perspective

In order to demonstrate the use of LCSA for products, an Impact Assessment was undertaken for one product from each of the three forestry scenarios: 1 m<sup>3</sup> radiata pine

framing, 1 m<sup>3</sup> rimu heartwood flooring, and 9,712 mānuka essential oil-filled 10mL bottles (10mL each). [Note: the number of mānuka essential oil-filled bottles represents 5% of the total essential oil produced]

The product results are presented along with associated background data which were used to help derive the final results. Section 7.3.1 presents the radiata pine framing results, Section 7.3.2 presents the rimu heartwood flooring results, and Section 7.3.3 presents the mānuka essential oil-filled bottle results. In addition, a summary of the product results and a display of the results along timelines are provided in Section 7.3.4.

The calculation of the product-based LCSA impacts are in line with PAS 2050 (BSI, 2011b) guidelines. The methodology used to calculate the product results for each forestry scenario can be found in Appendix I.

As with the land-use perspective results, it should be noted that the Cultural Indicator Matrix results are not scaled to the quantities of material utilised or activities undertaken in development of a product.

### **7.3.1. Scenario 1: radiata pine house framing**

The background data associated with the harvest-to-grave processes of the radiata pine scenario are presented in Table 16. The background data were used to determine the product results for one m<sup>3</sup> of radiata pine house framing. First, the background data will be discussed followed by the presentation of the radiata pine framing product results.

For the financial costs, it can be seen that Construction was an extremely costly activity (\$57,185 if utilising 83 m<sup>3</sup> of framing timber resulting from one hectare of radiata pine forest). This was largely due to the cost of purchasing the framing timber from the sawmill (\$380/m<sup>3</sup>).

The Sawmill process, therefore, had a high rate of profit (approximately \$10,000 per hectare of radiata pine forest). The profit displayed in Table 16 was inclusive of opportunity cost. However, due to time constraints, only the framing product was

considered in these calculations, not the entire range of wood-based products arising from one hectare of radiata pine forest.

For employment, the Construction process also had a significant amount of employment (289 hours to utilise 83 m<sup>3</sup> of framing timber). This was due to the fact that framing for one house (23 m<sup>3</sup>) was assumed to take two weeks to construct (see the “House Construction” description in Section 6.2.2 for further background details).

For the two indicators related to climate change, high GHG emissions were associated with the Transport activity (9,298 kgCO<sub>2</sub>eq) which was due to the use of diesel in the trucks for timber transport. For carbon sequestration, there was no further sequestration occurring after the tree has been harvested. These figures are presented in Table 16. However, there was a value associated with carbon storage within the radiata pine framing product, and this is discussed in Appendix I.

Finally, the Cultural Indicator Matrix values for radiata pine continued to indicate that the radiata pine scenario generally had a maintaining (mauri noho) effect on Ngāti Porou aspirations. The highest Cultural Indicator Matrix value was for the process of Construction (0.43) which may be due to the fact that there is a current housing shortage in the catchment of the participants (see Section 5.2.1). The lowest Cultural Indicator Matrix value was for the process of Felling (-0.43) which may be due to the participants’ concerns regarding harvesting radiata pine in their erosion-prone catchment and the vulnerability of the underlying soils as a result. Indeed the harvesting process can increase the potential for soil compaction and erosion (Cambi, Certini, Neri, & Marchi, 2015).

*Table 16. Product-based (and post-harvest) background data for the radiata pine scenario. The data highlighted in grey indicates that these processes are only a partial representation of the full life cycle of all products arising from one hectare of radiata pine forest.*

Pine (per ha)	m <sup>3</sup> / ha	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employ- ment / ha (hours)	GHG emissions / ha	Carbon sequest- ered / ha	Cultural Indicator Matrix
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					(kgCO <sub>2</sub> eq)	(kgCO <sub>2</sub> eq)	
Felling	761	4,297	-	9	910	-	-0.43
Extraction	677	4,413	-	16	1,721	-	-0.14
Skid site	677	6,342	-	24	2,048	-	-0.10
Transport	650	12,829	1,946	77	9,298	-	-0.14
Sawmill (framing only)	92	24,205	10,181	97	2,751	-	0.14
Construction (framing only)	83	57,185	3,431	289	784	-	0.43
De- construction (framing only)	83	2,690	-	45	247	-	0.00
Landfill (Construction wood waste and house framing)	92	9,666	-	40	8,470	-	-0.14

The LCSA impacts of one m<sup>3</sup> of radiata pine house framing are presented in Table 17. The results indicated a total life cycle cost of \$1,194 and a profit of \$156, the latter of which was primarily due to the profits gained as a result of the Sawmill process. The low employment (6 hours) and relatively high GHG emissions (330 kgCO<sub>2</sub>eq) were both due to the dominant use of machinery in the radiata pine scenario. The carbon stored (696 kgCO<sub>2</sub>eq) was in proportion to the 60-year lifespan of the house within which the framing product is used as well as the 40 years where the framing is stored in the landfill (inclusive of a delayed kgCO<sub>2</sub>eq release due to decaying); the total carbon storage amount was equivalent to a 100-year GWP time horizon. The Cultural Indicator Matrix result of 0.08 (maintaining (mauri noho) effect) was inclusive of the entire life cycle-value chain for the radiata pine framing product.

Table 17. The product-based LCSA results for one m<sup>3</sup> of radiata pine house framing.

	Total cost / m <sup>3</sup> framing	Profit / m <sup>3</sup> framing	Employ- ment / m <sup>3</sup> framing	GHG emissions / m <sup>3</sup> framing	Carbon stored / m <sup>3</sup> framing	Cultural Indicator Matrix

	(NZ\$)	(NZ\$)	(hours)	(kgCO <sub>2</sub> eq)	(kgCO <sub>2</sub> eq)	
One m <sup>3</sup> of radiata pine house framing	1,194	156	6	330	696	0.08

### 7.3.2. Scenario 2: rimu heartwood flooring

The background data associated with the harvest-to-grave processes of the rimu scenario are presented in Table 18. The background data were used to determine the product results for one m<sup>3</sup> of rimu heartwood flooring (Table 19). First, the background data will be discussed followed by the presentation of the rimu heartwood flooring product results.

For the financial costs, it can be seen that the Furniture process was an extremely costly activity (\$69,454 when recycling only the amount of heartwood flooring that remains after the original consumer use in housing (2.59 m<sup>3</sup>)). The Furniture process was so expensive because of the amount of employment hours required to recycle and refurbish rimu flooring material into a table (the product chosen to demonstrate the secondary product within the rimu life cycle) – 30 hours to make one table, and each table required 0.048 m<sup>3</sup> of timber. Indeed, employment costs amounted to over 93% of the total costs. The Construction process was also expensive due to the cost of purchasing the heartwood flooring product from the sawmill (\$9,731/m<sup>3</sup>), and represented nearly 82% of the cost of the Construction process.

The Sawmill process had a high rate of profit (\$29,691 per hectare of rimu forest where a) only 10% was selectively harvested, and b) only 4% of the delivered rimu log to the sawmill was suitable for heartwood flooring). The profit displayed in Table 18 was inclusive of opportunity cost. Interestingly, the Deconstruction phase also had an associated profit (\$3,805) which was due to the enduring life span of the rimu heartwood flooring and the related inherent value it maintained even after its use in a house. However, due to time constraints, only the heartwood flooring product was considered in

these calculations, not the entire range of wood-based products arising from one hectare of rimu forest.

For employment, the Furniture process had a significant amount of employment (1,620 hours to recycle and refurbish 2.59 m<sup>3</sup> of heartwood flooring timber). As mentioned above, this was due to the fact that 2.59 m<sup>3</sup> of heartwood flooring was able to provide enough timber to create approximately 54 tables, and each table took 30 hours to make (see the “Furniture making” description in Section 6.2.3 for further background details).

For the two indicators related to climate change, high GHG emissions were associated with the Extraction process (3,740 kgCO<sub>2</sub>eq). Helicopter extraction was chosen as an extraction method in order to minimise soil and forest disturbance, and is considered to be especially useful when harvesting on steep terrain. The implications of helicopter extraction, however, included a high rate of GHG emissions due to the use of jet fuel in the helicopter. For carbon sequestration, there was no further sequestration occurring after the tree has been harvested. These figures are presented in Table 18. However, there was a value associated with carbon storage within the rimu heartwood flooring product and subsequent table made from recycled rimu, and this is described in Appendix I.

Finally, the highest Cultural Indicator Matrix value for the rimu scenario was for the Felling process (1.90, a flourishing (mauri ora) effect). This high value for Felling of rimu may be attributed to the explicit use of aerial extraction techniques in order to minimise environmental damage from harvesting. In addition, the Cultural Indicator Matrix value for the Furniture process (1.48) illustrated the importance that the participants placed on being able to recycle the native rimu timber and repurpose it for another “life” or product. The lowest Cultural Indicator Matrix value was for the process of Landfilling (-0.67) which may be due to the participants’ displeasure regarding the landfilling of a culturally valuable native species.

Table 18. Product-based (and post-harvest) background data for the rimu scenario. The data highlighted in grey indicates that these processes are only a partial representation of the full life cycle of all products arising from one hectare of rimu forest.

Rimu (per ha)	m <sup>3</sup> / ha	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequestered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Felling	92	4,784	-	9	146	-	1.90
Extraction	83	11,307	-	3	3,740	-	0.90
Skid site	80	2,158	-	3	791	-	0.43
Transport	80	1,579	1,109	9	1,144	-	-0.14
Sawmill (flooring only)	3.20	1,426	29,698	3	96	-	0.95
Construction (flooring only)	2.88	34,320	14,820	41	4	-	1.38
De-construction (flooring only)	2.88	515	3,805	10	-	-	0.00
Furniture (rimu table only)	2.59	69,454	10,939	1,620	-	-	1.48
Landfill (rimu table only)	3.20	394	-	2	106	-	-0.67

The LCSA impacts of one m<sup>3</sup> of rimu heartwood flooring are presented in Table 19. The results indicated a total life cycle cost of \$39,632 and a profit of \$19,982, the latter of which is primarily due to the profits gained as a result of the Sawmill process. The high employment (645 hours) were mostly attributable to the labour required during the Furniture process. The relatively low GHG emissions (265 kgCO<sub>2</sub>eq) were due to the dominant reliance on manual labour throughout the rimu scenario. The carbon stored (898 kgCO<sub>2</sub>eq) was in proportion to the 120-year lifespan (80-year lifespan of the heartwood flooring and 40-year lifespan of the table made with recycled rimu) of the rimu flooring and table products. The Cultural Indicator Matrix result of 1.06 (enhancing

(mauri piki) effect) is inclusive of the entire life cycle-value chain for the rimu heartwood flooring product.

Table 19. The product-based LCSA results for one m<sup>3</sup> of rimu heartwood flooring.

	Total cost / m <sup>3</sup> flooring  (NZ\$)	Profit / m <sup>3</sup> flooring  (NZ\$)	Employ- ment / m <sup>3</sup> flooring  (hours)	GHG emissions / m <sup>3</sup> flooring (kgCO <sub>2</sub> eq)	Carbon stored / m <sup>3</sup> flooring (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
One m <sup>3</sup> of rimu heartwood flooring	39,632	19,982	645	265	898	1.06

### 7.3.3. Scenario 3: mānuka essential oil for 10mL bottles

The background data associated with the harvest-to-grave processes of the mānuka scenario are presented in Table 20. The background data were used to determine the product results for 9,712 mānuka essential oil-filled 10mL bottles (Table 21). First, the background data will be discussed followed by the presentation of the rimu heartwood flooring product results. [Note: the number of mānuka essential oil-filled bottles represented 5% of the total essential oil produced]

For the financial costs, it can be seen that the Distillation process was an extremely costly activity (\$496,813). This was in part due to the assumed reliance on diesel to operate the stills which required 15 litres of diesel to steam one tonne of mānuka brush. The Packaging process was also costly (\$120,917) primarily due to the cost of materials (glass bottle, labels, purchase of mānuka essential oil from the distillers) which represented 90% of the total cost.

The profits to be attained in the mānuka scenario were significant. A high rate of profit (\$74,282) occurred as a result of the Distillation process. This was due to the value of the distilled mānuka essential oil which was assumed to be \$300 per kilogram (a fairly conservative value in the current market). Therefore, the profit was approximately \$136

per tonne of mānuka brush and \$39 per kilogram of mānuka essential oil. The profit displayed in Table 20 is inclusive of opportunity cost.

For employment, the Distillation process also produced a significant amount of employment (2,176 hours). This was due to each tonne of mānuka brush requiring 4 hours to distil, and each hectare of mānuka produced 544 tonnes of brush per 15-year rotation.

For the two indicators related to climate change, high GHG emissions were associated with the Harvest/transport process (101,641 kgCO<sub>2</sub>eq). The GHG were relatively high throughout this life cycle, and can be attributed to the dominant use of intensive mechanised processes and the high volumes of diesel required to operate the forage harvester (approximately 50 litres of diesel needed to harvest one tonne of brush). In addition, intensive mānuka plantations involved more “stops and starts” to manoeuvre through planted rows thus resulting in slower processing times and a subsequent greater use of diesel. For carbon sequestration, there was no further sequestration occurring after the tree has been harvested, and there was no carbon storage in the oil itself (see Appendix I).

Finally, the Cultural Indicator Matrix results remain positive throughout the mānuka life cycle-value chain (apart from the Landfill process). This indicates once more the cultural value that the participants placed on pursuing native species and associated products as viable land options within their catchment. The highest Cultural Indicator Matrix value for the mānuka scenario was for the Harvest/transport process (1.43, between an enhancing (mauri piki) and a flourishing (mauri ora) effect). This high value for the harvesting of mānuka may be attributed to the participants’ understanding that harvesting (or trimming) of mānuka each year creates the potential for more of their community to re-connect with the mānuka tree on an economic, social, and cultural level. The lowest Cultural Indicator Matrix value was for the process of Landfilling (-1.33) of the mānuka essential oil glass bottle. This may be due to the potential for the glass bottle to be recycled instead of disposed of in a landfill.

*Table 20. Product-based (and post-harvest) background data for the mānuka scenario. The data highlighted in grey indicates that these processes are only a partial*

representation of the full life cycle of all products arising from one hectare of mānuka forest.

<b>Mānuka</b>	Total t of brush/ha (15 years)	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequestered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Harvest/transport	544	30,000	-	544	101,641	-	1.43
	Total kg of oil/ha (15 years)	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequestered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Distilling	1,904	496,813	74,282	2,176	24,394	-	0.62
	bottles / ha (5% of oil)	Total cost / ha (NZ\$)	Profit / ha (NZ\$)	Employment / ha (hours)	GHG emissions / ha (kgCO <sub>2</sub> eq)	Carbon sequestered / ha (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Packaging (5% of total oil)	9,712	120,917	44,130	324	220	-	0.90
Landfill (5% of total oil)	9,712	71	-	0.29	188	-	-1.33

The LCSA impacts of 9,712 mānuka essential oil-filled 10mL bottles are presented in Table 21. The results indicated a total life cycle cost of \$35,415 and a profit of \$5,921, the latter of which was primarily due to the profits gained as a result of the Distillation process. The employment (224 hours) were mostly attributable to the labour required during the Distillation process. The high GHG emissions (10,628 kgCO<sub>2</sub>eq) were due to the use of diesel during the Harvest/transport process. The carbon storage attributed to the growth of the mānuka trees was excluded as per the PAS 2050 (BSI, 2011a) guidelines; there was also no added carbon storage benefit related to the mānuka essential oil as a product. The Cultural Indicator Matrix result of 0.98 (enhancing (mauri piki) effect) was inclusive of the entire life cycle-value chain for the mānuka essential oil-filled bottles product.

Table 21. The product-based LCSA results for 9,712 mānuka essential oil-filled 10mL bottles (i.e. 5% of total oil produced per hectare).

	Total cost / oil for bottles (NZ\$)	Profit / oil for bottles (NZ\$)	Employment / oil for bottles (hours)	GHG emissions / oil for bottles (kgCO <sub>2</sub> eq)	Carbon stored / oil for bottles (kgCO <sub>2</sub> eq)	Cultural Indicator Matrix
Mānuka essential oil-filled bottles	35,415	5,921	224	10,628	0	0.98

### 7.3.4. Summary and timelines of product results

#### 7.3.4.1. Total indicator values for LCSA product results

The product-based LCSA results allow for an understanding of the full (cradle-to-grave) life cycle impacts attributed to the creation of each respective product. It should be noted that the three products cannot be directly compared with each other as their life cycles are not equivalent.

#### 7.3.4.2. Timelines for LCSA product results

Timelines for each forestry product can be seen in Figures 23-25. Each product represents the proportion of the overall LCSA results from respective scenarios which are directly attributable to a) one m<sup>3</sup> of radiata pine framing, b) one m<sup>3</sup> of rimu heartwood flooring, and c) 9,712 mānuka essential oil-filled 10mL bottles (i.e. 5% of total oil produced per hectare).

As seen in Figure 23, the possibilities for profit for radiata pine occurred at the sawmill gate, after creation of the framing product, and during the use of the framing in housing construction. The latter process had the most cost associated but also generates the most employment. Culturally, many radiata pine processes were believed to maintain or slightly enhance Ngāti Porou aspirations – housing construction in particular achieved

high marks due in part to the need for more adequate housing in the Waiapu region. However, several radiata pine processes had a diminishing effect on Ngāti Porou aspirations with the Felling process rated the worst. This was primarily because radiata pine in the Waiapu region is often sited on marginal, erosion-prone land, and harvesting of forests in these areas increase the potential for severe sedimentation issues.

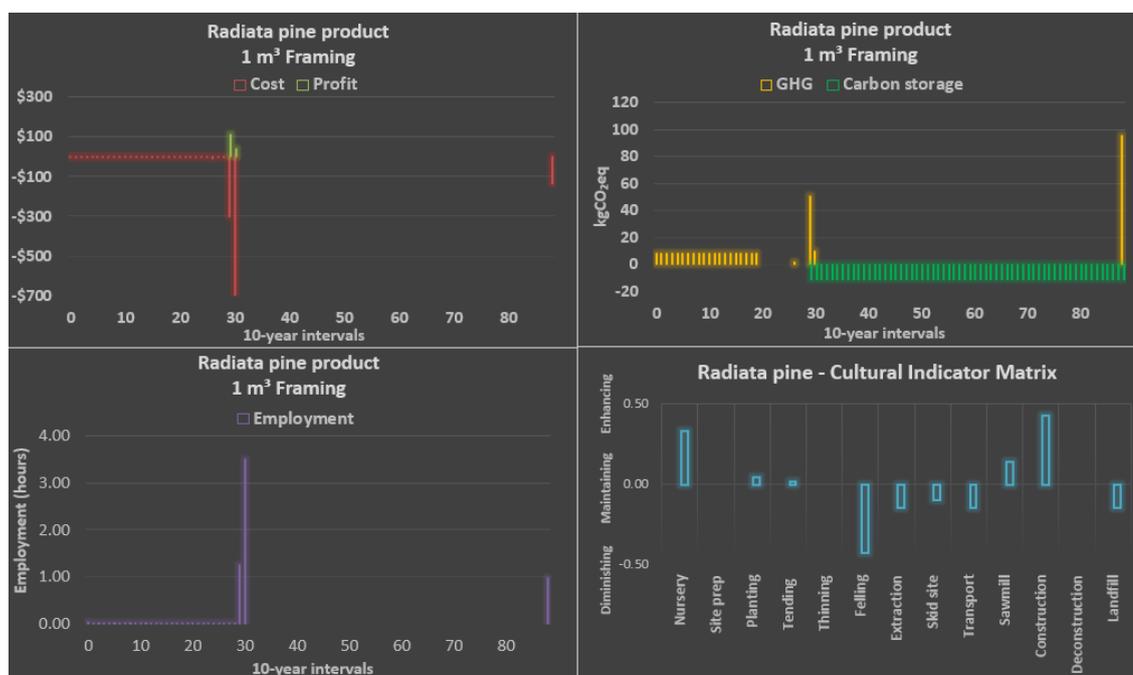


Figure 23. Proportion of LCSA results attributable to one m<sup>3</sup> of radiata pine framing. The product results represent the proportional effects of one 28-year rotation of radiata pine and the creation, use, and disposal of the subsequent framing product which lasts for 60 years. The Cultural Indicator Matrix results are presented per life cycle process and are not scaled to the quantities of material utilised or activities undertaken in development of a product.

As seen in Figure 24, the possibilities for profit for rimu occurred at the sawmill gate, after creation of the flooring product, during the use of the flooring in housing construction, during deconstruction (when the used flooring is sold for recycling purposes), and during creation of the table using recycled rimu. The highest amount of cost was attributed to the table making process (54 tables each needing 30 hours to make). The table making process also created a significant amount of employment which far exceeded any employment created elsewhere in the life cycle. Culturally, rimu was generally viewed as having the capability to help Ngāti Porou’s aspirations flourish. The

harvesting process rated much higher than with radiata pine which may be due to helicopter harvesting technique used in the scenario that has minimal impact to the vulnerable soils.

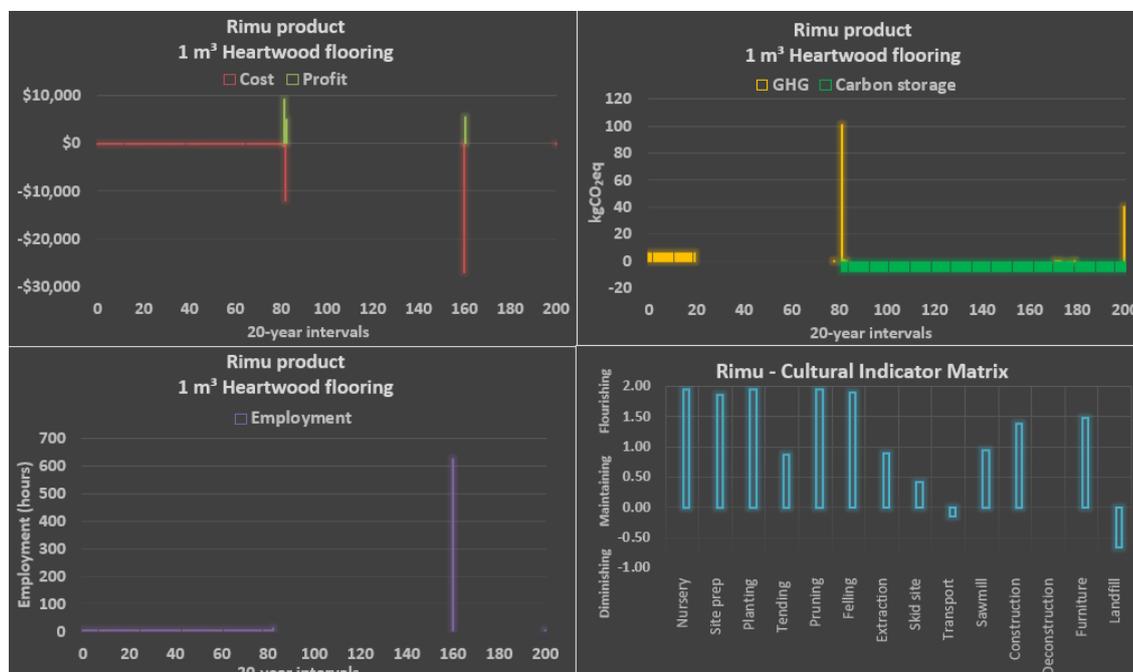


Figure 24. Proportion of LCSA results attributable to one m<sup>3</sup> of rimu heartwood flooring. The product results represent the proportional effects of one 80-year rotation of rimu, the creation and use of the subsequent flooring product which lasts for 80 years, and the creation, use, and disposal of the table using recycled rimu which lasts for 40 years. The Cultural Indicator Matrix results are presented per life cycle process and are not scaled to the quantities of material utilised or activities undertaken in development of a product.

As seen in Figure 25, the mānuka scenario had a steady occurrence of costs as well as profit. This was due to the annual nature of this scenario (i.e. annual trimming, distilling, and product creation). The possibilities for profit occurred after distillation and again after product creation. The GHG remained fairly constant due to the annual replacement of seedlings, and trimming and distillation of mānuka branches. The employment created, however, directly corresponded to the intensive nursery, harvesting, and distillation processes. Culturally, the mānuka scenario was largely seen to have an enhancing effect on Ngāti Porou’s aspirations.

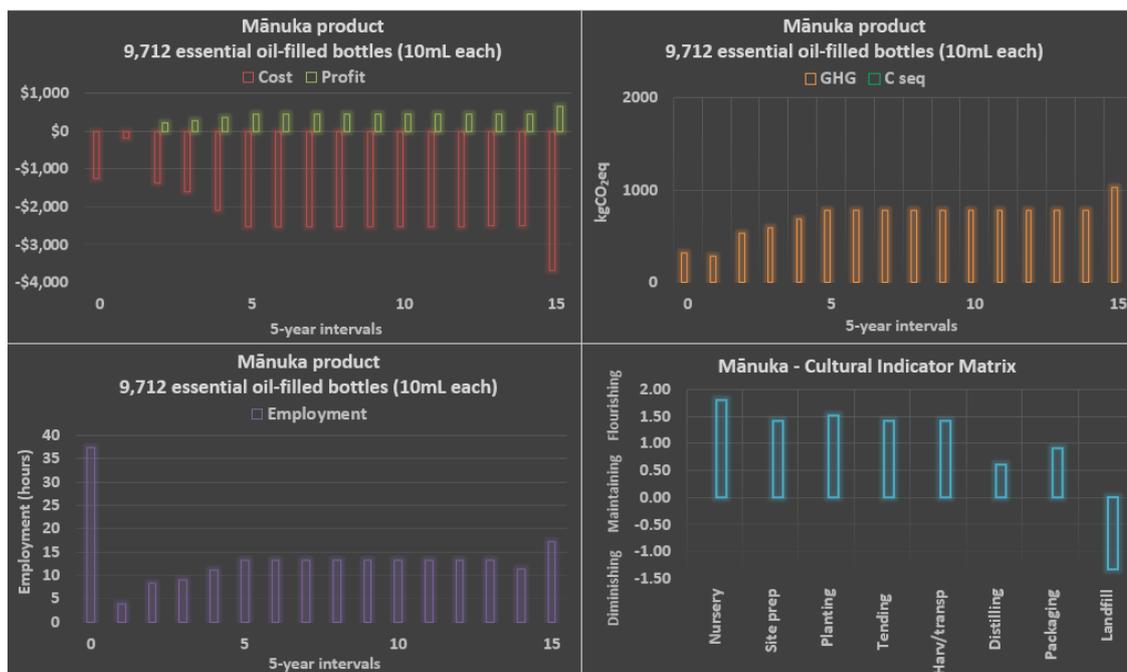


Figure 25. Proportion of LCSA results attributable to 9,712 mānuka essential oil-filled 10mL bottles (i.e. 5% of total oil produced per hectare). The product results represent the proportional effects of one 15-year rotation of mānuka and the yearly creation, use, and disposal of the subsequent essential oil product. The Cultural Indicator Matrix results are presented per life cycle process and are not scaled to the quantities of material utilised or activities undertaken in development of a product.

### 7.3.4.3. LCSA product results for the Cultural Indicator Matrix per Ngāti Porou aspiration

The Cultural Indicator Matrix results for the three forestry products can be seen in Figure 26. The results are shown per Ngāti Porou aspiration, were unweighted, and were averaged for each scenario's entire life cycle-value chain (i.e. from cradle to grave). Unlike other LCA results, the results were not scaled to the "quantity" of product/activity attributed to each scenario. However, since the Cultural Indicator Matrix represents qualitative beliefs in a numerical form, these results were able to sit alongside other quantitative LCSA results in a complementary manner. It can be seen that both the rimu and mānuka scenarios scored highly with each aspiration generally viewed to have an enhancing or flourishing impact. However, the radiata pine scenario scored lower for all the aspirations, and only for the aspirations of employment and infrastructure was radiata pine seen to be at all enhancing.

