REFORESTATION AND CLIMATE CHANGE IN BRITISH COLUMBIA
AN INSTITUTIONAL ASSESSMENT

by

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ABSTRACT

Reforestation is the most important part of any strategy intended to establish desired future forest conditions, including climate change resilience. Forest managers have a wide range of choices around forest regeneration. They can select among different tree species, genotypes, planting mixes; and silvicultural systems. Over time these choices influence forest composition, structure, and function that then affect the provision of forest values. In British Columbia (BC), climate change has been raised as major issue in terms of its current and projected impacts on forests resources, yet managing to address them remains uncommon. This raises questions about the institutional framework governing management and its influence on the capacity to use reforestation to adapt to climate change.

This study describes how climate is changing in BC, adaptations in the forest sector, and the adaptation research efforts to date. It describes the policy environment and associated regulations that direct and guide management on public land in BC and their influence on the ability to use reforestation for climate change adaptation. This includes requirements for reestablishing free growing timber stands, the treatment of silvicultural costs under the stumpage system, and the use of alternative forest stocking standards not found in government guidebooks.

Barriers to adaptive management are identified through two surveys of respondents directly involved in reforestation planning and implementation in BC. Important institutional barriers and risks to adaptation are identified as well as incentives and policy alternatives to facilitate it. Perspectives of government managers, licensees, researchers, and practitioners show a common belief that the climate is changing and that the responsibility to future generations for climate vulnerability reduction and forest resilience lies in the present. Nevertheless, differences in perspectives emerge at more operational levels and several factors may constrain the flexibility necessary for the use of adaptive reforestation strategies, especially, aversion to risk, timber supply impacts, stocking standard approval, free growing determination criteria, and silvicultural investment security. While sustainable forest management is the ideal framework for adaptation, it will not occur without policy adjustments to address these barriers and to provide an

environment in which forest resilience is a key management objective.

PREFACE

This study has been found to be acceptable on ethical grounds for research involving human subjects by the full University of British Columbia Behavioural Research Ethics Board (UBC BREB) or by an authorized delegated reviewer. The ethical review application was approved on January 8, 2011, UBCBREB Number: H10-03358.

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1. Introduction

Climate is a significant force that determines the distribution of the world's forest ecosystems, including the organisms and processes that constitute them (Holdridge, 1967; Woodward and Williams, 1987; Perry et al., 2008). It is a complex system driven by solar radiation composed of the atmosphere, oceans, land, snow, ice, surface water, and living things that evolves under its own influence as well as according to outside influences (Le Treut et al., 2007). Climate can be thought of as the average weather conditions in a geographic area over long periods of time, and it is often characterized in terms of temperature and precipitation. It has always been an important selective force in the evolution of forest ecosystems and their biota and can vary considerably between years, decades, centuries, and millennia, a reflection of short-term variability and long-term change (Holdridge, 1967; BC MWLAP, 2002; Pielke et al., 2003).

Climate is one of the principal causes for the condition of forests of the world, including the presence, absence, type, and form of trees and other vegetation, and it is often used to describe forest biomes (e.g. tropical forests, boreal forests, temperate forests). In turn, forests shape the climate through processes such as evapotranspiration and carbon sequestration. In our lifetimes, climatic conditions, including known patterns of variability, have promised at least some level of predictability in terms of tree growth, survivability, competition, and reproduction. This has facilitated the scientific development of useful tools and planning instruments, such as the system of biogeoclimatic ecosystem classification upon which modern forest management in British Columbia (BC) is based (Walker and Sydneysmith, 2007).

Increasing levels of atmospheric greenhouse gases (GHG) have been warming the atmosphere at unprecedented rates and driving global climate change (IPCC, 2007a). Since the mid to late twentieth century, fossil fuel consumption, agriculture, and land conversion have resulted in significant increases in their emissions globally (Warren and Eddington, 2007). Regardless of the sources, there is no doubt that concentrations of atmospheric carbon dioxide, the most important driver of global warming and climate change, have been steadily rising, and recently observed rates of accumulation have surpassed those projected by the International Governmental Panel on Climate Change (IPCC)[1] in its Fourth Assessment Report (AR4) (Leakey et al., 2009). In fact, mean annual atmospheric CO_2 concentration as higher in 2009 (384ppm) than it has ever been in the last 20 million years (Canadell et al. 2007; Leakey et al. 2009; NOAA 2011).

Changes in the mean condition and variability of climate factors such as precipitation and temperature are most readily experienced in the resultant short-term extreme weather events that occur as a result (Yohe and Tol, 2002). In combination with existing anthropogenic disturbances such as logging and road building, climate change and extreme events are testing the resilience limits of the socio-ecological forestry system in BC. This is exemplified in the interior regions of the province where rising mean winter temperatures, drought-like summers, an abundance of mature pine trees, and fire suppression have resulted in the unprecedented expansion of the ranges of forest pests, increased levels of infestation, and fires that have put communities, local economies, forest products industries, and ecological processes at risk (Parkins and MacKendrick, 2007; Dhar and Hawkins, 2011). Understanding the impacts of breaching ecosystem and forest management thresholds provides insight into short, middle, and long-term actions that may reduce vulnerabilities to those impacts. The ability to implement such actions in the BC forest sector depends on a number of factors or determinants of adaptive capacity.

Adaptive capacity is the ability to design and implement strategies within a system that reduce vulnerability to climate change related stimuli and to react to stresses in order to reduce the likelihood of a negative impact or seize opportunities; it requires the ability to learn from past experiences and apply lessons to future actions (Brooks and Adger, 2005). The main determinants of adaptive capacity for a community or region include economic wealth, technology, information and skills, infrastructure, institutions, and equity (Smit and Pilifosova, 2003).

[1] The IPCC is the leading international body for the assessment of climate change, established by the United Nations Environment Programme and the World Meteorological Organization, and endorsed by the UN General Assembly (IPCC, 2011).

Institutions are the rules, rights, and responsibilities of individuals and organizations that shape the way people interact with their environment (McIlgorm et al., 2010). Their design can facilitate and constrain actor's flexibility and choices including the way in which information can be used in decision-making and even the criteria for making decisions (Smit and Pilifosova, 2003). In British Columbia, the *Forest and Range Practices Act* (FRPA) and its associated legislation and policy is the principal institution guiding forest management planning and practices on public land in the province. While the FRPA regime has important implications for the ability to implement adaptation in BC forestry, willingness is just as important for adaptation to take place (Brooks and Adger, 2005).

Forest managers have essentially two primary types of actions that they can employ to affect change in the forest: they can remove trees and plant trees. Through adjustments in the way these kinds of activities are implemented, a great variety of objectives and goals can be achieved, including reducing climate change vulnerability and enhancing resilience. One activity is reforestation, which entails "re-establishing trees on denuded forest land by natural or artificial means, such as planting and seeding" (BC Ministry of Forests and Range, 2008). Through reforestation, forest managers can alter or maintain forest composition, structure, and function that in turn affect wildlife resource availability, fire risk, habitat connectivity, water quality, timber and non-timber product availability, recreational opportunities, and other values.

Reforestation is an important element of many climate change adaptation strategies in the forest sector (Spittlehouse and Stewart, 2003). For example, The Kamloops Future Forest Strategy TSA Team (2009) identified 80 forest management adaptations to reduce vulnerability to climate change impacts in the Kamloops Timber Supply Area in BC. A majority of these actions entail increasing the structural and functional diversity of forests at multiple scales. Of the actions identified, 22 involve reforestation in one form or another (The Kamloops Future Forest Strategy TSA Team 2009). Some examples of adaptive reforestation practices under climate change include (Barber, 2003):

1. Increasing diversity – increasing the number of plant species, seedlots and genotypes used to establish a new forest;

2. Facilitating migration – assisting in the transfer of species and seed sources beyond their current range, including the use of non-indigenous and exotic species;
3. Managing for species with shorter rotation lengths – such as broadleaves, including fast-growing hybrids; and
4. Selecting and breeding for adaptation and environmental stresses – planting trees selected and tested for adaptation to a broad range of environments, pest resistance or drought tolerance through provenance testing, traditional tree breeding, and biotechnology.

These adaptations emphasize the importance of reforestation as part of a comprehensive strategy to avoid and mitigate negative climate change impacts to forests and forest values, i.e. to adapt. How reforestation is governed in BC, therefore, has important implications for the ability of forest managers to utilize such strategies to reduce climate change vulnerability and increase resilience of the provincial forest land base and its values.

Climate change was not originally considered in the development of the FRPA; consequently, none of the objectives set by government for forest management in BC contain any reference to climate change nor are there any specific legal requirements for the consideration of future climate in developing strategies for public forests (Barber, 2003). To date, much research has been conducted to understand how the climate has been changing and the impacts of and sensitivities to such changes (impacts assessments), including the identification of ecosystem and management vulnerabilities (vulnerability assessments). Despite an increased understanding of impacts and vulnerability, planning and managing for climate change in public forests is still uncommon in the province (Nelson and Mathey, 2009). There remains a need to assess the feasibility of implementation of identified adaptation measures within the BC forest policy framework, and this warrants an exploration of the FRPA regime's influence on reforestation decisions in the context of climate change (Wellstead et al., 2006).

1.1. Research Goal and Objectives

This research seeks to describe how climate is changing in BC, the kinds of adaptations that exist within the forest sector, and the capacity of managers of public forests in BC to utilize reforestation to adapt to experienced and anticipated climate change impacts. It is an exploration of perspectives about climate change, adaptation, the role of forest management, and the influence that the Forest and Range Practices Act and associated laws and policies have on reforestation decisions in BC. It entails developing an understanding of the following four themes:

- Importance and acceptability of climate change and active adaptive forest management.
- Barriers to implementing adaptive reforestation practices to address climate change.
- Incentives for implementing adaptive reforestation practices under climate change.
- Needs for implementing adaptive reforestation practices under climate change.

The goal of this research is to increase the understanding of climate change and adaptation in forestry as well as the institutional factors that enhance or inhibit the use of reforestation as a tool for climate change adaptation in BC. The results could be used to:

- Inform the development of flexible forest policies that are robust under climate change.
- Develop testable hypotheses about specific laws and policies or reforestation practices thought to inhibit or promote climate change adaptation.
- Inform the development a set of diagnostic and/or predictive indicators of adaptive capacity for the forest sector in BC.

Active adaptive management is one model for the management of forest ecosystems under conditions of uncertainty. For this research, "active adaptive forest management" was defined as:

> The explicit, purposeful, and systematic testing of forest management hypotheses on-the-ground (i.e. experimentation) to develop information, increase knowledge, and build understanding through monitoring and evaluation in order to reduce the vulnerability of both forest ecosystems and management. Fundamental to this is the cyclical integration of what is learned into planning and policy development to guide new action (Stankey et al., 2005) .

Additionally, “alternative reforestation strategies” were defined as those strategies that are not currently recommended in provincial government guidelines, such as the *Establishment to Free Growing Guidebook*, the *Reference Guide for Development Plan Stocking Standards,* and other policy documents on stocking standard development and approval.

1.2. Methods

The four primary research themes were investigated through two main queries referred to as the the Adaptation Query and the Reforestation Query. The following subsections describe the methods used for each, and they follow a logical flow that employed the use of:

- Literature and document reviews.
- Attendance at key meetings of practitioners, consultants, and researchers in the fields of forest management and climate change.
- Discussions with experts in BC forest management and planning.
- Surveys.

1.2.1. Adaptation Query

The Adaptation Query consisted of a literature review, informal discussions with experts in BC forest management, a self-administered electronic survey, and participation at an international workshop on the integration of climate change adaptation and sustainable forest management.

The intent of Adaptation Query was to understand and capture expert opinions and beliefs about climate change and the use of active adaptive forest management as a strategy for implementing alternative reforestation strategies under climate change in BC. Topics explored during the literature review include:

- Observations and projections of air temperature and precipitation both globally and for BC.
- Concepts of climate change vulnerability and resilience.
- Climate change assessments, including impact, vulnerability, adaptation, integrated, and risk assessments.
- Climate change adaptation generally and in the BC forest sector.

Targeted participants for the survey included individuals with experience on the integration of climate change adaptation and forest management (e.g. through research or projects) who attended the *Climate Change Adaptation and Sustainable Forest Management Workshop* (CCA-SFM)[2] that took place at the University of British Columbia's Faculty of Forestry in Vancouver, BC, in February 2011.

The survey was created and administered using the FluidSurvey[3] online survey development software and designed using the Tailored Design Method (Dillman, 2000). It consisted of five sections:

- Opinions and beliefs about climate change and adaptive forest management.
- Opinions and beliefs about the priorities and responsibilities for implementing active adaptive forest management on public land in BC.
- Opinions and beliefs about alternative reforestation in post-harvested timber stands in BC.
- Opinions and beliefs about increasing flexibility in the use of old-growth management areas in BC.[4]
- Demographic information and experience.

This study was independent of the CCA-SFM Workshop, although the organizers felt that they shared common objectives and fully endorsed it. As such they were able to provide the email addresses of all workshop participants. Recruitment took place via email over one month, from January through February 2010. Two follow-up e-mails were sent to encourage higher response rates, one just before and another after the workshop took place.

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[2] Workshop website: http://www.forestry.ubc.ca/cca-sfm-workshop/home.aspx
[3] FluidSurveys (http://fluidsurveys.com) is a websurvey company located in Canada and as such is subject to Canadian laws.
[4] This section of the survey was ultimately omitted in order to narrow the scope of this research.

In total, 111 participants were contacted for participation and 58 responded for a response rate of 52.25%. However, of these, only 28 answered every question, for a completion rate of 48%.

The literature review revealed the utility of an active adaptive forest management approach to managing forests under conditions of uncertainty, and a number of potential institutional constraints that influence its implementation in BC forestry were identified, as well as through informal discussions with forestry practitioners (licensees, government employees, community members, consultants, researchers, etc.). This information was used to develop the survey that was distributed to the participants of the *CCA-SRM Workshop*. Chapter 2 and 3 of this thesis make up the literature review for the Adaptation Query and the survey results are presented in Chapter 5 and further discussed in Chapter 6.

1.2.2. Reforestation Query

Preliminary results from the Adaptation Query revealed a number of constraints to the implementation of active adaptive forest management and the use of alternative reforestation strategies under climate change. This information was used to conduct the Reforestation Query, which also consisted of a literature/government document review and a self-administered electronic survey.

The intent of this query was to understand the impacts of FRPA-related policies and regulations on reforestation decisions in BC and the factors that promote and constrain alternative reforestation strategies under climate change.

Targeted participants for the survey included people with experience in the process of developing/approving reforestation strategies and/or preparing/approving forest stewardship plans and stocking standards in BC.

The topics explored during the literature and government document review were:

- FRPA legislation and policies, especially that most relevant to reforestation.
- The impact of FRPA regulations and policies on reforestation decisions.

Survey: This survey was created and administered using the FluidSurvey online survey development software and designed using the Tailored Design Method (Dillman, 2000). It consisted of four main sections and several subsections:

- Opinions and beliefs about current reforestation practices and policy implementation in BC, including:
  - Stocking standards.
  - Free growing determination.
  - Stumpage appraisal.
  - Forest monitoring.
- Opinions and beliefs about climate change in BC
- Opinions and beliefs about alternative reforestation under climate change, including:
  - Strategies, risks, and barriers.
  - Incentives.
- Demographic information and experience.

Survey data was collected from individuals involved in Future Forest Ecosystem Scientific Council (FFESC) funded projects, Regional and District offices of the MFLNRO, and members of the BC Community Forest Association (BCCFA). Participation from these groups was solicited via email. In addition, a solicitation was placed in an electronic issue of the *Silviculture Magazine*[5] as well as on the *Tree Planter*[6] website, as these Canadian websites target readership that includes qualified participants. Data were collected from May through July 2011.

In total, 129 people responded to the solicitation and opened the electronic survey. Of these, 54 answered every question, for a completion rate of 42%.

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[5] www.silviculturemagazine.com
[6] www.tree-planter.com

Chapters 4 of this thesis constitutes the literature and government document review from this query. Chapter 5 presents the results of both surveys and Chapter 6 discusses the results and presents conclusions about the research themes encompassed by both queries.