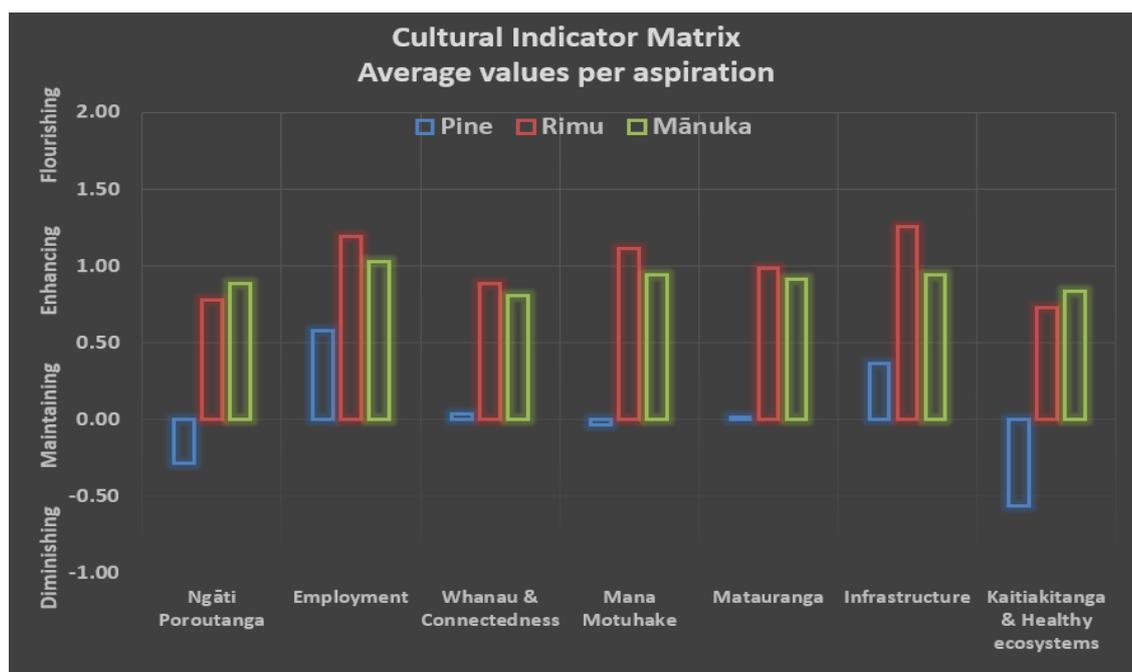


Figure 26. The results of each forestry scenario’s life cycle displayed on along a timeline for economic, environmental, and social indicators. The Cultural Indicator Matrix results are shown as average cultural values associated with each Ngāti Porou aspiration as derived from the three forestry scenarios.

## 7.4. Discussion of results

Three sets of results have been presented in this chapter: LCSA results of the Baseline scenario (Section 7.1), LCSA results using a land-use perspective (Sections 7.2, 7.2.1, 7.2.2, 7.2.3, 7.2.4, and 7.2.4.1), and LCSA results using a product perspective (Sections 7.3, 7.3.1, 7.3.2, 7.3.3, 7.3.4, and 7.3.4.1). In addition, the results were displayed on timelines for the land-use results (Section 7.2.4.2) and for the product results (Section 7.3.4.2). The Cultural Indicator Matrix results were displayed per Ngāti Porou aspiration for the land-use perspective (Section 7.2.4.3) and for the product perspective (Section 7.3.4.3).

The LCSA results for the land-use and product perspectives represent quadruple bottom line data regarding the life cycles of radiata pine forestry (with the related product of radiata pine framing), rimu forestry (with the related product of rimu heartwood flooring), and mānuka forestry (with the related product of mānuka essential oil). The collection and presentation of such data using the LCSA framework is valuable to decision makers

who are interested in “hot spot” identification (i.e. where the life cycle impacts are the highest), as well as to those who wish to better understand the impacts on sustainability indicators respective to each forestry scenario and/or product.

The LCSA results displayed on timelines has allowed for the clear presentation of impacts distributed over time instead of per life cycle process. Although the use of timelines to present results is uncommon in life cycle studies, this research has shown the advantages in using timelines. It is useful to see the impacts of all the forestry scenarios on indicator-specific timelines as this allows the decision maker to understand how the scenarios could interact. For instance, if Ngāti Porou were to pursue each of the forestry options throughout their catchment, the timelines suggest a staggered distribution of all benefits and impacts. This is a reasonable assertion since mānuka may be considered a short-term forestry option, radiata pine is medium-term, and rimu is long-term.

The Cultural Indicator Matrix results displayed per Ngāti Porou aspiration allows for the review of how the participants believed each forestry option and/or forestry product may help (or hinder) the process of achieving each individual aspiration. These results may be used to aid the decision making process of Ngāti Porou regarding the future development of forestry options and/or forestry products within their catchment. This subject is discussed further in Chapter 8.

The remainder of this discussion section will further review the following research findings: 1) the benefits of a quadruple bottom line approach (Section 7.4.1), 2) variation in Cultural Indicator Matrix scores between participants (Section 7.4.2), 3) the benefits of displaying LCSA results along a timeline (Section 7.4.3), and 4) the benefits of applying a product perspective (Section 7.4.4).

### **7.4.1. Benefits of a quadruple bottom line approach**

To demonstrate the quadruple bottom line (economic, social, environmental, and cultural) results of this culturally-focused LCSA research, a sample of the findings are presented in Figure 27. The land-use results (from Section 7.2) for each forestry scenario are shown relative to the radiata pine scenario, and allow for the concurrent interpretation of economic, social, environmental, and cultural information.

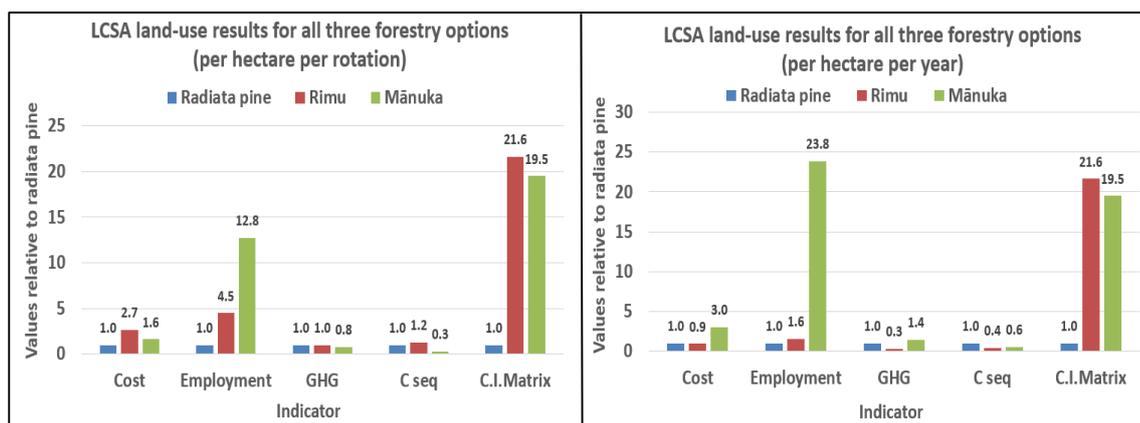


Figure 27a (on left) and Figure 27b (on right). Quadruple bottom line LCSA land-use results for the three forestry scenarios. The rimu and mānuka scenario results are shown relative to radiata pine which is assigned a value of “1”. The results are inclusive of land-use processes (i.e. from cradle-to-point of harvest), and are displayed as “per hectare per rotation” (on left) and “per hectare per year” (on right). [Note: “GHG” is greenhouse gas emissions, “C seq” is weighted average carbon sequestration, and “C.I.Matrix” is Cultural Indicator Matrix]

The land-use results highlight the collective quadruple bottom line impacts of the three forestry options. With all rimu and mānuka values displayed as relative to radiata pine values, one can easily interpret the differences between each scenario. In addition, the relative values are presented as both “per hectare per rotation” and “per hectare per year”; it is important to be able to view the results as “per rotation” and “per year” in order to better understand how rotation length affects sustainability indicators.

Regarding the “per hectare per rotation” results (Figure 27a), when compared with radiata pine rimu had 2.7 times the cost and 4.5 times the employment, while mānuka had 1.6 times the cost and 12.8 times the employment. Each of the scenarios had equivalent GHG emissions and both the rimu and the mānuka scenarios had less carbon sequestration. The Cultural Indicator Matrix showed that rimu was 21.6 times more culturally favourable than radiata pine, and mānuka was 19.5 times more favourable.

However, regarding the “per hectare per year” results (Figure 27b), when compared with radiata pine rimu had only 0.9 times the cost and 1.6 times the employment, while mānuka had 3 times the cost and 23.8 times the employment. The GHG emissions are now seen not to be equivalent with rimu producing a third of the emissions of radiata pine, and

mānuka producing nearly 50% more emissions. Carbon sequestration has changed slightly as rimu sequestered 40% of the carbon of radiata pine, and mānuka sequestered 60% of the carbon of radiata pine. The Cultural Indicator Matrix results did not change between the “per rotation” and “per year” analyses as these figures do not alter with differences in timescales.

Utilising quadruple bottom line information may enhance the potential for a robust decision making process as no singular objective can be pursued without the acknowledgement of its associated trade-offs. For example, when reviewing the “per year” results of Figure 27b, if the decision makers’ primary objective was to maximise employment then they would choose the mānuka option; yet, with the quadruple bottom line approach, the trade-offs of the mānuka option (highest cost, most GHG emissions) are also clearly and unavoidably presented. Therefore, the use of a quadruple bottom line approach helps to facilitate comprehensive and transparent decision making.

Another benefit of a quadruple bottom line approach is being able to review a range of impacts on chosen sustainability measures. In particular, the representation of culture within this LCSA research has led to its distinct recognition amongst the other aspects of sustainability (economic, social, and environmental). Placing culture at the forefront of sustainability assessments may help to ensure that cultural considerations and values are not lost during the decision making process, but rather are an active component.

Indeed, this was the first time the participants of this LCSA research were able to visually see and interpret information which distinctly represented their cultural values. This comprehensive analysis allowed them to view the potential impacts (both positive and negative) across a range of sustainability mid-point indicators. This is of critical importance as a noted “challenge for Māori is how to balance aspirations for cultural enrichment, retaining strong elements of traditional culture such as values, language and knowledge, with those more modern elements of advancement, growth, commerce, and economic development” (Durie, 1998; Jollands & Harmsworth, 2007, p. 720).

## **7.4.2. Variation in Cultural Indicator Matrix scores between participants**

The subjective scores of the Cultural Indicator Matrix are based entirely on each participant's own knowledge and experience. Seeking such empirical information, as noted in the S-LCA guidelines (UNEP & SETAC, 2009), will inevitably (and often most appropriately) result in subjective data. When completing the Cultural Indicator Matrix each participant relied upon their own understanding and generally did not independently seek further information regarding any particular process, even if they felt they had limited familiarity with it. Nothing prevented the participants from doing further research themselves; however, the participants decided to complete the matrix based on their current knowledge. Furthermore, at the point when the participants completed the matrix scores, the LCSA of the scenarios had not been completed, and so they did not have access to this information.

Each of the participants had different backgrounds as well as varied experience with forestry life cycle processes. It was unsurprising therefore to find a degree of variation between participant scores within the Cultural Indicator Matrix. The variation is not a negative result; indeed the variations may be representative of the wider Ngāti Porou tribe and the inherent range of alternative viewpoints. The variations in participant scores for each of the forestry scenarios can be seen in Figure 28.

There is a wide variation of participant scores both within each forestry scenario and across forestry scenarios. In the radiata pine scenario, the participants gave similar scores for the aspirations of “Whānau and Connectedness”, “Mana Motuhake”, and “Mātauranga”. In the rimu scenario, the participants gave similar scores for the aspirations of “Ngāti Poroutanga”, “Infrastructure”, and “Kaitiakitanga and Healthy ecosystems”. In the mānuka scenario, the participants gave similar scores only for the aspiration of “Kaitiakitanga and Healthy ecosystems”. Although it is evident that the three participants often had differing viewpoints regarding the three forestry scenarios, these differences do not diminish the validity of the results. Instead, these variations in scores may act as further confirmation that viewpoints amongst members of a cultural group (e.g. Ngāti Porou) are not always similar nor are they predictable; thus, using the

Cultural Indicator Matrix has allowed for the recognition of each participant’s distinct voice and opinion.

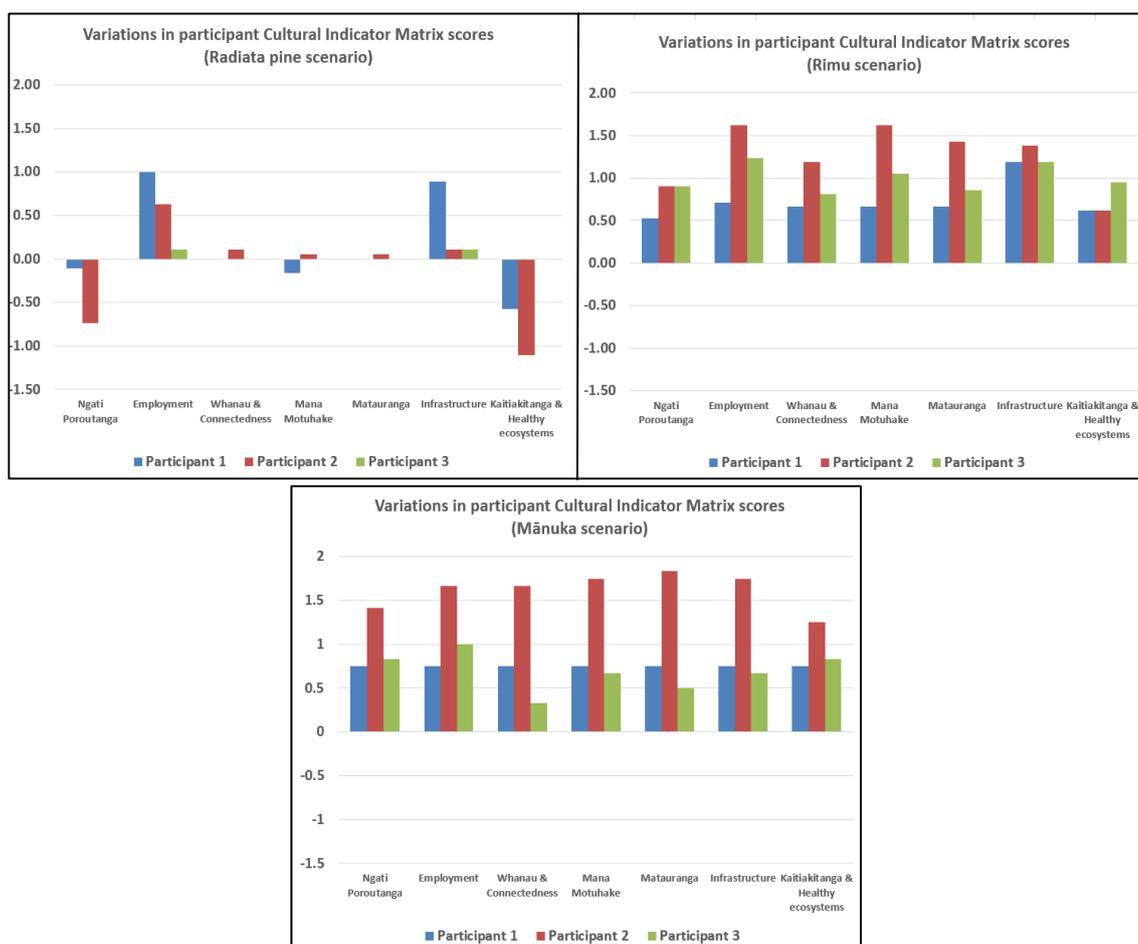


Figure 28. The individual Cultural Indicator Matrix participant scores per Ngāti Porou aspiration in each of the three forestry scenarios (based on averaging the scores for all of the processes involved in each forestry scenario). A value of “2” is a flourishing (mauri ora) effect on the aspiration, “1” is an enhancing (mauri piki) effect, “0” is a maintaining (mauri noho) effect, “-1” is a diminishing (mauri heke) effect, and “-2” is a degrading (mauri mate) effect.

### 7.4.3. Benefits of displaying LCSA results along a timeline

As described in the introduction of this chapter, using timelines to display and convey results is of great value and importance, particularly when assessing a relatively long-term industry such as forestry. Displaying the LCSA results along a timeline allowed for the visualisation of when sustainability indicator impacts may occur. Understanding how cost, profit, employment, and climate change impacts are distributed across time will help

the participants and other decision makers plan and prepare for the effects of any given forestry scenario. For instance, it is important to appreciate when profits may be realised in order to ensure that costs are adequately managed; although capital investment can induce burdensome debt, with acknowledgement of profit distribution such investments can be cost-effectively arranged.

Another benefit of the use of timelines has been that it has helped to visualise the inter-generational aspect of forestry, especially with the rimu scenario which exists over a 200-year timeline. Such a display of inter-generational impacts further accentuates the potential for forestry to help achieve the long-term aspirations of Ngāti Porou.

*We might be quite good at doing things inter-generationally but maybe not actually set up to manage things over a 200-year time frame. We just hope to pass it on to the next generation but this sort of exercise makes you, or the decision making group, have to start teasing out some infrastructure for that, even if it's just a plan. I like that the timeframe will make us have to set up and cast out (Int-4a-PP).*

#### **7.4.4. Benefits of applying a product perspective**

This LCSA research presented results from a land-use perspective and a product perspective. The former showed the impacts from cradle-to-point of harvest for one hectare of land respective to each forestry scenario, and the latter showed the cradle-to-grave impacts associated with the studied product of each forestry scenario. A distinct benefit of the product perspective is the inherent ability to detail the impacts of the product's full life cycle. This is particularly important for forestry and wood-based products due to the potential for carbon sequestration and storage which reduce the climate change indicator result.

The use of a product perspective further highlights the connection between all stages of the product's life cycle – from nursery to planting, from forest growth to harvest, from product development to product disposal. The product perspective has emphasised the variety of actors and activities involved in the creation, use, and disposal of each studied

product in this LCSA research. The value of understanding the implications of the full life cycle of a product include the knowledge of upstream and downstream impacts; such knowledge may lead to greater ownership and amelioration of identified impacts by all actors involved in the full life cycle.

The use of a life cycle product perspective has also been found to aid the analysis, for example, of the efficacy of product innovation (Viaggi, 2013), sustainable consumption techniques (Pehlken, Kirchner, & Thoben, 2014), and research and development investment (Kubáňková & Hyršlová, 2014) by presenting the opportunity for long-term, strategic assessment.

## **7.5. Further considerations and recommendations for future research**

### **7.5.1. Site-specific issues**

It is worth reiterating that this research was not based on a particular, site-specific hectare of land with defined biophysical characteristics. The case study parameters were described with the Waiapu catchment as the underlying setting, and where possible attempts were made to reflect the effects of this location (e.g. the radiata pine growth rate used in this research was indicative of the Waiapu catchment and surrounding region). However, processes such as Transport are obviously extremely sensitive to spatial variability and may subsequently have a significant impact on indicator results.

In addition, whether a site is located on flat land or steep land can have a large effect on sustainability indicators. Steep land is defined as terrain over 18° and has a considerable effect on forestry costs, efficiency, and safety (Forest Industries Training, 2000). The results presented in this chapter have been based on the assumption that all forestry activities took place on flat land, and thus all of the associated data reflects this assumption. In reality, however, the LCSA participants' catchment has relatively limited amounts of flat land as a significant amount of the area has steep slopes over 18°.

A steep land sensitivity analysis (Appendix G) was performed on the radiata pine and rimu scenarios (applying both a land-use and a product perspective); a steep land sensitivity analysis was not performed for the mānuka scenario as this scenario and its related processes can only take place on flat land. Data were collected for specific elements of the life cycle where steep terrain would have an effect. Processes affected included site preparation (aerial spraying and mechanical preparation), planting, tending (herbicide application and opportunity cost), thinning, felling, extraction, landing site (log making), and landing and roading construction.

For radiata pine, it is assumed that there is a slower growth rate on steep land (742 m<sup>3</sup> after one 28-year rotation) than on flat land (760 m<sup>3</sup> after one 28-year rotation) (total standing volume). For rimu, the same assumption applies with an estimated 920 m<sup>3</sup> produced on flat land and 828 m<sup>3</sup> produced on steep land (total standing volume). In general, steep land is more expensive to perform forestry operations. Two exceptions are that of Opportunity cost which is lower for steep land (\$208/ha year<sup>-1</sup>) than for flat land (\$1040/ha year<sup>-1</sup>), and Felling/flitching (which is due to steep land harvesting using a chainsaw instead of a more expensive mechanised harvester).

Overall, employment hours and greenhouse gas emissions are both higher on steep land due to greater hindrance issues (e.g. hazards, ground instability), a requirement for carefully arranged infrastructure (e.g. wider, highly contoured forest tracks), and longer processing times (e.g. manual felling with a chainsaw, extraction with a cable crane).

Future research endeavours should be focused on pursuing more site-specific datasets for these (and potentially other) forestry life cycle alternatives; this would increase the accuracy and applicability of the results, both which would significantly facilitate the real-world decision making process for the future of the Waiapu catchment.

### **7.5.2. Forest growth rates**

Another major influence on the results presented in this section includes that of the assumed tree growth rates and timber quality characteristics. Radiata pine, is extremely well-researched and therefore the assumptions for growth rates and timber quality were

very accurate. However, the rimu and mānuka scenarios relied on expert opinions and/or limited research; while this in itself does not render the results invalid it does make them less reliable. The mānuka scenario (intensive management for essential oil production) represents a fairly new and novel approach to mānuka as a land use in New Zealand, and precise estimations of branch and brush output per hectare are not currently available. The branch and brush yields used in this paper (i.e. average of 36 tonnes per hectare per annum) may reflect a “high-yield” scenario, while a “low-yield” scenario may only produce 16 tonnes per hectare per annum. There is also uncertainty associated with the following data used in this study: mortality rates, tree and brush quality, fertiliser requirements, and soil and water needs.

There is no carbon sequestration value that currently exists which may be associated with such an intensive mānuka plantation scenario. Furthermore, the effect of annual trimming of a mānuka tree on its carbon sequestration rate has never been measured. Future research is needed in this area to be able to more accurately determine the carbon sequestration rates of mānuka in an intensively managed, essential oil scenario.

Future research endeavours, particularly with rimu and mānuka forestry options, should include undertaking trials to determine the “cause and effect” of various parameters on their overall growth and quality.

### **7.5.3. The effects of time**

Each of the forestry scenarios presented in this chapter is assumed to convert from unmanaged shrubland to forestry and is modelled only for one rotation. However, in a real-world application, it is likely that these forestry scenarios will be applied for several rotations. For these subsequent rotations, many forestry processes and their related indicator values will be affected. For example, subsequent rotations will not require significant land preparation activities nor will in-forest roads and landing sites need to be installed.

In addition, the rimu scenario is the only forestry option which is not clear-felled at the end of the rotation; instead, the rimu scenario adopted continuous cover forestry practices where only 10% is initially harvested at year 80, and where 80 years was defined as one

rotation for rimu. In reality, a further 10% may be sustainably harvested after another 10 years has passed, and 10% harvested again 10 years after this ad infinitum. Essentially, therefore, the results presented in this assessment are only the initial “wave” of impacts.

Regarding the effects of time, it is also important to note that all economic costs and profits were presented using a 0% discount rate; the application of a discount rate will greatly affect the final economic figures, particularly for rimu with its long timeline. Discount rates are used to assess the net present value (NPV) of costs and benefits over time, and allow for economic comparisons between alternative scenarios. Gluch and Baumann (2004) state that when a “discount rate is set to 0% this means that the timing does not matter; the higher the discount rate the more importance is given to the near-present” (p. 575). Furthermore, a high discount rate will favour “short-term low capital cost options” while a low discount rate will favour “future cost savings” (Stern, 2000, p. 388).

Barry, Yao, Harrison, Paragahawewab, and Pannell (2014) argue that forestry discount rates can range from 4% (for net public benefits) to 8% (for net private benefits). Therefore, a sensitivity analysis was performed on each forestry scenario (and the steep land data for radiata pine and rimu) using a range of discount rates: 4%, 6%, and 8%. The results can be seen in Appendix H.

In the sensitivity analysis, the discount rate had a significant effect on the representation of costs and profits – particularly for the longer forestry scenarios of radiata pine (88 years) and rimu (200 years). For example, the transport process resulted in the first instance of profit for radiata pine (year 28) and for rimu (year 80). The non-discounted profit (per hectare) for radiata pine (flat land) after transport was \$1,946 while the 4% discount rate profit was \$650, the 6% discount rate was \$381, and the 8% discount rate was \$226. With its long rotation, rimu was much more affected by discount rates as the non-discounted profit (per hectare) for rimu (flat land) after transport was \$1,109 while the 4% discount rate was \$48, the 6% discount rate was \$10, and the 8% discount rate was \$2.

With its relatively short-rotation of 15 years and its potential to annually create essential oil product, mānuka was less affected by the discount rate sensitivity analysis. For

example, the distillation process was the first instance of profit and resulted in a non-discounted profit of \$74,282 per hectare while the 4% discount rate was \$52,389, the 6% discount rate was \$44,595, and the 8% discount rate was \$38,279.

Therefore, the choice of discount rate can significantly affect LCC and/or LCSA results as well as create a degree of uncertainty; performing a sensitivity analysis involving the assessment of a variety of discount rates can help to minimise uncertainty related to economic results (Hunkeler, Lichtenvort, Rebitzer, & Citroth, 2008; Sterner, 2000).

#### **7.5.4. Further steps for the Cultural Indicator Matrix**

The Cultural Indicator Matrix was shown to be a viable process and tool for the purpose of distinctly recognising culture alongside other sustainability indicator in LCSA. The culturally-focused LCSA results indicated that both the rimu and mānuka options were considered to have an overall positive and “enhancing” effect on Ngāti Porou’s ability to meet their cultural aspirations. The radiata pine option was 0.02 which signifies an impression by the participants that this option is “maintaining” their aspirations; a score of 0 or thereabouts is effectively indicating a “neutral” effect. Indeed, the participants scored radiata pine positively for providing employment and infrastructure but rated it poorly for enhancing tribal connections and ecosystem health.

Further steps can be taken to enhance the robustness of the Cultural Indicator Matrix as both a process and a tool. For instance, it may be interesting for the participants to redo the Cultural Indicator Matrix to see if their subjective-based scores change in light of the full LCSA results, especially regarding the intensive operations (and associated impacts) of the mānuka scenario. For instance, the mānuka scenario’s Nursery and Tending processes scored highly for the “Kaitiakitanga and Healthy ecosystem” aspiration (scoring “2” and “1.67” respectively) but these processes also use a significant amount of herbicide chemicals. It is possible that if the participants were explicitly aware of this chemical usage, they might score these processes lower for the “Kaitiakitanga and Healthy ecosystem” aspiration.

Additional recommendations for further development of the Cultural Indicator Matrix are made in Chapter 8.

### 7.5.5. Other benefits and challenges of forestry

This LCSA research addressed a small selection of indicators: cost, profit, employment, climate change, and the Cultural Indicator Matrix. However, forestry includes other benefits and challenges that were not represented in this research. For example, the participants also showed interest in the indicators of resource and material use, investment in research and development, wages and salaries, skill level, health and safety, household income, availability of rongoā Māori (Māori medicine), water quality and use, biodiversity, waste, and erosion prevention.

Furthermore, there are other forest-based activities (e.g. tourism, hunting, bioenergy) that were not included in this LCSA research but that do potentially hold economic, social, environmental, and cultural value.

*I think tourism in a native forest will be something that our whānau are interested in. So tourism and walks, mountain biking. If there are medicinal uses of...because you'll have the timber products for the higher species, the taller species but you're still going to have lower canopy natives like Kawakawa, there are a lot of opportunities that come out of those medicinal purposes. There's hunting tours, so we're very big on using our forests to populate with deer and pigs so that I think will grow as well and it can be something that you can grow a business out of. I think also we don't know much about the fauna and what will live there while we regenerate these forests so I don't know what else could be produced from that. It's also bioenergy, not necessarily we wouldn't be using the native crops for bioenergy but we may be using the offcuts because we don't even do that with pine yet but it's something that I thought we would be. But bioenergy certainly is an option for us (Int-3b-TP).*

In addition, none of the scenarios included any economic benefit for sequestering carbon or nitrogen. In New Zealand, carbon payments are made in return for carbon sequestration through the Emissions Trading Scheme (ETS); at the time of writing, current carbon payments are approximately \$11 tCO<sub>2</sub>eq (OMF, 2016). Nitrogen removal

payments are also being trialled in New Zealand added to the National Policy Statement for Freshwater Management (NPS-FM) which aims to ameliorate freshwater quality; payments for nitrogen permanently removed from the environment was around \$300 kgN in 2012 (Kerr, Greenhalgh, & Simmons, 2015). Therefore, inclusion of ETS and NPS-FM payments could add significant income to the profit margins of forestry, as demonstrated in a recent study by Monge, Parker, and Richardson (2016). Future LCSA and forestry research should endeavour to include these identified benefits and challenges – doing so will help to comprehensively account for the full range of impacts associated with forestry.

### **7.5.6. Risk**

There are numerous risks that should be considered with the pursuit and management of forestry. Risks can develop that affect the forest itself (pests, disease, invasive species), the surrounding environment (fire, drought, extreme wind), the workers in the forest (occupational health and safety), and the market price for forests and wood-based products (supply and demand).

The latter point of market risk is particularly important when considering the results of this LCSA research; the results presented have assumed values for profit based on current market prices for the proposed products in each study. The radiata pine market is a thriving industry in New Zealand with generally consistent consumer demand, especially internationally. However, the less-established rimu and mānuka options may be considered vulnerable as their resultant products currently have less market exposure; they are susceptible to the effects of unknown market behaviour and the associated impacts on product prices.

*The problem is that the market for pine is far more established than a market for mānuka. So we would have to show [the decision makers] the cost to develop the market for mānuka where you don't have to develop that for pine. And that's probably one of the biggest issues, too; they know that if they grow pine trees that someone will buy it. They don't want to be involved in a start-up venture that for them is rocky (TP) (Int-1-TP.PP.TW).*

In an analysis of new product performance, Henard and Szymanski (2001, p. 364) identify four critical areas which can greatly affect the success of a new product: 1) product characteristics (price, meeting customer needs, degree of innovation, advantage and/or differentiation over competing products); 2) strategy characteristics (the product developer's ability to appropriately time entry into the market and build on pre-existing market synergies, dedicated R&D resources); 3) process characteristics (proficient management of the product's development, performance, and marketing); and 4) marketplace characteristics (likelihood and intensity of competitive response to a new product, market potential/consumer demand).

Therefore, further research and investment is needed to increase the long-term market strength of both the rimu and mānuka forestry options. In particular, research and investment should be mindful of fulfilling a current identified customer demand (i.e. responsive market orientation) but also aim to discover ways of meeting latent needs of the customer, needs of which they are unaware (i.e. proactive market orientation) (Narver, Slater, & MacLachlan, 2004).

Further risk assessments (deterministic and stochastic) of the forestry scenarios presented in this research are required in order to better understand and prepare for risks.

### **7.5.7. Spatial suitability assessment**

In reality, some areas in the Waiapu catchment will be more suitable than others for each forestry scenario. It is likely that the intensive radiata pine scenario would be most appropriate on rolling land with minor slopes, the long-term continuous cover rimu forestry scenario would be placed on relatively inaccessible, steep sloped land, and the intensive mānuka scenario would be most appropriate on flat land (Int-4b-TW; Int-4c-TP; Int-9a-TW.PP). Mapping the potential placement of each of these scenarios gives the participants greater ability to visualise the future of forestry in their catchment, thus enhancing their strategic decision making capability.

A scoping exercise was undertaken to develop an initial overview of suitable areas for each forestry scenario (see Appendix J). However, it is recommended that further research is undertaken to utilise GIS (or other mapping software) to spatially display and overlay the LCSA data on the land in the Waiapu catchment.

## **7.6. Conclusions**

This chapter presented the quadruple bottom line results for the three LCSA forestry scenarios: radiata pine (with the related product of radiata pine framing), rimu (with the related product of rimu heartwood flooring), and mānuka (with the related product of mānuka essential oil).

The culturally-focused LCSA results for the forestry land-use and product perspectives represent a significant new body of knowledge. Such a comprehensive collection of data will allow for enhanced identification and assessment of trade-offs and hot-spots, both of which increase the potential for a robust decision making process. In addition, the communication of the LCSA results was facilitated through the development and use of timelines which have helped to visualise and interpret the effects of a potentially long-term industry such as forestry.

For the first time in LCSA, indigenous culture has been represented alongside other metrics of sustainability (economic, social, and environmental). This distinct recognition of culture has ensured that the cultural values and aspirations of the LCSA participants are at the forefront of this research and related results.

## Chapter 8

### 8. Discussion and critical review

This chapter discusses the culturally-focused LCSA (as a tool and as a process), including the participatory process, the case study results, and the Cultural Indicator Matrix. The participants were interviewed to understand and appreciate their insights on the relative benefits and challenges of the culturally-focused LCSA and its associated implications for Māori (Ngāti Porou) decision making. Finally, the answers from a short questionnaire that was disseminated to the wider Ngāti Porou iwi are reviewed and discussed.

#### 8.1. Participant impressions of a culturally-focused LCSA tool and indicator results

##### 8.1.1. Benefits

The dominant benefits of the culturally-focused LCSA results were the availability and consolidation of a vast amount of information regarding options for forestry and forest products. The data were seen as “substantiating” the visions of the participants, and lending credibility and viability to the endeavour of exploring alternative forestry options (Int-9a-TW.PP; Int-8c-TP). The sheer quantity and quality of data gathered and provided had never been done before within the Ngāti Porou, and the potential benefits to be achieved as a result was not lost on the participants.

*You’ve got pine, rimu, mānuka...the different things you’ve looked at in the processes of them, each step and phase and even each matrix there’re opportunities in each step and component as well as the big picture as well comparing the big pictures across. There is loads to get out of this (PP) (Int-9a-TW.PP).*

The participants identified that a useful aspect of the Cultural Indicator Matrix was that it allowed for users to assess the contribution of a process to their specific aspirations at any time, and as often as necessary. Undertaking a series of measurements over time could enhance the understanding and acknowledgement of a process’ affect upon aspirations.

Therefore, the Cultural Indicator Matrix could be used as a monitoring tool where mindful, regular observation of impacts upon aspirations may stimulate actions to rectify processes producing unfavourable impacts.

One of the most significant benefits of creating a culturally-focused indicator to incorporate within the LCSA technique was that it assured the participants that their cultural values and aspirations were recognised throughout each process of the life cycle. Not only would their cultural values be evident but they would also be visible in relation to the other economic, social, and environmental aspects. No longer would the decision making process rely on just one independent component as, resulting from this research, the quadruple bottom line was now transparently present.

*I think the aspirations, when you've got those it's inherently requiring you to consider your decisions based on these multiple factors and not just an economic factor or just one or two others, it's the whole lot. I think that's good for more principled and more informed decision making (Int-8b-PP).*

The use of fairly basic Excel graphs and charts was deemed “visually stimulating” (PP) (Int-9a-TW.PP) indicating the vast potential to further develop more sophisticated methods of result visualisation to facilitate the knowledge communication and dissemination process.

*I found the rimu one really interesting. I suppose to see the graphs and how they've mapped differently is visually stimulating. You know and can assume or theorise that the mānuka will work but to see it graphically and how it relates or doesn't relate to the previous two examples is great. To see it laid out graphically like this is like “whoa” (PP) (Int-9a-TW.PP).*

In addition, and without prompting, the participants identified the capacity for the LCSA results to be used in a hotspot-like analysis: focusing on areas in the life cycle-value chain where value does not currently exist. Preferably, the Cultural Indicator Matrix results would be utilised in an iterative hotspot analysis where areas of the life cycle that are scored differently by the participants are further reviewed to determine why and how the participants scored a process. It is within these areas (e.g. capitalising on waste by-

products of mānuka distillation) that the participants felt that they could be particularly innovative (Int-9a-TW.PP). This hotspot analysis may – or may not - lead to more educational efforts by the owners/operators of the process in question to increase the participants’ understanding of a previously unfamiliar process.

*That’s great to make [cultural aspirations] more visible. One of the other good benefits of it is that it makes transparent the processes that often aren’t considered directly impacting commercial returns. That transparency means that it could improve your brand. For example, traceability when you’re selling your product at the end and being able to say that you’ve complied with cultural requirements and that’s adding value to the product, you’re buying a product that is coming from a culturally compliant forest. That’s a long way down the track obviously but it’s a definite benefit of getting a tool that helps makes decisions from a culturally compliant factor. (Int-8c-TP).*

*I don’t want to cut down a native unless I know we’re getting a premium for it. And the other way I can do that is to have a brand that adds value to the product or otherwise we’re the same as everybody else. And even for our pine. And that is why we have to differentiate ourselves (Int-5b-TP).*

### **8.1.2. Challenges**

The Cultural Indicator Matrix was experienced by the participants as a thorough approach to ascertain and represent cultural values within the LCSA technique. However, it became apparent that a difficulty arose when participants were asked to score aspects of the forestry value chains that they were entirely unfamiliar with. In these instances, the participants relied on tenuous knowledge, hearsay, or even speculation. For example, the distillation process of the mānuka value chain scored “0.62” which equates to halfway between “mauri noho” (maintaining) and “mauri piki” (enhancing) Ngāti Porou aspirations. Since the distillation process scored lower than other mānuka processes, I queried it with the participants; one participant indicated that it was due to an unfamiliarity with the process (Int-9a-TW.PP). The Cultural Indicator Matrix therefore provides an opportunity to identify where along the life cycle-value chain exists potential

deficits in knowledge and subsequently the possibility to rectify through targeted education or information dissemination.

Presenting and communicating LCSA results to the wider community and key decision makers was seen as being a challenge. The data are complex and extensive, and a degree of previous forestry knowledge is beneficial for contextual purposes. The inherently dry, linear approach to presenting and communicating LCSA results (e.g. bar graphs) may not be entirely appropriate for an unexperienced audience. Further work is needed to make LCSA results more visually stimulating and dynamic (and perhaps even interactive).

As Māori are the kaitiaki (guardians) of the land, they inherently have a deep connection with the land, its ecosystems, and all living and non-living elements therein. As such, one participant in particular had difficulty in accepting that, in each of the scenarios, the hectare of unmanaged land would have to be completely stripped of existing vegetation in order to prepare the land for one of the three forestry options. Instead, the participant felt that special consideration should be made at the start of each forestry land preparation process to assess and account for the current growth on the land and, where possible, build upon that existing value (Int-9a-TW.PP).

Furthermore, as the main “commissioner” of this LCSA research, each of the life cycle scenarios were largely based around the priorities of the participants and situated within the Waiapu catchment. As such, the Cultural Indicator Matrix was specific to the participants (and their wider tribe). If the life cycle-value chain were to be expanded and thus include other geographical areas with different cultural groups, then the Cultural Indicator Matrix would need to be completed with any cultural group that the commissioner of the LCSA research (in this case, the participants) determined should be included in the cultural assessment.

### **8.1.3. Recommendations**

The participants highlighted the tendency for indicators to take on a negative connotation (Int-4a-PP); indeed, most life cycle indicators (or “impact categories”) have a negative association such as with acidification, global warming, eco- and human toxicity, ozone

depletion, noise, radiation, and casualties. The participants, as both decision makers and facilitators in decision making, felt that more positive indicators would be useful – and especially when communicating life cycle results to their community. For example, “casualties” could be reported as “worker safety” where 0% “casualties” would translate to 100% “worker safety” – a much more encouraging and optimistic figure, despite the fact that both essentially have the same meaning.

This LCSA research was only able to provide results for one key product associated with each forestry scenario. Each of the participants immediately showed interest in what other products could be achieved from processing any given tree. This result is unsurprising given that two of the participants had relatively limited knowledge of what can be produced from a tree and therefore were keen to learn as much as possible about the full range of potential benefits to be gained from timber product development (Int-4b-TW; Int-9a-TW.PP).

*I entered into this with a focus on land use, not so much on what that production side and economic emphasis. But seeing it, wow, and those numbers are just for a fraction of the tree. So yeah, what other products can we make? (PP) (Int-9a-TW.PP).*

In addition, the participants wanted to be able to compare various products to understand which may be the best products to pursue (PP) (Int-9a-TW.PP). The ability to assess alternative products than those produced from radiata pine was seen as essential if the decision makers are to be adequately persuaded to make any shift from the current status quo.

*To me if we're going to get people not planting pine we have to show the product streams and what they mean. Because up here it's like what goes is the one that is easiest to go with – so when there's a whole infrastructure and industry built around pine it's always going to be easier than rimu. And that's just part of persuading them to change land use is to show them that product stream and all the rest that goes with it (PP) (Int-9a-TW.PP).*

Finally, confidence in and uptake of the culturally-focused LCSA (tool and process) by the wider iwi community will be aided if appropriate context is given. Such context includes, for example, how the Cultural Indicator Matrix was developed, who was involved, and what cultural considerations were taken into account.

*I think you'd need to give it some context and maybe use it, and this may sound boastful, but to use our name and to say that we were part of the process to develop it so that people feel more confident in the cultural sector that it was based on. (Int-8c-TP).*

## **8.2. Participant impressions of a culturally-focused LCSA process**

### **8.2.1. Benefits**

One clear benefit of using LCSA as a process (rather than just a data-providing assessment tool) was that the participants began to have more detailed discussions around extending their potential involvement to additional areas of the life cycle-value chain. The action of reviewing and considering these processes (processes that are generally operated by non-Māori) led to the participants more consciously envisioning their future within these areas. Their vision was not only limited to providing the labour force but also included developing and investing in expertise in order to become leaders in the “downstream” life cycle processes. These findings align with other similar work such as research by Thabrew, Wiek, and Ries (2009) who argued that stakeholder involvement throughout the research and decision making processes of an LCA study will lead to a more comprehensive and robust assessment, and provide “stakeholders a holistic view that they otherwise may not have”.

As a result of utilising LCSA as a process, the identification of a need to formally include a Cultural Compliance process within the LCSA was made in the fifth interview and is detailed in Section 5.4.2. It is unlikely that this insight would have been reached if it were not for the participatory engagement focus of this LCSA research. The participants believe that recognition and inclusion of the Cultural Compliance process in forestry operations could provide standardised and transparent evidence of observing culturally-

related regulations (e.g. Forest Stewardship Council certification), and meeting the cultural expectations of the stakeholders and Ngāti Porou tribe. The participants also felt that inclusion of the Cultural Compliance process would enable decision makers (Māori and non-Māori alike) to have more robust discussions regarding cultural factors in the forestry life cycle, and ultimately the process would lend credibility, traceability value, and strength to Māori branding of forestry products. In reality, however, cultural compliance (and Māori culture in general) cannot be so conveniently summarised and segmented; therefore care was taken by the LCSA researcher to ensure that the participants were comfortable with defining and promoting the Cultural Compliance process within the life cycle.

The utilisation of LCSA as a participatory process greatly enhanced the ability to honestly and accurately represent Māori culture. The participants were involved at every step of the LCSA process, giving their impressions, recommendations, refinements, guidance, and approval. This required much more of their time but this level of commitment resulted in culturally appropriate and meaningful results that they were able to take ownership of as co-developers. Furthermore, as they were involved throughout the LCSA process their ability to understand the results was enhanced (Int-9a-TW.PP).

*We're looking at a [long-term] restoration goal and let's do it right, let's empower people every step of the way (Int-8a-TW).*

The approach of using LCSA as a process actively sought participant engagement during each phase of the research development which allowed for dynamic feedback, refinement, and affirmation of progress and associated assumptions. Furthermore, it was recognised that development and inclusion of the Cultural Compliance process made LCSA (a technique with a fairly “westernised” perception) more culturally sensitive (Int-5b-TP); this is a significant result arising from the use of a participatory LCSA approach.

The culturally-focused and participatory LCSA process created a strong and trusting relationship between myself, the researcher, and the participants. Moreover, this relationship gave the participants positive impressions of the organisations that I represent (i.e. Massey University, Scion, and New Zealand Life Cycle Management Centre). Such

long-term and meaningful LCSA engagement therefore had a subsequent effect of “breaking down so many barriers” (Int-9a-TW.PP).

### **8.2.2. Challenges**

The actual LCSA process is not necessarily straightforward; indeed, it can be difficult (Ciroth et al., 2011) and challenging (Traverso, Finkbeiner, Jørgensen, & Schneider, 2012), with potential problems in attaining “knowledge at a scientific level” (Sala et al., 2012a). In this research, the participatory LCSA process was experienced as successful and beneficial by both the participants and the practitioner; however, the participants felt that the “right person” (i.e. a culturally-sensitive individual with expertise in LCSA) was needed to advocate, explain, and implement the LCSA process and tool (Int-9a-TW.PP; Int-9b-TP).

This, in turn, raises the issue of LCSA researcher bias. As the participants were neither LCSA nor forestry experts, the LCSA researcher had to provide guidance to ensure the participants were as informed as possible before making the life cycle- or forestry-based decisions that guided the case study. In this research, the introduction of researcher bias (as delivered through guidance) was unavoidable yet ultimately beneficial; without such guidance the participants would not have been able to fully engage with the LCSA process.

### **8.2.3. Recommendations**

It was identified that this culturally-focused participatory LCSA process was not one whose applicability and pertinence would be restricted to only one community; indeed, the participants felt that Māori and non-Māori alike could benefit from this process (Int-8c-TP; Int-9a-TW.PP; Int-9b-TP). This implies that the LCSA process is robust yet flexible enough to account for a range of potential interests and user-groups.

*So it's not just the studies done here but the tool can be used in any district or tribe that want to bring those sorts of considerations in (Int-9a-TW.PP).*

Replication of this process with another user group or community would provide an opportunity to compare use of the technique, learn from other user groups, and ultimately refine and improve upon the current process. This would be of great significance as certainly there is no “one” set of Māori values, and the results attained in this participatory LCSA process do not represent all Māori communities.

An interesting comment also arose around the LCSA process and its inherent educational potential in a classroom-type setting (PP) (Int-9a-TW.PP). The participant highlighted the need for the education curriculum in the catchment to be more localised, and recognised that the LCSA process may be a suitable mechanism for assessing the effects on sustainability caused by local activities or products. Particularly with a culturally-focused LCSA, these young students would gain access to knowledge (environmental, economic, social, and cultural), learn how to identify and measure impacts, and appreciate the integrated and expansive effects associated with product life cycles – and all within their own community. The potential therefore exists to promote LCSA in a less traditional setting, and utilise the LCSA process and tool to help fulfil the educational requirements of young students.

### **8.3. Māori (Ngāti Porou) decision-making using culturally-focused LCSA**

Decision making is a complex and often sensitive process within Ngāti Porou. Indeed the participants recognised certain weaknesses in the decision-making processes within their iwi such as an attitudinal resistance to change, a dominant focus on profit (even at the expense of other values), and the false assumption that the people and the land are content with the effects of past decisions (Int-9a-TW.PP).

*So while [culture is] a part of us we're actually not that good at making decisions that embrace or integrate those things into those decisions. We actually use other people's decision making processes and models and we need to step up and incorporate [culture] in...it's in making these things integral to the decisions we make is where the real power is I feel. To me, it'll make the decision making more robust – not just one track profit-oriented or one track jobs-oriented. The*

*complexity is that it is multi-dimensional but our decision making has to get more multi-dimensional as well (Int-4a-PP).*

A critical challenge within Māori decision making is determining better ways to make decisions. This entails generating enough momentum and confidence to take the first steps towards embracing other approaches (e.g. LCSA) and associated data to help attain sustainable and culturally appropriate decisions.

*Part of the equation around others getting value off the land is that we need to value ourselves properly to make good decisions. We have generations of poor decision makers that now they think that's what it's meant to be, that's what they think that land development needs to be – farming or forestry, and that's why they've never looked at anything else. It's a terrible hangover that we're stuck with until they're kicked off the land trust or they die basically. It is an attitudinal shift from our people as well as engaging in a way with outsiders that keeps us connected or even reconnects us with our land and starts up these better decisions getting made (PP) (Int-9a-TW.PP).*

Overall, the participants felt that using a culturally-focused LCSA approach would enhance their decision-making capabilities. Utilising the LCSA tool and process was seen as an opportunity to remedy these weaknesses as it is able to reflect the often complex Ngāti Porou decision-making process and “lead them down a trail that they’ve never thought of” (PP) (Int-9a-TW.PP). In addition, the inclusion of the Cultural Compliance process would also beneficially affect decision making (Int-7b-PP).

*It's like you have the two pictures where you'd say that “Ok, this is what we currently have and the values and deficiencies that we're aware of. But if we did it this way we could add more value here and here”. It's almost like you have to do that or otherwise they just go along thinking that everything is fine, just carry on replanting in pine cause it's all going “really well”. But we can see that there's so much more value that you can even add to pine if you do things a little bit differently. But you've got to say that this is how we've been doing it and these are a few scenarios of how we could do it with some small changes, and you can have so much more value, whether it's cultural, economic, ecological value...because*

*nobody has done that. And now you've come in and done this work and we've got to say how we can use this and have multiple benefits from this one piece of work (TW) (Int-9a-TW.PP).*

Similar to the recommendation in Section 7.5, the decision making capabilities of the participants and Ngāti Porou iwi members would be greatly enhanced if more research and development could occur around viable alternative products from each forestry scenario. Mānuka essential oil in particular has an immense amount of room for growth in various markets (e.g. pharmaceutical, cosmetics, medical supplies) but without investment in research and development the oil will not be able to achieve its potential.

It was identified that to help enact and progress the use of a culturally-focused LCSA approach within the Ngāti Porou decision making process would require the use of a “change manager” – an individual who would serve as a champion of the approach as well as facilitate its utilisation and application of results (Int-9a-TW.PP). As there is currently “no infrastructure for change management” (PP) (Int-9a-TW.PP), a somewhat radical shift in Ngāti Porou’s decision-making process (perhaps involving a radical shift in the decision makers themselves) would need to occur to ensure both the short- and long-term success of LCSA within the catchment.

#### **8.4. Impressions from the wider iwi community**

On the 11<sup>th</sup> of April 2015, I presented my research approach and findings to a large community-based hui (meeting) based in Ruatoria on the East Coast of the North Island, the heart of the Waiapu case study region. Due to time constraints I was only able to present on the mānuka results. Regardless, many members were interested in the completed work and also with how to both apply and progress it within their region.

A short questionnaire comprising four questions was developed and disseminated to the hui audience. The primary ambition of this questionnaire was to be able to understand, even at a basic level, what those of the wider hapū and iwi knew (or would like to know) of forestry options for their land, as well as if they thought it beneficial to represent their cultural aspirations in forestry decision making and decision making tools.

Of the approximately 100 hui attendees, 14 questionnaires were completed and returned. Many of the respondents wrote detailed and often heartfelt answers indicating their passion for knowledge, their hapū and iwi, and the future of their lands, culture, and people.

For the first question (**What is your knowledge of forestry options for your land?**), six respondents stated they had little to no knowledge, while the rest felt they had “reasonable” knowledge which was often based around their personal experience with owning and operating forest blocks. With nearly half of the respondents indicating a complete (or nearly complete) lack of knowledge regarding forestry options there is an obvious potential for future information dissemination endeavours.

For the second question (**What information would you like to know about forestry options for your land?**), a few respondents showed an interest in any information regarding options that would be “compatible in the Waiapu Valley”. Other respondents were more specific stating their desire to know more about forestry legislation and legal entities, forest suitability, natives as sources of medicine and food, and riparian plantings. A powerful statement from one respondent’s answer was her acknowledgement of the hapū and iwi being “ready for solutions within the context of culture”. This statement supported one of the most fundamental aspects of this PhD research: culturally-focused solutions.

For the third question (**Would you find it beneficial to see your cultural aspirations and values more represented in forestry decision making? Why, or why not?**), 100% of the respondents answered “yes” and highlighted the beneficial strength of culturally-focused decision making. Pursuing more representation of cultural aspirations in decision making was seen to aid the process of raising the standards of well-being, living, environmental sustainability, and prosperity of the Ngāti Porou people.

For the fourth and final question (**Is it useful to have a tool available to help identify how forestry processes affect your cultural aspirations? Why, or why not?**), once again 100% of the respondents answered “yes” and stated how they would find this approach and/or tool able to “assist with cultural sustainability”. In particular, the respondents identified that this tool would “provide a broader understanding of

sustainability of whenua Māori” while helping them to recognise and articulate what is culturally important to decision makers at all levels (i.e. local communities to national government). In addition, one respondent’s statement that “through this [tool’s] availability, the road is open for progress for the generations to come” emphasises the significance of understanding how activities (forestry or otherwise) affect cultural aspirations and values. This, in turn, supports the reasoning behind the pursuit of distinctively recognising culture within LCSA as a separate pillar of sustainability, not merely embedded within the sub-indicators of a Social-LCA. According to the answers provided by the questionnaire respondents, creating a clear and transparent space for culture (including cultural aspirations and values) was acknowledged as needed, deserved, and potentially quite powerful.

The questionnaire’s answers indicate a general lack of knowledge regarding forestry options while, at the same time, a significant thirst for information about forestry options. The need to have a more explicit representation of culture and cultural aspirations in forestry decision making was clearly recognised, and the concept of a tool to facilitate such decision making was entirely welcomed. Therefore, this questionnaire provided some insight into the likely opinions of the wider iwi community regarding the case for progressing cultural LCSA work as well as the alternative forestry scenarios described in this research.

## **8.5. Conclusions**

The participants felt that the culturally-focused LCSA results gave them “validation” and “direction”, and further justified their desire to pursue alternative forestry options for their land (Int-9a-TW.PP; Int-9b-TP).

*In our heart we’ve known we wanted these other options and now you’ve shown us that they are valuable and viable (TW) (Int-9a-TW.PP).*

Both the process and the results can be used to aid the traceability, “story telling”, and branding potential of Māori-owned forestry and associated products. A particularly relevant place in the value chain for this to occur is during the product development and

packaging stage as generally the Māori story and legitimacy of the associated brand will be promoted on the actual product (Int-9a-TW.PP). However, the actual formation and progression of a Māori brand is seen as a “long way down the track” (Int-8c-TP). Therefore, significantly more work is needed in this area.

The participatory aspect of this culturally-focused LCSA was particularly important. Without the active and frequent guidance of the Ngāti Porou participants it would have been impossible to represent their culture within LCSA in a meaningful, transparent, and respectful manner. From an end-user perspective, the participants also feel that the participatory aspect was crucially important; the open and consistent communication between themselves and the LCSA practitioner provided them more control, access to information, understanding of the LCSA process, and acceptance and uptake of the final results.

## Chapter 9

### 9. Representing culture in LCSA

#### 9.1. Research questions revisited

##### 9.1.1. Research question 1: How can Māori culture be represented in LCSA studies involving forestry value chains options?

There are two ways in which Māori culture can be represented in LCSA studies involving forestry value chain options: 1) adapting the LCSA process to be more culturally-focused, and 2) adapting the LCSA tool to incorporate the Cultural Indicator Matrix. Regarding the LCSA process, a culturally-focused LCSA can be achieved by utilising a participatory research approach. Such collaborative participatory engagement with research participants will allow for their cultural input, preferences, and knowledge at each stage of the LCSA process. Regarding the LCSA tool, one of the most significant results from this PhD research is the development of the Cultural Indicator Matrix that can be incorporated into the LCSA technique. This advancement in LCSA methodology allows for the distinct representation of culture alongside other pillars of sustainability (economic, social, and environmental).

To replicate the Cultural Indicator Matrix, there are six methodological steps which should be followed. These six steps are described in more detail below.

##### Step 1: Identification of participants, their aspirations, and their decision-making process

The first step of participatory engagement is to determine which participants to engage with; this indeed aligns with other participatory life cycle research recommendations (e.g. Mathe, 2014). This process in itself is often not straightforward and may involve careful consideration of the research capabilities and/or objectives.

Once the participants agreed to commit to the proposed research, it was necessary to pursue a process of reviewing their aspirations (i.e. goals and desired state of well-being) for their culture and community, and how these fitted with the proposed LCSA research itself. This helped develop a common understanding between the LCSA practitioner and the participants of what the LCSA research could and should achieve. Essentially, this was part of the “goal and scope” phase of the study. Furthermore, this process was essential to reflect and represent cultural values within the LCSA process and tool.

In this research, this step was fulfilled by first identifying and forging a research relationship with three Ngāti Porou participants, and spending the first interview reviewing and discussing their aspirations and decision-making process.

#### Step 2: Co-define the scenarios and life cycle processes to be investigated

A further component of the “goal and scope” phase of the research was to identify alternative forestry scenarios for the case study area. During this step, the functional unit and system boundaries are also determined.

In this research, to facilitate the discussion about the choice of scenarios, the participants were presented with pictures and background information (e.g. environmental needs, time before harvest, potential economic and cultural value) about various tree species and types of forest management. The pictures and information helped to stimulate dialogue around forestry options, life cycle thinking, and long-term land use decisions. The participants were encouraged to vocalise their visions for the future of forestry in their catchment, and to work collaboratively towards defining alternative forestry scenarios to explore within the LCSA research.