2. Climate Change in British Columbia

This chapter is a literature review. It sets the stage for later chapters on climate change adaptation and forest management by identifying observed changes to climate trends as well as projections for British Columbia (BC). It begins with a description of the factors that influence BC's climate including those that drive its inherent natural variability at multiple scales. It proceeds with a presentation of observations of two indicators of climate, air temperature and precipitation, within a global context and for the last hundred years in BC. This is followed by a discussion of future climate modelling and related uncertainties. The final sections present projections of climate change, their impact on extreme climate and weather events, and the implications for forest ecosystems. This provides context for a discussion of climate change adaptation, reforestation, and the adaptive capacity needs of the BC forest management regime.

2.1. Introduction

British Columbia is one of the most physically and biologically diverse regions in all of Canada (Meidinger et al., 2005; Walker and Sydneysmith, 2007). This is a product of its vast size (95 million hectares), large-scale topography, and proximity to the Pacific Ocean, North American landmass, and the Arctic Circle (Rodenhuis et al., 2009). The most important determinants of climate and weather in the province are the mountains and the ocean, a source of significant heat and moisture over which prevailing westerly winds originate (Meidinger and Pojar, 1991). Generally, the province is mild and cool, but there are also areas with Mediterranean-type, semi-arid, subarctic, and alpine climates (Meidinger and Pojar, 1991).

In winter, the westerlies bring weather systems from the Pacific Ocean that encounter the mountains of Vancouver Island, the Queen Charlotte Islands, and the Coast Mountains as they move east, precipitating rain and snow in the higher elevations as the relatively warm air is forced upward and cools (Meidinger and Pojar, 1991). The inland valleys east of the Coastal Mountain chain are some of the driest zones in British Columbia, where cold dry air descends the mountains and is warmed as it continues across the Interior Plateau (Meidinger and Pojar, 1991). Air masses then pick up moisture as they continue and are again driven up in elevation by the Monashee, Selkirk, and Purcell Mountains, the Cariboo and Cassiar Ranges, and lastly the Rocky Mountains where they cool and precipitate (Meidinger and Pojar, 1991).

In the summer, the westerlies weaken and the climate becomes primarily driven by a high-pressure air mass over the Pacific that expands northward, reducing the severity and impact of the Pacific storms and coastal precipitation (Meidinger and Pojar, 1991). With the exception of the Great Plains region north of the Rockies, the north-south running mountain chains in the province effectively block cold continental Arctic air masses from east of the Rockies, protecting most of BC from the extreme cold experienced in the central parts of the Canada (Meidinger and Pojar, 1991).

Climate is the most important determinant of terrestrial ecosystems and contributes to the great diversity forest types across British Columbia (Meidinger and Pojar, 1991). Because of this strong link, forest ecosystems in BC are classified through an integration of three elements at three different scales: climate, vegetation, and soil at the regional, local, and chronological scales. This system is known as the biogeoclimatic ecosystem classification (BEC) and there are fourteen broad zones named after the dominant tree species in each, exemplifying the great diversity of regional and local climates and their influence on forest composition and structure (Meidinger and Pojar, 1991; Moore et al., 2010). The BEC system is the framework upon which resource management in British Columbia is based (BC Ministry of Forests and Range (MOF), 2011).

2.1.1. Spatial variability

The interaction of British Columbia's diverse topography with large-scale climate patterns contributes greatly to the variety of regional and microclimates and weather (Moore et al., 2010). Consequently, the province is divided into five physiogeographic regions with distinct climates within which the various BEC zones are located; they are the 1) Coast Mountains and Islands, 2) Northern and Central Plateaus and Mountains, 3) Interior Plateau, 4) Great Plains, and 5) Columbia Mountains and Southern Rocky Mountains (Moore et al., 2010).

These zones are useful for organizing discussions of temperature and precipitation patterns across the province, and each zone has a number of weather stations within it from which observed climate data has been summarized (Table 1). The Coast Mountains and Island's zone receives heavy precipitation and has generally mild temperatures; the Interior Plateau is much drier with more of a continental climate; the Northern/Central Plateaus and Mountains zone has evenly distributed precipitation with cool summers and cold winters that are relatively dry; the Great Plains zone experiences very short summers and long cold winters; and the Columbia and Rocky Mountain zone has warm/dry summers in the valleys with cold winters, and cooler and wetter conditions in the higher elevations (Environment Canada, 2011).

Physiographic Region	Weather Stations	Mean Temperature (°C)	Mean Rainfall (mm)	Mean Snowfall (cm)
Coast Mountains and Islands	*Vancouver*, Comox	10.1	1154.7	48.2
Northern/Central Plateaus and Mountains	*Smithers,* Aitlin	3.9	354.1	204
The Great Plains	*Fort St. John,* Fort Nelson	2	312	185
Interior Plateau	*Kamloops,* Prince George	8.9	217	75.5
Columbia Mountains and Southern Rocky Mountains	*Revelstoke,* Cranbrook	6.9	617	424.6

Table 1. Physiogeographic regions across British Columbia and climate data at selected weather stations within them. Data reported are from (Environment Canada, 2011) for weather stations at airports in the italicized locations.

2.1.2. Temporal variability

In addition to regional variability, there is also a great deal of seasonal and longer-term variability across years and decades. The Pacific pressure systems associated with changing ocean temperature and currents are especially important for BC's inter-annual and inter-decadal climate variability, having impacts on ecological systems around the world (Mantua et al., 1997; Walker and Sydneysmith, 2007). Two phenomena influenced by these systems that are particularly important for the Pacific North West are the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), and both reveal the truly dynamic nature of climate (Walker and Sydneysmith, 2007). A third phenomenon is the Atlantic Multi-Decadal Oscillation (AMO)

ENSO is an atmosphere-ocean cycle that occurs every three to seven years with two distinct phases, referred to as El Niño and La Niña, most clearly detected in the equatorial regions of the Pacific (Trenberth et al., 2007). The Southern Oscillation is the atmospheric component and driving force of the ENSO cycle. It consists of fluctuations in surface air pressure that trigger warming or cooling of sea surface temperatures (of at least ±0.5°C) on the Pacific Ocean near the International Date Line (roughly 180° longitude, in the middle of the Pacific), thereby shifting the direction of the transpacific ocean current (Trenberth et al., 2007). El Niño events are associated with a weakening of the normally westward moving trade winds which allows warm surface waters to move from the east toward the western coast of North and South America bringing warmer and drier conditions to British Columbia (Walker and Sydneysmith, 2007; Fleming and Whitfield, 2010). During La Niña events, the prevailing trade winds strengthen and the opposite occurs: warm waters spread west, facilitating an upwelling of deep cold ocean water along the Pacific coast of the Americas, generally bringing cooler and wetter conditions to British Columbia (Walker and Sydneysmith, 2007; Fleming and Whitfield, 2010). Effects of ENSO are strongest in BC in the winter and spring, and the influence on temperature tends to decrease as one moves inland from the coast; nevertheless, impacts do extend into the interior and eastern portions of the province as well as later into the year (Fleming and Whitfield, 2010). ENSO effects on precipitation are more variable and include an inverse response along the BC coast from about the northern portion of Vancouver Island and Bella Coola (Fleming and Whitfield, 2010). During El Niño events, areas south of this rough inversion line experience drier winter and spring conditions, while north of this point, wetter conditions occur during the same seasons (Fleming and Whitfield, 2010)

ENSO events create much of the annual variability in the province, and indicators of these such as sea surface temperature and sea surface height are regularly monitored. Once an ENSO event is detected, there is a reasonable degree of certainty of its influence on the Pacific Northwest climate system. Throughout the 20th century, El Niño events occurred approximately every 3 to 7 years, alternating with La Niña events, and lasted between 6 and 18 months (Mantua and Hare, 2002). The following is a list of some of the past effects of ENSO phases on the weather in British Columbia:

- 1982 - 1983, El Niño – mild winter with wet snow and numerous avalanches, flooding, and landslides across the province. Vancouver experienced only 4 cm of snow, compared to an average of 50cm (Environment Canada, 2010a).
- 1988 - 1989, La Niña – longest February cold spell in Vancouver, remaining below freezing for 16 straight days. Heavy snow fell across the province (Environment Canada, 2010b).
- 1995 – 1996, La Niña – above normal snowfall in southern BC, temperatures as low as 2°C below normal in the Yukon; a harsh winter began in late November with cold temperatures from the Yukon to northern BC, and a record one-day consumption of natural gas on the 9th of January for Vancouver (Environment Canada, 2010b).
- 1997 - 1998, El Niño – another mild winter resulting in premature thawing of logging roads and as a result, temporary mill closures in the north of the province. This was arguably the strongest ENSO event on record, and the shift to La Niña in 1998 the most dramatic episode of climate change in modern times (Peterson and Schwing, 2003).
- In 2002 - 2003, El Niño produced severe coastal storms that brought record winter warmth and destructive winds to the southwest of the province as well as the worst wildfire season in August (Levinson and Waple, 2005; Environment Canada, 2010a).

The most recent ENSO events were the 2009-2010 moderate El Niño that led to record February warmth in south eastern BC, impacting the Winter Olympics that year, and the mid-2010 La Niña that contributed to a significant blizzard across the eastern United States and parts of Canada. It appears to have persisted through January 2012 and is anticipated to weaken and dissipate through the spring of that year (NOAA, 2012)

The Pacific Decadal Oscillation (PDO) is another significant source of climate variability, although on decadal time scales rather than annual. The PDO describes changes in North Pacific sea surface temperatures that affect the strength of the winter Aleutian low-pressure system in the north Pacific, wind patterns, ocean temperatures, and biological productivity across the Pacific Northwest (Trenberth et al., 2007). It is often referred to as a long-lived ENSO-like pattern of Pacific climate variability, although the two are distinct (Mantua, 1999). During a positive phase PDO, sea surface temperatures on the eastern side of the North Pacific Ocean warm while western surface temperatures cool, resulting in an El Niño-like effect (Mantua, 1999). This causes an increased flow of warm moist air to British Columbia that brings milder winter and spring conditions with variable precipitation (Walker and Sydneysmith, 2007). Negative phases of PDO are correlated with La Niña-like climate patterns, namely cold and wet conditions for British Columbia (Mantua, 1999; Walker and Sydneysmith, 2007). PDO phases last between 20 and 30 years and the strongest signals are located in the northern Pacific Ocean, unlike ENSO, which occurs in the tropics. There have been two full PDO cycles in the 20th century: a negative phase, or cool regime, predominated from 1890 to 1924 and again from 1947 to 1976, and a positive phase, or warm regime, prevailed from 1925 to 1946 and from 1977 to 1998 (Mantua, 1999; Peterson and Schwing, 2003).

When ENSO and PDO are in the same phase (e.g. El Niño event and a positive PDO), there is a significantly stronger response in winter temperatures over western Canada, stronger than either phenomenon alone (Bonsal et al., 2003). When they are not in the same phase, weak or even opposite temperature responses occur. For example, an El Niño event during a positive phase PDO yielded almost double the summer precipitation at Nelson, BC relative to a La Niña event in the same PDO phase (Fleming and Whitfield, 2010). Despite the spatial variability, ENSO and PDO are detectable and to an extent predictable both in terms of when they will occur and their impacts on weather and ecological systems (Peterson and Schwing, 2003).

A third large-scale natural climate pattern that occurs over time that may influence BC's climate is the Atlantic Multi-decadal Oscillation (AMO). This cycle also occurs over several decades and has to do with changing sea surface temperatures over the North Atlantic Ocean (mostly between the equator and Greenland) with warm and cool phases that last for 20-40 years (NOAA, 2005). The temperature difference between each extreme is about 1°F. Currently, it is thought that AMO cycles may impact the PDO, and therefore BC climate, with effects occurring 11-12 years after an AMO oscillation (Wu et al., 2011).

2.1.3. Detecting climate change

With climate variability occurring at several scales, climate change is often difficult to detect and describe. Even in British Columbia numerous factors interact (e.g. topography and oceanic, continental, and arctic air masses) to create great diversity in climate and weather. Vancouver, for example, is significantly wetter than Lillooet, only 250 km away (1,199 mm precipitation per year, versus 329.5 mm/year) (Environment Canada, 2011). Average snowfall at Vancouver International Airport is 48.2cm, although some years have seen upwards of 240cm (Environment Canada, 2011). It may seem difficult, therefore, to determine what is within the normal range of variability and what constitutes change. Despite this, it is important to identify and measure change as even the slightest amount places social, economic and ecological, systems at risk (Parry et al., 2007). The rapid expansion and proliferation of the mountain pine beetle and the consequential catastrophic outbreaks in response to an increase of >1°C in average annual temperature is a testament to this (Carroll et al., 2006). In order to detect changes in climate and understand impacts, accurate records of the past are necessary to identify and track relevant and measurable indicators and their impact thresholds over time.

There are a number of indicators one can use to detect climate change, and their utility ultimately depends on one's objectives. Trends in air temperature and precipitation are the most relevant for detecting and measuring climate change and its impacts on physical, biological, and ecological processes upon which forest ecosystems are based. In fact, they are the foundation of a number of other commonly used indicators such glaciers, snowpack, extreme weather, sea-level, ice-cover, and streamflow (Eddington et al., 2009). Both are easily measurable and arguably have a better historical record than other indicators, so they are useful for identifying changes and making projections into the future.

The BC Ministry of Environment has reported on a number of environmental indicators since 1993 including temperature and precipitation. The most recent report on these indicators, *Environmental Trends in British Columbia 2007,* contains one of the most current overviews of observed temperature and precipitation patterns for the province. The most up to date overview, upon which this summary also draws heavily, is the product of a team of researchers from the Pacific Climate Impacts Consortium of the University of Victoria titled, *Climate Overview 2007: Hydro-climatology and Future Climate Impacts in British Columbia*, which was updated in 2009.

2.2. Observations of Air Temperature

Warming of the earth's surface, atmosphere, and oceans (i.e. global warming) is attributed to the positive radiative force of natural and anthropogenic greenhouse gases in the atmosphere from sources around the world. Radiative forcing refers to the direction and extent to which an atmospheric gas or aerosol (a suspended liquid or fine particle in the air) influences the exchange of radiant energy across the earth's atmosphere. Positive radiative forcing occurs when a gas or aerosol prevents outgoing radiant energy from escaping the earth's atmosphere into space, thereby increasing global temperatures. Gases that have a positive radiative force are called greenhouse gases because of their warming effect. Negative radiative forcing is associated with a cooling of the earth's temperature due to a reflection of incoming solar radiation by atmospheric elements. Both gases and aerosols can have a positive or negative radiative force, and each kind varies in the strength of that force. Currently, the most significant contributions to global warming are from the positive radiative force of emissions of gases from fossil fuel use, land-use change, and agricultural activities (IPCC, 2007b). The most important of these are carbon dioxide, methane, and nitrous oxide, with carbon dioxide contributing most of the global warming effect (IPCC, 2007b).

Observations show that over the last hundred years (1906-2005) average global surface air temperatures have increased by about 0.74°C (± 0.18°C), primarily in two phases between 1910 and 1940 (+ 0.35°C) and between the 1970s and the present (+0.55°C) (IPCC, 2007c). Eleven of the years between 1995 and 2006 (excluding 1996) were among the twelve warmest years since 1850, indicating an increasing rate of warming (IPCC, 2007c). In fact, the rate of warming over the last 50 years (0.13°C ± 0.03°C per decade) has been nearly twice that for the last 100 years (Solomon et al., 2007).

Global daily temperature extremes have also been changing. Since the 1950s, there has been a general increase globally in the number of extremely hot days and warm nights and a decrease in the number of extremely cold days and nights (IPCC, 2007c). In addition, changes in the mean and extreme global temperatures have not been uniform; much regional and temporal variability exists with the greatest increases having occurred in the winter, on land, and/or in the northern latitudes (IPCC, 2007a).

Warming in British Columbia has been occurring at a rate more than one and a half times faster than the average global rate for the last hundred years (1900–2004), a factor partially attributed to its high northern latitude (Rodenhuis et al., 2009). Over the last century, annual mean temperatures have increased by 2°C, annual maximum temperatures have risen 0.6°C on average, and annual minimum temperatures have increase by 1.7°C on average (Rodenhuis et al., 2009). This indicates that the province as a whole is becoming less cold, as opposed to substantially warmer, and the daily temperature range is shortening as the lowest temperatures move closer to the highs (Rodenhuis et al., 2009). Despite this, temperature trends vary seasonally and regionally across the province.