#### Step 3: Co-select the indicators to be measured

While the selection of life cycle indicators aligns with the “goal and scope” phase of the LCSA research, the data collection aligns with the “inventory analysis” and “impact assessment” phases. The purpose of this phase is to select (and populate with data) indicators from each pillar of sustainability that are meaningful, of interest, and will empower the decision making process of the participants.

In this research, during the fifth interview, the LCSA researcher provided the participants with a list of example environmental, social and economic indicators, and from this list the participants could debate, revise, dismiss, or add indicators. It was considered useful to at least have something from which the participants could begin forming their opinions and preferences on indicators. Once the indicators were selected, the LCSA researcher began the process of data collection.

Step 4: Have the user group(s) or community complete the Cultural Indicator Matrix (utilising the identified aspirations and life cycle processes within the matrix)

The Cultural Indicator Matrix should be populated with the participant aspirations (from Step 1) along the top row of the matrix while every main life cycle process involved in the study at hand (from Step 2) is listed in the far left column. The Cultural Indicator Matrix is then completed by each participant who subjectively measures the impact they perceived each forestry process or product has upon their range of aspirations. The impacts are measured according to an impact scale ranging from -2 to +2 where: -2 signifies that a life cycle process is perceived to have a “degrading” effect on the aspiration(s), -1 signifies a “diminishing” effect, 0 signifies a “maintaining” effect, +1 signifies an “enhancing” effect, and +2 signifies a “flourishing” effect.

In this research, seven Ngāti Porou aspirations (discussed and defined in Step 1) and three forestry life cycle scenarios (discussed and defined in Step 2) were included in matrix resulting in three Cultural Indicator Matrices (one for each forestry scenario). The three participants completed the Cultural Indicator Matrix by providing their personal evaluation (impression, score) on the impact they perceived that process had on each aspiration. In addition, in this research the Cultural Indicator Matrix impact scale used both English and Māori definitions. As the matrix was developed during the participatory LCSA process, this ensured that the scale was meaningful and appropriate to the participants’ culture and language.

The Cultural Indicator Matrix is only applicable for the distinct cultural aspect of the quadruple bottom line LCSA; the data for the environmental, social, and economic indicators are collected by the LCSA researcher.

Step 5: Collate culturally-focused LCSA results for communication and deliberation

This phase is associated with the Life Cycle Impact Assessment phase. It involves calculation of the final indicator results and production of meaningful graphs and tables.

For the Cultural Indicator Matrix, the process entails summing the scores from the participants for each cell in the matrix, and then dividing by the number of participants involved. The results are then summed and averaged in three ways. First, sum the scores per process and divide by the number of aspirations to produce one overall score per process. Second, sum the scores per aspiration and divide by the number of processes to produce one overall score per aspiration. And third, sum the scores within the entire matrix and divide by the total number of cells to produce one overall score inclusive of the whole life cycle-value chain and all cultural aspirations. The Cultural Indicator impact scale (Step 4) is used to further translate the scores.

The resulting figures therefore enable interpretation and assessment of the perceived impacts that 1) an individual process has upon the cultural aspirations, 2) a life cycle-value chain has upon each individual cultural aspiration, and 3) the entire life cycle-value chain has upon the entire range of cultural aspirations.

In this research, the Cultural Indicator Matrix results from each participant were collated and averaged thus producing one set of matrix results for each of the three forestry scenarios. These results were interpreted per process, per aspiration, and as an overall score of the forestry scenario. For example, the radiata pine scenario received an averaged overall score of 0.02 (mauri noho/maintaining), the rimu scenario received an averaged overall score of 0.99 (mauri piki/enhancing), and mānuka received an averaged overall score of 0.91 (mauri piki/enhancing).

Step 6: Present and collaboratively discuss (and refine, if need be) the final LCSA results with the user group(s) or community

Analogous to the Interpretation phase in Life Cycle Assessment, the final phase involves reviewing the LCSA results with the participants. The final Cultural Indicator Matrix

results are placed alongside other LCSA indicators for the different processes in the selected scenarios.

In this research, each participant completed the Cultural Indicator Matrix individually and not as a group. However, each participant indicated the potential usefulness of coming together as a group, reviewing their individual answers, deliberating and discussing how and why they arrived at each score, and then developing one group-based score (for each matrix cell) together. This is a logical and useful next step for this methodology. Further discussion and refinement may also be pursued with the wider community.

### **9.1.2. Research question 2: What are the relative benefits and disadvantages of using LCSA in Māori decision-making situations?**

Addressing the second PhD research question led to several useful insights regarding the benefits and disadvantages of using LCSA in Māori decision-making situations.

One clear benefit of using LCSA as a process (rather than just a service-providing tool) is that the participants began to have more detailed discussions around their potential involvement in additional areas of the life cycle-value chain. Furthermore, they were provided with a significant amount of forestry LCSA results and information. The action of reviewing and considering these processes (processes that are generally operated by non-Māori) allowed for the participants to more readily envision and prepare for their future involvement in these areas.

As a result of utilising LCSA as a process, an opportunity was identified to formally include a Cultural Compliance process as part of the LCSA. It is unlikely that this insight would have been reached if it were not for the participatory engagement focus of this LCSA research. The participants believe that recognition and inclusion of the Cultural Compliance process in forestry operations could provide standardised and transparent evidence of observing culturally-related regulations (e.g. Forest Stewardship Council certification), and meeting the cultural expectations of the stakeholders and Ngāti Porou tribe. The participants also felt that inclusion of the Cultural Compliance process would

enable decision makers (Māori and non-Māori alike) to have more robust discussions regarding cultural aspects in the forestry life cycle and ultimately the process would lend credibility, traceability value, and strength to Māori branding of forestry products.

However, a particular disadvantage of using LCSA in Māori decision-making situations is the fact that a LCSA study is not necessarily straightforward or simple to carry out. The participants believed that they would require someone with expertise in LCSA in order to advocate, explain, and implement future LCSA work.

Overall, the participants felt that using a culturally-focused LCSA approach would enhance their decision-making capabilities. The LCSA tool and process was seen as able to reflect the often complex Ngāti Porou decision-making process and generate unforeseen potential solutions or options. Utilising a culturally-focused LCSA approach may present the opportunity to remedy weaknesses in Ngāti Porou decision making.

## **9.2. Summary of LCSA study results**

The participants decided on three forestry-based options for the land: intensive management of radiata pine (the “status quo” option) with the product of house framing (to enhance the aspiration of infrastructure), continuous cover forestry management of rimu with the product of high-end heartwood flooring (to enhance the aspirations of employment and mana motuhake), and intensive management of mānuka for essential oil production (to enhance the aspirations of connectedness and mātauranga).

For the land-use perspective scenarios, this PhD research identified quadruple bottom line results for the three LCSA forestry scenarios: radiata pine, rimu, and mānuka. Of the three scenarios, the mānuka scenario is the most profitable, the most costly, and generates the most employment hours and GHG emissions per hectare. The radiata pine option, with its high growth rate in the case study region, sequesters the most carbon (cumulatively over the 28-year rotation). However, the rimu scenario rated the highest for the Cultural Indicator Matrix results.

For the product perspective scenarios, only one product was investigated for each scenario due to the time constraints of the LCSA researcher. The main aim was to demonstrate the capacity for a culturally-focused LCSA to be performed on products in future projects.

### **9.3. Recommendations**

A number of recommendations for further research have been made throughout the thesis. These recommendations include:

- Visualise LCSA results through the utilisation of GIS (or other mapping software) to spatially display and overlay the LCSA data on the land in the case study area.
- Develop contextual background and support documents describing how the Cultural Indicator Matrix was developed, who was involved, and what cultural considerations were made. The transparent acknowledgement of this information will increase the confidence in and acceptance of the culturally-focused LCSA (tool and process) by the wider iwi community.
- Replicate the Cultural Indicator Matrix process with another user group or community. This would provide an opportunity to compare use of the technique, learn from other user groups, and ultimately refine and improve upon the current process.
- Repeat the culturally-focused LCSA process for other forestry products that may arise from both exotic and indigenous forests.
- Collect more site-specific datasets for these (and potentially other) forestry life cycle-value chain alternatives; this would increase the accuracy and applicability of the results, both which would significantly facilitate the real-world decision making process for the future of the Waiapu catchment.
- Undertake trials to determine the “cause and effect” of various parameters on the overall growth and quality of rimu and mānuka.
- The participants highlighted the negative connotations of many indicators. The participants, as both decision makers and facilitators in decision making, felt that more positive indicators would be useful especially when communicating life cycle results to their community.

## **9.4. Final Conclusions**

This research has determined that indeed there is a place for culture in LCSA. The co-development of the Cultural Indicator Matrix by the LCSA researcher and the case study participants has made significant progress towards representing culture transparently and distinctively in LCSA. This first use of the Cultural Indicator Matrix was experienced by the participants as an effective mechanism for gathering community impressions of how forestry life cycle processes impact upon their cultural aspirations. They also felt that the participatory aspect was crucially important; the open and consistent communication between themselves and the LCSA practitioner provided them with more control, access to information, and understanding of the LCSA process, and this led to greater acceptance of the final results.

The development and inclusion of a Cultural Compliance process within each scenario's life cycle was a direct result of the participatory LCSA process. Without the active involvement and guidance of the participants, it is unlikely that the Cultural Compliance element would have been identified. The transparent addition of Cultural Compliance throughout the life cycle-value chains offers greater assurance (to both culturally-focused regulatory agencies and Ngāti Porou in general) that protection and observation of cultural processes is being achieved.

For the first time, indigenous culture has been represented alongside economic, social, and environmental impacts in LCSA. This comprehensive presentation of results facilitates the decision-making process by providing the decision maker(s) with information about the “big picture”, thus supporting educated and informed decisions. Furthermore, a culturally-focused LCSA approach helps to ensure that culture is not lost during the decision-making process, but rather is an active component.

Finally, of critical importance, both the culturally-focused LCSA process and associated results will further enable the recognition cultural groups, including their values and aspirations. The explicit acknowledgement of culture in LCSA will engender more awareness and protection for culture, lessen the isolation and marginalisation of culture, and empower cultural groups to develop and pursue brave choices.

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## Appendix A: Interview questions

### Interview 1

1. Previous research
  - a. In thinking about previous research with the Ngāti Porou community, how has it (or how has it not) benefited you?
  - b. What are the aspects that worked or didn't work?
  - c. What would you change about how that research was done or delivered?
2. Ngāti Porou aspirations
  - a. Have Ngāti Porou aspirations and concerns changed from the previous work? If so, how have they changed and why?
  - b. What is your short-term vision (after 10 years, after 30 years) for the Ngāti Porou community?
  - c. What are your immediate priorities?
  - d. What is your long-term vision (after 50 years, after 100 years) for the Ngāti Porou community?
3. Ngāti Porou decision-making process
  - a. What is the decision-making process like for Ngāti Porou? What are the key decision-making stages?
  - b. Who are the key actors/people involved at each stage?
  - c. What information is sought at during each stage?
  - d. Where/how is this information attained?

### Interview 2

4. General forestry questions
  - a. Why are you primarily interested in forestry development for the region?
  - b. What would you like to achieve with your forested land?
  - c. Which of your aspirations might be achieved with your selection of forests, forest management, and forest products?
5. Tree species
  - a. Would you rather have indigenous or exotic trees on your land?
  - b. What are the reasons for your answer?
  - c. What do you perceive are the implications (pros/cons) of having indigenous trees?

- d. What do you perceive are the implications (pros/cons) of having exotic trees?
  - e. What are your thoughts around planting a mixture of indigenous and exotic trees?
  - f. Which of your aspirations might be achieved with your selection of tree species?
6. Understory or secondary species
- a. Are you interested in planting an additional tree/plant species with your forested land? Why or why not?
  - b. What do you perceive are the implications (pros/cons) of planting an additional tree/plant species?
  - c. Which of your aspirations might be achieved with your selection of an additional tree/plant species?

### Interview 3

7. Forest management
- a. What are your impressions of continuous cover forestry?
  - b. Are you be comfortable with harvesting indigenous species? Why or why not?
  - c. What are your impressions of short-rotation forestry?
  - d. Are you comfortable with harvesting trees to make woodchips for energy purposes?
  - e. What are your impressions of intensive forestry?
  - f. Would you prefer not to have intensive forestry at all? Why or why not?
  - g. Are you comfortable with using pesticides and/or herbicides on your land?
8. Products
- a. Are you interested in developing non-timber products with your forested land? Why or why not?
  - b. What type of product is interesting to you (e.g. medicinal, wood-based, food)?
  - c. What are the reasons for your answer?
  - d. Would you prefer a product with a short life span or a long life span?
  - e. What would you like to achieve with your product?
  - f. Which of your aspirations might be achieved with your selection of products?

#### Interview 4

##### 9. Potential forestry scenarios

- a. What aspirations do you think this forestry scenario might fulfil?
- b. What challenges do you think might arise out of this scenario?
- c. What could we change to avoid that challenge?
- d. Would you prefer to harvest Manuka at the end of the honey production cycle and then replant, or let it grow until it begins to decay?
- e. Once it starts to decay, would you prefer to harvest it or let it decay on the land?

##### 10. Potential product scenarios

- a. Of the three potential Manuka products (honey, essential oil, and firewood) which would you like me to pursue?
- b. Are the products chosen for the case studies suitable? Why or why not?
- c. Would you prefer I look at a different product?

#### Interview 5

##### 11. Potential indicators

- a. Which of the indicators that I have listed speak the loudest to you? Why?
- b. What other measures of success would you like to see included in the study?

##### 12. Cultural Indicator Matrix

- a. What would be the most significant cultural measure of success?
- b. How might we be able to measure that throughout the forestry value chain?
- c. Can some of the Ngāti Porou aspirations be grouped together?
- d. Can you define what the aspirations mean to you?
- e. Do you think we can apply a weighting to the aspirations?

#### Interview 6

##### 13. Cultural Compliance process

- a. When in each value chain does this process occur?
- b. What are the figures associated with costs, employment, wages, and machinery used?

#### Interview 7

##### 14. Cultural Compliance process and Cultural Indicator Matrix

- a. Why is Cultural Compliance necessary?
- b. Will it always be necessary when dealing with land use?

- c. What are the benefits of including Cultural Compliance in the value chains? In the short-term? In the long-term?
- d. Do you feel that Cultural Compliance add economic value to the value chain product?
- e. Does Cultural Compliance relate to branding or certification? If so, how?
- f. Are there any issues regarding scale and terminology regarding the Cultural Indicator Matrix?
- g. Do you think the Cultural Indicator Matrix is functional and transferrable?
- h. Do the forestry vale chain processes make sense in the Cultural Indicator Matrix?

#### Interview 8

##### 15. Review and refinement of the Cultural Indicator Matrix

- a. What are your impressions of the Cultural Indicator Matrix?
- b. Is it too long?
- c. Is it meaningful?
- d. Is it confusing?
- e. Is it culturally appropriate?
- f. Can you see this being useful in decision making?
- g. Any aspects you would change?
- h. How long did it take you to complete?
- i. Would you prefer to complete the Matrix alone, in a group, or alone then in a group?

#### Interview 9

##### 16. Review and discussion of the culturally-focused LCSA results

- a. Where do you currently see yourselves in this life cycle-value chain?
- b. Has seeing all of this data made you interested in pursuing other forestry processes? If so, which ones and why?
- c. Do you feel this LCSA technique/process can aid your decision making? Why or why not?
- d. What would you need to carry this work forward yourselves?
- e. Has seeing these results changed or confirmed your thinking on any particular process?
- f. With this data in mind, what do you see are the next steps?

## Appendix B: List of interview codes

- Research
  - Collaboration
  - Outcomes
  - Needs
  - Pitfalls
- Aspirations
  - Environment
  - Fulfilling aspirations
  - Indicators
  - Infrastructure
  - Interconnection
  - Leadership
  - Mana motuhake
  - Multi-dimensional
  - Reconnection
  - Relationships
- Vision and willingness
  - Wellbeing for family
  - Wellbeing for environment
  - Wellbeing for community
  - Challenges
- Decision making
  - Empowerment
  - Future developments
  - Knowledge
  - Needs
  - Pitfalls
  - Process
  - Relationships
  - Value chain
- Forestry
  - Mānuka

- Benefits
- Market
- Products
- Challenges
- Opportunities
- Processing
- Pine
  - Benefits
  - Negatives
- Natives
  - Rimu
  - Markets
- Future forestry needs
  - Co-operatives
- Knowledge
- Preferences
- Products
- Challenges
- Exotics
- Forest management
  - Continuous Cover Forestry
  - Intensive
  - Harvesting
  - Scenarios
    - Challenges
    - Mānuka
    - Natives
    - Aspirational benefits
  - Cultural Compliance
    - Branding and marketing
    - Wahi tapu
    - Cultural monitor
    - Karakia

- Kaitiakitanga
- Benefits to owners
- Cultural safety
- PhD research justification
- Indicators
  - Measures of success
  - Cultural indicator
    - Aspirations
      - Employment
      - Te reo
      - Connectedness
      - Mana motuhake
      - Healthy ecosystems
      - Kaitiakitanga
      - Ngāti Poroutanga
      - Leadership
    - Scoring definitions
    - Weighting
    - Review
    - Benefits
    - Challenges
    - Improvements
- Final Discussion
  - LCSA process
  - LCSA results
  - Recommendations and Future work

## Appendix C: MUHEC application approval letter



MASSEY UNIVERSITY  
TE KUNENGA KI PŪREHUŌA

16 September 2013

Stefania Pizzirani  
Scion  
Te Pap Tipu Innivation Park  
49 Sala Street  
ROTORUA 3046

Dear Stefania

**Re: HEC: Southern B Application – 13/58**  
**A culturally focused life cycle sustainability assessment: Analysis of forestry value chain options with Māori land owners**

Thank you for your letter dated 10 September 2013.

On behalf of the Massey University Human Ethics Committee: Southern B I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

A handwritten signature in black ink, appearing to read 'N. Matthews'.

Dr Nathan Matthews, Chair  
Massey University Human Ethics Committee: Southern B

cc A/Prof Sarah McLaren  
IFNHH  
PN452

Prof Richard Archer, HoI  
IFNHH  
PN452

Dr Margaret Forster  
School of Maori Art, Knowledge & Education  
PN601

Prof Robert Jahnke, HoS  
School of Maori Art, Knowledge & Education  
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Massey University Human Ethics Committee  
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# Appendix D: Cultural Indicator Matrix

## Introduction page:

E ngā mana, e ngā iwi, e ngā hau e whā. Tēnā koutou, tēnā koutou, tēnā tatou katoa.

Several researchers have highlighted how forestry can meet key objectives and aspirations of Māori land owners. However, a methodology is lacking which is able to illustrate economic, social, environmental, and cultural data related to land use.

This research is focussed on exploring alternative forestry practices (e.g. indigenous forestry) and wood-based products to help achieve Māori aspirations. In order to do this effectively a holistic life cycle technique will be utilised to analyse the environmental, economic, social and cultural impacts of these new forestry and wood product options.

This survey represents a specific Māori-developed cultural indicator which will ultimately represent the cultural impacts of the new forestry and wood product options. Survey participants are asked to reflect upon each wood-based process and score each process according to how they believe it impacts (positively or negatively) their cultural aspirations. These cultural impacts will be represented alongside the environmental, economic, and social impacts throughout each forestry life cycle being explored in this research.

This participatory research will ultimately help Māori landowners explore 'what if' scenarios and make future forestry-related decisions. The integration of indigenous cultural values within the life cycle process will be the first of its kind.

For further information or if you have any questions, please do not hesitate to contact Stefania Pizzirani at stefania.pizzirani@scionresearch.com

Massey University Human Ethics Committee  
 This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 13/58. If you have any concerns about the conduct of the research, please contact Dr Nathan Matthews, Chair, Massey University Human Ethics Committee: Southern B, telephone 06 350 5799 x 80877, email humanethicsouthb@massey.ac.nz.

Introduction | Definitions | Pine scenario | Rimu scenario | Mānuka scenario

## Definition page:

Cultural aspiration definitions	
Connectedness	Ahi kaa, hau kairangi (those that live at home, keeping the home fires burning, occupation of ancestral lands) Ro waho (those who live outside of the tribal area). Contribution to the hapu, iwi and whenua. Clos
Employment	Work, occupation. Livelihoods underpinned by the cultural, social and economic aspirations of the people
Healthy Ecosystems	Conserving biodiversity – the variety of life on Earth – is essential in order to sustain healthy ecosystems – dynamic complexes of plants, animals, micro-organisms and their non-living environment, of which hu
Infrastructure	The basic, underlying framework or features of a system or organization. The governance, management and systems required to enable cultural aspirations objectives and outcomes to take effect in way that s
Kaitiakitanga (Mana Tiaki)	Guardianship, custodianship
Leadership	Male or female, leadership is inherited or achieved. Leadership occurs at many levels. Whanau, hapu and iwi. Marae, community, religious, organisational, intergenerational. Pakeke and kaumatua hold statu
Mana Motuhake	AUTONOMY. Authority, mana means spiritual power and authority since authority is a spiritual gift delegated by the Gods, man always remains the agent or channel – never the source of mana[1]
Matauranga	Knowledge and understanding
Ngāti Poroutanga	Culture, language and identity. What it means to be Ngāti Porou to identify with and whakapapa to Ngāti Porou, contributing to Ngāti Porou and being a person or group from the descent line of the eponymou
Te reo me ona tikanga	Te reo Maori the Maori language and associated values, customs and practices
Whakapapa	Family Tree, Genealogy, Orderly Sequence
Whanau/Hapu	Family units made up of three generations. Hapu share an identified geographical area that includes lands, waters, forests, marine and foreshore, air and subterranean and an identified male and female epony
Forest process definitions	
Burning (end of life)	Final disposal of used timber by incineration.
Consumer/ use of essential oil	Consumer use of Manuka essential oil.
Consumer/use of furniture	Consumer use of furniture made from recycled native timber.
Consumer/use of house	Consumer use of a house.
Cultural compliance (throughout chain)	Application and recognition of cultural compliance at various points in the forest value chains. Includes Wahi tapu, a Cultural monitor, Karakia, Maori brand marketing, Kaitiakitanga, and Distribution of benefits
Distillation	The harvested material is chopped through a cutter into short lengths and this mixture of leaves and stems is packed evenly into a sealed distillation vessel. Distillation process is required to extract the oil from
Extraction	Removal of cut wood from the forest.
Extraction (helicopter)	Removal of cut wood from the forest using a helicopter.
Felling (clearfelling)	Clearfelling is the process of cutting down all the stand of same-aged trees at the one time, leaving a bare area. This is the most common harvesting system for plantation grown forests around the world.
Felling (selective felling)	Selective felling often occurs where trees are being cut from natural forest, where there is a mixture of species and ages, and where it may be desirable to remove only individual trees that have attained the rig
Form pruning	Cutting branches from trees to produce high quality timber without knots.
Freight transport (throughout chain)	Transport of products by truck at various points in the forest value chains.
Furniture making facility using recycled timber	Use of recycled native timber to create a furniture product.
Harvesting of Manuka branches	Green leaves and small branches are cut from Manuka bushes.

Introduction | Definitions | Pine scenario | Rimu scenario | Mānuka scenario

Radiata pine scenario:

	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems
<b>Pine processes</b>							
Nursery							
Site prep							
Planting							
Tending							
Thinning (to waste)							
Felling (clear felling)							
Extraction							
Skid site							
Landing construction							
Roading							
Roading - maintenance							
Timber transport (44t logging truck)							
Sawmill							
Housing construction							
Consumer/use of house							
House deconstruction							
Burning (end of life)							
Cultural compliance (throughout chain)							
Freight transport (throughout chain)							
<b>Scoring value</b>	<b>English meaning</b>	<b>Maori meaning</b>					
2	Flourishing	Mauri ora					
1	Enhancing	Mauri piki					
0	Maintaining	Mauri noho					
-1	Diminishing	Mauri heke					
-2	Degrading	Mauri mate					

Rimu scenario:

	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems
<b>Rimu processes</b>							
Nursery							
Site prep							
Planting							
Tending							
Form pruning							
Selective felling							
Extraction (helicopter)							
Skid site							
Landing construction							
Roading							
Roading - maintenance							
Portable sawmill							
Housing construction							
Consumer/use of house							
House deconstruction							
Furniture making facility using recycled timber							
Consumer/use of furniture							
Burning of furniture (end of life)							
Cultural compliance (throughout chain)							
Freight transport (throughout chain)							
<b>Scoring value</b>	<b>English meaning</b>	<b>Maori meaning</b>					
2	Flourishing	Mauri ora					
1	Enhancing	Mauri piki					
0	Maintaining	Mauri noho					
-1	Diminishing	Mauri heke					
-2	Degrading	Mauri mate					

Mānuka scenario:

	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems
<b>Mānuka processes</b>							
Nursery							
Site prep							
Planting							
Tending							
Harvesting of branches							
Distillation							
Packaging							
Retailer							
Consumer use of essential oil							
Landfill (of bottle)							
Cultural compliance (throughout chain)							
Freight transport (throughout chain)							
<b>Scoring value</b>	<b>English meaning</b>	<b>Maori meaning</b>					
2	Flourishing	Mauri ora					
1	Enhancing	Mauri piki					
0	Maintaining	Mauri noho					
-1	Diminishing	Mauri heke					
-2	Degrading	Mauri mate					

## Appendix E: Cultural Indicator Matrix results

Baseline/unmanaged land results (combined answers):

Baseline (unmanaged land) - COMBINED ANSWERS	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems	TOTAL
Unmanaged land	1.33	-1.00	0.67	0.67	1.33	0.00	1.67	0.67

Radiata pine scenario results (combined answers):

Pine processes - COMBINED ANSWERS	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems	TOTAL
Nursery	0.00	0.67	0.33	0.33	0.33	0.67	0.00	0.33
Site prep	-0.33	0.67	-0.33	0.00	0.00	0.33	-0.33	0.00
Planting	-0.33	0.67	-0.33	0.33	0.00	0.33	-0.33	0.05
Tending	-0.33	0.67	0.33	0.00	0.00	0.33	0.00	0.14
Thinning (to waste)	-0.33	0.67	0.33	0.00	0.00	0.00	-0.67	0.00
Felling (clear felling)	-0.67	0.67	-0.33	-0.67	-0.67	0.00	-1.33	-0.43
Extraction	-0.33	0.33	0.00	0.00	0.00	0.00	-1.00	-0.14
Skid site	-0.33	0.33	0.00	0.00	0.00	0.33	-1.00	-0.10
Landing construction	-0.33	0.33	0.00	0.00	0.00	0.67	-1.00	-0.05
Roading	-0.33	0.33	0.00	0.00	0.00	0.67	-1.00	-0.05
Roading - maintenance	-0.33	0.33	0.00	0.00	0.00	0.67	-0.67	0.00
Timber transport (44t logging truck)	-0.33	0.67	0.00	0.00	-0.33	0.00	-1.00	-0.14
Sawmill	-0.33	1.33	0.00	-0.33	0.33	0.67	-0.67	0.14
Housing construction	0.00	1.00	0.33	0.00	0.33	1.33	0.00	0.43
Consumer/use of house	0.33	0.67	0.33	0.00	0.33	1.00	0.00	0.38
House deconstruction	0.00	0.33	0.00	0.00	0.00	0.00	-0.33	0.00
End of life	-0.33	0.33	0.00	-0.33	0.00	0.00	-0.67	-0.14
Cultural compliance (throughout chain)	-0.33	0.33	0.00	0.00	0.00	0.00	-0.33	-0.05
Freight transport (throughout chain)	-0.67	0.67	0.00	0.00	0.00	0.00	-0.33	-0.05
<b>TOTAL</b>	<b>-0.28</b>	<b>0.58</b>	<b>0.04</b>	<b>-0.04</b>	<b>0.02</b>	<b>0.37</b>	<b>-0.56</b>	<b>0.02</b>

Rimu scenario results (combined answers):

Rimu processes - COMBINED ANSWERS	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems	TOTAL
Nursery	2.00	2.00	1.67	2.00	2.00	2.00	2.00	1.95
Site prep	2.00	2.00	1.67	1.67	1.67	2.00	2.00	1.86
Planting	2.00	2.00	1.67	2.00	2.00	2.00	2.00	1.95
Tending	2.00	2.00	1.67	2.00	2.00	2.00	2.00	1.95
Form pruning	2.00	2.00	1.67	2.00	2.00	2.00	2.00	1.95
Selective felling	2.00	2.00	2.00	1.00	2.00	1.67	1.67	1.90
Extraction (helicopter)	0.33	1.00	1.00	2.00	0.67	1.33	1.00	0.90
Skid site	-0.33	1.00	0.33	1.00	0.33	1.00	-0.33	0.43
Landing construction	-0.33	1.00	0.33	1.00	0.33	1.00	-0.33	0.43
Timber transport (44t logging truck)	-0.33	0.67	0.00	0.00	-0.33	0.00	-1.00	-0.14
Roading	-0.67	0.67	0.00	0.67	0.33	1.00	-0.33	0.24
Roading - maintenance	-0.67	0.67	0.00	0.67	0.33	1.00	0.00	0.29
Portable sawmill	0.33	1.33	1.00	1.00	1.00	1.67	0.33	0.95
Housing construction	1.00	1.67	1.33	1.67	1.33	1.67	1.00	1.38
Consumer/use of house	1.33	0.67	1.67	1.67	1.33	1.67	1.00	1.33
House deconstruction	-0.33	-0.33	-0.33	0.00	0.33	0.67	0.00	0.00
Furniture making facility using recycled tin	1.67	2.00	1.33	1.33	1.33	1.33	1.33	1.48
Consumer/use of furniture	1.00	1.00	1.00	0.67	0.67	1.00	0.67	0.86
End of life	-0.67	-0.67	-0.67	-0.67	-0.67	-0.33	-1.00	-0.67
Cultural compliance (throughout chain)	1.67	1.67	1.33	1.67	1.67	1.33	1.67	1.57
Freight transport (throughout chain)	0.33	0.67	0.00	0.00	0.33	0.33	-0.33	0.19
<b>TOTAL</b>	<b>0.78</b>	<b>1.19</b>	<b>0.89</b>	<b>1.11</b>	<b>0.98</b>	<b>1.25</b>	<b>0.73</b>	<b>0.99</b>

## Mānuka scenario results (combined answers):

Mānuka processes- COMBINED ANSWERS	1. Ngati Poroutanga (including Whakapapa, Te Reo, tikanga)	2. Employment	3. Whanau & Connectedness	4. Mana Motuhake	5. Matauranga	6. Infrastructure	7. Kaitiakitanga & Healthy ecosystems	TOTAL
Nursery	2.00	2.00	1.67	1.67	1.67	1.67	2.00	1.81
Site prep	1.33	1.33	1.67	1.33	1.33	1.33	1.67	1.43
Planting	1.67	1.67	1.33	1.33	1.33	1.33	2.00	1.52
Tending	1.33	1.67	1.33	1.33	1.33	1.33	1.67	1.43
Harvesting of branches	1.00	1.67	1.33	1.67	1.33	1.33	1.67	1.43
Distillation	0.33	0.67	0.33	1.00	1.00	1.00	0.00	0.62
Packaging	1.00	1.00	0.67	1.00	1.00	1.00	0.67	0.90
Retailer	0.67	1.00	0.67	1.00	0.67	1.00	0.00	0.71
Consumer use of essential oil	1.33	1.00	0.67	1.00	1.00	1.00	0.33	0.90
Landfill (of bottle)	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33	-1.33
Cultural compliance (throughout chain)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Freight transport (throughout chain)	-0.67	-0.33	-0.67	-0.67	-0.33	-0.33	-0.67	-0.52
<b>TOTAL</b>	<b>0.89</b>	<b>1.03</b>	<b>0.81</b>	<b>0.94</b>	<b>0.92</b>	<b>0.94</b>	<b>0.83</b>	<b>0.91</b>

## **Appendix F: Life cycle inventory data (economic, social, and environmental)**

This appendix details the data assumptions, estimations, and sources pertaining to the three forestry scenarios (radiata pine, rimu, and mānuka). The appendix presents: 1) the data specific to each forestry scenario, 2) the data assumptions and exclusions, 3) the use of an opportunity cost within the LCC dataset, and 4) the data regarding the Cultural Compliance process (see Section 5.4.2 for more information on this process).

There are economic, social, and environmental data presented for each forestry scenario; the Cultural Indicator Matrix data are presented in Appendix F.

### **Radiata pine scenario**

- **Nursery**
  - Nursery details:
    - The nursery process is assumed to be a small- to medium-scale enterprise producing roughly 480,000 radiata pine seedlings per year (K. Te Kani, personal communication, October 8, 2014). The amount of pine seedlings required for one hectare of land is 833 seedlings (P. Hall, personal communication, August 18, 2014). The nursery data includes both capital expenditure and operational costs. The life of the nursery is assumed to be 50 years and so all figures are divided by and associated to the total number of seedlings produced over 50 years (i.e. 50 years x 480,000 seedlings per year = 24,000,000 seedlings).
  - Costs and profit, and employment:
    - Total capital costs are estimated to be \$492,195 (or \$9,844 per year), and total running costs are estimated to be \$326,451 per year. Total cost per seedling (inclusive of materials and labour) is \$0.70 (K. Te Kani, personal communication, October 8, 2014).
    - Employment and wages are inclusive of a full-time nursery manager (\$60,000/year salary), full-time nursery technician (\$40,000/year salary), one additional full-time staff (for manual tasks; \$14.25/hour wage), and four part-time seasonal casual staff (\$14/hour wage; 180

days each per year) (K. Te Kani, personal communication, October 8, 2014).

- GHG emissions and carbon sequestration:
  - Machinery (predominantly tractors) use approximately 1,440 litres of diesel per year (2.5 litres per hectare), whilst electricity use is approximately 36,000kWh per year (63kWh per hectare) (K. Te Kani, personal communication, October 8, 2014).
  - It is estimated that 833 radiata pine seedlings sequester 11 kgCO<sub>2</sub>eq in their first year (Beets, Kimberley, Paul, & Garrett, 2011); for the purposes of this research, the full 11 kgCO<sub>2</sub>eq was applied to the Nursery process.
- **Site preparation**
  - Site preparation details:
    - Site preparation involves spraying the land via helicopter with an herbicide to desiccate the existing grasses and shrubs.
    - Fertiliser, which can be applied on the site before planting, was assumed to not be required.
    - The mechanical soil preparation is assumed to be required on only 8% of a hectare (P. Hall, personal communication, 15 March, 2014).
    - The helicopter pilot can spray 52 hectares of flat land per hour (Anonymous industry expert, personal communication, 10 March, 2014).
  - Costs and profit, and employment:
    - Employment and wages are inclusive of a helicopter pilot (\$175/hour wage), a support technician to mix the herbicide chemicals (\$35/hour wage), and an excavator operator (\$18/hour wage) (Anonymous industry expert, personal communication, 10 March, 2014).
    - The site preparation cost per hectare associated with the Cultural Compliance process (Section 5.4.2) is \$1.65.
    - The site preparation employment per hectare associated with the Cultural Compliance process is 0.02 hours.
  - GHG emissions and carbon sequestration:

- The Iroquois helicopter uses 6.33 litres of Jet A1 fuel per hectare, the support truck for the aerial herbicide spray uses 1.19 litres of diesel per hectare (Anonymous industry expert, personal communication, 10 March, 2014), and an excavator for the soil preparation uses 3.84 litres of diesel per hectare (for 8% coverage per hectare) (P. Hall, personal communication, 15 March, 2014).
- The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 17,400 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (ISO, 2013).

- ***Planting***

- Planting details:
  - The planting process includes only the labour cost of planting 833 stems per hectare. The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not also included during the planting process.
- Costs and profit, and employment:
  - It takes an employee 8 hours (\$20/hour wage) to plant one hectare with 833 stems of radiata pine (P. Hall, personal communication, 15 March, 2014).
  - The planting cost per hectare associated with the Cultural Compliance process is \$1.47.
  - The planting employment per hectare associated with the Cultural Compliance process is 0.02 hours.
- GHG emissions and carbon sequestration:
  - There are no GHG emissions nor carbon sequestration associated with this process.

- ***Tending***

- Tending details:
  - The tending process includes weed control (aka – “releasing”) using herbicides via helicopter, disease control of both Red Needle Cast (*Phytophthora pluvialis* (Reeser et al., 2013)) and Dothistroma needle blight (*Dothistroma septosporum* (Dorog.) M. Morelet) via helicopter spraying, inventory assessment, and the annual activities of forest management, rates and fire insurance, fence and track maintenance, and animal (pest) control.
  - Forest management includes such aspects as forest planning, protection (security, recreation, hunting, tourism, fire), research, inventory, roading, and engineering.
  - Included in the tending activities are the processes of landing and roading (in the forest) construction. These activities occur towards the end of the forest growth cycle at year 26 in preparation for harvesting activities. Generally, landing and roading construction are not considered to be “tending” activities but they have been grouped under this heading to simplify the LCSA analysis.
  - Roading external to the forest was excluded as it was assumed that no additional infrastructure was required.
- Costs and profit, and employment:
  - Wages for aerial spraying are inclusive of a helicopter pilot (\$175/hour wage) and a support technician to mix the herbicide chemicals (\$35/hour wage) (L. Bulman, personal communication, 3 March, 2014).
  - An overall salary for a forest manager to manage a forest is \$80,000 per year (based on a forest estate size of 5,000 hectare) (P. Hall, personal communication, 15 March, 2014).
  - Forest management is estimated to account for two hours of employment per hectare per year (P. Hall, personal communication, 15 March, 2014).
  - Employment related to rates (i.e. land value tax) and fire insurance are excluded due to its minimal impact on the life cycle indicators.
  - Both a) fence and track maintenance and b) animal (pest) control are assumed to employ workers with an hourly wage of \$18, and

require approximately nine minutes per hectare per year and three minutes per hectare per year respectively (P. Hall, personal communication, 15 March, 2014).

- The inventory process involves sampling forest sites within a stand to determine its quality and projected value. This process is estimated to take one worker (\$20/hour wage) 30 minutes per hectare to survey (P. Hall, personal communication, 15 March, 2014).
  - The in-forest workers (\$30/hour wage) install 40 metres of roading per hectare in 6.33 hours (S. Hill, personal communication, March 12, 2014).
  - The in-forest landing site workers (\$30/hour wage) require nearly 66 hours to complete one landing site, or 7.67 hours per hectare (S. Hill, personal communication, March 12, 2014).
  - The tending cost per hectare associated with the Cultural Compliance process is \$54.13, and represents the annual cost of protecting the environment through Kaitiakitanga.
  - The tending employment per hectare associated with the Cultural Compliance process is 0.28 hours, and represents the annual employment needed for protecting the environment through Kaitiakitanga.
- GHG emissions and carbon sequestration:
- Weed control (“releasing”) occurs three times during years one, two, and three. The helicopter pilot can spray 52 hectares of flat land per hour for weed control purposes. The Iroquois helicopter used for this process uses 6.33 litres of Jet A1 fuel per hectare and the support truck for the aerial herbicide spray uses 1.19 litres of diesel per hectare (Anonymous industry expert, personal communication, 10 March, 2014).
  - Dothistroma needle blight spray occurs three times during years two, seven, and twelve. It is assumed that only a small proportion of each forest hectare requires spraying; therefore, the helicopter pilot can tend to 1,500 hectares per day or 187.5 hectares per hour (L. Bulman, personal communication, 3 March, 2014).

- Total above-ground carbon sequestered by the radiata pine forest (cumulative over 28 years) is estimated to be 918,499 kgCO<sub>2</sub>eq (Beets et al., 2011). This value includes the effects of the thinning process (described below).
  - Red needle cast is known to be spread more readily in forest stands than Dothistroma and so requires more spray. It is assumed that Red needle cast figures will be approximately 50% higher than with Dothistroma. Therefore, the helicopter pilot can tend to 1,000 hectares per day or 125 hectares per hour (L. Bulman, personal communication, 3 March, 2014).
  - Both Dothistroma and Red needle cast processes require a pre-spray assessment (via helicopter) which identifies where the affected stands are and what proportion are affected (L. Bulman, personal communication, 3 March, 2014). This separate monitoring process has been excluded due to its minimal impact on the life cycle indicators.
  - The in-forest roading process assumes 40 metres of roading per hectare (S. Hill, personal communication, March 12, 2014). The process uses a gravel cartage truck and a “spread and roll” machine; combined diesel usage for these machines is approximately 164 litres of diesel per hectare.
  - The landing construction process assumes that approximately 8.6 hectares of forest will be served by each landing site. The process uses a bulldozer and excavator; combined diesel usage for these machines is approximately 230 litres of diesel per hectare.
  - An opportunity cost of \$1,040 per hectare per year was applied based on current average flat land valuations in the case study region of Gisborne. Further discussion on opportunity cost is made in towards the end of this appendix.
- **Thinning (to waste)**
    - Thinning (to waste) details:
      - The thinning process is assumed to reduce the total number of planted stems per hectare from 833 to 450 at year 10.

- The thinnings are left on-site to decompose.
  - Costs and profit, and employment:
    - It is estimated that a worker (\$20/hour wage) requires 7.6 hours per hectare to thin (to waste) (P. Hall, personal communication, 15 March, 2014).
  - GHG emissions and carbon sequestration:
    - A chainsaw is used for this process and uses 7.44 litres of petrol per hectare (P. Hall, personal communication, 15 March, 2014).
- **Clear felling**
  - Clear felling details:
    - The clear felling process involves the cutting of the entire forest stand.
    - Felling occurs at year 28 and the total standing volume at the time of felling is estimated at 760.5 m<sup>3</sup> per hectare (MacLaren & Knowles, 2005), where 1 m<sup>3</sup> is assumed to be harvested softwood under bark.
  - Costs and profit, and employment:
    - One “feller-delimber-buncher” (FDB) operator (\$22/hour wage) is required for this process (P. Hall, personal communication, 15 March, 2014).
    - It is estimated that one m<sup>3</sup> takes approximately 43 seconds to fell; therefore, one hectare takes 9.13 hours to clear fell (P. Hall, personal communication, 15 March, 2014).
    - The clear felling cost per hectare associated with the Cultural Compliance process is \$9.28.
    - The clear felling employment per hectare associated with the Cultural Compliance process is 0.16 hours,
  - GHG emissions and carbon sequestration:
    - The FDB machine uses 0.4 litres of diesel to fell one m<sup>3</sup>; therefore, one hectare uses approximately 304 litres of diesel (P. Hall, personal communication, 15 March, 2014).
- **Extraction**

- Extraction details:
  - The extraction process involves removing the felled stems from the site and depositing them at the landing site for further handling.
  - It is estimated that 11% of the original total standing volume (760.5 m<sup>3</sup> per hectare) is left on-site during extraction and landing site operations (P. Hall, personal communication, 15 March, 2014). This amounts to a volume loss of approximately 84 m<sup>3</sup> per hectare.
  - Volume left on-site may include material from the stumps, tree tops, and branches.
- Costs and profit, and employment:
  - Two extraction operators (\$22/hour wage) are required for this process (P. Hall, personal communication, 15 March, 2014).
  - It is estimated that one m<sup>3</sup> takes 1.44 minutes to extract; therefore, one hectare of felled material takes 16.24 hours to extract (P. Hall, personal communication, 15 March, 2014).
- GHG emissions and carbon sequestration:
  - Two grapple skidders are required for the extraction process, together using 0.85 litres of diesel per m<sup>3</sup>; therefore, one hectare of felled material uses approximately 575 litres of diesel to extract (P. Hall, personal communication, 15 March, 2014).
- **Landing site**
  - Landing site details:
    - Landing site operations primarily include log making (i.e. cutting the stems into pre-determined log lengths) and loading (i.e. placing the logs onto the logging trucks for timber transport).
    - It is estimated that 4% of the original volume deposited at the landing site (676.84 m<sup>3</sup>) is left on-site, thus amounting to 27.07 m<sup>3</sup> left at the landing site (P. Hall, personal communication, 15 March, 2014).
    - This loss of volume is attributed to the log making process and any stem breakage that may occur during handling.
  - Costs and profit, and employment:

- Six log making operators (\$18.50/hour wage) and three loading operators (\$18.50/hour wage) are required for this process (P. Hall, personal communication, 15 March, 2014).
- It is estimated that for one m<sup>3</sup> log making takes 4.32 minutes to process and loading takes 2.16 minutes; therefore, one hectare of felled material takes 73.1 hours to process through the landing site (P. Hall, personal communication, 15 March, 2014).
- GHG emissions and carbon sequestration:
  - A chainsaw is used to cut the stems into logs, and uses 0.57 litres of petrol per m<sup>3</sup> (386 litres of petrol per hectare).
  - Two excavator-loaders are used to load the logs onto the logging truck, and use 0.56 litres of diesel per m<sup>3</sup> (379 litres of diesel per hectare) (P. Hall, personal communication, 15 March, 2014).
- **Timber transport**
  - Timber transport details:
    - The logs are transported to a sawmill.
    - The volume transported per hectare is 650 m<sup>3</sup> (i.e. the remaining volume after harvesting and landing site operations).
    - Although a given radiata pine stem consists of both sawlog and pulp wood, it is assumed that all of the wood is transferred to the same sawmill.
    - Subsequent processing of the logs in the sawmill yard is excluded from the assessment due to its anticipated insignificant contribution to the indicator results.
    - One m<sup>3</sup> of radiata pine is approximately equivalent to one tonne of radiata pine (New Zealand Institute of Forestry, 2005).
    - The transport distance (one-way) is assumed to be 86 km (NZ FOA Transport Authority, 2007).
    - The logging truck is assumed to be a 6x4 truck with a 4-axle trailer. The unloaded weight is 14.5 tonnes and a log payload weight of 29.5 tonnes, thus the total logging truck weight is 44 tonnes (P. Hall, personal communication, 15 March, 2014).
  - Costs and profit, and employment:

- The timber truck driver (\$30/hour wage) requires 7.2 minutes per  $\text{m}^3$  (3.54 hours per loaded truck) to travel from the landing site to the sawmill gate (P. Hall, personal communication, 15 March, 2014).
  - GHG emissions and carbon sequestration:
    - The timber truck uses 4.78 litres of diesel per  $\text{m}^3$  (141 litres of diesel per loaded truck) (P. Hall, personal communication, 15 March, 2014).
- **Sawmill**
  - Sawmill details:
    - The sawmill process is modelled to account for the production of framing product for residential housing purposes. Specifically, the framing product is defined as “SG8” where “SG” denotes “stress grade” and is used in areas of high weight load such as roof trusses and load bearing walls. SG8 is the most valuable type of framing product.
    - The sawmill figures are based on the output of a large sawmill with a volume intake of 350,000  $\text{m}^3$ .
    - Of the sawlog material, approximately 18% will be suitable for framing (Jack et al., 2013).
    - Of the original 650  $\text{m}^3$  per hectare delivered to the sawmill, only 92  $\text{m}^3$  per hectare will be processed into framing product.
    - It is assumed there is no chemical treatment of the framing product (D. Gaunt, personal communication, 20 February, 2015).
  - Costs and profit, and employment:
    - \$94/ $\text{m}^3$  is paid for the delivered logs at the sawmill gate. This value was derived first by using the “radiata pine calculator” (Kimberley, 2005) to determine the proportion of merchantable timber volume: 10.2% Structural log 1 (S1; 40cm small end diameter (SED)), 26.1% Structural log 2 (S2; 30cm SED), 28% Structural log 3 (S3; 20-30cm SED), 2.3% Large branch logs 1-3 (L1, L2, L3; 35cm SED), and Pulp log (10cm SED). Second, the  $\text{m}^3$  values for each log grade were attained from AgriHQ (2015) based on domestic

median prices paid per m<sup>3</sup> delivered to the sawmill: \$112 per m<sup>3</sup> S1 and S2 log, \$98 per m<sup>3</sup> S3 log, \$102 per m<sup>3</sup> L1, L2, and L3 log, and \$52 per m<sup>3</sup> Pulp log. Third, the weighted average was calculated and applied to the 650 m<sup>3</sup> of wood delivered to the sawmill.

- Sawmill employment is inclusive of production labour (\$33/hour wage), charge hand labour (\$38/hour wage; e.g. foreman), specialist labour (\$47/hour wage; e.g. tradesmen, electrician, blade sharpeners), office labour (\$25/hour wage), and management labour (\$67/hour wage). The weighted average wage across the sawmill is \$35/hour (P. Hall, personal communication, 15 March, 2014).
- The framing product requires 1.06 hours/m<sup>3</sup> to produce (P. Hall, personal communication, 15 March, 2014).
- The sawmill cost per hectare associated with the Cultural Compliance process is \$4.96.
- The sawmill employment per hectare associated with the Cultural Compliance process is 0.06 hours,
- GHG emissions and carbon sequestration:
  - The sawmill runs on electricity, and uses 169.5kWh to produce 1 m<sup>3</sup> of framing product (i.e. kiln dried planed softwood timber) (Jack et al., 2013).
  - The kiln drying process uses 2.16GJ per m<sup>3</sup> (Jack et al., 2013), however, wood waste resulting from sawmilling activities is burned in biomass boiler; thus, the kiln drying process may be considered to be a process using renewable energy, and has zero carbon emissions.

- **House construction**

- House construction details:
  - The house construction process is based on a large home production business (e.g. Stonewood) that have a significant intake of wood, and therefore could buy direct from sawmill. This

assumption therefore circumvents the process of retail operation to sell the sawn timber.

- Waste generation is assumed to be 10% during the construction process.
- As this is a theoretical “what if” LCSA scenario, it was assumed that minimal transport was needed to travel from the sawmill to the house construction site, and thus was excluded from the assessment due to its anticipated insignificant contribution to the indicator results.
- A generic, “exemplar” house (BRANZ, 2010; Love & Szalay, 2007; Willson, 2002) was chosen to represent the ‘house construction’ process, and contains 195 m<sup>2</sup> of floor area. Given the timber framing component of the house is estimated to weigh 10,367.8 kg (or 4.69% of the total house weight) (McDevitt & Allison, 2012) and the density of oven dried wood with a 16% moisture content is 450 kg/m<sup>3</sup> (Sandilands & Nebel, 2010b), there is approximately 23 m<sup>3</sup> of framing product in the exemplar house.
- Maintenance of the house was excluded as framing rarely, if ever, requires maintenance.
- The life of the house was assumed to be 60 years (McDevitt & Allison, 2012).
- Costs and profit, and employment:
  - The price paid for sawn timber framing is \$480/m<sup>3</sup> (P. Hall, personal communication, February 25, 2015).
  - Employment includes two weeks to construct the house framing, and an average wage cost of approximately \$60/m<sup>3</sup> (BRANZ, 2012).
- GHG emissions and carbon sequestration:
  - Assumed diesel usage of 3.18 litres per m<sup>3</sup> to manoeuvre timber around on-site (P. Hall, personal communication, February 25, 2015).
- **House deconstruction**
  - House deconstruction details:

- Costs and figures for house deconstruction are based on an industry quotation (J. Davy, personal communication, January 12, 2015).
  - The house deconstruction process occurs after 60 years of use of the house.
- Costs and profit, and employment:
  - Average house deconstruction cost of \$16,000.
  - With the framing component of the house accounting for 4.69% of the total house weight then it may be estimated that framing deconstruction costs \$750, or \$32.60/m<sup>3</sup> (based on a total of 23 m<sup>3</sup> of framing).
  - Employment involves approximately 30 minutes per m<sup>3</sup> at \$30/hour wage (J. Davy, personal communication, January 12, 2015).
- GHG emissions and carbon sequestration:
  - Diesel usage to de-construct framing is not significant but has been included at 1 litre of diesel needed to de-construct 1 m<sup>3</sup> of framing (J. Davy, personal communication, January 12, 2015).
- **Landfill (end-of-life)**
  - Landfill details:
    - The end-of-life process for the radiata pine house framing is comprised of wood waste from both the construction and deconstruction processes – a total of 92 m<sup>3</sup>.
    - With the density of framing waste after 60 years of consumer use being 420kg per m<sup>3</sup> (New Zealand Institute of Forestry, 2005), then 1 m<sup>3</sup> is equivalent to 0.42 tonne of waste.
  - Costs and profit, and employment:
    - Current landfill costs are \$251 per tonne of commercial waste (Gisborne District Council, 2015).
    - Therefore, the cost for one m<sup>3</sup> of radiata pine wood waste is \$105.42.
    - It was assumed that employment costs comprised 10% of the total costs (i.e. \$10.54/m<sup>3</sup>) and required 0.43 of an hour to process 1 m<sup>3</sup>

of radiata pine wood waste (Anonymous industry expert, personal communication, 18 November, 2015).

- An hourly wage of \$22 which is in-line with hourly wages of industry workers elsewhere in the radiata pine value chain.
  - The landfill cost per hectare associated with the Cultural Compliance process is \$4.96.
  - The landfill employment per hectare associated with the Cultural Compliance process is 0.06 hours,
- GHG emissions and carbon sequestration:
- As per the PAS 2050 guidelines regarding the landfill process (Annex B.1.2), calculations were made to determine the weighted average impact of “delayed release” landfill emissions (BSI, 2008). The following steps and assumptions were made:
    - One kg of dry wood is equivalent to 1.83 kgCO<sub>2</sub>eq (Sandilands & Nebel, 2010a), thus 420 kg (i.e. 1 m<sup>3</sup>) of wood is equivalent to 769 kgCO<sub>2</sub>eq entering the landfill after 60 years of product use.
    - To complete the assessment of a 100-year timeframe, 40 years of a landfill process have been accounted for.
    - A decay rate of wood in a landfill environment after 40 years is estimated to be 15% (Ximenes, Gardner, & Cowie, 2008).
    - With the release of carbon through decaying, it is assumed that 50% is released as CO<sub>2</sub> and 50% is released as methane (CH<sub>4</sub>), 42% of the CH<sub>4</sub> is “captured and flared” to create CO<sub>2</sub>, and 10% of the remaining CH<sub>4</sub> is oxidised into CO<sub>2</sub> (Sandilands & Nebel, 2010a, p. 30).
    - Thus, the total amount released over 40 years in the landfill is 359 kgCO<sub>2</sub>eq/m<sup>3</sup>, and the total amount stored in the landfill is 411 kgCO<sub>2</sub>eq/m<sup>3</sup>.
    - The total amount of kgCO<sub>2</sub>eq/m<sup>3</sup> released each year is assumed to be released evenly, therefore of the carbon

released each year is 2.5%, or approximately 9 kgCO<sub>2</sub>eq/m<sup>3</sup> each year.

- Using the equation for delayed release of landfill emissions in Annex B.1.2 of the PAS2050 specifications (BSI, 2008), the total weighted factor for average time the landfill emissions are in the atmosphere is 0.21.
- Multiplying the weighted emissions factor by the total kgCO<sub>2</sub>eq/m<sup>3</sup> released equals 73.6 kgCO<sub>2</sub>eq/m<sup>3</sup>.
- Machinery in a landfill include compactors, tractors, loaders, hauling and loader units, articulated trucks, and excavators (Bliss, 2014), and utilise approximately 6.28 litres of diesel per m<sup>3</sup> of radiata pine wood waste (Anonymous industry expert, personal communication, 18 November, 2015).