The warming trend is greatest across much of British Columbia for the winter months, especially overnight temperatures (i.e. minimum daily temperatures). Measurements in the Great Plains region in the northeast of BC (Fort St. John) show an increase in the winter overnight low of 5.3°C (± 2.8°C) in the 56 years between 1950 and 2006 (BC MOE, 2007). In the Interior Plateau in central BC (Prince George), winter overnight lows have increased by 4.0°C (± 3.0°C) during the same period (BC MOE, 2007). This trend of large increases in minimum daily winter temperatures has been observed in all five physiogeographic regions of BC but is greatest in the south-central interior and northeast regions of the province. In the Coast Mountains and Islands region, however, the greatest warming has occurred in the minimum spring temperatures; for example, the spring overnight low at Comox increased 2.2°C (± 1.5°C) between 1950 and 2006 (BC MOE, 2007). Rodenhuis et al. (2009) found a similar trend of statistically significant increases in winter and spring lows over the last hundred years (1900–2004), with the largest trends in the northeast and south-central portions of the province, although the reasons remain unclear. Over shorter periods (i.e. 50 years), maximum temperature increases have been occurring at rates comparable to minimum temperatures (Rodenhuis et al., 2009).

While only a few select weather stations in each of the physiographic regions are depicted here, there has nevertheless been a statistically significant[7] increase in minimum, mean, and maximum average temperatures at most monitoring stations across British Columbia for the period between 1950 and 2006 (BC MOE, 2007).

In summary, British Columbia is warming differentially across spatial and temporal scales, and rates of temperature increases across the province are greater than those observed globally. Minimum temperatures are increasing faster in the province than maximum temperatures, resulting in a reduction in the daily temperature range. The greatest warming has been occurring in the winter and spring months in the northern and southern-interior regions of the province (Table 1).

Observed Change in Mean Temperature (°C) During the 20th Century			
Region	Change in Mean Winter Temperature	Change in Mean Summer Temperature	Change in Mean Annual Temperature
Global	--	--	+0.13
Canada	--	--	+0.3*
British Columbia	--	--	+1.5
Coast Mountains and Islands (Comox)	+1.29	+1.4	+1.15
Northern/Central Plateaus and Mountains (Smithers)	+3.14	+0.78	+1.68
The Great Plains (Fort St. John)	+5.49	+0.62	+1.74
Interior Plateau (Prince George)	+3.70	+1.57	+2.13
Columbia Mountains and Southern Rocky Mountains (Revelstoke)	+2.41	+0.73	+1.46

Table 2. Observed changes in mean temperatures from selected climate stations (in parentheses) in each physiographic region of British Columbia from 1900 – 2006. Adapted from BC MOE (2007). * During the years 1950 – 1998, from Zhang et al. (2000).

[7] Statistically significant means there is a 95% probability that an observed trend is not due to chance (BC MOE, 2007).

2.3. Observations of Precipitation

As radiative forcing alters the global heating system, evaporation and atmospheric humidity are affected, amongst other factors, altering patterns of precipitation and the earth's hydrological cycle (Trenberth et al., 2007). Changes in the amount, frequency, intensity, duration and type of precipitation have been much more variable than temperature (Trenberth et al., 2007). Significant increases have occurred in places throughout North and South America, northern Europe and northern and central Asia, while decreases have been observed in the Sahel, Mediterranean, southern Africa and parts of southern Asia (IPCC, 2007a). Overall, it is likely that the number of areas affected by drought have been increasing since the 1970s (IPCC, 2007a).

In British Columbia, trends are just as variable as global ones, although as a whole, there has been an increase in precipitation, with the annual mean increasing by 22% in the last century (1900–2004), compared to a 12% increase across all of Canada (from 1900 – 1998) (BC MOE, 2007; Rodenhuis et al., 2009). The greatest increases have occurred in the summer months in the Interior Plateau zone (+50%), where small changes represent great percentages relative to absolute amounts, as well as in the north coast area (BC MOE, 2007; Rodenhuis et al., 2009).

An important consideration for changes in precipitation is the variability across seasons and years. Seasonally, the most significant and largest increases in precipitation occurred during the winter and spring months (BC MOE, 2007; Rodenhuis et al., 2009). Nevertheless, eastern BC has seen a decrease in annual and winter precipitation (Rodenhuis et al., 2009). Increases in annual precipitation occurred primarily between the 1920s and 1970s (Rodenhuis et al., 2009). For the 50 years between 1950 and 2001, the east of the province experienced a decrease in annual precipitation (BC MOE, 2007). With respect to extreme events, there has been a general increase in the area of land where extreme wet and extreme dry conditions occurred (Rodenhuis et al., 2009).

In summary, there has been a general increase in precipitation across the province over the last century (+22%), which is consistent with trends in the Pacific Northwest as a whole. There has also been a rise in the number of both extreme wet and extreme dry events.

However, there is great spatial and seasonal variability. The greatest increases have occurred in the Interior Plateau region and northern coast during the summer months. The greatest decreases in precipitation have occurred in the last 50 years and have been especially notable in the interior and eastern regions of the province during the winter months. Table 3 summarizes both temperature and precipitation trends for British Columbia during the 20th century.

20th Century climate trends across British Columbia				
Region	**Climate Factor**	**Snow/Rain**	**Seasonal**	**Annual**
BC	Temperature	—	Daily minimum and maximum temperatures higher in all seasons; greatest warming in spring and winter	0 °C isotherm shifting northward
	Precipitation	Decreased snow to total precipitation (more rain, less snow during cold season)		Slightly wetter (greater total annual precipitation)
Southern BC	Temperature	—	Warming in spring, fall, and winter, but not summer	—
	Precipitation	Less annual snowfall in last 50 years; ratio of rain to snow increased (more rain, less snow) in Okanagan, decreased snowpack in spring and at lower elevations	Wetter in spring, summer, fall; drier in winter, wetter in summer in Okanagan; drier in winter interior	Wetter in 20th century, with majority of increase before 1945
Northern BC	Temperature	—	Warmer winters, cooler falls	Warmer average annual temperature
	Precipitation	More snowfall since 1950s	Wetter in all four seasons	—
Coastal BC	Temperature	—	Warmer in spring and fall; Georgia Basin-Puget Sound region warming in all seasons, especially last 30 years	—
	Precipitation	—	Wetter in winter (more rain), except Georgia Basin (no trend November to March)	—

Table 3. A summary of historical climate trends across British Columbia. Adapted from Walker and Sydneysmith (2007).

2.4. Projecting Climate Change

2.4.1. Climate modelling

Contemporary global climate projections are primarily derived from computer models that simulate the earth's climate system. These are called General Circulation Models, or General Climate Models (GCMs), and they have been around in some form or another since the 1970s (Cohen and Waddell, 2009). Today, projections are made with GCMs that couple both atmosphere and ocean models and are sometimes referred to as Atmosphere-Ocean Global Climate Models, or AOGCMs. These incorporate the laws of physics in sophisticated mathematical representations of atmospheric, oceanic, and land processes and their interactions, including the influence of atmospheric gases, aerosols, global carbon cycles, and vegetation (e.g. fluid motion, atmospheric chemistry, sea ice, clouds, radiative forcing, carbon feedbacks) (Randall et al., 2007; Cohen and Waddell, 2009).

Several countries have independently developed AOGCMs, with differences and similarities in their level of complexity, resolution, parameterizations, and assumptions. One component which varies is the basic state of the climate system from which projections are based; it must be accurate enough to reflect current conditions if it is to reliably project potential future conditions (Randall et al., 2007). If this basic state is inaccurate for a particular geographic area, it may reflect an underlying misrepresentation of one or more physical and/or dynamic processes (Randall et al., 2007). Nevertheless, it is impossible for any one model to simulate every process of the climate system, so trade-offs must be made in model design and parameterization, depending on the intended use and the region of interest (Tebaldi and Knutti, 2007). Therefore, it is important that models be tested and carefully selected for the intended region and purpose. Fortunately, regular model evaluations have been on going for more than a decade, and the results are well documented (Randall et al., 2007). Programs such as that for Climate Model Diagnosis and Intercomparison and climate service organizations such as the Pacific Climate Impacts

Consortium provide accessible resources, tools, and compiled information on model evaluation and comparison, including recommendations for their application.[8]

2.4.2. Downscaling

Another important issue with respect to climate modelling is resolution, which can also vary from model to model. AOGCM resolution is coarse, with each unit of analysis or grid cell typically representing about 160,000 km^2 (Cohen and Waddell, 2009). This means that much of the climate variability due to elevation and land cover is lost, reducing the reliability of an AOGCM to make local projections and limiting its regional applications. However, there are several approaches for improving resolution, including the use of high-resolution atmosphere-only GCMs (AGCMs), variable resolution AGCMs (VRGCMs), and downscaling AOGCM data (Christensen et al., 2007). Downscaling is the most commonly used approach, for which there are two methods: dynamic and statistical.

Dynamic downscaling entails the use of high-resolution Regional Climate Models (RCMs) that draw on observed or lower-resolution AOGCM grid data to define their boundary conditions (Christensen et al., 2007). RCMs provide a 50 km scale of resolution on average and some work at scales of 15 km or even 5km, with limitations (Christensen et al., 2007). Dynamic downscaling is ideal because it can capture non-linear effects and provide information among multiple climate variables at the regional scale; however, it requires a great deal of computational power (Christensen et al., 2007).

Statistical downscaling is relatively less costly in terms of computational requirements and entails the use of observed local data statistically applied to the coarse scale AOGM data (Christensen et al., 2007). While this permits access to finer detail than the dynamic approach, it requires long term data and observed past climate variability is passed forward into projections, thereby assuming that it will remain constant, despite potential changes to variability as a consequence of global warming (Christensen et al., 2007).

[8] Program for Climate Model Diagnosis and Intercomparison and Pacific Climate Impacts Consortium: http://www-pcmdi.llnl.gov/ and http://pacificclimate.org/ , respectively.

2.4.3. Ensembles

It has become common practice to use an ensemble for climate modelling rather than only one model to project climate futures at multiple scales. Since individual models consist of different assumptions, parameterizations, and simplifications, a multi-model approach may cancel out some individual model errors and provide more "skilful" climate projections (Tebaldi and Knutti, 2007). An ensemble approach increases the reliability, consistency, and performance of model forecasts, especially when more than one diagnostic or variable is being tested, such as temperature and precipitation (Meehl et al., 2007; Tebaldi and Knutti, 2007). In addition to being able to provide estimates of plausible climate futures, an ensemble approach permits the quantification of uncertainty that, combined with the range of projections, facilitates decision making and planning (Rodenhuis et al., 2009).

2.4.4. Emission scenarios

Important drivers of climate and climate models are changes in the amounts of atmospheric gases and their radiative forces. The radiative forces of gases have a strong influence because they create shifts in the balance of earth's incoming and outgoing radiation, resulting in temperature changes in the climate system. Greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, create a warming effect because of their positive radiative force, while many anthropogenic and natural aerosols such as sulfates have a negative radiative force that result in cooling. The relative amounts of these gases in the atmosphere is a consequence of global fossil fuel consumption, changes in land-use (e.g. converting a forest for agricultural use), natural sequestration through terrestrial and marine sinks (e.g. forests and oceans), as well as the intensity of economic development which drives consumption and land-use (Canadell et al., 2007).

Assumptions about global development, therefore, are fundamental to climate projections since they largely determine the amount anthropogenic emissions contribute to the climate modelling. Such assumptions are based on emissions scenarios that are essentially storylines of future demographic development, socio-economic development, and technological change that translate into quantitative amounts of emissions over time. Such scenarios are not predictions of the future; rather, they are descriptions of plausible futures that have a direct and indirect effect on greenhouse gas emissions. The IPCC has facilitated the development of emissions scenarios for use by the global climate modelling community and has described them in detail in its 2000 Special Report on Emissions Scenarios (SRES).[9] Researchers around the world can use these standardized scenarios to produce research results that are comparable. Table 4 describes the four main families of SRES emissions scenarios in use today.[10]

SRES Scenario Family	**Basic Storyline**
A1(A1FI, A1B, A1T)	Global economic imperatives represented.
B1	Global environmental imperatives represented.
A2	Regional economic imperatives represented.
B2	Regional environmental imperatives represented.

Table 4. SRES emission scenario families and their basic storyline. Adapted from Cohen and Waddell (2009).

These families represent 40 SRES scenarios that have been prepared by the IPCC, each with its own storyline of global and regional development with differences in their environmental, economic, technological, and social dimensions (Nakicenovic and Swart, 2000). The A1 family has three groups within in it that characterize alternative technological developments: A1FI (fossil fuel intensive energy sources), A1B (balanced used of energy sources), and A1T (predominantly non-fossil fuel energy sources) (Nakicenovic and Swart, 2000). Individual scenarios within each family and/or group include quantitative interpretations of anthropogenic emissions and their radiative force for use in climate modelling. The IPCC recommends climate modellers use a range of SRES emissions scenarios from more than one family, as there is no single most likely scenario.

Carbon dioxide is the single most important driver of global warming due to its highly positive radiative force and relatively high volume of emissions. Over the last 250 years

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[9] The 2000 SRES report is available online at www.ipcc.ch.

[10] The IPCC's 5th Assessment Report, to be completed in 2013/2014, will include a new set of scenarios based on radiative forcing. Rather than starting with detailed storylines of socioeconomic pathways, the new approach begins with the identification of important characteristics for scenarios of radiative forcing that could occur under a number of different development pathways (Moss et al., 2010). The end result will be the ability to model using "representative concentration pathways," (RCP) each with a radiative forcing trajectory, rather than SRES scenarios, in climate modelling (Moss et al., 2010).

(1750–2005), the amount of carbon dioxide in the atmosphere increased by 100 parts per million (ppm[11]), with the biggest jump occurring in the last 10 of those years (Forster et al., 2007). In 2009, carbon dioxide emissions from fossil fuel burning dropped by 1.3% as a result of the global financial and economic crisis. Nevertheless, fossil fuel and cement emissions still contributed to an all-time high of 30.8 billion tons of carbon dioxide that year (8.4 ± 0.5 Pg[12] of carbon), and this figure is rising as the global economy recovers (IPCC, 2007a; Friedlingstein et al., 2010). By the end of 2009, the level of atmospheric carbon dioxide was 387.2 ppm million, up 39% above the pre-industrial era (1000–1750) and representing an overall rate of increase of 1.9 ppm per year since the year 2000 (GCP, 2010).

To date, observed rates of global atmospheric carbon dioxide accumulation have surpassed those reported by the IPCC (Canadell et al. 2007). Annual rates of increase of carbon dioxide between 2000 and 2006 were 2.9%, compared to the 0.7% increase per year through the 1990s (Canadell et al., 2007). In addition, there is evidence that global carbon sinks, such as forests and oceans have undergone a reduction in their capacity to accumulate carbon (either absolutely or relative to increasing emissions), that source regions could have intensified, and/or that sinks have transitioned to sources (Canadell et al., 2007).

2.5. Projections of Air Temperature

Global mean surface air temperature is projected to continue to increase through the 21st century as a direct result of anthropogenic greenhouse gases for all emissions scenarios (Table 5) (Meehl et al., 2007). Up through the year 2030, there is close agreement on the extent of surface warming in all the models used by the IPCC (for the B1, A1B, and A2

[11] Parts per million is an expression for the concentration of a gas in the atmosphere expressed as the ratio of two volumes. In this case it is of carbon dioxide and air. 1ppm of CO_2 is one part carbon dioxide per million parts of air.
[12] 1 Pg = 1 petagram = 1 billion tonnes = 10^{15} grams

scenarios), indicating that despite any reductions in GHG now, warming will still occur for some time (Meehl et al., 2007). It is not until the mid-21st century that the choice of emission scenario really begins to make a difference in the magnitude of warming, and by the late 21st century the differences become great as "new" emission sources based on the scenarios become introduced (Meehl et al., 2007).

Period (years)	Emissions Scenario	Change in Temperature (°C)
2011 - 2030	All scenarios	+ 0.64 to 0.69
2046 - 2065	B1	+ 1.3
	A1B	+ 1.8
	A2	+1.7
2090 - 2099	B1	+1.8 (1.1 to 2.9)
	B2	+2.4 (1.4 to 3.8)
	A1B	+2.8 (1.7 to 4.4)
	A1T	+2.4 (1.4 to 3.8)
	A2	+3.4 (2.0 to 5.4)
	A1FI	+4.0 (2.4 to 6.4)

Table 5. Multi-model mean global air surface temperature projections for the 21st century, excluding greenhouse gas mitigation emission scenarios (Meehl et al., 2007).