## **Rimu scenario**

- *Nursery*
  - Nursery details:
    - Rimu seedlings are produced in a nursery and take 12 months to grow from a seed to seedlings ready for planting.
    - Nurseries primarily use fungicides and pesticides, electricity for heating the greenhouse, and diesel for operating the tractors on-site.
    - The amount of rimu seedlings required for one hectare of land is 1,100 seedlings (G. Steward, personal communication, November 19, 2014).
    - The nursery process is assumed to be a small- to medium-scale enterprise producing roughly 240,000 rimu seedlings per year (K. Te Kani, personal communication, October 8, 2014).
    - The nursery data includes both capital expenditure and operational costs.
    - The life of the nursery is assumed to be 50 years and so all figures are divided by and associated to the total number of seedlings produced over 50 years (i.e. 50 years x 240,000 seedlings per year = 12,000,000 seedlings).
  - Costs and profit, and employment:

- Total capital costs are estimated to be \$492,195 (or \$9,844 per year), and total running costs are estimated to be \$326,451 per year (K. Te Kani, personal communication, October 8, 2014).
- Total cost per seedling (inclusive of materials and labour) is \$1.40 (K. Te Kani, personal communication, October 8, 2014).
- Employment and wages are inclusive of a full-time nursery manager (\$60,000/year salary), full-time nursery technician (\$40,000/year salary), one additional full-time staff (for manual tasks; \$14.25/hour wage), and four part-time seasonal casual staff (\$14/hour wage; 180 days each per year) (K. Te Kani, personal communication, October 8, 2014).
- GHG emissions and carbon sequestration:
  - Machinery (predominantly tractors) use approximately 1,440 litres of diesel per year (6.6 litres per hectare), whilst electricity uses approximately 36,000kWh per year (165kWh per hectare) (K. Te Kani, personal communication, October 8, 2014).
  - It is estimated that 1,100 radiata pine seedlings sequester 83 kgCO<sub>2</sub>eq in their first year (G. Steward, personal communication, November 19, 2014); for the purposes of this research, the full 83 kgCO<sub>2</sub>eq was applied to the Nursery process.
- **Site preparation**
  - Site preparation details:
    - In the rimu scenario, site preparation process was assumed to utilise minimal intensive techniques. Thus, rimu site preparation involved initially hand spraying the land with an herbicide to desiccate the existing grasses and shrubs.
    - Mechanical preparation of the soil was avoided in favour of the less mechanically intensive (albeit more labour intensive) process of “screefing” (i.e. “removal of the surface vegetation with a spade or grubber to expose the soil” (Douglas et al., 2007, p. 146).
    - In this scenario, it was assumed that fertiliser was not required.
  - Costs and profit, and employment:

- Herbicides are estimated to cost \$20 per hectare (G. Steward, personal communication, November 19, 2014).
- Hand spraying of herbicides requiring 3.5 hours per hectare (\$18/hour wage) (G. Steward, personal communication, November 19, 2014).
- Screening and mulching (of removed surface vegetation) requires 7.7 hours per hectare (\$18/hour wage) (G. Steward, personal communication, November 19, 2014).
- The site preparation cost per hectare associated with the Cultural Compliance process is \$1.65.
- The site preparation employment per hectare associated with the Cultural Compliance process is 0.02 hours.
- GHG emissions and carbon sequestration:
  - Machinery use is limited during the site preparation of this scenario and so has been excluded from analysis due to its minimal impact on the life cycle indicators.
  - The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 63,800 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (ISO, 2013).
- **Planting**
  - Planting details:
    - The planting process includes only the labour cost of planting 1,100 stems per hectare.
    - The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not also included during the planting process.
  - Costs and profit, and employment:

- It takes an employee approximately one minutes to plant one rimu seedling (\$20/hour wage), or 17.97 hours to plant 1,100 rimu seedlings per hectare.
- The planting cost per hectare associated with the Cultural Compliance process is \$1.47.
- The planting employment per hectare associated with the Cultural Compliance process is 0.02 hours,
- GHG emissions and carbon sequestration:
  - There are no GHG emissions nor carbon sequestration associated with this process.
- ***Tending***
  - Tending details:
    - The tending process involves the management, protection, and maintenance of the forest throughout its growth.
    - rimu tending was assumed to include weed control (via hand weeding), tree inventory assessment (i.e. determining the value of the standing forest), and the annual activities of forest management, rates (land tax) and fire insurance, fence and track maintenance, and animal (pest) control.
    - The tending activities included the processes of construction of in-forest roading and landing sites (i.e. cleared areas where felled trees are processed and prepared for transport). These activities occur before the first selective harvesting process at year 78 in preparation for harvesting activities.
    - Roothing external to the forest was excluded as it was assumed that no additional infrastructure was required.
    - Hand weeding occurs twice a year in years 1, 2, and 3 after planting, and incurs only labour-related costs.
    - Replacement of dead seedlings (“blanking”) occurs once in year 1 after planting. Mortality is assumed to be 5% of the initial 1,100 seedlings planted per hectare, or 55 seedlings. It is assumed that no further mortality occurs (G. Steward, personal communication, November 19, 2014).

- There are no diseases currently affecting rimu; therefore, no disease management costs have been included in this process.
- Continuous cover rimu forestry is assumed to require less in-forest roading than clearfelled radiata pine. In-forest roading costs and figures are based on the radiata pine scenario but it is estimated that rimu forestry will only require 5 metres of in-forest roading per hectare i.e. 1/8<sup>th</sup> of the roading required in radiata pine plantations (S. Hill, personal communication, March 12, 2014).
- The landing construction process costs and figures are based on those of the radiata pine scenario but have been proportionally decreased in alignment with a lesser amount of rimu volume extracted per hectare than radiata pine. In other words, a landing site for continuous cover forestry rimu (which only fells 10% of the trees per hectare) will require a smaller landing site. Approximately 8.6 hectares of forest will be served by each landing site.
- Quarrying for the gravel (used for in-forest roading and landing construction) has been excluded from this assessment as it is outside the system boundaries.
- Costs and profit, and employment:
  - Hand weeding time per seedling is estimated to require 1.4 minutes in year 1, 1 minute in year 2, and 0.5 minutes in year 3; as the seedling matures it is able to out-compete weeds and grasses (G. Steward, personal communication, November 19, 2014).
  - Hand weeding labour (\$18/hour wage) is inclusive of mortality rates and estimated weeding times varying by year of seedling growth.
  - Weeding labour in year 1 is 48.77 hours per hectare, in year 2 is 36.67 hours per hectare, and in year 3 is 18.33 hours per hectare (G. Steward, personal communication, November 19, 2014).
  - Replacement (“blanking”) labour requires 0.92 hours per hectare (G. Steward, personal communication, November 19, 2014).
  - Cost of replacement seedlings is included in the Nursery process.

- An overall salary for a forest manager to manage a forest is \$80,000 per year (based on a forest estate size of 5,000 hectare) (P. Hall, personal communication, 15 March, 2014).
- Forest management is estimated to account for two hours of employment per hectare per year (P. Hall, personal communication, 15 March, 2014).
- Employment related to rates (i.e. land value tax) and fire insurance are excluded due to its minimal impact on the life cycle indicators.
- Both a) fence and track maintenance and b) animal (pest) control are assumed to employ workers with an hourly wage of \$18, and require approximately nine minutes per hectare per year and three minutes per hectare per year respectively (P. Hall, personal communication, 15 March, 2014).
- The inventory process involves sampling forest sites within a stand to determine its quality and projected value. This process is estimated to take one worker (\$20/hour wage) 30 minutes per hectare to survey (P. Hall, personal communication, 15 March, 2014).
- The in-forest roading construction workers (\$30/hour wage) install 5 metres of roading per hectare in 0.79 hours (S. Hill, personal communication, March 12, 2014).
- The landing site construction workers involved (\$30/hour wage) require nearly 12.54 hours to complete one landing site, or 1.46 hours per hectare.
- The rimu landing site is estimated to cost approximately 19% of the radiata pine landing site i.e. \$285 per hectare (S. Hill, personal communication, March 12, 2014).
- An opportunity cost of \$1,040 per hectare per year was applied based on current average flat land valuations in the case study region of Gisborne.
- The tending cost per hectare associated with the Cultural Compliance process is \$154.67, and represents the annual cost of protecting the environment through Kaitiakitanga.

- The tending employment per hectare associated with the Cultural Compliance process is 0.80 hours, and represents the annual cost of protecting the environment through Kaitiakitanga.
- GHG emissions and carbon sequestration:
  - In-forest roading construction uses a gravel cartage truck and a “spread and roll” machine; combined diesel usage for these machines is approximately 19.52 litres of diesel per hectare.
  - The landing site construction process uses a bulldozer and excavator; combined diesel usage for these machines is approximately 43.85 litres of diesel per hectare.
  - Total above-ground carbon sequestered by the rimu forest (over 80 years) is estimated to be 763,000 kgCO<sub>2</sub>eq (Kimberley, Beets, & Bergin, 2014).
- **Form pruning**
  - Form pruning details:
    - The form pruning process ensures that each tree grows with a single, straight stem and removes any steep-angled branches which may impact upon timber quality as the tree matures.
    - Form pruning occurs three times during the initial growth phase of planted rimu: at year 8 to remove steep-angled branches and double leaders (i.e. one tree growing two stems), and at years 18 and 28 to raise branch height (G. Steward, personal communication, November 19, 2014).
  - Costs and profit, and employment:
    - It is estimated that a worker (\$18/hour wage) requires approximately 7.34 minutes to form prune each tree, or 134.59 to form prune one hectare of planted rimu (G. Steward, personal communication, November 19, 2014).
  - GHG emissions and carbon sequestration:
    - It is assumed that no machinery is used for the form pruning process.
- **Selective felling**

- Selective felling details:
  - The selective felling process involves the partial harvesting of a rimu stand (i.e. 10% per hectare).
  - With the total standing volume at the time of felling estimated at 920 m<sup>3</sup> per hectare (G. Steward, personal communication, November 19, 2014), 92 m<sup>3</sup> was selectively felled at year 80.
  - Selective felling involves three activities: surveying the stand before felling and marking the trees to be felled, felling the marked trees with a chainsaw, and cutting the felled trees into suitable logs for subsequent helicopter removal. 1 m<sup>3</sup> is assumed to be harvested softwood under bark.
- Costs and profit, and employment:
  - Surveying the stand and marking which trees are to be felled takes two workers (\$22/hour wage) one hour per hectare.
  - Felling each marked tree and cutting it to allow for helicopter extraction are both done with a chainsaw. Each of these activities require 0.04 hours per m<sup>3</sup>, or 0.08 hours per m<sup>3</sup> in total (J. Dronfield, personal communication, March 18, 2014). The total felled per hectare is 92 m<sup>3</sup>, or 10% of the total standing volume at year 80 (i.e. 920 m<sup>3</sup>). Therefore, the total employment per hectare from felling is 7.36 hours.
  - With 10% of each hectare selectively harvested, the Cultural Compliance cost per 80m<sup>3</sup> of heartwood timber is \$0.93.
  - With 10% of each hectare selectively harvested, the Cultural Compliance employment per 80m<sup>3</sup> of heartwood timber is 0.02 hours.
- GHG emissions and carbon sequestration:
  - Felling is estimated to use 0.34 litres of petrol to process one m<sup>3</sup>. Therefore, the total petrol use per hectare is 62.56 litres (J. Dronfield, personal communication, March 18, 2014).
- **Extraction**
  - Extraction details:

- The extraction process involves removing the felled stems (via helicopter) from the site and depositing them at the landing site for further handling.
- A proportion of the original felled volume (92 m<sup>3</sup> per hectare) is left on-site and may include material from the stumps, tree tops, and branches.
- It is assumed that there is less wastage with rimu harvesting than with Pine due to the extra care that would be taken during the felling process; minimisation of wastage increases the recoverable volume of each tree and thus increases the attainable value from each tree.
- It is estimated that 9% (approximately 9 m<sup>3</sup>) of the total standing volume is woody material left on-site; therefore, the amount of m<sup>3</sup> actually handled during extraction is 83 m<sup>3</sup>.
- Costs and profit, and employment:
  - Employment requires two pilots (\$175/hour wage), a fuel truck driver (\$22/hour wage), and an engineer (\$30/hour wage) (J. Dronfield, personal communication, March 18, 2014).
- GHG emissions and carbon sequestration:
  - Extraction times via helicopter are based on the potential for 19 helicopter turns per hour with a carrying capacity of 1.4 tonnes per turn (a “turn” is one return flight from the landing site, to the forest to pick up logs, and back to the landing site to drop off the logs) (J. Dronfield, personal communication, March 18, 2014).
  - It is estimated that 17.88 litres of Jet A1 fuel is used to extract one m<sup>3</sup> of felled log.
  - The diesel used by the fuel truck driver has been excluded due to its minimal impact on the life cycle indicators.
- **Landing site**
  - Landing site details:
    - It is estimated that 4% of the original volume deposited at the landing site (83 m<sup>3</sup>) is left on-site, thus amounting to 3 m<sup>3</sup> left at the landing site (P. Hall, personal communication, 15 March,

- 2014). This loss of volume is attributed to the log making process and any stem breakage that may occur during handling.
- It is assumed that the operation of “log making” at the landing site is not required as the logs are cut to transport size in the forest for helicopter extraction. Thus, the landing site process for the rimu scenario includes only the loading operation (J. Dronfield, personal communication, March 18, 2014).
- Costs and profit, and employment:
    - Three loading operators (\$18.50/hour wage) are required for this process (P. Hall, personal communication, 15 March, 2014).
    - It is estimated that loading for one m<sup>3</sup> takes 2.16 minutes; therefore, the felled rimu material (83 m<sup>3</sup>) takes approximately 3 hours to process through the landing site (P. Hall, personal communication, 15 March, 2014).
  - GHG emissions and carbon sequestration:
    - A chainsaw is used to cut the stems into logs, and uses 0.57 litres of petrol per m<sup>3</sup> (386 litres of petrol per hectare).
    - Two excavator-loaders are used to load the logs onto the logging truck, and use 0.56 litres of diesel per m<sup>3</sup> (379 litres of diesel per hectare) (P. Hall, personal communication, 15 March, 2014).
- **Timber transport**
    - Timber transport details:
      - The logs are transported to a semi-portable sawmill.
      - The volume transported per hectare is 80 m<sup>3</sup> (i.e. the remaining volume after harvesting and landing site operations).
      - Although a given rimu stem consists of both sawlog and pulp wood, it is assumed that all of the wood is transferred to the same sawmill.
      - Subsequent processing of the logs in the sawmill yard is excluded from the assessment due to its anticipated insignificant contribution to the indicator results.
      - One m<sup>3</sup> of rimu is approximately equivalent to one tonne of rimu (New Zealand Institute of Forestry, 2005).

- The transport distance (one-way) is assumed to be 86 km (NZ FOA Transport Authority, 2007).
  - The logging truck is assumed to be a 6x4 truck with a 4-axle trailer. The unloaded weight is 14.5 tonnes and a log payload weight of 29.5 tonnes, thus the total logging truck weight is 44 tonnes.
  - Costs and profit, and employment:
    - The timber truck driver (\$30/hour wage) requires 7.2 minutes per m<sup>3</sup> (3.54 hours per loaded truck) to travel from the landing site to the sawmill gate.
  - GHG emissions and carbon sequestration:
    - The timber truck uses 4.78 litres of diesel per m<sup>3</sup> (141 litres of diesel per loaded truck).
- **Sawmill**
    - Sawmill details:
      - The sawmill process is modelled to account for the production of rimu residential flooring. Specifically, the flooring product is defined as “rimu heartwood flooring – dressing A grade”.
      - The sawmill figures are based on the output of a small, semi-portable sawmill with a volume intake of 15,000 m<sup>3</sup> (P. Hall, personal communication, May 15, 2014).
      - Although the output of a small sawmill is lower, it has the distinct benefit of being able to allocate greater time on timber recovery; a higher rate of timber recovery leads to a greater value attained per tree. Recovery rates (i.e. how much sawlog material can be cut from each tree) are based on those of radiata pine but adjusted to account for greater time given to processing and subsequent rise in accuracy and optimisation.
      - There is no timber quality data for planted rimu that is harvested at 80 years. As such, extrapolations from current fieldwork regarding planted rimu estimate that 4% of each log is suitable for heartwood flooring timber.

- Therefore, of the original 80 m<sup>3</sup> per hectare delivered to the sawmill, only 3.2 m<sup>3</sup> per hectare will be processed into rimu heartwood flooring product.
- The flooring product is estimated to require one hour per m<sup>3</sup> to produce. Wastage is assumed to be 10%, therefore the total amount of rimu flooring produced is equivalent to 2.88 m<sup>3</sup>.
- Costs and profit, and employment:
  - \$358/m<sup>3</sup> is paid for the delivered rimu logs at the sawmill gate (KPMG, 2013).
  - Sawmill employment is inclusive of seven full-time equivalent workers whose skill sets are assumed to cover the range of sawmill requirements (i.e. production labour charge hand labour, specialist labour, office labour, and management labour). The weighted average salary across the sawmill is approximately \$71,000 per year.
  - With 4% of the total (heartwood) timber processed from each hectare, the Cultural Compliance cost per 3.2m<sup>3</sup> of heartwood timber for sawmilling is \$0.19
  - With 4% of the total (heartwood) timber processed from each hectare, the Cultural Compliance employment per 3.2m<sup>3</sup> of heartwood timber for sawmilling is negligible.
- GHG emissions and carbon sequestration:
  - The sawmill runs on electricity, and is assumed to be equivalent to the energy requirements (per m<sup>3</sup>) of a radiata pine sawmill. Thus, 170Wh is needed to produce one m<sup>3</sup> of framing product (i.e. kiln dried planed rimu flooring) (Jack et al., 2013).
  - As in the radiata pine scenario, the kiln drying process uses 2.16GJ per m<sup>3</sup>, however, wood waste resulting from sawmilling activities is burned in biomass boiler; thus, the kiln drying process may be considered to be a process using renewable energy, and has zero carbon emissions.
- **House construction**
  - House construction details:

- The house construction process is based on a large home production business (e.g. Stonewood) that have a significant intake of wood, and therefore could buy direct from sawmill. This assumption therefore circumvents the process of retail operation to sell the sawn timber.
  - Waste generation is assumed to be 10% during the construction process, and so 2.88 m<sup>3</sup> rimu heartwood flooring is actually used as flooring in the constructed house.
  - As this is a theoretical “what if” LCSA scenario, it was assumed that minimal transport was needed to travel from the sawmill to the house construction site, and thus was excluded from the assessment due to its anticipated insignificant contribution to the indicator results.
  - A generic, “exemplar” house (BRANZ, 2010; Love & Szalay, 2007; Willson, 2002) was chosen to represent the “house construction” process, and contains 195 m<sup>2</sup> of total floor area (including flooring for the loft, garage, etc). However, the area realistically suitable for high-end rimu heartwood flooring product in the exemplar house is 147 m<sup>2</sup> (Willson, 2002).
  - Assuming the rimu heartwood flooring has a thickness of 19mm (Timspec, 2014), then one m<sup>2</sup> of flooring is equivalent to 0.019 m<sup>3</sup>, and 52.6 m<sup>2</sup> is equivalent to one m<sup>3</sup>. Therefore, the exemplar house requires 2.8 m<sup>3</sup> of rimu flooring product.
  - Maintenance (i.e. occasional sanding and oiling) of the flooring was excluded due to its minimal impact on the life cycle indicators.
  - The life of the house with rimu flooring was assumed to be 80 years (South Pacific Timber NZ, personal communication, 22 October, 2014).
- Costs and profit, and employment:
    - The price paid for one m<sup>2</sup> of rimu flooring is estimated to be \$185 (Timspec, 2014), or \$9,731 per m<sup>3</sup>.
    - The cost to install the rimu flooring is \$325 per m<sup>2</sup> and includes sanding, gluing, and nailing. This cost is inclusive of the rimu flooring product, labour, finishing products, and sanding

- equipment. It is assumed that the flooring is installed as overlay on particle board (South Pacific Timber NZ, personal communication, 22 October, 2014).
- Employment includes 40 hours (\$25/hour wage) to install 147 m<sup>2</sup>, or 2.8 m<sup>3</sup>. Therefore, it takes 14.3 hours to install one m<sup>3</sup> of rimu flooring (South Pacific Timber NZ, personal communication, 22 October, 2014).
  - GHG emissions and carbon sequestration:
    - A drum belt floor sander is required to install the rimu flooring. A Clarke EZ8 model with 110 volt/12 amp power capacity is assumed to be used. It is estimated that sanding 2.8 m<sup>3</sup> takes 16 hours, or 5.7 hours per m<sup>3</sup> (South Pacific Timber NZ, personal communication, 22 October, 2014). Energy usage therefore is 7.5 kWh per m<sup>3</sup>.
  - **House deconstruction**
    - House deconstruction details:
      - The house deconstruction process occurs after 80 years of use of the house. This estimation is based on industry knowledge (South Pacific Timber NZ, personal communication, 22 October, 2014), and accounts for the long life expectancy of rimu flooring.
    - Costs and profit, and employment:
      - Costs and figures for house deconstruction are based on the installation times for rimu flooring. It was assumed that it takes 25% of the time to uninstall the 2.8 m<sup>3</sup> of rimu flooring as it does to install it (South Pacific Timber NZ, personal communication, 22 October, 2014).
      - Employment involves 3.58 hours per m<sup>3</sup> (\$30/hour wage), and is assumed to take 25% as long as the installation process (South Pacific Timber NZ, personal communication, 22 October, 2014).
      - One m<sup>3</sup> of recycled rimu is worth \$1,500 (Timber Recycling representative, personal communication, January 19, 2015).
    - GHG emissions and carbon sequestration:

- Any material cost or fuel usage is assumed to be negligible (South Pacific Timber NZ, personal communication, 22 October, 2014), and so has been excluded due to its minimal impact on the life cycle indicators.
- **Furniture making**
  - Furniture making details:
    - The furniture making process utilises the used rimu flooring and recycles it into a product; for the purposes of this demonstrative exercise, a rimu table was selected as the product using recycled rimu flooring.
    - It is assumed that the process of furniture making incurs 10% waste (Simply Wood representative, personal communication, January 23, 2015); therefore, of the 2.8 m<sup>3</sup> of rimu flooring that was removed from in the exemplar house approximately 2.5 m<sup>3</sup> of recycled rimu wood will exist in the final table product.
    - The rimu table was assumed to have dimensions of 1600mm x 1000mm x 20mm.
    - Conversion of one table into m<sup>3</sup> is based on multiplying the dimensions (i.e. 1600mm x 1000mm x 20mm = 32,000,000mm<sup>3</sup>, or 32,000cm<sup>3</sup>), adding approximately 50% more wood volume to account for the table legs (i.e. 16,000cm<sup>3</sup>), and then converting the total cm<sup>3</sup> volume to m<sup>3</sup> volume (i.e. 48,000 cm<sup>3</sup> = 0.048 m<sup>3</sup>). Thus, one rimu table (of the specified dimensions) uses 0.048 m<sup>3</sup> of recycled rimu (Simply Wood representative, personal communication, January 23, 2015).
    - If each table requires 0.048 m<sup>3</sup> of wood, then the amount of recycled rimu flooring is enough to create approximately 52 tables.
  - Costs and profit, and employment:
    - One m<sup>3</sup> of recycled rimu flooring is worth \$1,500 (Timber Recycling representative, personal communication, January 19, 2015).
    - The rimu wood required for one table costs \$72.

- The value of one completed rimu table is \$1,489 (Simply Wood representative, personal communication, January 23, 2015).
  - Employment involves a worker 30 hours (\$20/hour wage) to produce one rimu table (Simply Wood representative, personal communication, January 23, 2015).
  - GHG emissions and carbon sequestration:
    - Fuel and electricity use is negligible and has been excluded due to its minimal impact on the life cycle indicators.
- **Landfill (end-of-life)**
  - Landfill details:
    - The end-of-life process for the rimu heartwood flooring is comprised of wood waste from the construction, deconstruction, and furniture making processes – a total of 3.2 m<sup>3</sup>.
    - The density of rimu wood waste after 120 years of consumer use (80 years as flooring, 40 years as a recycled table) is 490kg per m<sup>3</sup> (New Zealand Institute of Forestry, 2005), and so 1 m<sup>3</sup> is equivalent to 0.49 tonne of waste.
  - Costs and profit, and employment:
    - As current landfill costs are \$251 per tonne of commercial waste (Gisborne District Council, 2015), the cost for one m<sup>3</sup> of rimu wood waste is approximately \$123.
    - It was assumed that employment costs (\$22/hour wage) comprised 10% of the total costs (i.e. \$12.30/m<sup>3</sup>) and required 0.50 of an hour to process 1 m<sup>3</sup> of rimu wood waste (Anonymous industry expert, personal communication, 18 November, 2015).
    - With 4% of the total (heartwood) timber processed from each hectare, the Cultural Compliance cost per 3.2m<sup>3</sup> of heartwood timber for landfill is \$0.02.
    - With 4% of the total (heartwood) timber processed from each hectare, the Cultural Compliance employment per 3.2m<sup>3</sup> of heartwood timber for landfill is negligible.
  - GHG emissions and carbon sequestration:

- As the landfill process occurs after the 100-year timeframe, the GHG emissions attributed to the decomposition of the wood waste were excluded.
- Machinery in a landfill include compactors, tractors, loaders, hauling and loader units, articulated trucks, and excavators (Bliss), and utilise approximately 11.07 litres of diesel per m<sup>3</sup> of rimu wood waste (Anonymous industry expert, personal communication, 18 November, 2015).

## **Mānuka scenario**

- *Nursery*
  - Nursery details:
    - Mānuka seedlings are produced in a nursery and take 12 months to grow from a seed to seedlings ready for planting.
    - Nurseries primarily use fungicides and pesticides, electricity for heating the greenhouse, and diesel for operating the tractors on-site.
    - The nursery process is assumed to be a small- to medium-scale enterprise producing roughly 300,000 mānuka seedlings per year (K. Te Kani, personal communication, October 8, 2014).
    - The nursery data includes both capital expenditure and operational costs.
    - The life of the nursery is assumed to be 50 years and so all figures are divided by and associated to the total number of seedlings produced over 50 years (i.e. 50 years x 300,000 seedlings per year = 15,000,000 seedlings).
    - The amount of mānuka seedlings required for one hectare of land is 15,000 seedlings (for the initial planting) and, over the 15-year mānuka rotation, approximately 10,000 additional seedlings will be required to replace any dead seedlings (P. Caskey, personal communication, February 2, 2015).
    - Requirements for replacing dead seedlings are based on annual mortality rates that are assumed to be 10% (1,500 seedlings) in year two, 7% (1,050 seedlings) in year three, and 5% (750 seedlings) every

year thereafter (P. Caskey, personal communication, February 2, 2015).

- Costs and profit, and employment:
  - Total capital costs are estimated to be \$492,195 (or \$9,844 per year), and total running costs are estimated to be \$326,451 per year. Total cost per seedling (inclusive of materials and labour) is \$1.12 (K. Te Kani, personal communication, October 8, 2014).
  - Employment and wages are inclusive of a full-time nursery manager (\$60,000/year salary), full-time nursery technician (\$40,000/year salary), one additional full-time staff (for manual tasks; \$14.25/hour wage), and four part-time seasonal casual staff (\$14/hour wage; 180 days each per year) (K. Te Kani, personal communication, October 8, 2014).
- GHG emissions and carbon sequestration:
  - Machinery (predominantly tractors) use approximately 1,200 litres of diesel per year (60 litres per hectare for initial planting, 40.2 litres of diesel per hectare for replacement plantings), whilst electricity uses approximately 36,000kWh per year (1,800 kWh per hectare for initial planting, 1,206 kWh per hectare for replacement plantings) (K. Te Kani, personal communication, October 8, 2014).

- ***Site preparation***

- Site preparation details:
  - Site preparation involves spraying the land to kill existing vegetation, and mechanical preparation of the soil.
  - In this scenario, it was assumed that fertiliser was required and thus includes an initial soil analysis process and subsequent application of (urea) fertiliser.
  - Irrigation was assumed to not be required.
  - The mechanical soil preparation is assumed to be required on only 8% of a hectare (P. Hall, personal communication, 15 March, 2014).
  - The helicopter pilot can spray 52 hectares of flat land per hour (Anonymous industry expert, personal communication, 10 March, 2014).

- Costs and profit, and employment:
  - Soil analysis is estimated to cost \$34 per hectare, and requires approximately 0.85 hours (\$20/hour wage) (Lawrence, 2013).
  - Fertiliser requirements are based on recommendations from Donaghys (2014) and include 80kg of urea per hectare at a cost of approximately \$69 per hectare.
  - It is assumed that a worker requires 0.25 hours (\$18/hour wage) to apply fertiliser on one hectare using a 45 kW tractor.
  - The process of herbicide application requires a helicopter pilot (\$175/hour wage) and a support technician to mix the herbicide chemicals (\$35/hour wage) for a combined time of 0.06 hours per hectare.
  - Assuming 8% of the hectare requires mechanical soil preparation, an excavator operator (\$18/hour wage) can process one hectare in 0.19 hours (Anonymous industry expert, personal communication, 10 March, 2014).
  - The site preparation cost per hectare associated with Cultural Compliance is \$1.65.
  - The site preparation employment per hectare associated with Cultural Compliance is 0.02 hours.
- GHG emissions and carbon sequestration:
  - GHG emissions per kg of urea is 1.85 kgCO<sub>2</sub>eq (Sandilands & Nebel, 2010b).
  - Data regarding machinery use (45 kW tractor) is based on research from Mila i Canals, Burnip, and Cowell (2006) where it is estimated that a 45 kW tractor spraying herbicides uses 5 litres of diesel per hour. Given the assumption that 0.25 hours are required to spray one hectare, 1.25 litres of diesel are used per hectare for machinery use.
  - The Iroquois helicopter uses 6.33 litres of Jet A1 fuel per hectare, and the support truck for the aerial herbicide spray uses 1.19 litres of diesel per hectare (Anonymous industry expert, personal communication, 10 March, 2014).