A direct result of the increase in emissions is warming from radiative forcing, which is expected to occur faster over land at a rate approximately twice that of the global average (Meehl et al., 2007). In addition, warming is expected to be greatest for the northern latitudes, such as in British Columbia, which is consistent with observations of the 20th century (Meehl et al., 2007). Less warming will likely occur over the southern oceans and North Atlantic (Meehl et al., 2007).

For projecting future climate in British Columbia, Rodenhuis et al. (2009) have broken up the province into seven hydro-climate regions where similar patterns of air temperature, precipitation, and hydrology occur, similar to the physiographic zones first described by Meidinger and Pojar (1991). As a starting point for the analysis of each region, they use 30 projections from a 15 GCM ensemble for the A2, B1, and A1B emissions scenarios to provide a range of plausible future temperature conditions for British Columbia. Their results are the first for British Columbia to include the latest projections prepared for the IPCC's most recent Fourth Assessment Report (AR4) (Rodenhuis et al., 2009).

At this coarse level of GCM analysis (350 km resolution), the average projection for the 2050s (i.e. 2041 – 2070) is an increase in mean annual temperature of 1.7°C (+1.2°C to +2.5°C) above the 1961-1990 baseline (Rodenhuis et al., 2009). Furthermore, one projection for the 2050s under A2, the high emission scenario, is +2.6°C warmer than the baseline (Rodenhuis et al., 2009). The ensemble average for winter and summer temperatures in the 2050s is +1.9°C (+0.5°C to +2.7°C) and 1.8°C (+1.2°C to +2.7°C) warmer, respectively, than the baseline (Rodenhuis et al., 2009). By the end of the 21st century (2070-2100), BC's annual temperature is projected to be +2.8°C (+1.5°C to +4.0°C) warmer than the 1961-1990 baseline (Rodenhuis et al., 2009).

CGM Projections of Temperature Change (°C) for the 2050s (2041–2070)			
Hydro-climate Region	**Winter**	**Summer**	**Annual**
British Columbia	+1.9	+1.8	+1.7
Columbia Basin	+1.8	+2.4	+1.9
Peace Basin	+1.9	+2.0	+1.8
North Coast	+1.5	+1.4	+1.4
North East Interior	+2.4	+1.8	+1.9
Northwest	+2.0	+1.8	+1.8
Okanagan	+2.0	+2.6	+2.1
South Coast	+1.5	+1.7	+1.5

Table 6. Average ensemble projections of 15 Global Climate Models (for A2 and B1 emission scenarios) for temperature changes in regions across British Columbia for the 2050s (2041-2070) from the 1961 – 1990 conditions. Reproduced from (Rodenhuis et al., 2009).

Dynamic downscaling with a Regional Climate Model captures more of the spatial variability attributed to topography and land cover (45 km resolution). However, due to high computational costs, (Rodenhuis et al., 2009) have reported projections from only one RCM rather than an ensemble. Nevertheless, they are the first projections using the latest version of the Canadian Regional Climate Model (CRCM4) in British Columbia, and an ensemble of RCM results is currently underway (Rodenhuis et al., 2009). Annual temperatures may increase by 2.6°C over the 1961-1990 baseline in the 2050s (2040-2070) under the A2 emissions scenario (Rodenhuis et al., 2009). Annual temperatures will likely increase the most in the north of the province, the central interior, and over the Rocky Mountains (Rodenhuis et al., 2009). The RCM shows winter warming (+3.3°C in the 2050s) increasing faster than the summertime warming (+2.3°C in the 2050s), consistent with the GCMs, although the greatest summer increases occur over the Coast Mountains (Rodenhuis et al., 2009).

In summary, both GCMs and the RCM project continued warming in British Columbia through the 21st century. The range of warming is great, both for the middle and end of the 21st century; nevertheless, even the lowest projections, +1.2°C on average for the 2050s, are still cause for concern in terms of impacts. By the end of the 21st century, warming may even be as high as 4°C on average across the province. Warming is also variable spatially, with the fastest warming expected in the northern regions of the Province as well as the southern interior. Seasonally, winter temperatures are warming faster than summer temperatures.

2.6. Projections of Precipitation

Global warming directly impacts the earth's hydrological cycle, resulting in changes to patterns of precipitation (Meehl et al., 2007). In the tropics, mean and extreme precipitation increases are anticipated, especially over the Pacific and high latitudes (Meehl et al., 2007). In the subtropics, a decrease in precipitation is expected, and in the mid-latitudes there will likely be an increase in drought risk during the summer (Meehl et al., 2007). Regardless of the direction of change (i.e. wetter or drier), an increase in the intensity of precipitation events is projected globally for the rest of the 21st century (Meehl et al., 2007).

In British Columbia, GCM ensemble averages show an increase in the percentage of precipitation in the 2050s (i.e. 2041-2070) of 6% (+3% to +11%) from the 1961-1990 baseline (Rodenhuis et al., 2009). Winter precipitation is projected to be 7% wetter (-2% drier to +15% wetter) than the baseline, while summer precipitation may decrease by 3% (-9% drier to +2% wetter) from the baseline (Rodenhuis et al., 2009). Furthermore, one projection for the 2050s under A2, the high emission scenario, is +14% wetter than the baseline (Rodenhuis et al., 2009). By the 2080s (2070-2100), the province is projected to be +10% wetter (+6% to +17%) than the baseline (Rodenhuis et al., 2009).

Hydro-climate Region	GCM Projections of Changes in Precipitation (%) for the 2050s (2041 – 2070)		
	Winter	Summer	Annual
British Columbia	+7%	-3%	+6%
Columbia Basin	+7%	-8%	+4%
Peace Basin	+8%	-4%	+7%
North Coast	+6%	-8%	+6%
North East Interior	+9%	+3%	+7%
Northwest	+10%	+4%	+8%
Okanagan	+5%	-8%	+5%
South Coast	+6%	-13%	+6%

Table 7. Average ensemble projections of 15 Global Climate Models (for A2 and B1 emission scenarios) for precipitation changes in regions across British Columbia for the 2050s (2041-2070) from the 1961–1990 conditions. Reproduced from Rodenhuis et al. (2009).

Downscaling GCM data with an RCM shows an increase of precipitation +13% above the 1961-1990 baseline (Rodenhuis et al., 2009). For the winter and summer, increases are projected to be +14% and +10% wetter, respectively, than the baseline (Rodenhuis et al., 2009).

In summary, the province as a whole will continue to get wetter; however, finer scale modelling reveals the variability, especially across the seasons. Southern BC is expected to get much drier during the summer months, and the northern regions are projected to receive a greater increase in precipitation in the winter than the rest of the British Columbia. There is a higher degree of uncertainty for projections of precipitation than for temperature, especially for the RCM (Rodenhuis et al., 2009).

2.7. Extreme Climate and Weather Events

Extreme climate and weather events directly impact disturbances such as fire, landslides, and floods, that shape forest structure and species composition and are important for understanding ecosystem impacts (Oliver and Larson 1996). Additionally, extremes are arguably the greatest climate change risk to people and communities (Oliver and Larson, 1996). These refer to both climate statistics such as very high temperatures, extreme daily rainfall, as well as more complex events such as windstorms, snowstorms, and hail (Walker and Sydneysmith, 2007). Such extreme events are part of the inherent natural variability of the BC climate, making it somewhat difficult to attribute any one event, such as a blizzard or drought, to climate change. However, changes in the duration, intensity, and frequency of extreme climate and weather events are useful indicators of change, and there is evidence that patterns of these are changing as a result of global warming (Easterling et al., 2000; Emanuel, 2005).

A climate or weather event is considered extreme when the variable in question, such as temperature or storm intensity, lies within the 10th or 90th percentile in the frequency distribution of the climate or weather phenomenon in question (Meehl et al., 2000; Trenberth et al., 2007). In other words, they are those events that lie at the extremes of a normal distribution curve for a particular occurrence. A major concern with climate change is that there will be a resultant change in the frequency and intensity of such events, with the potential to severely affect global human and natural systems. Because such events lie at the tail ends of a normal distribution, even a small change in mean conditions, variance[13], or both can have large impacts in terms of extremes (Meehl et al., 2000; Trenberth et al., 2007).

Given observed global and regional increases in temperature and precipitation minimums, maximums, and means, it is expected that there would be consequences for extremes. In fact, observations from around the world show increases in the number of extreme temperature and precipitation events, including a rise in droughts, excessively wet periods, and storms (Meehl et al., 2000; Emanuel, 2005). In Canada, for example, the number of areas experiencing extreme dry and extremely wet summer conditions has increased, and in the southwest of the country there has been a significant increase in the percentage of heavy rainfall (up to +7%) in May through July from 1950-1995 (Easterling et al., 2000). There is also a connection between the interaction of ENSO with PDO and extreme climate and weather events. During cool PDO/La Nina years, precipitation is 19% to 25% higher than during warm PDO/El Nino years (Stone et al., 2000; Rodenhuis et al., 2009). Furthermore, since warm El Nino and warm phase PDO reinforce each other, it is likely that such years also see an increase in extreme weather events (Rodenhuis et al., 2009). Modelling done by the IPCC and others since its last report (AR4) project global increases in the number of extreme high temperature events, decreases in the number of extreme

[13] Variance is a measure of how far apart a set of numbers is spread apart from one another.

low temperatures, increases in the intensity of precipitation events, and increases in droughts around the world (Rodenhuis et al., 2009). Kharin et al. (2007) summarize the observations of changes to climate extremes in British Columbia and some are listed in Table 8.

20th century Observations of Climate Extreme in British Columbia		
Region	**Climate Factor**	**Extremes**
BC	Temperature	Increased warm extremes; fewer extreme cold days and nights; fewer frost days; more extreme warm nights and days; longer frost-free period
	Precipitation	More precipitation days, decreased consecutive dry days, decreased mean daily precipitation; no consistent changes in extremes
Southern BC	Temperature	Interior warmed more than coast
	Precipitation	Wetter winter wet periods
Northern BC	Temperature	—
	Precipitation	—
Coastal BC	Temperature	Coast warmed less than the interior
	Precipitation	Less snow throughout, more than 40% less at some sites; greatest loss of snow in Pacific Northwest on south coast; more locations with no snow on April 1

Table 8. A summary of historical trends in extremes across British Columbia. Adapted from Walker and Sydneysmith (2007).

2.8. Summary

Climate is an important determinant of forest ecosystem structure, function, and process. It is one of three fundamental elements (climate, vegetation, and soils) that make up the biogeoclimatic ecosystem classification system (BEC) used widely in forestry in British Columbia and the framework upon which natural resource management in the province is based (Walker and Sydneysmith (2007). In fact, the BEC system has numerous practice and policy applications including the determination of suitable tree species for regeneration and seed transfer zones. Understanding climate variability and change is therefore very important for understanding impacts on forest ecosystems and management as well as the policies to address them.

Climates across British Columbia are driven primarily by the influences of the province's diverse topography, the Pacific Ocean, as well as the continental and Arctic air masses that originate around it. These factors, overlain with seasonal, annual, and decadal cycles such as the El Nino-Southern Oscillation and the Pacific Decadal Oscillation contribute a great deal of variability across multiple spatial and temporal scales. The influences of these phenomena have been observed and recorded both globally and for the province and are sufficiently well understood to make broad predictions about their timing and impacts on general environmental patterns. Nevertheless, the effect of recently observed and predicted climate change will have on these and other sources of variability are still poorly understood.

Two useful indicators of climate change and its impacts on physical, biological, and ecological systems are temperature and precipitation, for which historical observations in British Columbia reveal statistically significant seasonal, annual, and regional trends for the 20th century. As a whole, the province has increased in average annual temperature by 1.5°C between 1900 and 2006, compared to the global increase of 0.13°C, and there is evidence that the rate of warming is increasing. Seasonally, winter temperatures are increasing faster than summer temperatures, especially overnight lows. Regionally, the greatest increases have been observed in the southern Interior Plateau and Great Plains physiographic regions of BC. British Columbia is also getting wetter as a whole (+22% from 1900 to 2004), although regional observations at shorter time scales show that less precipitation has been occurring in portions of the province such as the Great Plains and Interior Plateau. In sum, winters are getting warmer and wetter in BC and summers getting drier while at the same time the daily temperature range is narrowing as minimum temperatures have been increasing faster than maximum temperatures, especially in the winter.

Historical climate records developed from monitoring stations and paleoclimatology have proven useful for developing and testing global climate models over the last 40 years. Today, sophisticated atmosphere-ocean coupled climate models have the capacity to make projections of future trends in temperature and precipitation that can precisely represent observed atmospheric, oceanic, and terrestrial processes and their interactions. Generally speaking, there is greater confidence in projections for the middle of the century than the end, and greater uncertainty exists for projections of precipitation than temperature.

While there is a high degree of uncertainty that any one projection is accurate, however, the use of an ensemble approach, downscaling, and high and low emission scenarios in modelling facilitates the development of a great deal of knowledge through the examination of a range of plausible scenarios of climate change at finer scales. Having a clear understanding of model limitations, assumptions, and parameterizations is important for understanding trends and identifying impacts, sensitivities, and vulnerability. Information and data produced through modelling permits the evaluation of impact thresholds, which is essential for planning and decision-making.

Recent observations of greenhouse gas emissions and atmospheric levels of carbon dioxide reveal that the world is already on a GHG emission trajectory above the A1FI scenario, the highest change scenario (+4°C globally by the 2050s) available for use in climate modelling at this time (Walker and Sydneysmith, 2007). Nevertheless, projections of future temperature and precipitation across BC under the A2, B1, and A1B scenarios, which are commonly used to represent a range of future GHG emissions in the province, depict a significant amount of alteration to the climate system (Canadell et al., 2007). For example, RCM analysis shows, on average, an increase in Okanagan winter and summer temperatures by 2°C and 2.6°C, respectively, by the 2050s. In addition, model outputs show the Okanagan becoming wetter by 5% in the winter and drier by 8% in the summer on average. By the end of this century, projections show even more dramatic changes. If this trend is accurate, then there may be a significant reduction in snowpack, perhaps earlier spring melts, and a shortage of water during a hotter growing season in the Okanagan. In addition, changes in mean temperature have already demonstrated a link with climate and weather extremes.

These and other anticipated changes will significantly affect both the ecology and management of British Columbia's forests in different ways across the province. In the past, species have responded to global warming primarily by shifting their ranges pole-ward; however with the current rapid rates of climate change, species that do not migrate will have to adapt to new conditions or face extirpation in many places (Rodenhuis et al., 2009). As a result of 20th century warming, there is evidence of such a migration as well as an upward shift in range elevation. For some species, population range shifts are directly attributed to infrequent and severe climatic events, demonstrating the importance of extremes (Kharin et al., 2007). Additionally, future novel climates, for which there are no past or present analogues, present an additional challenge, and will no doubt bring lots of "ecological surprises" (Williams and Jackson, 2007).

This raises questions about the role of forest management. What options exist for mitigating climate change and adapting to it, and what implications do they have on forest values such as timber, culture, biodiversity, and recreation? In terms of changes to forest ecosystems, should we resist it, enable ecosystem realignment, promote resilience, or do nothing and let nature run its course? The answers likely entail a combination of place specific action and inaction. Additionally, forest management will have to be coordinated and designed at the landscape level with clear objectives and targets rather than in a piecemeal fashion at the stand level. Because of the levels of uncertainty, decisions will have to be flexible and management actions will have to be designed in ways that maximize learning.

This review of the literature on climate change has provided a brief look at the level of exposure that the BC forest sector must address. It demonstrates the kind of influence that climate change has on forest ecosystems and management, and the need for action to mitigate additional negative impacts that may be in store and take advantage of any opportunities. The following chapter is a review of the literature on climate change adaptation, to understand the kinds of actions and options the BC forest sector has with respect to climate change as well as a look at what has been done so far.

3. Climate Change Adaptation

This chapter reviews the literature on climate change adaptation and draws on examples from forestry and other sectors. It defines important concepts relevant to adaptation including vulnerability and resilience and presents current approaches for assessing climate change and implementing adaptation. Lastly, a presentation of the foundation for climate change research in the BC forest sector leads to an overview of climate change assessment and adaptation efforts in the province. Important gaps in BC forest policy related to adaptation to climate change are highlighted.