- An excavator for the soil preparation uses 3.84 litres of diesel per hectare (for 8% coverage per hectare) (P. Hall, personal communication, 15 March, 2014).
  - The loss of above-ground carbon when grassland with woody biomass is converted to forestry is 47,850 kgCO<sub>2</sub>eq per hectare (Wakelin & Beets, 2013). The loss of soil carbon (to 30 cm depth) when grassland with woody biomass is converted to forestry is 17,400 kgCO<sub>2</sub>eq per hectare (Hewitt et al., 2012). These carbon values are included in each of the three forestry scenarios as they represent a change in land use and as such the subsequent change in carbon is included as GHG (ISO, 2013).
- **Planting**
    - Planting details:
      - The planting process includes only the labour cost of planting the initial 15,000 seedlings per hectare.
      - The cost of the seedlings was accounted for during the nursery process so, to avoid double counting, the seedling cost is not also included during the planting process.
    - Costs and profit, and employment:
      - Planting times are based on those of radiata pine, namely that it take 35 seconds to plant one seedling (P. Hall, personal communication, 15 March, 2014).
      - Therefore, to plant 15,000 seedling per hectare requires approximately 145 hours (\$20/hour wage).
      - The planting cost per hectare associated with Cultural Compliance is \$1.47.
      - The planting employment per hectare associated with Cultural Compliance is 0.02 hours.
    - GHG emissions and carbon sequestration:
      - There are no GHG emissions nor carbon sequestration associated with this process.
- **Tending**

- Tending details:
  - The tending process includes weed control (aka – “releasing”) using herbicides via helicopter, disease control of mānuka blight from the scale insect (*Eriococcus orariensis* Hoy) via hand spray, replacement of dead seedlings (aka – “blanking”), and the annual activities of fertiliser application, rates and fire insurance, fence and track maintenance, and animal (pest) control.
  - No in-forest construction for landing sites and roading infrastructure is required for the mānuka scenario.
  - Weed control (“releasing”) occurs three times during years one, two, and three. The helicopter pilot can spray 52 hectares of flat land per hour for weed control purposes.
- Costs and profit, and employment:
  - Mānuka blight spray to combat the scale insect occurs every year during the mānuka rotation. It is assumed that approximately half of the hectare will require hand spraying; therefore, it takes 1.75 hours (\$18/hour wage) to hand spray one hectare (P. Caskey, personal communication, February 2, 2015).
  - An opportunity cost of \$1,040 per hectare per year was applied based on current average flat land valuations in the case study region of Gisborne.
  - Further soil analysis occurs annually and is estimated to cost \$34 per hectare, and requires approximately 0.85 hours (\$20/hour wage) (Lawrence, 2013).
  - Annual urea fertiliser treatment is assumed to be required but at half the intensity of the initial application. Thus, the materials cost is approximately \$26 per hectare and it requires 0.13 hours (\$18/hour wage) to apply fertiliser on one hectare using a 45 kW tractor.
  - Wages for aerial spraying are inclusive of a helicopter pilot (\$175/hour wage) and a support technician to mix the herbicide chemicals (\$35/hour wage) (L. Bulman, personal communication, 3 March, 2014).

- Employment related to rates (i.e. land value tax) and fire insurance are excluded due to its minimal impact on the life cycle indicators.
- Both a) fence and track maintenance and b) animal (pest) control are assumed to employ workers with an hourly wage of \$18, and require approximately nine minutes per hectare per year and three minutes per hectare per year respectively (P. Hall, personal communication, 15 March, 2014).
- The tending cost per hectare associated with Cultural Compliance is \$29.00, and represents the annual cost of protecting the environment through Kaitiakitanga.
- The tending employment per hectare associated with Cultural Compliance is 0.15 hours, and represents the annual cost of protecting the environment through Kaitiakitanga.
- GHG emissions and carbon sequestration:
  - The Iroquois helicopter used for the spraying of herbicides for the weed control (“releasing”) process uses 6.33 litres of Jet A1 fuel per hectare and the support truck for the aerial herbicide spray uses 1.19 litres of diesel per hectare (Anonymous industry expert, personal communication, 10 March, 2014).
  - Total carbon sequestered by a natural mānuka forest (over 15 years) is estimated to be 214,500 kgCO<sub>2</sub>eq per hectare (or 14,300 kgCO<sub>2</sub>eq per hectare per year). These values are based on carbon sequestration analysis of wild- or naturally-grown mānuka by Scott et al. (2000); however, there is currently no carbon sequestration data for annually trimmed mānuka. Scott et al. (2000) estimate that 24% of the above-ground carbon is in the branch and leaf material. Annual trimming removes 2/3 of the branch and leaf material (for oil distillation purposes) resulting in 16% (i.e. 2/3 of 24%) of the aboveground carbon removed each year. Therefore, the carbon sequestered by one hectare of production mānuka (over 15 years, with annual trimming) is estimated to be 180,180 kgCO<sub>2</sub>eq (or 12,012 kgCO<sub>2</sub>eq per hectare per year).

- GHG emissions per kg of urea is 1.85 kgCO<sub>2</sub>eq (Sandilands & Nebel, 2010b).
- **Harvesting and transport of branches**
  - Harvesting and transport details:
    - The harvesting of branches process occurs annually after the flowers have dropped from the mānuka tree (typically in February or March).
    - Harvesting (or trimming) of each mānuka tree removes 2/3 of the total branch material.
    - Harvesting is done with the simultaneous operation of a forage harvester and a truck with trailer. The forage harvester cuts and immediately deposits material into the trailer. Therefore, the harvesting and transport processes have been combined in this scenario; there is no additional transport process required.
    - The average amount of branch material trimmed each year is 3 kg per mānuka plant, or 34 tonnes per hectare (P. Caskey, personal communication, February 2, 2015).
    - Over the 15-year rotation, 544 tonnes of branch material is harvested per hectare.
  - Costs and profit, and employment:
    - It is estimated that a worker (\$25/hour wage) requires 1 hour to harvest one tonne of branch material (P. Caskey, personal communication, February 2, 2015).
    - Normally, royalties are paid to the land owner at a rate of \$100 per tonne of branch material. However, in this research it is assumed that the land owner is the main ‘entity’ (encapsulating the nursery, distillation, and packaging facilities); thus, land owner royalties were not included in this assessment.
    - The harvesting cost per hectare associated with Cultural Compliance is \$9.28.
    - The harvesting employment per hectare associated with Cultural Compliance is 0.16 hours.
  - GHG emissions and carbon sequestration:

- A forage harvester uses 50 litres of diesel per hour and a truck with trailer uses 12.5 litres of diesel per hour (P. Caskey, personal communication, February 2, 2015).
  - The distillation facility is assumed to be next door to the mānuka establishment therefore no significant transport of harvested material is needed.
- **Distillation**
    - Distillation details:
      - The distillation process involves steam distilling the mānuka branch material to produce mānuka essential oil.
      - Approximately 3.5 kg of essential oil is produced for every tonne of mānuka branch material distilled (P. Caskey, personal communication, February 2, 2015).
      - Therefore, if 544 tonnes of mānuka branch material is produced during one 15-year rotation, then 1,904 kg of essential oil is created during the distillation process.
    - Costs and profit, and employment:
      - A distillation plant has a capital cost of \$100,000 and a running cost (over the 25 year life span) of approximately \$363,000. The plant includes two ‘cooker’ machines for the distillation process. One tonne of branch material can be processed in each distillation ‘cook’ (P. Caskey, personal communication, February 2, 2015).
      - Employment is inclusive of two distillation “cooks” per day with each ‘cook’ requiring four hours. Workers receive \$25/hour wage (P. Caskey, personal communication, February 2, 2015).
      - One kg of essential oil was assumed to be worth \$300 (P. Caskey, personal communication, February 2, 2015).
      - The distillation cost per hectare associated with Cultural Compliance is \$4.96.
      - The distillation employment per hectare associated with Cultural Compliance is 0.06 hours.
    - GHG emissions and carbon sequestration:

- The distilling machines use 60 litres of diesel per “cook”, or 15 litres of diesel per hour (P. Caskey, personal communication, February 2, 2015).
- **Packaging (9,712 mānuka essential oil-filled (10mL) bottles; i.e. 5% of the total oil produced)**
  - Packaging details:
    - Of the total amount of mānuka essential oil produced (1,904 kg or approximately 1.9 million mL), it is estimated that 5% is utilised for packaging in 10mL bottles (P. Caskey, personal communication, February 2, 2015). Thus, 5% of the total oil produced 97,125 mL, or 9,712 10mL mānuka essential oil-filled bottles.
    - Converting from kg oil to ml of oil requires the density of mānuka essential oil which, at 20°C, is 0.98 (New Zealand Manuka Bioactives). So, 3.5 kg of oil produced per tonne of branch material is equivalent to 3,571 mL per tonne.
  - Costs and profit, and employment:
    - The cost of each glass bottle is approximately \$0.25, and the amount of glass in each bottle is approximately 28g (P. Caskey, personal communication, February 2, 2015).
    - Employment (\$18/hour wage) was estimated at 2 minutes required to package each bottle (P. Caskey, personal communication, February 2, 2015).
  - GHG emissions and carbon sequestration:
    - Greenhouse gas emissions per kg of glass was estimated using the GaBi database (i.e. 0.808 kgCO<sub>2</sub>eq per kg of glass).
    - Transport of the empty glass bottles as well as the production and transport of the plastic top were excluded from this analysis due to their minimal impact on the life cycle indicators.
- **Landfill (end of life).**
  - Landfill details:

- The empty mānuka essential oil glass bottles are assumed to be disposed of in a landfill.
- Each glass bottle weighs 28 grams, therefore the total amount of glass waste from 9,712 bottles is approximately 272 kg (or 0.272 tonne).
- Costs and profit, and employment:
  - As current landfill costs are \$251 per tonne of commercial waste (Gisborne District Council, 2015), the cost for 9,712 10mL glass bottles is approximately \$68.
  - It was assumed that employment costs (\$22/hour wage) comprised 10% of the total costs (i.e. \$6.83/ha) and required 0.28 of an hour to process 9,712 10mL glass bottles (Anonymous industry expert, personal communication, 18 November, 2015).
  - With 5% of the total distilled oil being bottled, the landfill cost per 9,712 bottles associated with Cultural Compliance is \$0.25.
  - With 5% of the total distilled oil being bottled, the landfill employment per 9,712 bottles associated with Cultural Compliance is 0.003 hours.
- GHG emissions and carbon sequestration:
  - Machinery in a landfill include compactors, tractors, loaders, hauling and loader units, articulated trucks, and excavators (Bliss), and utilise approximately 4.07 litres of diesel per 9,712 10mL glass bottles (Anonymous industry expert, personal communication, 18 November, 2015)..
  - Using the GaBi database, an additional 0.0071 kgCO<sub>2</sub>eq per kilogram of glass is emitted in the landfill.
  - It is assumed that the mānuka essential oil (in 10mL glass bottles) are used and disposed of by the consumer within one year. The first mānuka essential oil bottles are disposed of in the landfill at year 3 (362 bottles) and continue until year 16 (1,085 bottles), totalling 9,712 glass bottles. Thus, when considering a 100-year timeframe, the bottles may be in the landfill from 84-97 years (depending on when the bottle were disposed). The emissions for this glass decomposition in the landfill process are 175 kgCO<sub>2</sub>eq.

## **Steep-land life cycle inventory data (economic, social, and environmental)**

A Steep-land Sensitivity analysis (Appendix G) was performed on the radiata pine and rimu scenarios, and used some different data to the data noted above (which represents flat land). The forestry processes that required steep-land data for the sensitivity analysis were: site preparation (spraying, aerial spraying, mechanical preparation, screefing/mulching, land rental), planting, tending (releasing (i.e. herbicide management, hand weeding, blanking (i.e. replacement of dead seedlings), marking trees for felling), thinning (to waste), form pruning, felling, extraction, skid site (log making and loading), landing construction, and roading construction.

In most instances, the main differing factor between the flat- and steep-land data is the time it takes to perform a process. Therefore, to avoid repetition, only the pertinent differences between flat- and steep-land data are presented below.

### **Radiata pine scenario (steep land)**

- ***Site preparation***
  - Aerial spraying can cover 40 hectares of steep land per hour (instead of 52 hectares per hour on flat land) (Anonymous industry expert, personal communication, 10 March, 2014).
  - Mechanical preparation takes 1.5 times as long as on flat land (P. Hall, personal communication, 15 March, 2014).
  - Opportunity cost on steep land is \$208 (rather than \$1,040 on flat) due to its significantly lower land value and limited viability for other land uses (P. Hall, personal communication, 15 March, 2014).
- ***Planting***
  - Planting takes 1.5 times as long as on flat land (P. Hall, personal communication, 15 March, 2014).
- ***Tending***
  - Releasing via helicopter can cover 40 hectares (as noted in “site preparation” above) (Anonymous industry expert, personal communication, 10 March, 2014).

- **Thinning (to waste)**
  - Thinning is assumed to take 1.5 times as long as on flat land (P. Hall, personal communication, 15 March, 2014).
- **Felling**
  - Total felling cost is 5.6% of total harvesting cost of \$8,904 (P. Hall, personal communication, 15 March, 2014).
  - One person is required for felling with a chainsaw with an employment rate of 0.025 hours per m<sup>3</sup>.
- **Extraction**
  - Total extraction cost is 31.8% of total harvesting cost of \$8,904 (P. Hall, personal communication, 15 March, 2014).
  - Three people are required for extraction with a cable hauler with an employment rate of 0.075 hours per m<sup>3</sup> (P. Hall, personal communication, 15 March, 2014).
- **Log making at skid site**
  - Total log making cost is 28% of total harvesting cost of \$8,904 (P. Hall, personal communication, 15 March, 2014).
  - Five people are required for log making with a chainsaw with an employment rate of 0.125 hours per m<sup>3</sup> (P. Hall, personal communication, 15 March, 2014).
- **Loading**
  - Total loading cost is 34.6% of total harvesting cost of \$8,904 (P. Hall, personal communication, 15 March, 2014).
  - Six people are required for log making with excavator loaders with an employment rate of 0.15 hours per m<sup>3</sup> (P. Hall, personal communication, 15 March, 2014).
- **Landing construction**
  - Landing construction is assumed to take 1.5 times as long as on flat land (S. Hill, personal communication, March 12, 2014).
- **Roading**
  - There are various costs attributed to roading on steep land such as: machine cost = \$960 (using \$24/m for construction), gravel cost = \$1000 (assuming \$25/m<sup>3</sup> gravel), gravel cartage cost = \$710 (assuming \$0.5/km

x 60km), spread and roll machine cost = \$200 (assuming \$5/metre). The total cost of roading per hectare is \$3,656 (S. Hill, personal communication, March 12, 2014).

- Employment is approximately 10 hours per hectare (S. Hill, personal communication, March 12, 2014).

### **Rimu scenario (steep land)**

- ***Site preparation***

- Hand spraying is assumed to take 1.5 times as long as on flat land (G. Steward, personal communication, November 19, 2014).
- Screefing/mulching is assumed to take 1.5 times as long as on flat land (G. Steward, personal communication, November 19, 2014).
- Opportunity cost on steep land is \$208 (rather than \$1,040 on flat) due to its significantly lower land value and limited viability for other land uses (P. Hall, personal communication, 15 March, 2014).

- ***Planting***

- Planting takes 1.5 times as long as on flat land (G. Steward, personal communication, November 19, 2014).

- ***Tending***

- Hand weeding occurs in years 1, 2, and 3. Costs and employment are based on the average weeding time required per plant: 1.4 minutes in year 1, 1 minute in year 2, and 0.5 minutes in year 3 (G. Steward, personal communication, November 19, 2014).
- Mortality for steep land seedlings is 7% in both years 1 and 2 (G. Steward, personal communication, November 19, 2014).
- Blanking (replacing dead seedlings) is required in years 1 and 2, and requires 1 minute to replace each dead seedling (G. Steward, personal communication, November 19, 2014).

- ***Form pruning***

- Form pruning occurs 3 times over the rotation and requires 139.5 hours of employment per hectare.

- ***Marking trees for felling***

- Marking takes 1.25 times as long as on flat land (J. Dronfield, personal communication, March 18, 2014).
- **Felling**
  - Felling takes 1.25 times as long as on flat land (J. Dronfield, personal communication, March 18, 2014).
  - A chainsaw is used to fell on steep slopes.
- **Extraction via helicopter**
  - Increased hindrance factor so slower turn times (i.e. the time it takes for the helicopter to extract timber, drop it at the skid site, and return to harvested area). Assumed 15 turns are made on steep land (instead of 19 on flat land) (J. Dronfield, personal communication, March 18, 2014).
  - Employment required is 0.05 hours per m<sup>3</sup>.
- **Loading**
  - Loading takes 1.25 times as long as on flat land (J. Dronfield, personal communication, March 18, 2014).
- **Landing construction and Roding**
  - Same as in the radiata pine steep-land data

### **Data exclusions, inclusions, and other considerations**

There are a number of data and assumptions that are applicable to several processes throughout each scenario; instead of repeating these data throughout the appendix they are listed below.

- General details:
  - All helicopter usage was assumed to use an Iroquois helicopter.
  - To simplify the life cycles of each scenario, some processes were removed that were identified as having little impact on the life cycle indicators. These process include: freight transport between processes (apart from timber transport), retailing or selling of products, and consumer use of products.
  - All timber and associated products are assumed not to be stored in any facilities before further processing or consumer use occurs.

- This LCSA is not site-specific so all costs and figures are based on averages for New Zealand, or, where possible, for the Gisborne case study region.
- All forest management (e.g. planting, harvesting) figures are based on flat land operations.
- Costs and profit, and employment:
  - Employee travel to and from their working location (e.g. forest site, sawmill, house construction site) was excluded as per the PAS 2050 guidelines (BSI, 2011b, p. 17).
  - All costs are presented in New Zealand dollars.
  - The social, environmental, and cultural impacts associated with creating the machinery used (e.g. excavators, helicopters, chain saws, timber trucks) in the life cycles were excluded as this was outside the system boundaries for the analysis. The exclusion of GHG emissions associated with such capital goods aligns with the PAS2050 guidelines (BSI, 2011b).
  - The capital (economic) costs associated to the creation of the main building structures (i.e. nurseries and sawmills in the radiata pine and rimu life cycles, and nursery and distillation plant in the mānuka life cycle) were included. Only these main building structures were included due to their sizable capital investment requirements, without which the LCC component of these processes would be underrepresented.
  - Capital depreciation and interest costs as well as material costs are embedded in the overall costs of each process.
  - Labour overheads are included in the overall labour cost of each process. The wage and salary figures noted in the process descriptions do not include overheads.
  - All figures presented in Chapter 7 and this appendix used a 0% discount rate. A sensitivity analysis (Appendix I) of discount rates (4%, 6%, and 8%) were applied to present a range of potential net present values.
- GHG emissions and carbon sequestration:

- Oil and other lubricants were not accounted for as they generally represented less than 0.01% of the total energy use in any given machinery process (Sandilands & Nebel, 2010b).
- Conversion factors taken from: Sandilands and Nebel (2010): 1L diesel = 2.99kgCO<sub>2</sub>eq, 1L Kerosene (aviation fuel) = 2.52kgCO<sub>2</sub>eq, 1L petrol = 2.33kgCO<sub>2</sub>eq.
- All electricity use is assumed to be medium voltage with an associated carbon footprint rate of 0.177kg CO<sub>2</sub>eq per kWh (Sacayon, 2015).

### **Opportunity cost**

An opportunity cost was included in the LCC of each life cycle scenario. Opportunity cost can be included in LCC, particularly within the life cycle phases involving material acquisition and product manufacturing/operation (Rahman & Vanier, 2004). Opportunity cost is also discussed in an LCC-context when referring to the selection of an appropriate discount rate (i.e. ‘the opportunity cost of money for the decision maker’) (Lutz et al., 2006; Swarr et al., 2011).

An opportunity cost may be viewed as an internal economic check; when one option is chosen over another the forfeited economic gain from the option not pursued is included within the chosen option. It is an economic methodology commonly used to ensure that decisions (e.g. within this case study, regarding forestry land use options) are made which account for other options. In addition, the inclusion of opportunity costs exists within various forestry-related research (e.g. Barry et al., 2014; Fisher et al., 2011; Golub, Hertel, Lee, Rose, & Sohngen, 2009), natural resource management (e.g. Pearce & Markandya, 1987), and conservation studies (e.g. Chomitz, 1999).

The opportunity cost in this research was based on an alternative land option (i.e. besides forestry) of land rental as this is often a decent estimate of opportunity cost (Prokofieva & Thorsen, 2011). The determination of this opportunity cost was done through the evaluation of current flat and steep land for sale in the case study region, and taking 4%

of the average land values; 4% is considered to be a minimum return on investment amount (P. Hall, personal communication, March 4, 2015).

### **Cultural Compliance process – figures and assumptions**

The Cultural Compliance process (as described in Section 5.4.2) has associated costs, employment, and greenhouse gases emissions (similar to other life cycle processes). There is culturally-specific opportunity cost due to “choosing aspirations over financial gains” and if there is an “avoidance of a breach of compliance” (Int-7a-TP.TW) but this has not been included in the Cultural Compliance process at this stage; further research needs to be dedicated to this topic.

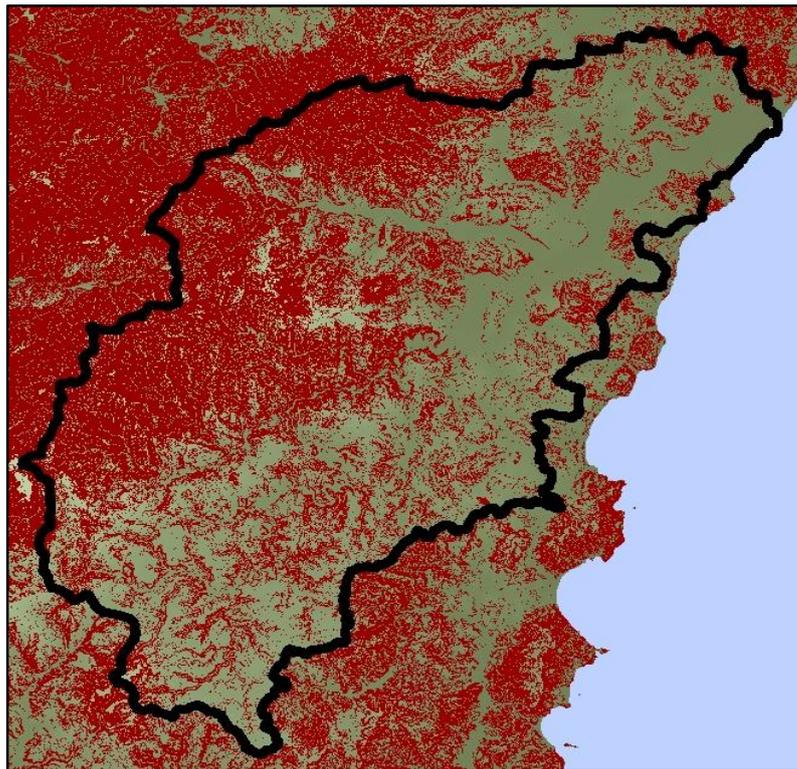
The figures listed in Table 22 may be “confronting” to some as they openly present the realities of cultural costs (TP) (Int-7a-TP.TW); every effort has been made throughout this thesis to eliminate any sense of crassness associated with the Cultural Compliance process, and to promote the potential cultural and aspirational benefits of its inclusion within the LCSA research. The GHG emissions are anticipated to be minimal and thus have been excluded from the LCSA analysis.

*Table 22. Estimations of per hectare costs and employment as associated with fulfilment of Cultural Compliance.*

Cultural compliance processes	Total costs (NZ\$)	Employment (hours)
1) Wahi tapu	1.93	0.01
2) Cultural monitor	2.47	0.04
3) Cultural Health and Safety	0.37	0.002
4) Marketing	14.88	0.17
5) Kaitiakitanga (annual cost)	1.93	0.01
6) Benefits to owners	2.67	0.09

## Appendix G: Steep land sensitivity analysis

A sensitivity analysis was performed regarding growing and harvesting radiata pine and rimu on steep land; steep land is defined as terrain over 18° and has a considerable effect on forestry costs, efficiency, and safety (Forest Industries Training, 2000). Each scenario assumed that all forestry activities took place on flat land, and thus all of the associated data reflects this assumption. In reality, however, the case study catchment has relatively limited amounts of flat land as a significant amount of the area has steep slopes over 18° (see Figure 29). Data was collected for specific elements of the life cycle-value chains where steep terrain would have an effect. Processes affected included site preparation (aerial spraying and mechanical preparation), planting, tending (herbicide application and opportunity cost), thinning, felling, extraction, skid site (log making), landing construction, and roading. See Appendix F for further details regarding data for steep land forestry.



*Figure 29. The Waiapu catchment case study site (outlined in black) with the areas of steep terrain (18° or more) indicated in red colour.*

### **Flat versus steep land-use results**

The flat land versus steep land sensitivity analyses for the land-use perspective of the radiata pine and rimu scenarios are shown in Tables 23 and 24. The product-based (and post-harvest) background data for the radiata pine and rimu steep land scenarios are shown in Tables 25 and 26 respectively. Finally, the flat land versus steep land sensitivity analyses for the product perspective of one m<sup>3</sup> of radiata pine framing and one m<sup>3</sup> of rimu flooring are shown in Tables 27 and 28.

A steep land sensitivity analysis was not performed for the mānuka scenario as this scenario and its related processes require being located on flat land; to pursue intensive mānuka plantations for essential oil production on steep land would be economically unviable. The Cultural Indicator Matrix was not completed for the steep land analysis; future work could be carried out in this area to determine if there is a cultural difference between flat and steep land forestry.

For the purposes of this research, once the harvesting and extraction is complete the rest of the life cycle-value chain has the same amount of benefits and impacts. For example, it is assumed that one m<sup>3</sup> of log costs the same to transport (per kilometre) and costs the same to sawmill, regardless of if it grew on flat or steep land. In a site-specific case study, however, there undoubtedly will be differences between steep and flat land transport.

For radiata pine, it is assumed that the growth rate is slightly slower on steep land than on flat land producing approximately 742 m<sup>3</sup> and 760 m<sup>3</sup> respectively (total standing volume). For rimu, the same assumption applies with an estimated 920 m<sup>3</sup> produced on flat land and 828 m<sup>3</sup> produced on steep land (total standing volume). In general, steep land is more expensive to perform forestry operations. Two exceptions are that of Opportunity cost which is lower for steep land (\$208/ha year<sup>-1</sup>) than for flat land (\$1040/ha year<sup>-1</sup>), and Felling/flitching (which is due to steep land harvesting using a chainsaw instead of a more expensive mechanised harvester).

Overall, employment hours and greenhouse gas emissions are both higher on steep land due to greater hindrance issues (e.g. hazards, ground instability), a requirement for carefully arranged infrastructure (e.g. wider, highly contoured forest tracks), and longer processing times (e.g. manual felling with a chainsaw, extraction with a cable crane).

Table 23. Land-use results for the radiata pine flat land versus steep land sensitivity analysis.

Radiata pine (per ha per rotation)	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence
	Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl. / ha (hours)	Empl. / ha (hours)		GHG emission s / ha (kgCO <sub>2</sub> eq)	GHG emission s / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Nursery	584	584	0%	-	-	-	20.55	20.55	0%	19	19	0%	4	4	0%
Site prep	183	213	14%	-	-	-	0.25	0.35	28%	111,686	111,697	0.01%	-	-	-
Planting	324	405	20%	-	-	-	8.10	10.12	20%	-	-	-	-	-	-
Tending	7,218	9,071	20%	-	-	-	76.38	84.87	10%	1,270	1,941	35%	313,724	298,660	-5%
Opportunity cost	29,120	5,824	-400%	-	-	-	-	-	-	-	-	-	-	-	-
Thinning	320	480	33%	-	-	-	7.60	11.40	33%	17	26	33%	-	-	-
Radiata pine (per ha yr <sup>-1</sup> )	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence
	Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl. / ha (hours)	Empl. / ha (hours)		GHG emission s / ha (kgCO <sub>2</sub> eq)	GHG emission s / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Nursery	21	21	0%	-	-	-	0.73	0.73	0%	0.68	0.68	0%	0.13	0.13	0%
Site prep	7	8	14%	-	-	-	0.009	0.013	28%	3,989	3,989	0%	-	-	-
Planting	12	14	20%	-	-	-	0.29	0.36	20%	-	-	-	-	-	-
Tending	258	324	20%	-	-	-	2.73	3.03	10%	45.36	69	35%	11,204	10,666	-2%
Opportunity cost	1,040	208	-400%	-	-	-	-	-	-	-	-	-	-	-	-
Thinning	11	17	33%	-	-	-	0.27	0.41	33%	0.62	0.93	33%	-	-	-

Table 24. Land-use results for the rimu flat land versus steep land sensitivity analysis.