3.1. Introduction

Mitigation and adaptation are two responses for addressing climate change. One aims to reduce greenhouse gas (GHG) emissions that drive change and enhance GHG sinks, such as forests, to alleviate change (mitigation). The other consists of actions to reduce the negative effects or even benefit from climate change (adaptation). Even though the timeframe and distribution of their benefits are different, adaptation and mitigation are inextricably linked as one reduces the rate and magnitude of climate change impacts and the other reduces the consequences of such impacts (Dang et al., 2003; Carter et al., 2007; Halsnaes et al., 2007). Traditionally, the mitigation response has received more attention from a scientific and policy perspective because it helps reduce impacts and because GHG emissions are relatively easy to monitor and quantify (Füssel and Klein, 2006). Adaptation, however, is the natural response for reducing the risks of unavoidable climate change. It is a response that can be efficiently implemented down to the local level without having to wait for national or international recognition or agreement to realize benefits.

In order to adapt to climate change, an understanding of the vulnerability of natural–human systems to current climate and future climate change, both with and without adaptation/mitigation, is needed (Carter et al., 2007). Fortunately, assessments of climate impacts, vulnerability, and adaptation have advanced considerably over the last decade to include methods for managing uncertainty and incorporating climate change with other sources of risk into assessments that aid decision-making and adaptation implementation (Carter et al., 2007). However, the outcomes of such assessments are highly dependent on assumptions about the capacity to implement adaptation activities that are poorly understood in many places and sectors, including forestry in BC (Carter et al., 2007).

In the BC forest sector, research has been conducted to understand how climate has been changing and the impacts of and sensitivities to such change (impacts assessments), including the identification of vulnerabilities to ecosystems and forest management (vulnerability assessments). Despite an increased understanding of climate change impacts and vulnerability, planning and managing for climate change in public forests is still uncommon in the province (Nelson and Mathey, 2009). There remains a need to assess the feasibility of implementation of identified adaptation measures within the BC forest sector. This includes identification and analysis of factors within the current forest management framework (i.e. legislation, policies, procedures, and systems that direct management) that constrain and enable adaptation efforts.

3.2. What is Climate Change Adaptation?

Numerous definitions of adaptation within the context of global climate change have been proposed, although that of the Intergovernmental Panel on Climate Change (IPCC) fairly well encapsulates them: adaptation is adjustment in natural or human systems in response to actual or expected climatic-related stimuli or their effects, which moderates harm or exploits beneficial opportunities (Smit and Wandel, 2006; IPCC, 2007d). Smit and Wandel (2006) identify evolutionary biology as the origin of the present use of the term adaptation in the context of environmental change and have traced its use in other fields within the natural and human sciences such as anthropology, sociology, cultural ecology, and political ecology.

Adaptation to climate change can take a number of forms depending on the intent, scope, extent, and effect (Smit et al., 2000). In natural systems, adaptation is primarily reactionary and occurs at the individual level, it is a response to changes that have already occurred, such as the rufous hummingbird which has dramatically expanded its winter range northward from Mexico into the United States in response to a 1°C increase in winter temperatures (Parmesan, 2006). In human or socio-economic systems, adaptation can be reactionary or anticipatory, spontaneous or planned, and widespread or localized depending on the nature of the stimulus and the processes in place that facilitate or inhibit adaptation (Smithers and Smit, 1997; Smit et al., 2000).

In order for human systems to adapt to climate-related stresses, it is helpful to have some understanding of the nature of variability and change and their impacts; the susceptibility of a system to danger (vulnerability); as well as the capacity and means to adapt (adaptive capacity) (Smit et al., 2000). In other words, to adapt to climate change, information is required on 1) what to adapt to, 2) who or what should adapt, and on 3) how to adapt and the resources required (Smit et al., 2000). In addition, options must be evaluated and implemented in ways that maximize learning and can be applied in contexts other than just climate change (Smit et al., 2000; Füssel and Klein, 2006).

Smit et al. (2000) describe the three fundamental questions that constitute adaptation: 1) adaptation to what, 2) who or what adapts, and 3) how does adaptation occur? A critical component of this framework are "non-climate forces and conditions" that influence who or what adapts. Smit et al. (2000) refer to these as "intervening conditions" characteristic of the system undergoing adaptation, and they can directly influence adaptive capacity. For example, in a coastal forest-based community, non-climate forces affecting the ability of community members to address the significant wildfire risk posed by seasonal hurricanes could include a lack of municipal funding to establish firebreaks around the community or even a lack of understanding of the relationship between hurricanes and wildfire. Such intervening conditions can be environmental, socio-cultural, or political-economic forces that influence the capacity to adapt within a system.

3.2.1. Adaptation to what?

Climate change is a very broad term that encapsulates numerous variables (e.g., temperature, rain, snow, air pressure, humidity, etc.) that build on each other to create complex events (e.g., droughts, heat waves, floods) that occur at several spatial and temporal scales and impact natural and human systems. In order for adaptation to be operational, the concept of climate change must be broken down into the factors or phenomena (e.g., rising mean winter temperatures, increasing frequency of droughts) that impact specific elements of a system (e.g., forest productivity, commercial shipping). Smit et al. (2000) refer to such phenomena as "climate-related stimuli", others have called them stresses, disturbances, hazards, or perturbations. An adaptation is an adjustment in response to a specific climate-related stimulus (herein "climate stimulus" or "stimuli") or some combination of them. These stimuli can be understood to be climate conditions (e.g., average summer temperatures), their effects (e.g., severe storms, heat waves, wild fires), as well as the impacts of those effects (e.g., changes in species' range, loss of income, water shortages), and they may be expressed in terms of risk, perceived risk, and opportunity (Smit et al., 2000). Adaptation strategies can either reduce system vulnerability to the impacts of climate stimuli or enhance the ability to better cope with them (Bedsworth and Hanak, 2010).

Climate occurs at three different scales, with different implications for the nature of resultant stimuli and adaptations to cope with them. These include:

- Means – changes in mean climate conditions (e.g., temperature); these take place over longer timeframes.
- Variability – these are changes in the variance of climate attributes such as the frequency or probability of El Niño events or seasonal temperature ranges.
- Extremes – these are generally acute events or conditions, such as droughts and storms.

Global warming affects climate processes at all three scales with implications for the most appropriate adaptive response. These scales are not necessarily independent of each other; changes in mean conditions or variance, for example, have the potential to significantly alter the frequency of extreme values.

It is useful to distinguish these scales as the adaptive response to an increase in the frequency of heat waves (extreme events), for example, is different from the response to a gradual increase in average annual winter temperatures (long-term changes in mean) (Smit et al., 2000). Of particular importance are extreme climate-related events, which are anticipated to increase in frequency and severity over time and to which many communities and systems are highly vulnerable (Schneider et al., 2007; Harford et al., 2008). Overlain on each of these levels and influencing adaptation is the rate, duration, and spatial scale at which they occur. Consequently, adaptation to climate stimuli can take on different forms depending on whether they are a response to one or more of the following (Adger et al., 2007):

- Current variability in climate and weather.
- Observed medium and long-term trends in climate.
- Long-term model-based scenarios of future climate change.

3.2.2. Who or what adapts?

Climate change adaptations refer to adjustments within a system to observed or anticipated climate stimuli that result from changes in the mean, variability, and extremes of climate attributes. An affected system can be almost anything, such as a farmer's field, a boreal forest, a local community, a forest industry, or a major city, so it must be defined in terms of its a) nature or scope (e.g., ecosystem, economic sector, social structure, or political entity), b) spatial scale (e.g., individual, community, region, nation, globe), and c) temporal scale (e.g., short, middle, long-term over) (Smit et al., 2000).

Once a system is clearly defined and delineated, the "who" or "what" of adaptation can be identified and its vulnerability to climate stimuli can be assessed. Within the BC forest sector (a system), a short-term and regional adaptation to the catastrophic mountain pine beetle outbreaks (climate stimulus) has been for the Chief Forester (who) to temporarily increase allowable levels of timber harvesting in specific management units to salvage beetle damaged timber rather than minimize economic benefit from it.

3.2.3. How does adaptation occur?

Adaptations are manifestations of adaptive capacity, and they can occur in a variety of forms through various processes (Smit and Wandel, 2006; Adger et al., 2007). Smithers and Smit (1997) and Smit et al. (2000) and have identified in the literature six common attributes present in the numerous typologies of human adaptation to climate stimuli: intent, timing, temporal scope, spatial scope, extent, and effect Figure 1.

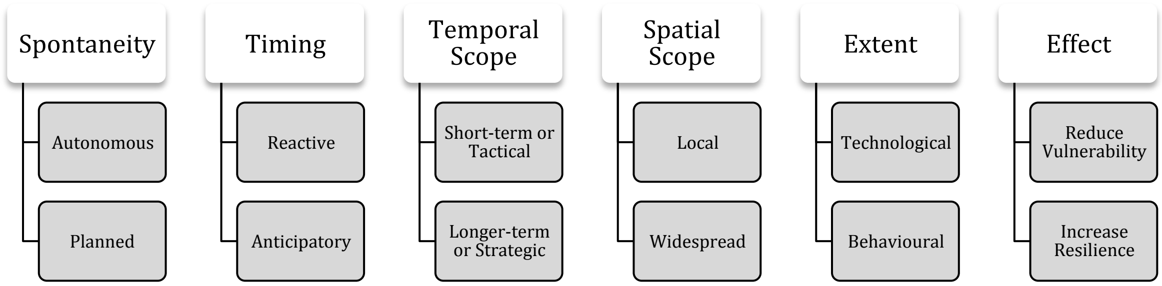

Figure 1 Typology of the forms of climate change adaptation summarized in Smithers and Smit (1997) and Smit et al. (2000).

Spontaneity:

- *Autonomous adaptation* – adaptation to climate stimuli that occurs naturally or spontaneously without forethought or planning, as in the case of unmanaged natural systems, individuals, or private actors without interventions by public agencies; these are usually reactive (Smit et al., 2000; Malik et al., 2010).
- *Planned adaptation* – adaptation that occurs deliberately and intentionally as a result of purposeful decisions, as in the case of public-level adaptation in government (Smithers and Smit, 1997; Malik et al., 2010).

Timing:

- *Reactive* – adaptation that occurs during or after climate stimuli have been observed or impacts experienced (Smit et al., 2000). Plants and animals in unmanaged natural systems are likely to adapt this way. In managed forests this might entail changing the density of trees during reforestation after having observed that a certain spacing limited overall volume production in a particular stand type and site class.
- *Anticipatory* – proactive adaptation that occurs prior to observing climate stimuli to prepare for the potential impacts. This requires foresight and planning (Smit et al., 2000).

Temporal scope:

- *Short-term* – adaptation that occurs in the short-term; in human systems, such an adaptation could be referred to as a tactical response (Smit et al., 2000). An example from forestry is creating and maintaining a firebreak within a wildland-urban interface.
- *Longer-term* – adaptation that may occur over longer periods of time such as several years or that may even become permanent; in human systems such an adaptation could be referred to as strategic response, such as selecting trees from different provenances for use during reforestation (Smit et al., 2000).

Spatial scope:

- *Local* – adaptation in response to localized risks and impacts from climate change such as action taken on the part of an individual possessing a woodlot license.
- *Widespread* – adaptation in response to broader-scale risks and impacts, perhaps at the regional, national, or international level such as a government programs to disseminate information on climate change to forest tenure holders.

Extent or form of adaptation:

- *Technological* – adaptation that attempts to "manage" climate change impacts through the use of resource technology such as utilizing more resilient seed stock for reforestation (Smithers and Smit, 1997).
- *Behavioural* – adaptation that occurs through the modification of practices of individuals, groups, or institutions such as creating a climate change secretariat to coordinate adaptation efforts or modifying forest management objectives (Smithers and Smit, 1997).

Effect:

- *Reduce Vulnerability* – adaptation reduces the impact of climate stimuli, by reducing exposure or sensitivity (Adger et al., 2007).

- *Increase Resilience* – adaptation increases the ability of a system to cope with the impacts of change and variability (Adger et al., 2007; Campbell et al., 2009).

These six attributes are commonly used to classify climate change adaptation, although others may be more useful for evaluating the appropriateness of responses or removing constraints and identifying opportunities (Smit and Pilifosova, 2003). These include characteristics such as the roles and responsibilities of individuals, communities, private and public institutions, governments, and international organizations; costliness; equity; and effectiveness (Smithers and Smit, 1997; Smit et al., 2000; Smit and Pilifosova, 2003). In addition, adaptation to climate stimuli does not occur independently of other contexts, so adaptive actions must be able to fit within a variety of existing economic, social, political, and environmental situations other than climate change. As such, climate change adaptation must address non-climate stresses in ways that are consistent with existing policy criteria, development objectives, and management structures in order to be effective (Smit and Pilifosova, 2003).

3.2.4. How is adaptation implemented in forestry?

Forestry is a social-ecological system with biological, cultural, institutional, and economic elements that are all interconnected and affected by on-going climate change. Human actions for adaptation within forestry entail reducing sensitivity to change, altering exposure to change, increasing resilience to cope with change, facilitating inevitable change, and strengthening the capacity to be able to adapt in all facets of forestry (Adger et al., 2005; Chapin et al., 2006).

One of the most important challenges to managing any system under climate change is the uncertainty. It is inherent in the timing and extent of projections of future climate, resultant climate-related events, and in the impacts of these on both human and natural systems. Despite this, change can be expected, such as in new environmental conditions, patterns of disturbance, species assemblages, and forest productivity. Such changes will influences a number of social values placed on forests such as timber, non-timber forest products, recreation, culture, biodiversity, etc.

For forest management, decisions must focus on ecological process rather than structure and composition alone (Millar et al., 2007). In addition, approaches to management that rely on the past or even the present may no longer provide reliable insight on the future; instead, approaches that assume information about a future that is inadequately known must be employed (Millar et al., 2007). This entails designing management systems to maximize learning by treating actions as experiments and permitting adjustments as understanding increases; this in turn requires increased institutional flexibility (Millar et al., 2007). Institutions are the formal and informal rules, rights, and responsibilities of individuals and organizations that shape the way people interact with their environment (McIlgorm et al., 2010).

Such an experimental approach to management can maximize learning opportunities and offer a way to reduce uncertainty. Since knowledge of ecological systems is incomplete and often difficult to achieve, there is value in tracking resource conditions and utilizing information learned as natural resources are managed in different ways (Stankey et al., 2005; Williams, 2010). Put more simply, active adaptive management is learning by doing different things and adapting based on what is learned (Williams, 2010). Active adaptive management provides a scientifically based framework that maximizes learning for policy development and future management (Stankey et al., 2005). The goal is to improve both management and understanding of natural resources through deliberate experimentation and iterative, structured decision making with objectives, action alternatives, predictions, recognition of uncertainties, and monitoring rather than *ad hoc* trial and error (Williams, 2010). In addition to the technical learning that takes place through this approach, the framework facilitates learning about the decision-making process itself, permitting process adjustments as social and institutional relations and stakeholder values evolve over time (Williams, 2010).

While the theory is sound and has been around for decades, successful implementation of the kind of active adaptive management that climate change demands has been challenging. Stankey et al. (2005) attribute the difficulty to institutional constraints on rapid knowledge acquisition, effective information flow, and processes for creating shared understanding. Nevertheless, adaptive management provides an ideal framework for designing forest management under climate change, as well as for identifying institutional needs and facilitative governance structures.

Spittlehouse and Stewart (2003) argue that climate change adaptation must begin immediately, despite a currently hazy view of the future climate, forest, and socio-economic context. Recognizing these uncertainties, they propose a number of actions to ensure effective adaptation policy under a diversity of circumstances, including:

- Establishing objectives for the future forest under climate change.
- Increasing awareness and education within the forestry community about adaptation to climate change.
- Determining the vulnerability of forest ecosystems, forest communities, and society.
- Developing present and future cost-effective adaptive actions.
- Managing the forest to reduce vulnerability and enhance recovery.
- Monitoring to determine the state of the forest and identify when critical thresholds are reached.
- Managing to reduce the impact when it occurs, speed recovery, and reduce vulnerability to further climate change.

They go on to describe a framework for planning adaptive actions that consist of four steps:

- Define the issue.
    - Example: effect of warmer annual and drier summer conditions on tree growth in southern British Columbia.
- Assess vulnerability (exposure, sensitivity and adaptive capacity)[14] of the forest, forest communities, and society.
    - Example: reduced forest regeneration success.
- Develop and undertake adaptive actions in the short term (to reduce vulnerability and enhance resilience).
    - Example: plant alternative tree genotypes or new species.

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[14] The elements of vulnerability are discussed in the following sections.

- Identify adaptations required for the future.
    - Example: modify tree seed transfer zones.

Spittlehouse and Stewart (2003) view adaptation as part of a risk management component of sustainable forest management that should be conducted at the landscape scale across all parts of the forest sector. It is a useful approach; nevertheless, their framework assumes that identified actions can and will be implemented. Wellstead et al. (2006) take this framework a step further by explaining the necessary policy component, with examples from the response to the recent mountain pine beetle epidemic in British Columbia. They describe several well-known policy process frameworks to explore how policy changes that facilitate adaptation can be incorporated into public policy; however, they do not make any explicit policy recommendations.

Spittlehouse and Stewart (2003) organize adaptive actions in forestry into seven management topics: gene management, forest protection, forest regeneration, silviculture, forest operations, non-timber resources, park, and wilderness areas (Table 9). In addition, the Kamloops Future Forest Strategy TSA Team (2009) has completed, with significant stakeholder involvement, a detailed analysis of adaptation options for the Southern Interior region of British Columbia; actions identified are likely relevant in other places across the province.

Table 9 is meant to be illustrative to provide an idea of adaptive actions in forestry, but the list is by no means exhaustive. It is important to note that although some of the objectives may be novel, the associated actions are not; they are already elements of sustainable forest management. This table also demonstrates the important role that reforestation has in climate change adaptation as most of the listed actions (e.g. planting, breeding, seed zoning, altering forest structure, enhancing forest recovery, assisting migration, reducing rotation age, etc.) are all facilitated through reforestation strategies.

An appropriate adaptation is dependent not only on the objective to reduce climate-related vulnerability, but also on other management goals and societal values for any given place and time as well as other criteria such as cost, equity, net benefit, etc.

Adaptive Management Topic	Example Adaptation (i.e. Action)	Example Goal
Gene Management	Develop climate based seed zones that change over time	Maintain genetic diversity and resilience
	Breed for pest resistance and a wider tolerance of climate stresses and extremes	
	Plant a mixture of provenances at a site	
Forest Protection	Focus protection on areas with high economic or social value, and allow fire to burn in other areas	Address potential changes in forest fire regimes
	Alter forest structure to reduce risk/extent of disturbance and increase the use of prescribed burning to minimize fuel loading	
	Enhance forest recovery after fire disturbances	
Forest Regeneration	Identify drought tolerant genotypes	Facilitate adjustment to climate change
	Assist the migration of trees from their present ranges to future ranges through artificial regeneration.	
	Plant provenances that grow adequately under a range of conditions or planting stock from a range of provenances at a site.	
Silviculture Management	Selectively thin or remove suppressed, damaged or poor quality individuals to increase growing space to remaining trees	Manage declining and disturbed stands
	Reduce rotation age followed by planting to speed establishment of better-adapted forest types	
	Reduce vulnerability to future disturbances by managing tree density, species composition, forest structure, and location and timing of management activities.	
Forest Operations	Increase the use of forest biomass energy	Address the implications of climate change on forest operations such as access to cut blocks, timber quality and availability, shifting markets , etc.
	Include adaptation planning in forest certification as part of a risk management strategy	
	Increase the amount of timber from salvage logging or fire- or insect- disturbed stands	
Non-timber Resources	Minimize habitat fragmentation and maintain connectivity across a landscape	Minimize impediments to autonomous adaptation
	Maintain representative forest types across environmental gradients	
	Maintain diversity of functional groups as well as species within groups	
Park and Wilderness Area Management	Conserve biodiversity and maintain connectivity in a varied and dynamic landscape to aid species migration	Enhance ecosystem resilience.
	Identify and plant alternate tree species	
	Manage to delay, ameliorate, and direct change.	

Table 9. Examples of climate change adaptations in forestry. From Spittlehouse and Stewart (2003).

To be able to implement adaptive management actions in forestry, institutional processes such as regulations, property rights, and social norms, must facilitate and encourage them (Adger et al., 2005). In British Columbia, this may require modifications to existing forest management guidelines, policies, regulations, and planning processes. In fact, actions to build awareness of climate change and its potential impacts, disseminate new information, provide additional incentives for adaptation, promote communication, and integrate objectives to achieve forest management under climate change constitute adaptations in themselves. The last section in this chapter explores the work completed to date to understand the capacity of the BC forest management regime to facilitate adaptation in BC.

3.3. Vulnerability and Resilience

The end result of adaptation to climate change is either a reduction in the vulnerability of the system to climate stimuli or an enhancement of its resilience. It is appropriate that a discussion of adaptation includes these concepts as they are somewhat abstract and their definition varies depending on the circumstances. In this case, the context for vulnerability and resilience is that of forestry as a social-ecological system.

3.3.1. Vulnerability

The nature and magnitude of climate change, resulting stresses, and the characteristics of an affected system have implications for the system's need and ability to adapt as well as how adaptations are prioritized and implemented (Smit et al., 2000). System characteristics that determine the nature and extent of an adaptive response climate change impacts are exposure (E) and sensitivity (S) to climate change stimuli, as well as adaptive capacity (A). These three characteristics (E, S, and A) constitute the vulnerability (V) of a natural or human system. Vulnerability is defined as the extent to which a system is susceptible to, and unable to cope with adverse effects of climate change, variability, and extremes, and it can be expressed as follows: $V = f(E, S, A)$ (Johnston and Williamson, 2007; IPCC, 2007d).

The exact interrelationship among E, S, and A depends greatly on local conditions and context, so it varies from system to system; nevertheless, vulnerability is always a positive function of a system's exposure and sensitivity, and a negative function of its adaptive capacity (Johnston and Williamson, 2007). Exposure refers to the nature and extent to which a system is exposed to climate stimuli, and sensitivity is the degree to which it is affected, positively or negatively by the stimuli (Füssel and Klein, 2006). Adaptive capacity is the ability or potential of a system to respond successfully to climate stimuli, both current or future, in order to expand its coping range (Brooks and Adger, 2005; Adger et al., 2007). This framework is useful because vulnerability can be assessed in qualitative or quantitative terms.

Numerous external and internal factors that can vary over time determine and influence the adaptive capacity of a system such as economic and natural resources, social networks, entitlements, institutions, governance, human resources, and technology (Adger et al., 2007). Even cognition can play an important role, as the way in which people perceive climate change can influence the extent to which they feel empowered to adapt (Kuruppu and Liverman, 2011). Depending on the system, adaptation may necessitate a collective willingness to adapt and general agreement on the appropriate actions. Governance mechanisms that facilitate communication and conflict resolution, therefore, are important factors that increase adaptive capacity (Brooks and Adger, 2005). A willingness to assume responsibility to adapt also implies an acceptance of risks posed by climate stimuli, which is strongly influenced by economic and ideological factors (Brooks and Adger, 2005). More recently, it has been proposed that the adaptive capacity of economies has a significant effect on overall capacity of social-economic systems, and that features and properties of economies such as the role of markets, government intervention, economic diversity, market efficiency and failure, etc., should be included when assessing adaptive capacity (Williamson et al., 2010).

Having a high adaptive capacity does not necessarily mean that actions will be taken to reduce climate change vulnerabilities (Adger et al., 2007). Adger et al. (2007) identify several "largely insurmountable" physical, ecological, and technological limits to adaptation. In addition, weak incentives as well as a poor understanding of feasibility, cost, effectiveness, and the likelihood and extent of actual implementation may discourage adaptation (Adger et al., 2007). Williamson et al. (2010) use an economic framework to understand and describe adaptive capacity and adaptive capacity deficits, or the disparity between having a high adaptive capacity and remaining vulnerabilities to climate change. Deficits in adaptive capacity arise from poorly distributed adaptive capacity, poor investment in adaptive capacity, or reduced efficiency of existing adaptive capacity assets (Williamson et al., 2010).

It is important to understand vulnerability prior to taking adaptive action, as the wrong response could increase adverse impacts. For example, in the BC southern interior, populations of Douglas-fir elicited different drought tolerances based on their provenance climates; those found in drier areas tended to be more sensitive to variability in precipitation and ambient heat moisture than populations from wetter environments. In fact, growth responses to climate variables (e.g., heat moisture) may have even induced contrary responses in Douglas-fir populations at opposite extremes of the climate spectrum (cold and wet vs. warm and dry) (Griesbauer et al., 2011). This example also demonstrates the importance of a site-based approach to assessing vulnerability that recognizes local conditions and characteristics, in this case ecological but also social, political, and economic (Johnston and Williamson, 2007).

3.3.2. Resilience

The theory of resilience was originally developed in the field of ecology to understand and explain how complex ecosystems adapt to, recover from, or change as a result of disturbances such as hurricanes, fires, or insect outbreaks that often cause catastrophic impacts to ecosystems (Gallopín, 2006; Campbell et al., 2009). In this context, resilience has been defined in two ways that reflect different concepts of stability, important for their implications on adaptive action (Holling and Gunderson, 2002).

The more traditional definition, called *engineering resilience*, is the ability of a system to resist and return to an original state after a disturbance; stability exists at a state of equilibrium, and resilience is measured as the time it takes to return to that state (Holling and Gunderson, 2002). The second definition, termed *ecosystem resilience*, is the magnitude of disturbance that can be absorbed before a system redefines its structure (i.e. moves to a new stable state) by changing the variables and processes that control behaviour (Gunderson, 2000; Holling and Gunderson, 2002). These two views of stability and resilience, ultimately have implications for how the complexity of change is evaluated, understood and managed in natural systems (Holling and Gunderson, 2002). According to *engineering resilience*, there is only one stable state, and, as an engineer's goal is typically to develop optimal systems with one operating objective, management and policy within this paradigm emphasizes system efficiency, control, constancy, and predictability (Holling and Gunderson, 2002). This can be dangerous in the context of climate change where uncertainty is great and the best or optimal approach is not known. Holling and Gunderson (2002) argue that employing the concept of *ecological resilience* is ideal for maintaining sustainable human-natural relationships in dynamic evolving systems with high uncertainty, such as forestry under climate change. Gunderson (2000) points out that in ecological systems multiple stable states can exist, and resilience can change over time, providing several examples from empirical investigations of shallow lakes, wetlands, and semi-arid rangelands.

These concepts of resilience are also useful within social systems. Resilience has been defined as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change" (Adger, 2000). Institutional structures are a key link between ecological and social resilience as they govern the use of natural resources and create incentives for sustainable or unsustainable use (Adger, 2000).

3.4. Climate Change Assessments

In the most recent IPCC Climate Change Assessment Report (AR4), Carter et al. (2007) identify four main approaches for assessing climate change impacts, vulnerability, and adaptation: 1) impact assessments, 2) vulnerability assessments, 3) adaptation assessments, 4) integrated assessments, and, more recently, a risk management approach has emerged. Füssel and Klein (2006) present an overview of the evolution of these, noting an expansion in the purpose of climate change assessment from research-oriented analyses that provide estimates of climate change risk to those that contribute to policy development. Risk management approaches have emerged has a means of directly confronting issues of uncertainty in decision-making by defining risk in terms of the probability of an event multiplied by some measure of its consequence, which can be accomplished either quantitatively or qualitatively (Carter et al., 2007). Risk management approaches are gaining favour among practitioners, policy-makers, and stakeholders as an analytic tool informed by vulnerability assessments because they are familiar in both the public and private arenas (Yohe and Leichenko, 2010). Incorporating climate change assessments and risk management approaches into existing decision-making processes that account for climate change is referred to as "mainstreaming," now a popular buzz word.

3.4.1. Impact assessments

Impacts assessments utilize a scenario approach to estimate observed and potential impacts and risks associated with climate change on natural and human systems under varying degrees of global greenhouse gas emissions (Carter et al., 2007; Joyce and Jano, 2011). These assessments typically answer questions such as, what changes in climate are likely to occur, how will projected changes affect various sectors (e.g., agriculture, water resources, fisheries, energy, forestry, tourism, health, infrastructure), what impacts are most likely to be experienced, and what level of uncertainty exists around such impacts? These are important for raising awareness of a problem, assessing the need for mitigation and adaptation, and identifying research priorities and even adaptation options. The kind of model-based projections used for impact assessments generally exist at scales too coarse and long-term for adaptation decisions, though they do explicitly explore management options to address impacts or the capacity to adapt (Füssel, 2007; Joyce et al., 2009).

3.4.2. Vulnerability assessments

Vulnerability assessments go a step further by evaluating the degree to which resources, ecosystems, and other systems and features are susceptible to impacts through consideration of both climate and non-climate factors (e.g. social, political, economic, technological) (Füssel and Klein, 2006; Carter et al., 2007). The most valuable vulnerability assessments are tailored to fit the system of interest, as such, local stakeholders must be involved to provide input based on their experiences and to link adaptation directly to their activities (Füssel, 2007; Joyce and Jano, 2011). Vulnerability assessments use a range of scenarios of future conditions to explore uncertainty and identify relevant no-regret adaptation options that are robust regardless of the resolution and reliability of climate impact projections (Füssel, 2007). Vulnerability assessments inform management planning efforts by identifying risk and recommending adaptation options to reduce vulnerability, however, they generally do not explicitly evaluate the feasibility and needs for implementing adaptation activities and increasing adaptive capacity (Carter et al., 2007; Joyce and Jano, 2011).

3.4.3. Adaptation assessments

Smit and Wandel (2006) identify four purposes for which different aspects of adaptation may be explored, each requiring different methods and producing distinct results. The first area of analysis addresses questions about climate change impact exposure, in which adaptation practices are assessed to understand the extent to which they can alleviate negative impacts or realize benefits from climate change. Such analyses are conducted at broad scales to evaluate the effect of adaptation on estimated impacts using modelling rather than empirical investigation. A second area of analysis seeks to differentiate and evaluate adaptation options to identify the best options using criteria such as cost, benefit, effectiveness, efficiency, and equity (Smit and Wandel, 2006). These two adaptation analyses typically assume that there is in place a mechanism to select and implement adaptations, and the focus is not on policy and decision-making processes required for execution (Smit and Wandel, 2006).

A third kind of analysis focuses on evaluating vulnerability, including adaptive capacity, of a system such as a community or region to provide information on where to allocate adaptation efforts and potentially scarce resources (Smit and Wandel, 2006). However, the determinants of adaptive capacity and vulnerability are not identified, nor are the necessary policies and decision-making processes for implementation addressed (Smit and Wandel, 2006).

The fourth type of analysis seeks practical application, to understand adaptive capacity and its needs in order to implement initiatives and increase adaptive capacity within a system (Smit and Wandel, 2006). Such an analysis is empirical, from the community perspective, utilizing experience and knowledge to ground an assessment of exposure, sensitivities, and adaptive capacity (Smit and Wandel, 2006). The focus is on understanding how a system experiences climate change and incorporating adaptation into existing processes and decision-making frameworks with the recognition that it must be considered in contexts other than climate change (Smit and Wandel, 2006; Carter et al., 2007). Füssel and Klein (2006) refer to this fourth kind as 'adaptation-policy assessments' to emphasize that the main purpose is to contribute to policy-development. Johnston et al. (2008) compare three approaches for such an analysis: the general approach, the community capacity approach, and the behavioural approach.

The general approach is based on a bottom-up identification of adaptive capacity determinants (e.g., economic resources, technology, political influence, information, equity) and is useful because of its broad application, practicality, ease of use for policy analysis, and intuitiveness. The community capacity approach is based on social theories of capital and risk perception. From this point of view, various forms of community capital constitute assets and resources to which access and ownership increase the capacity to adapt to sudden climate stimuli and contribute to long-term sustainability. Williamson et al. (2010) present a number of forms of community capital described in the literature, including natural, human, economic, social, political, and cultural capital. Other determinants of adaptive capacity include institutional and organizational factors that provide incentives, rules, mechanisms, tools, and means to motivate and direct adaptation and investment in adaptive capacity (Williamson et al., 2010). The community capacity approach provides an enhanced understanding of these factors, assets, and resources from the perspective of social processes and systems (Williamson et al., 2010).