Rimu (per ha per rotation)	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference
	Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl. / ha (hours)	Empl. / ha (hours)		GHG emissions / ha (kgCO <sub>2</sub> eq)	GHG emissions / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Nursery	1,618	1,649	0%	-	-	-	56	59	5%	50	51	2%	42	40	0%
Site prep	423	635	33%	-	-	-	11	17	33%	111,655	111,655	0%	-	-	-
Planting	719	1,078	33%	-	-	-	18	27	33%	-	-	-	-	-	-
Tending	10,381	10,872	4%	-	-	-	283	284	0%	189	294	36%	389,837	333,665	-11%
Opportunity cost	83,200	16,640	-400%	-	-	-	-	-	-	-	-	-	-	-	-
Pruning	4,845	5,023	4%	-	-	-	135	140	4%	-	-	-	-	-	-
Rimu (per ha yr <sup>-1</sup> )	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference	Flat	Steep	% Difference
	Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl. / ha (hours)	Empl. / ha (hours)		GHG emissions / ha (kgCO <sub>2</sub> eq)	GHG emissions / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Nursery	20	21	0%	-	-	-	0.7	0.71	2%	0.63	0.64	2%	0.53	0.50	0%
Site prep	5	8	14%	-	-	-	0.14	0.21	33%	1,396	1,396	0%	-	-	-
Planting	9	13	20%	-	-	-	0.22	0.34	33%	-	-	-	-	-	-
Tending	130	136	20%	-	-	-	3.54	3.55	0%	2.37	3.7	36%	4,873	4,171	-11%
Opportunity cost	1,040	208	-400%	-	-	-	-	-	-	-	-	-	-	-	-
Pruning	61	63	33%	-	-	-	1.68	1.75	4%	-	-	-	-	-	-

Table 25. Product-based (and post-harvest) background data for the radiata pine steep land scenario

Radiata pine (per ha)	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence.	Flat	Steep	% Diff- erence
	m <sup>3</sup> / ha	m <sup>3</sup> / ha		Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl./ ha (hours)	Empl. / ha (hours)		GHG emissi ons / ha (kgCO <sub>2</sub> eq)	GHG emissi ons / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Felling	761	743	-2%	4,297	1,359	-216%	-	-	-	9	19	51%	910	293	-211%	-	-	-
Extraction	677	646	-5%	4,413	6,727	34%	-	-	-	16	48	66%	1,721	2,183	21%	-	-	-
Skid site	677	646	-5%	6,342	13,234	52%	-	-	-	24	178	86%	2,048	3,923	48%	-	-	-
Transport	650	620	-5%	12,829	12,237	-5%	1,946	11,862	84%	77	73	-5%	9,298	8,868	-5%	-	-	-
Sawmill (framing only)	92	87	-5%	24,205	23,088	-5%	9,999	9,537	-5%	97	93	-5%	2,751	2,624	-5%	-	-	-
Construction (framing only)	83	79	-5%	57,185	54,546	-5%	3,431	3,273	-5%	289	275	-5%	784	748	-5%	-	-	-
Deconstruction (framing only)	83	79	-5%	2,690	2,566	-5%	-	-	-	45	43	-5%	247	235	-5%	-	-	-
Landfill (Construction and framing wood waste)	92	87	-5%	9,666	9,219	-5%	-	-	-	40	38	-5%	8,470	8,079	-5%	-	-	-

Table 26. Product-based (and post-harvest) background data for the rimu steep land scenario.

Rimu (per ha)	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence	Flat	Steep	% Diff- erence.	Flat	Steep	% Diff- erence
	m <sup>3</sup> / ha	m <sup>3</sup> / ha		Total cost / ha (NZ\$)	Total cost / ha (NZ\$)		Profit / ha (NZ\$)	Profit / ha (NZ\$)		Empl./ ha (hours)	Empl. / ha (hours)		GHG emissi ons / ha (kgCO <sub>2</sub> eq)	GHG emissi ons / ha (kgCO <sub>2</sub> eq)		Carbon seq. / ha (kgCO <sub>2</sub> eq)	Carbon seq. / ha (kgCO <sub>2</sub> eq)	
Felling	92	82	-12%	4,784	5,330	10%	-	-	-	9	10	13%	146	162	10%	-	-	-
Extraction	83	74	-12%	11,307	12,399	9%	-	-	-	3	3	11%	3,740	4,101	9%	-	-	-
Skid site	80	71	-13%	2,158	2,405	10%	-	-	-	3	11	73%	791	748	-6%	-	-	-
Transport	80	71	-13%	1,579	1,401	-13%	1,109	2,105	47%	9	8	-13%	1,144	1,016	-13%	-	-	-
Sawmill (flooring only)	3.20	2.84	-13%	1,426	1,265	-13%	29,698	26,371	-13%	3	3	-13%	96	85	-13%	-	-	-
Construction (flooring only)	2.88	2.56	-13%	34,320	30,459	-13%	14,820	13,153	-13%	41	37	-13%	4	3	-13%	-	-	-
Deconstruction (flooring only)	2.88	2.56	-13%	515	457	-13%	3,805	3,377	-13%	10	9	-13%	-	-	-	-	-	-
Furniture (rimu table only)	2.59	2.30	-13%	69,454	61,641	-13%	10,939	9,708	-13%	1,620	1,438	-13%	-	-	-	-	-	-
Landfill (Construction, furniture making, and rimu table wood waste)	3.20	2.84	-13%	394	349	-13%	-	-	-	1.61	1.43	-13%	106	94	-13%	-	-	-

Table 27. Product-perspective results for the radiata pine flat land versus steep land sensitivity analysis.

LCSA impacts (1 m <sup>3</sup> radiata pine framing)	Total cost / m <sup>3</sup> framing  (NZ\$)	Profit / m <sup>3</sup> framing  (NZ\$)	Employment / m <sup>3</sup> framing  (hours)	GHG emissions / m <sup>3</sup> framing  (kgCO <sub>2</sub> eq)	Carbon sequestered / m <sup>3</sup> framing  (kgCO <sub>2</sub> eq)
Flat land	1,194	156	6	330	696
Steep land	1,174	172	6	342	696

Table 28. Product-perspective results for the rimu flat land versus steep land sensitivity analysis.

LCSA impacts (1 m <sup>3</sup> rimu heartwood flooring)	Total cost / m <sup>3</sup> flooring  (NZ\$)	Profit / m <sup>3</sup> flooring  (NZ\$)	Employment / m <sup>3</sup> flooring  (hours)	GHG emissions / m <sup>3</sup> flooring  (kgCO <sub>2</sub> eq)	Carbon sequestered / m <sup>3</sup> flooring  (kgCO <sub>2</sub> eq)
Flat land	39,632	19,982	645	265	898
Steep land	39,818	20,002	645	290	898

## Appendix H: Discount rate sensitivity analysis

Discount rates are used to assess the net present value (NPV) of costs and benefits over time, and allow for economic comparisons between alternative scenarios. Gluch and Baumann (2004) state that when a “discount rate is set to 0% this means that the timing does not matter; the higher the discount rate the more importance is given to the near-present” (p. 575). Furthermore, a high discount rate will favour ‘short-term low capital cost options’ while a low discount rate will favour ‘future cost savings’ (Stern, 2000, p. 388).

Selection of a discount rate is critically important in LCC and indeed represents a point where value judgement plays a significant role (Gluch & Baumann, 2004). The choice of discount rate can significantly affect LCC and/or LCSA results as well as create a degree of uncertainty; performing a sensitivity analysis involving the assessment of a variety of discount rates can help to minimise uncertainty related to economic results (Hunkeler et al., 2008; Stern, 2000).

A discount rate is able to convey ‘the investor’s time preference for funds’, and is a common part of forestry investment decision making (New Zealand Institute of Forestry, 2005). Forest valuation, for example, often utilises a discount rate ranging from 7 to 9.5% (Manley, 2003). However, Barry et al. (2014) argue that forestry discount rates can range from 4% (for net public benefits) to 8% (for net private benefits). Therefore, a range of discount rates was chosen for this sensitivity analysis: 4%, 6%, and 8%. Although the cradle-to-grave timelines for each scenario vary in length (15 years for mānuka, 88 years for radiata pine, and 200 years for rimu), the discount rates did not change over time. Several authors advocate to use a discount rate which decreases over time, particularly when evaluating environmental or societal impacts (e.g. Gollier, 2002; Weitzman, 1998). However, for the purposes of this research each discount rate was applied as a constant throughout each life cycle’s timeline.

The discount rates for radiata pine are presented in Table 29, for rimu in Table 30, and for mānuka in Table 31.

Table 29. Discount rates for the radiata pine scenario (flat and steep land).

<b>Pine, FLAT, per hectare per rotation</b>	Year process occurs	m <sup>3</sup> per ha	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost /ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Nursery	0	-	584	584	584	584	-	-	-	-
Site prep	0	-	183	183	183	183	-	-	-	-
Planting	0	-	324	324	324	324	-	-	-	-
Tending	0-28	-	7,218	3,603	2,728	2,159	-	-	-	-
Opportunity cost	0-28	-	29,120	17,330	13,942	11,493	-	-	-	-
Thinning	10	-	320	234	201	173	-	-	-	-
Felling	28	761	4,297	1,433	841	498	-	-	-	-
Extraction	28	677	4,413	1,472	863	512	-	-	-	-
Skid site	28	677	6,342	2,115	1,241	735	-	-	-	-
Transport	28	650	12,829	4,278	2,510	1,487	1,949	650	381	226
Sawmill	29	92	24,205	7,761	4,467	2,598	10,181	3,265	1,879	1,093
Construction	29	92	57,185	18,336	10,554	6,138	3,431	1,100	633	368
Deconstruction	88	92	2,690	85	16	3	-	-	-	-
Landfill	88	92	9,666	306	57	11	-	-	-	-
<b>Pine, STEEP, per hectare per rotation</b>	Year process occurs	m <sup>3</sup> per ha	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost /ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Nursery	0	-	584	584	584	584	-	-	-	-
Site prep	0	-	213	213	213	213	-	-	-	-
Planting	0	-	405	405	405	405	-	-	-	-
Tending	0-28	-	9,071	4,322	3,196	2,474	-	-	-	-
Opportunity cost	0-28	-	5,824	3,466	2,788	2,299	-	-	-	-
Thinning	10	-	480	351	301	259	-	-	-	-
Felling	28	743	1,359	453	266	158	-	-	-	-
Extraction	28	646	6,727	2,243	1,316	780	-	-	-	-
Skid site	28	646	13,234	4,413	2,589	1,534	-	-	-	-
Transport	28	620	12,237	4,081	2,394	1,418	11,865	3,957	2,321	1,375
Sawmill	29	87	23,088	7,403	4,261	2,478	9,711	3,238	1,900	1,126
Construction	29	87	54,546	17,490	10,067	5,854	3,273	1,091	640	379
Deconstruction	88	87	2,566	81	15	3	-	-	-	-
Landfill	88	87	9,219	292	55	11	-	-	-	-

Table 30. Discount rates for the rimu scenario (flat and steep land).

<b>Rimu, FLAT, per hectare per rotation</b>	Year process occurs	m <sup>3</sup> per ha	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Nursery	0	-	1,618	1,615	1,614	1,613	-	-	-	-
Site prep	0	-	423	423	423	423	-	-	-	-
Planting	0	-	719	719	719	719	-	-	-	-
Tending	0-80	-	10,381	5,379	4,701	4,295	-	-	-	-
Opportunity cost	0-80	-	83,200	24,872	17,169	12,972	-	-	-	-
Pruning	8, 18, 28	-	4,845	2,516	1,895	1,464	-	-	-	-
Felling	80	92	4,784	19,095	4,160	933	-	-	-	-
Extraction	80	83	11,307	40,716	8,871	1,989	-	-	-	-
Skid site	80	83	2,158	94	20	5	-	-	-	-
Transport	80	80	1,579	5,480	1,194	268	1,109	48	10	2
Sawmill	81	3.20	1,426	190	41	9	29,698	1,239	265	58
Construction	81	2.88	34,320	4,123	881	194	14,820	618	132	29
Deconstruction	160	2.88	515	3	0	0	3,805	7	0.34	0.02
Furniture	160	2.59	69,454	339	16	1	10,939	21	1	0.05
Landfill	200	3.20	394	0.40	0.01	0	-	-	-	-
<b>Rimu, STEEP, per hectare per rotation</b>	Year process occurs	m <sup>3</sup> per ha	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Nursery	0	-	1,649	1,645	1,643	1,641	-	-	-	-
Site prep	0	-	635	635	635	635	-	-	-	-
Planting	0	-	1,078	1,078	1,078	1,078	-	-	-	-
Tending	0-80	-	10,872	5,591	4,928	4,516	-	-	-	-
Opportunity cost	0-80	-	16,640	4,974	3,434	2,594	-	-	-	-
Pruning	8, 18, 28	-	5,023	2,608	1,965	1,518	-	-	-	-
Felling	80	82	5,330	231	50	11	-	-	-	-
Extraction	80	74	12,399	538	117	26	-	-	-	-
Skid site	80	74	2,405	104	23	5	-	-	-	-
Transport	80	71	1,401	61	13	3	2,123	92	20	4
Sawmill	81	2.84	1,265	53	11	2	26,371	1,100	235	52
Construction	81	2.56	30,459	1,271	272	60	13,153	549	117	26

Deconstruction	160	2.56	457	1	0	0	3,377	6	0	0
Furniture	160	2.30	61,641	116	6	0	9,708	18	1	0
Landfill	200	2.84	349	0	0	0	-	-	-	-

Table 31. Discount rates for the mānuka scenario (flat land only).

Mānuka, per hectare per rotation	Years process occurs	tonnes per ha	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Nursery	0-13	-	28,081	25,824	24,956	24,217	-	-	-	-
Site prep	0	-	1,350	1,350	1,350	1,350	-	-	-	-
Planting	0	-	5,832	5,832	5,832	5,832	-	-	-	-
Tending	0-15	-	9,628	7,365	6,527	5,832	-	-	-	-
Opportunity cost	0-15	-	15,600	11,563	10,101	8,902				
Mānuka, per hectare per rotation	Years process occurs	Total t of brush/ ha (15 years)	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Harvest/ transport	2-15	544	30,000	21,158	18,010	15,460	-	-	-	-
Mānuka, per hectare per rotation	Years process occurs	Total kg of oil/ ha (15 years)	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Distilling	2-15	1,904	496,813	350,386	298,259	256,020	74,282	52,389	44,595	38,279
Mānuka, per hectare per rotation	Years process occurs	bottles / ha (5% of oil)	Total cost / ha	4% Total cost / ha	6% Total cost / ha	8% Total cost / ha	Profit / ha	4% Profit / ha	6% Profit / ha	8% Profit / ha
Packaging	2-15	9,712	120,917	85,313	72,621	62,336	44,130	31,136	26,504	22,750
Landfill	1-15	9,712	71	50	42	36	-	-	-	-

## Appendix I: Methodology for generating LCSA product results

### Radiata pine scenario

The following steps were taken to attain the final LCSA (cost, profit, employment, and GHG) results for the functional unit of one m<sup>3</sup> of radiata pine framing:

1. The land-use (i.e. pre-harvest) figures were summed.
2. The total land-use figure per indicator was multiplied by 0.14 (the proportional amount of framing product (92 m<sup>3</sup>) divided by the total timber produced per hectare (650 m<sup>3</sup>)) in order to allocate the impacts only to the framing product. [Note: as per the allocation recommendations of (Sandilands & Nebel, 2010a), timber waste in the sawmill process was reviewed. However, as timber waste in the sawmill is minimal (i.e. generally less than 1% of the timber entering the sawmill (Jack et al., 2013)) timber waste was therefore not accounted for in the product calculations.]
3. The figures resulting from Step 2 are then divided by the total m<sup>3</sup> of framing (92 m<sup>3</sup>) to achieve a figure as per the functional unit.
4. The product-use (i.e. post-harvest) figures were summed.
5. The figures from Step 3 and Step 4 are combined to attain the LCSA impacts for one m<sup>3</sup> of radiata pine framing.

Additional steps had to be taken to determine the carbon storage (inclusive of carbon sequestration) per functional unit during both land-use (Steps A-C) and product-use (Steps D-G):

- A. Determine the median carbon value for one radiata pine rotation (363,000 kgCO<sub>2</sub>eq per hectare). The median carbon value is used instead of the final carbon value so as to not overestimate the carbon stored.
- B. The global warming potential (GWP) factor is used in LC(S)A to describe the impact of CO<sub>2</sub> emissions/storage over time. The standard time period is 100 years. The radiata pine scenario, however, assumes a 28-year time period, and so the GWP factor was adjusted to reflect the shortened length of time that the carbon stored is removed from the atmosphere. Thus, the median carbon value for one radiata pine rotation (363,000 kgCO<sub>2</sub>eq per hectare) was multiplied by 0.28 (i.e. 28-year rotation/100-year GWP standard).

- C. The result of Step B is then allocated per m<sup>3</sup> of radiata pine framing.
- D. Once the radiata pine framing has been made, the product is assumed to be in use (i.e. carbon stored) for a total of 60 years. The end-of-life process is disposal in a landfill and, for the purposes of representing a 100-year timeframe, 40 years of “delayed release” landfill carbon storage effects were included in the calculations. As is Step B above, the GWP factor must be adjusted to reflect the shortened length of time that the carbon is removed from the atmosphere.
- E. The carbon storage value in one m<sup>3</sup> of radiata pine framing is based on the carbon content in one kg of dry wood (1.833 kg CO<sub>2</sub> (Sandilands & Nebel, 2010a)) multiplied by the density of dry radiata pine (420 kg/m<sup>3</sup> (New Zealand Institute of Forestry, 2005)). This equates to approximately 770 kgCO<sub>2</sub>eq in one m<sup>3</sup> of radiata pine framing.
- F. With approximately 9 kgCO<sub>2</sub>eq/m<sup>3</sup> released each year in the landfill (see radiata pine’s landfill process in Appendix F), then 1.2% of the carbon stored in one m<sup>3</sup> of radiata pine framing is released each year. Using the equation for ‘calculation of weighted average impact of carbon storage in products’ in the PAS2050 Annex C.1.2 (BSI, 2008) and the carbon release rate noted in Step E, the weighted GWP factor for radiata pine framing over a 100-year timeframe is 0.9 (i.e. (60 years of product use + weighted carbon emissions over 40 years)/100-year GWP standard).
- G. The result from Step E is then multiplied by the revised GWP factor of 0.9.
- H. Finally, the carbon storage value from land-use (Step C) and the carbon storage value from product-use (Step F) are combined to attain the total carbon storage for one m<sup>3</sup> of radiata pine framing.

### **Rimu scenario**

The calculation of the product-based LCSA impacts for one m<sup>3</sup> of rimu heartwood flooring followed the same steps outlined in Section 7.2.1 for radiata pine framing. The main revision made for the rimu flooring calculations was an adjustment of the assumed rimu rotation and total harvested amount of timber. These revisions were made because, unlike radiata pine, the rimu scenario is based on a continuous cover forestry regime where only 10% is harvested at year 80, and further harvestings of 10% occur every 10 years thereafter. Thus, at year 170 one full hectare of rimu (920 m<sup>3</sup>) will have been

harvested. It is important to account for one full hectare of forest growth, harvest, and product creation to align with the radiata pine and mānuka scenarios.

Other details used for the rimu calculations include: the proportional amount of heartwood flooring is 0.04 (Step 2), the total amount of heartwood flooring produced over the 170 years is 36.8 m<sup>3</sup> (Step 3), the median carbon value of one hectare of rimu is approximately 426,000 kgCO<sub>2</sub>eq and assumes gains and losses due to selective harvesting (Step A), the GWP factor is equivalent to 1 since rimu's timeline is greater than 100 years (Step B), the rimu heartwood flooring product and its subsequent recycled product of a table exist in total for 120 years and thus have a GWP factor of 1 (Step D), and the density of rimu is 490 kg/m<sup>3</sup> (Step E).

### **Mānuka scenario**

The calculation of the product-based LCSA impacts for mānuka essential oil-filled bottles followed the same steps outlined in Section 7.2.1 for radiata pine framing. The essential oil used for the 10mL bottles represents 5% of the total essential oil produced per hectare over the course of one 15-year rotation.

Other details used for the mānuka calculations include: the proportional amount of essential oil used for the 10mL bottles is 0.05 (Step 2), the median carbon value of one hectare of mānuka is approximately 102,000 kgCO<sub>2</sub>eq and assumes gains and losses due to annual trimming (Step A), the GWP factor is equivalent to 0.15 which is mānuka's 15-year rotation divided by the 100-year GWP standard (Step B), and the mānuka essential oil-filled bottle product do not have any carbon storage potential and thus have a GWP factor of 0 (Step D).

## Appendix J: Spatial suitability assessment

To demonstrate the visualisation of the forestry scenarios, a spatial analysis was carried out. The suitability for mānuka to grow was reviewed by utilising a variety of biophysical data (e.g. soil classification and drainage, temperature, rainfall, elevation, soil moisture content (Newsome, Wilde, & Willoughby, 2008)). Parameters and thresholds under which radiata pine, rimu, and mānuka may grow were attained by reviewing literature (e.g. Barton, 2008; Department of Conservation; Maclaren, 1993). In addition, current land use was considered using the Land Use Capability dataset (Newsome et al., 2008), and all valuable arable land use was removed from this assessment. Finally, in alignment with the participant's suggestions noted above, a slope threshold was applied. According to slope definitions by Forest Industries Training (2000), suitable areas for mānuka were limited to flat slopes (less than 11°), rimu was limited to steep slopes (greater than 18°), and radiata pine was placed in remaining suitable areas on steep, moderate, and flat slopes.

The resulting map (see Figure 30) indicates the potential for the Waiapu catchment to develop its land to accommodate a variety of forestry options. Further refinement and thresholds can be enacted on the data to account for forest areas which may not be viable for other non-biophysical reasons such as distance to communities or access to processing infrastructure. Therefore, it is recommended that further research is undertaken to utilise GIS (or other mapping software) to spatially display and overlay the LCSA data on the land in the Waiapu catchment.

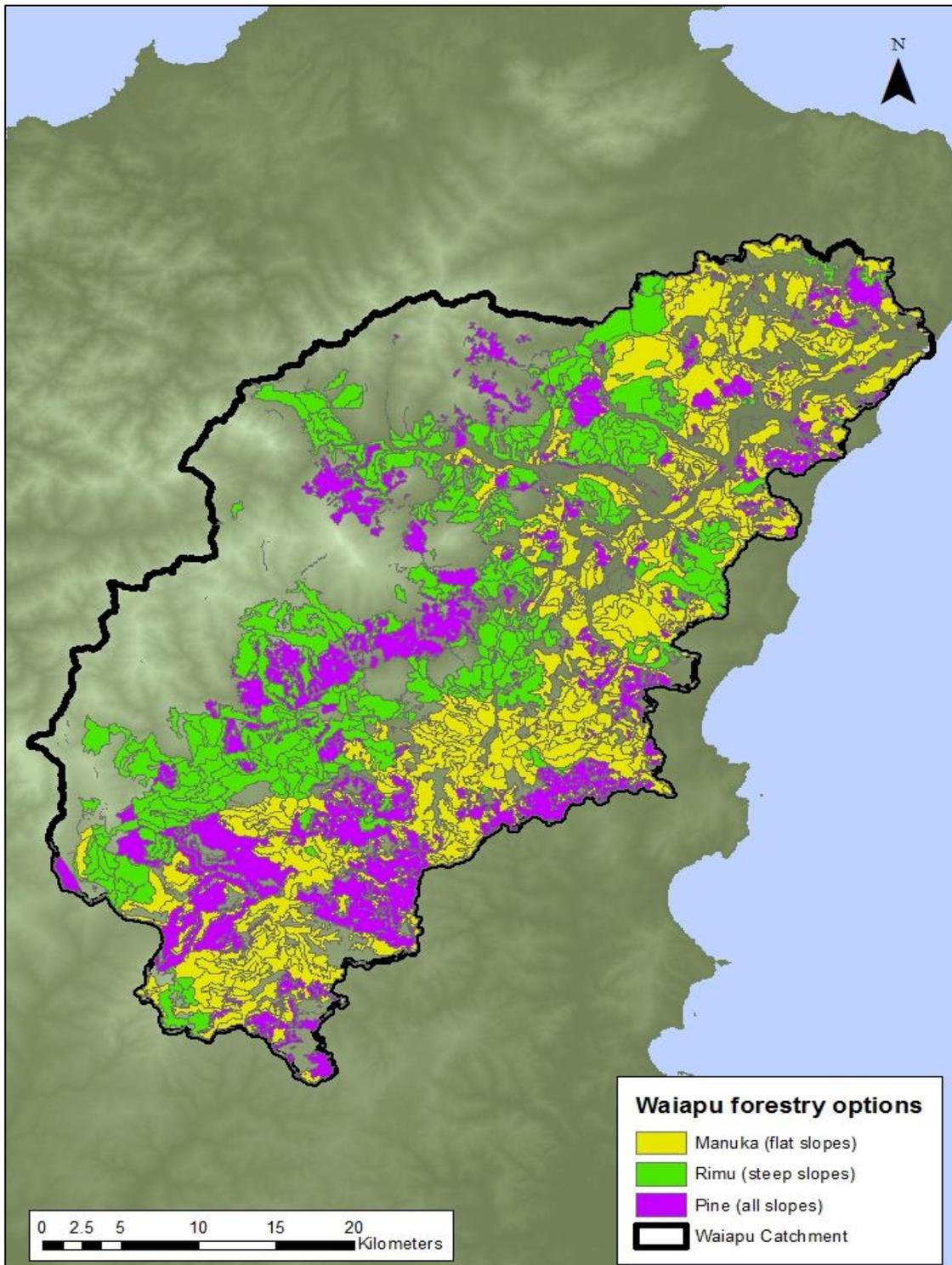


Figure 30. Spatial suitability assessment of where each of the three forestry options may be best suited according to both land- and product-based perspectives.

# Appendix K: Statements of contribution to Doctoral thesis containing publications (DRC 16 form)

DRC 16



MASSEY UNIVERSITY  
GRADUATE RESEARCH SCHOOL

## STATEMENT OF CONTRIBUTION TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Stefania Maria Pizzirani

Name/Title of Principal Supervisor: Dr Sarah McLaren

Name of Published Research Output and full reference:

Pizzirani, S., McLaren, S. J., & Seadon, J. K. (2014). Is there a place for culture in life cycle sustainability assessment? *The International Journal of Life Cycle Assessment*, 19 (6), 1316-1330. doi: DOI 10.1007/s11367-014-0722-5

In which Chapter is the Published Work: Chapter 2

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate:  
and / or
- Describe the contribution that the candidate has made to the Published Work:

The candidate performed the literature review, interpreted and reviewed the findings, and wrote the majority of the paper.

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STATEMENT OF CONTRIBUTION  
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(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Stefania Maria Pizzirani

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Name of Published Research Output and full reference:

Pizzirani, S., Forster, M. E., McLaren, S. J., Pohatu, P., Porou, T., & Warmenhoven, T. A. (in review). The distinctive recognition of culture within LCSA: realising the quadruple bottom line. *International Journal of Life Cycle Assessment*.

In which Chapter is the Published Work: A large portion of Chapters 4, 5 and 8, but also elements of Chapters 2 and 9.

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate:  
and / or
- Describe the contribution that the candidate has made to the Published Work:

The candidate developed theoretical approach, performed all interviews, created the culturally-inclusive LCSA tool and process, interpreted and reviewed the findings, and wrote the majority of the paper.

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STATEMENT OF CONTRIBUTION  
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(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Stefania Maria Pizzirani

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Name of Published Research Output and full reference:

Pizzirani, S., Hall, P., Steward, Caskey, P., McLaren, S. J. "Sustainability of radiata pine, rimu, and mānuka life cycle options in New Zealand using quadruple bottom line assessments", *New Zealand Journal of Forestry Science*, in review.

In which Chapter is the Published Work: Large sections of Chapters 3, 5, 6, and 7, and Appendix F.

Please indicate either:

- The percentage of the Published Work that was contributed by the candidate:  
and / or
- Describe the contribution that the candidate has made to the Published Work:  
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