The behavioural approach recognizes that investment in adaptive capacity occurs because it serves some function relative to the owner's goals and objectives, and the types of assets and their magnitude obtained are based on conscious choices (Williamson et al., 2010). Such choices are affected by rules, norms, standards, policies, regulations, institutions, markets, customs, prices, costs, and incomes (Williamson et al., 2010). This approach is useful because it recognizes that the ability to address climate change has more to do with increasing adaptive capacity assets, and that complex interactions among social systems, markets, and institutions affect the ability to realize adaptive capacity or invest in it.

3.4.4. Integrated assessments

Integrated assessments compile knowledge in a single analysis framework to provide up to date consolidated information on all aspects of climate change from which policy options and insight for prioritizing research can be drawn (Morgan and Dowlatabadi, 1996; Downing et al., 2001). "Integrated assessment is an interdisciplinary process of combining, interpreting, and communicating knowledge from diverse scientific disciplines in such a way that the whole set of cause-effect interactions of a problem can be evaluated" (Rotmans and Dowlatabadi (1998) cited in Downing et al. (2001)). These assessments utilize computer-aided modelling (integrated assessment models), stakeholder participation, and experts from several disciplines to understand complex interactions across systems, sectors, and/or spatial and temporal scales to gain policy-level insight about climate change impacts (Morgan and Dowlatabadi, 1996; Carter et al., 2007). These are commonly regional, national, or global assessments that explore the activities that give rise to GHG emissions, climate responses, impacts of climate change, ecological, human, and economic system responses (Downing et al., 2001). Integrated assessments can be useful for identifying multi-sectoral impacts, costs of impacts and adaptation measures, exploring future scenarios and adaptation options, understanding how climate change is perceived and decisions are made, and for highlighting the influence of differing development pathways on adaptive capacity (Cohen and Neale, 2006). This type of information provides some degree of clarity with respect to climate change risks and how uncertainty can be reduced and managed. Through the identification of cause-and-effect relationships and the costs of action and inaction, support is provided to decision and policy-makers seeking ways to address climate change risk in a manner that does not compromise financial and personal security or increase exposure to other sources of risk (Cohen and Neale, 2006). More recently, however, it has been argued that cost-benefit comparisons are not appropriate in the context of climate change, as many cannot be monetized. There are problems comparing present-day dollar values with future ones, and there is a great deal of uncertainty with respect to the consequences of climate change, despite sophisticated modelling (Yohe and Leichenko, 2010). Hence, a risk management approach to climate change has emerged.

Risk management

Risk is the probability of an event multiplied by some measure of its occurrence, and risk management is an iterative process that includes both mitigation and adaptation (IPCC, 2007a). Its management requires information about the impact of both high-probability low-consequence events as much as low-probability high-consequence events from climate stimuli (IPCC, 2007a; Yohe and Leichenko, 2010). Risk management provides a decision-making framework that complements cost-benefit analyses with familiar hedging approaches for dealing with uncertainty such as diversification, risk spreading, and contingency planning (Yohe and Leichenko, 2010). Such an approach acknowledges the important role of uncertainty in identifying policy objectives and initiatives (Yohe and Leichenko, 2010). Management of uncertainty and risk involves consultation and communication with stakeholders, monitoring and reviewing, improved information and flexible decision-making. Concepts of vulnerability and risk and methods of their assessment have been developed by both the natural hazard and climate change communities with similarities, differences, and opportunities for synergies (Renaud and Perez, 2010). Romieu et al. (2010) note there has been limited interaction between these two intellectual and policy communities and argue strongly for their integration toward a shared notion of vulnerability.

3.5. Adaptation in British Columbia Forestry

3.5.1. Foundation of climate change research

Haeussler (2010) has summarized a number of international, national, provincial, and regional initiatives conducting research and other work relevant to the climate change adaptation needs of the BC forest sector. At the provincial and regional level, a number of organizations have been developed, primarily since 2007, in both the private and public sectors, these include:

- BC Climate Action Secretariat (CAS) – supports municipal and regional mitigation and adaptation efforts and coordinates climate action activities across government branches and stakeholders in the province.

- BC Climate Action Team (CAT) – an interdisciplinary multi-stakeholder team, including climate scientists that provide advice to the BC provincial Cabinet Committee on actions to reduce greenhouse gas emissions within government.
- Pacific Carbon Trust (PCT) – a provincial Crown corporation that provides carbon offsets.
- Pacific Institute for Climate Solutions (PICS) - led by the University of Victoria with the University of British Columbia, Simon Fraser University and the University of Northern British Columbia, this consortium conducts research on climate change impacts, vulnerabilities, and mitigation/adaptation options. Established in 2008, its mission is to partner with governments, the private sector, researchers, and civil society to conduct research, monitor, assess potential climate change impacts, develop viable mitigation and adaptation strategies, and communicate issues to inform policy development and action (PICS, 2011).
- Pacific Climate Impacts Consortium (PCIC) - housed at the University of Victoria, this group provides information on the physical impacts of climate change.
- Northern Climate Change Network (NCCN), Resources North Association - based in Prince George, this association is the outcome of an amalgamation of the Integrated Resource Management Partnership of Northern BC and the former McGregor Model Forest Association, and it serves as an extension service for climate change and natural resource management related topics in northern BC.
- BC Climate Exchange – managed by the Fraser Basin Council, this program provides outreach and education on a variety of climate change related topics.
- FORREX – the Forum for Research and Extension in Natural Resources is an extension network based in the southern interior region of BC with more than 70 partners; it conducts research and provides services related to on climate change impacts, vulnerability, and adaptation, including in the forest sector.

In 2005, the BC Chief Forester launched the Future Forest Ecosystems Initiative (FFEI) to begin and lead the process of adapting the BC forest and range management framework to climate change. To date, this initiative has been the impetus for a number of assessments in the province, funded primarily through the Future Forest Ecosystem Scientific Council

(FFESC). The council consists of a partnership between the BC Ministry of Forests and Range (now the Ministry of Forests, Lands, and Natural Resource Operations – MFLNRO) and the Universities of British Columbia and Northern British Columbia. It was established in March 2008 to allocate and manage a $5.5 million grant-in-aid for research toward the objectives of the FFEI, including understanding and forecasting climate change impacts, developing adaptation options to reduce impacts, and evaluating economic and social consequences of impacts and adaptation measures in the forest sector (Haeussler, 2010).

PICS and PCIC have also provided significant funding for forest and climate related research in the province with a $94.5 million grant from the BC Ministry of Environment (Haeussler, 2010). PCIC was formed in 2005 by the BC Ministry of Environment, BC Hydro, and the University of Victoria's Canadian Institute for Climate Studies to promote collaboration between government, universities, and industry to reduce vulnerability to climate change impacts (Haeussler, 2010). The program is organised around four themes: hydrologic impacts, regional climate impacts, climate analysis and monitoring, and ocean influences (PCIC, 2011a). Research areas include: low carbon emissions economy, social mobilization, sustainable communities, resilient ecosystems, and carbon management in BC forests (PICS, 2011).

In 2009, the FFEI internal budget was eliminated and BC Ministry of Forests' Forest Investment Account-Forest Science Program[15] cancelled funding for new projects. Since then all non-salaried costs of FFEI work have been funded through the FFESC grant, which is due to terminate on March 31, 2012 (Haeussler, 2010). PICS and PCIC continue to fund research related to climate change and forest ecosystem and management. At the provincial and regional levels of government of BC, most climate change work is conducted by regular staff within individual departments rather than by climate change experts (Haeussler, 2010). In addition, the University of Northern British Columbia, University of

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[15] The BC Ministry of Forests' (now the Ministry of Forests, Lands, and Natural Resource Operations) Forest Investment Account has also funded a number climate related projects in the past (Haeussler, 2010). Its purpose is to provide funding for a number of government, non-government, and private entities to conduct research and implement projects that improve the public forests, increase returns from the utilization of public timber, and supports practices as a whole.

British Columbia (UBC) Vancouver, UBC Okanagan, Thompson Rivers University, and Vancouver Island University, as well as non-profit research centres such as the Columbia Mountains Institute in Revelstoke, and Bulkley Valley Research Centre in Smithers all conduct regional climate change research (Haeussler, 2010).

Climate change assessments and forestry

Climate observations and projections have been compiled for British Columbia and on-going work continues to improve the resolution of climate models to better predict the rate, magnitude and nature of climate change throughout the province (BC MWLAP, 2002; Spittlehouse, 2006; BC MOE, 2007; Christensen et al., 2007; Mbogga et al., 2009; Rodenhuis et al., 2009; UBC, 2011; PCIC, 2011b, 2011c). In addition, work has been conducted to increase understanding of the sensitivity of both the biotic and abiotic components and processes of BC forest ecosystems to climate change. Such impact assessments raise awareness of the potential scale and magnitude of climate change impacts on both ecosystems and management systems, providing a foundation for vulnerability and adaptation assessments, and while they often recognize the importance of mitigation and adaptation to address impacts, they do not directly address determinants of adaptive capacity or adaptation implementation. A number of other on-going research projects in BC related to forest ecosystems and climate change, for which results are expected in the coming years, can be found on FFESC, PICS, and PCIC websites.[16]

Utzig and Holt (2009) have conducted a broad scale impact assessment of BC ecosystems utilizing observations and projections of climate change and impacts in the published literature. Other examples of climate impact assessments for Canada and the Pacific Northwest forest sectors include those conducted by Lemmen et al. (2008); Miles et al. (2010); Gayton (2008); T. B. Williamson et al. (2008). For more recent ecosystem and climate change impacts and sensitivity literature relevant to BC not included in the Utzig

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[16] FFESC - http://www.for.gov.bc.ca/hts/future_forests/council/index.htm
PICS - http://www.pics.uvic.ca/research.php
PCIC - http://pacificclimate.org/resources/projects

and Holt assessment, see (Leith and Whitfield, 1998; Abbott et al., 2007; Aitken et al., 2008; Nitschke and Innes, 2008a, 2008b; Chhin et al., 2008; Marlon et al., 2009; Simard, 2009; Van Mantgem et al., 2009; Welsh et al., 2009; Fagre et al., 2009; Grant et al., 2009; Heineman et al., 2010; Klingenberg et al., 2010; Mather et al., 2010; Rehfeldt and Jaquish, 2010; Wang, Flannigan, et al., 2010; Wang, O'Neill, et al., 2010; Coops and Waring, 2010; Coops et al., 2010; McLane et al., 2011; Metsaranta et al., 2011; Wallis et al., 2011; CMIAE, 2011; Daniels et al., 2011; Griesbauer et al., 2011). In addition, Eddington et al., (2009) have identified a number of indicators for monitoring species and ecological processes in British Columbia, useful for identifying and responding to climate change impacts.

Only until recently have assessments of the vulnerability of forest ecosystems and management to climate change in BC been conducted. In 2009, the FFEI Vulnerability Assessment Working Group completed the first phase of a high-level climate change vulnerability assessment for provincial forest and range resources. This entailed conducting a series of workshops with topical experts and policy makers to discuss and synthesize current understanding of climate change impacts on ecosystems, to develop climate change scenario narratives to capture the implications of different scales of change on forest values and management, and to engage in a conversation about the policy implications of climate change under the forest management framework (FFEI, 2011). In addition, an integrated ecological impact assessment report was developed that incorporated the results of some of these workshops with existing background information (Utzig and Holt, 2009). This first phase was instrumental in defining the steps necessary to complete a provincial vulnerability assessment as well as synthesizing and consolidating the research, experience, and understanding of climate change impacts on the forests and their management in BC. However, a number of steps remain to complete the second phase of the assessment including an interpretation of the exposure, sensitivity, and adaptive capacity (i.e. vulnerability); a detailed assessment of forest policy from a vulnerability perspective; and identification of risks and appropriate adaptation policies (FFEI, 2011). Unfortunately, the FFEI funding freeze has left the current status of this effort unclear.

Summaries of the workshop and the ecological impact assessment report are available on the FFEI website.[17]

Also in 2009, the first national level assessment of tree species vulnerability was conducted by the Canadian Council of Forest Ministers (CCFM) (Johnston and Williamson, 2007; Johnston, 2009). This project provides information necessary to improve understanding of how and where tree species are vulnerable, management implications, adaptation options, and research needs (Johnston and Williamson, 2007; Johnston, 2009). More recently and at the regional level, Nitschke (2010) used a model-based approach to conduct a regional regeneration vulnerability assessment for tree species in the central interior of British Columbia. Additionally, the CCFM is also conducting more comprehensive research that considers climate change in a broader context to understand climate change vulnerabilities of sustainable forest management across the country, including a case study from BC to develop local decision-support tools (Johnston, 2009; Haeussler, 2010).

In 2007-08, the Kamloops Future Forest Strategy (K1) was initiated as a pilot project in the Southern Interior Region of BC by the former Ministry of Forests and Range to provide management direction for future planning processes that considers the changing context and uncertainty provided by climate change (The Kamloops Future Forest Strategy TSA Team, 2009). To date, this has been the most comprehensive vulnerability assessment to evaluate local exposure, sensitivity, and adaptive capacity, including the identification of existing institutional, regulatory, and policy barriers to implementing adaptation. K1 utilized a participatory vulnerability assessment framework to qualitatively determine ecosystem and management sensitivities to projections of climate change in workshops and recommend integrated management objectives at multiple scales to address them. Adaptive capacity was assessed on the basis of the relative ease of implementing recommendations within the existing forest management framework. The Kamloops project is currently in its second phase (K2), utilizing a participatory modelling approach to refine K1 assumptions about impacts and adaptations in the region (Nelson, 2010). K2 is

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[17] FFEI - http://www.for.gov.bc.ca/hts/future_forests/

essentially a vulnerability and adaptation assessment in that is seeks to quantify, through the use of modelling, the ability of alternative management strategies to reduce climate change vulnerability and to identify those that are robust under several change scenarios to inform management and policy decisions.

In 2009, ecological sensitivities for the Strathcona Timber Supply Area were also assessed for the BC Ministry of Forests and Range utilizing a similar participatory mental-model framework as K1. It is expected that this project will continue using the K1 experience as a prototype to identify vulnerabilities for that management unit (Symmetree Consulting Group, 2011). The West Kootenay Vulnerability Assessment is another project underway in the Southern Interior Region of the province. Like K1, this project is an integrated vulnerability assessment that utilizes mental modelling to assess ecosystem vulnerabilities and their linkages with social aspects of the BC forest system (WKF Research Team, 2011). What is unique, however, is that the West Kootenay assessment occurs across both area and volume based forest tenure types while K1 and K2 deal only with volume-based tenures within one timber supply area. It will be interesting to discover the implications of tenure type on adaptive capacity through a comparison of these assessments. Other vulnerability and integrated assessments funded by the FFESC, PICS, and PCIC that are currently under way can be found on their websites.[18]

3.5.2. Needs for adaptation

Despite the growing understanding of impacts and vulnerabilities to climate change in the forest sector and the numerous actions that have been proposed, actual adaptation of forest practices is still wanting in British Columbia. The existing disparity between local innovation and mainstream adaptive thinking with respect to climate change and forestry is due in part to a gap between identified actions for adaptation and the necessary policies to promote and facilitate them. There is a significant body of work on forest policy development and analysis, and in recent years such research has included the integration

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[18] FFESC - http://www.for.gov.bc.ca/hts/future_forests/council/index.htm
PICS - http://www.pics.uvic.ca/research.php
PCIC - http://pacificclimate.org/resources/projects

of climate change considerations into forest policies. However, for British Columbia, many questions still remain about how to do this.

This disparity is also evident in the literature. Numerous articles discuss the need to address institutional and policy barriers to reduce climate change vulnerability, however very few identify specific forest policies in BC and to date, only the K1 project has done so explicitly. Spittlehouse (2005) gives a few examples of such barriers, namely: seed planning zones, reforestation standards, hydrologic and wildlife management guidelines that have been designed with the current climate regime in mind, and a lack of requirements or guidelines for developing adaptation strategies in forest management plans. He puts forth some important questions about climate change risks to the future timber supply, parks, and protected areas and their implications for policy choices.

Wellstead et al. (2006) recognized the disparity between adaptation and policy and discuss several approaches to implement the adaptation framework for BC proposed by Spittlehouse and Stewart (2003). Nelson and Mathey (2009) have also observed that despite the growing discussion and awareness of climate change risks and vulnerabilities, there have been no significant changes in forest management plans or actions in British Columbia. They propose a modelling framework to assess forest management policy scenarios, defined by their objectives and forest management strategies, under climate change. They feel that this quantitative approach will increase opportunities for policy implementation, as opposed to the qualitative approaches that have dominated vulnerability assessments to date. This kind of scenario analysis is useful for communicating the complexity of climate change and its impacts as well as a tool for evaluating decisions for issues with high levels of uncertainty, including trade-offs (Hallegatte, 2009; Nelson and Mathey, 2009). The authors identified timber supply planning in BC as a potential medium for the incorporation of such an analysis as it relies on long term planning and modelling. This quantitative integrated modelling framework proposed by Nelson and Mathey is similar to the adaptation policy assessment described by Füssel and Klein (2006) in that it links research with policy-making to advance adaptation (Nelson and Mathey, 2009).

The FFESC has also recognized the implementation gap and recommended in 2009 that funding be allocated to projects that embed researchers in government departments to work directly with decision-makers and management staff on specific policies or guidelines (Haeussler, 2010). Nevertheless, the FFESC was unable to realize this recommendation as a result of an inflexible Ministry of Forests workplace environment and a complete hiring freeze (Haeussler, 2010). Nevertheless, out of the more than twenty FFESC funded projects, several of them do address the legal and economic implications of climate change for BC forest and range legislation and policy, though results are likely still preliminary and at this time have not been made public.

In December of 2009, PICS convened a group of more than thirty scientists and policy experts from BC and elsewhere for a workshop in Victoria to provide input into a new Resilient Ecosystems research theme to address climate change.[19] From this gathering, several important research questions emerged, and those related to adaptive management and governance were identified as a clear priority (Hall, 2009). Questions such as, "how does climate change affect the ground rules for management," "how do current government policies create incentives and disincentives related to adaptive capacity," "how do we build institutions that experiment, learn, and pass on knowledge," and "how robust are governance systems and policies for the long-term provision of ecosystem services to uncertainty and transformational change associated with climate change" reinforce the need for adaptation policy research (Hall, 2009).

In February 2011, another workshop titled *Climate Change Adaptation and Sustainable Forest Management* was held at the University of British Columbia in Vancouver. This three-day workshop featured presentations on climate change modelling, experienced and anticipated impacts on forests, and adaptation in forest management with case studies from BC, the Pacific Northwest, and around the world. There was general agreement on a number of points, including the need to translate and communicate climate change science

[19] PICS' Resilient Ecosystem research theme is one of four (Resilient Ecosystems, the Low-Carbon Emissions Economy, Sustainable Communities, and Social Mobilization) being developed to address climate change (Hall, 2009).

in meaningful ways for its incorporation into decision-making (such as in terms of risk and risk management), the need to translate ideas to action, and questions about the capacity of traditional forest institutions to adapt to climate change. Adaptive collaborative management came up a number of times as the best way to implement climate change adaptation, despite it being much easier said than done (Klenk et al., 2011). In addition, barriers to adaptation were discussed, an important one being the imbalance between the need to make management decisions under conditions of uncertainty without definitive answers to many questions and the fact that most forest management policies are evidence-based (Klenk et al., 2011).

The public forests of British Columbia represent a valuable resource and asset. Rich with environmental goods and providing countless environmental services, it is the responsibility of the government of British Columbia to ensure that these resources remain healthy to ensure they provide the greatest benefits in the long term. Often, this entails generating new information and building on existing research to reduce scientific uncertainties. Climate change presents an additional challenge for the management of these forests, and although it is costly to produce new information, it is in the best interest of the people, state, and forests that research continue to be conducted and disseminated to improve management and policy decisions. The extensive and on-going efforts to understand climate change, impacts, vulnerability, and adaptation in British Columbia should not sit idle, unemployed on the shelves of researchers. Developing means of disseminating new understanding and integrating critical lessons about climate change into daily thinking is important for adaptation to occur.

3.6. Summary

Adaptation is the natural response to unavoidable climate change. Specifically, it entails taking action to reduce the vulnerability or enhance the resilience of a system impacted by climate-related stimuli or stresses such as rising temperatures, altered ecosystem productivity, floods, and forest fires. The scale and timing of impacts are influenced by the nature of climate change (e.g., change in means, variability, or extremes of climate factors) and in turn dictate the appropriate adaptive response. Adaptation can occur in a number of ways, and in human-natural systems, such as forestry, it can be anticipatory and planned. A few examples from forestry include alternative methods of: gene management, forest protection, forest regeneration, silviculture management, forest operations, non-timber resource management, and protected area management. Identifying appropriate adaptation requires an understanding of the vulnerability to the impacts of future climate stimuli, including the capacity to adapt, as well as knowledge of place, local goals and values. Implementation requires an adaptive approach best facilitated by flexible institutions that provide additional incentives if needed, encourage the acquisition of skills to work under conditions of uncertainty, incorporate lessons iteratively into policy and management, and disseminate them as information is gained through action.

There are numerous frameworks for assessing climate change impacts and adaptation needs and even more methods and approaches for conducting them. Nevertheless, they can be organized into four broad types of assessment: impact, vulnerability, adaptation, and integrated assessments of climate change. Over the years, such assessments have expanded in scope in order to contribute to policy and decision-making.

Impact assessments are useful for raising awareness of the issues related to climate change and for highlighting a number of uncertainties, important for identifying additional research as well as the need for adaptation and mitigation efforts. The best vulnerability assessments utilize a place-based approach with local stakeholder input to understand the susceptibility of a system to climate change as well as the non-climate factors that increase or decrease its capacity to adapt. These are useful for informing management and planning process, yet they do not explicitly identify mechanisms for producing institutional change that may be necessary to enhance the adaptive capacity of a system.

Adaptation assessments are conducted for a number of purposes including to understand the extent to which an adaptation can alleviate negative impacts or realize benefits from climate change and to evaluate and select the best adaptation options. While such objectives are important, they do not address any implementation issues that may exist, such as policy or economic constraints. Nevertheless, two other objectives also housed under this category of assessment: the evaluation of adaption options and capacity in order to allocate scarce resources to maximize benefits, and the incorporation of adaptation into existing institutional processes and decision-making frameworks (i.e. adaptation-policy assessments).

Integrated assessments focus on the big picture. They compile information on impacts and vulnerability to model and understand interactions across systems and sectors as well as the costs associated with adaptation/mitigation. They are useful in that they identify cause and effect relationships as modelled impacts trickle through a system. They also assess the effects of action and inaction, primarily through cost-benefit analysis. Such assessments provide support for policy-makers because they highlight relationships within large systems and provide information necessary to balance objectives and competing interests. A complement to such a cost-benefit approach for incorporating climate change into main-stream decision-making is viewing climate change impacts as risks that must be managed, like any other. Such an approach is useful in that it allows actors to address climate change with familiar risk reduction activities such as contingency planning, implementing "no-regrets" actions, diversification, etc. A risk management approach acknowledges uncertainty and promotes flexible decision-making and policies.

In the British Columbia forest sector, climate change assessments have been under way since at least since 2005 when the Future Forest Ecosystems Initiative (FFEI) was launched. However, it has not been until relatively recently that the adaptive capacity of the forest management framework has begun to be assessed. Unfortunately, funding is currently uncertain for the completion of an assessment at the provincial level has already been on hold for the two last years. Regionally, a few projects have taken place or are underway, but to date, only the Kamloops Future Forestry Strategy project (2007-2008) has produced available results that shed light on the institutional barriers to adaptation. This project can serve as a model for current and future vulnerability and adaptation assessments. Despite the enhanced understanding provided by this project, there remains a critical need for adaptation-policy assessment that can bridge the gap between research on impacts, vulnerability, and adaptive actions and the implementation of actions in the British Columbia forestry sector. This disparity is evident in the literature, recognized by research organizations, and has been discussed repeatedly in climate change workshops and conferences throughout the province.

It is important to design public forest policies that address climate change in ways that permit management to continue to meet the values, goals, and objectives of society into the future. Granted, climate change puts into question traditional sustainable forest management (SFM) values and objectives (most are about maintaining values), meriting a dialogue with the broader BC community about the future of BC forests. Fortunately, the *Healthy Forests Healthy Communities* movement has initiated that discussion (HFHC, 2011). Nevertheless, the relatively fast rates of climate change and the long term implications of forest management actions taken today requires the implementation of adaptive actions now that will reduce vulnerability, enhance resilience, and increase learning and understanding.

Therefore, an assessment of the adaptive capacity of the BC forest management framework is critical for the development of institutional processes that are flexible enough to facilitate adaptation and evolve as societal values change and as new knowledge on the direction of climate change and its impacts is developed. An understanding of how and why existing management options and adaptive alternatives are selected by actors within the BC forestry system will shed light on the effect organizations, institutions, economics, and technology have on those choices. The following chapters initiate such as assessment. They utilizes reforestation in BC to ground an examination of the influence of the current forest management framework on BC's capacity to implement adaptation recommendations. It answers specific questions about the influence of a number of components of the BC forest policy framework on decisions made by the actors responsible for managing the public forests of British Columbia.

4. Reforestation and the BC Forest Management Regime

This chapter lays the foundation for an institutional analysis of the capacity to utilize reforestation as part of a climate change strategy in BC. It presents the BC forest management regime, i.e. the institutional framework for forest management in the province, specifically the Forest and Range Practices Act, and how it may affect the reforestation decisions and strategies of timber tenure holders.

4.1. Introduction

On average, about 165,000 hectares of forest is harvested annually in British Columbia.[20] While this may not seem like much, over 10 years it amounts to approximately 1.65 million hectares of forest requiring some form of reforestation after logging. According to the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), in addition to provincial regeneration needs from ongoing logging, there remain about 236,000 ha of forestland requiring reforestation from past logging and other natural disturbances such as wildfire and pests[21] (Snetsinger, 2011). On top of all this, by 2010, 17.5 million ha of land had experienced some level of mortality from the mountain pine beetle with up to 775,000 ha having the potential to become not satisfactorily restocked (Snetsinger, 2011). The total figure of land that is in need of reforestation across the province is the subject of a large debate amongst forest professionals and the public in the province. Some argue that the amount is well above the figure the MFLNRO has published and estimate it at over nine million hectares, an area three times the size of Vancouver Island (Britneff, 2011). Regardless of the debate, considering the extent of regularly occurring logging, wildfire, pest outbreaks, disease, and other natural disturbances on public forestland, the importance of reforestation efforts is clear.

Climate change impacts on the frequency and intensity of natural disturbance events put at risk a number of forest values and further emphasize the important role reforestation has

[20] That is about 412 times the area of Stanley Park.

[21] 149,000 ha from disturbances (including logging) that occurred prior to 1987 and 87,000 ha from disturbances (excluding logging) that occurred after 1987. In 1987, there was a major change in BC to include the requirement for reforestation after logging.

in meeting value-based objectives other than timber production. Adaptations in forest management thought to be robust under observed trends in climate change and the uncertainty of future impacts include (Spittlehouse and Stewart 2003):

- Utilizing planting stock from a mixture of provenances or provenances that grow well under a range of conditions.
- Altering forest structure to reduce the risk and extent of disturbance.
- Enhancing forest recovery after fire disturbances.
- Utilizing drought tolerant tree genotypes.
- Assisting the migration of trees from their present ranges to future ranges.
- Managing tree densities, species compositions, and forest structure.
- Minimizing habitat fragmentation.
- Maintaining habitat connectivity in a varied and dynamic landscape.
- Identifying and planting alternate tree species.

All of these adaptations involve reforestation practices at some level, whether the selection of seed stock from different provenances, the choice of tree species to plant, experiments with planting densities, or the utilization of enhanced genotypes. Current and future reforestation strategies in BC could play a large part in the implementation of these and many other climate change adaptations in forestry. The capacity to adapt to climate change therefore depends in part on a flexible system of forest governance that facilitates and promotes the use of reforestation research and science-based planning and practices to meet a number of social, environmental and economic objectives.

This chapter examines the influence of the rules and policies in BC that direct and guide forest management on public forestland available for timber harvesting. This is a first step in understanding the regulatory and policy opportunities, barriers, and needs for the use of reforestation strategies to implement climate change adaptation. Relevant legislation, regulations, policies, and other guidance that steer forest management are presented and their influence on reforestation planning and practices is discussed in each of the following chapter sections:

- Forest tenures
- Annual allowable cut
- Forest stewardship plans
- Land use plans
- Stocking standards, regeneration delay, and free growing
- Standards for seed use

4.1.1. The forested landbase

Approximately 55 million hectares, or nearly 60%, of BC's 95 million ha land base is forested and timber harvesting is considered to be acceptable and feasible on about 22 million hectares (40%) of this (British Columbia, 2010). Approximately 14.1 million hectares of the forestland base is protected, primarily within provincial and federal parks (British Columbia, 2010). In terms of percentages, the timber harvesting land base (THLB) represents about 40% of the forestland base and protected forests constitute roughly 26%. The Chief Forester determines the amount of timber that can be extracted from management units on the THLB across the province, and this amount has remained relatively stable between the years 2000-2010 at around 69 million cubic meters of timber (British Columbia, 2010).

The public owns 95% of all land in British Columbia,[22] private owners hold 4%, and First Nations own about 0.24%. In 2009, 52% of the harvestable timber on public land was held in large, long-term licenses with approximately 44% of the total volume controlled by the 10 largest companies operating in the province. The other 48% was held in smaller short-term licenses such as Community Forest Agreements, woodlots, and First Nation Woodland Agreements (British Columbia, 2010).

4.1.2. The forest management regime

Management of the BC forestland is governed through expectations that originate in both the legal and non-legal realms. The legal realm consists of a framework of legislation,

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[22] Of this, 94% is provincially owned and 1% federally owned.

professional standards of conduct, and principles of common law established through the courts. The non-legal realm consists of societal expectations and obligations that are informed by scientific and technical knowledge (Reader, 2006). Together, these two realms form a performance-based framework for forest management that enables informed professional judgments to be made about the development and implementation of forest plans and practices on public land. The framework contains several levels of accountability for practicing experts. There are also a series of restrictions and performance standards that seek to ensure a balance among social, economic, and environmental values. Collectively, the legal and non-legal realms make up the BC forest management regime and provide direction and guidance for reforestation practices in the province.

Public forests are primarily managed through a system of tenure that allocates timber harvesting rights to license holders as well as the responsibility to practice sustainable management toward a number of social, economic, and environmental objectives. Forest management planning and practices such as the determination of harvesting levels, road building, logging activities, and silviculture are governed primarily through the *Forest and Range Practices Act* (FRPA), the *Forest Planning and Practices Regulation* (FPPR), and the *Forest Act*. Natural resource professionals charged with developing and implementing management plans are governed primarily through their professional associations that are empowered through additional legislation such as the *Forester's Act*. Other supporting federal and provincial statutes relevant to forest management and practices include the *Land Act*, *Heritage Conservation Act*, *Wildlife Act, Fisheries Act*, and *Species at Risk Act*, amongst others.

Resource management professionals play an important role within the BC forest management regime. The results-oriented nature of FRPA and associated Acts[23] compel practicing resource professionals, upon whose judgment and advice government officials, licensees, and society rely for the sound management of forest resources, to be stewards of BC's public forests. This concept of "professional reliance" is engrained in the BC forest

[23] Associated Acts includes the Forester's Act, the College of Applied Biology Act, and the Agrologists Act.

management regime, and with this freedom and responsibility for management comes "professionally accountability." This means that resource professionals must act within the legal expectations created by both the statutory regimes that apply to their profession as well as those created by common law principles of civil liability[24] (Reader, 2006).

Professional reliance and accountability also extend into the non-legal realm through societal expectations, as a great majority of the forested landbase is publicly owned and open for the use and enjoyment of all. This source of expectations is arguably more important than those from the legal realm as the freedoms provided by FRPA to manage public forest resources are only bestowed to those professionals that succeed in fulfilling societal expectations (Reader, 2006).

4.2. Forest Tenures

Timber tenures are the mechanism through which the provincial government allocates rights to access and use forest timber resources on public land. They come in the form of agreements, licenses, or permits that provide individuals, communities, or companies the right to exploit forest land, including timber harvesting (BC Ministry of Forests and Range, 2006a). The *Forest Act* and its regulations[25] define the basic rights, responsibilities, and obligations of tenure holders, or licensees, as well as the duration and administration of the various forms of tenures. Management responsibilities and requirements vary according to the nature of the organization (e.g., government, industry, community, First Nation) and/or the type of tenure or license issued.

Timber tenures are either volume-based or area-based. The former grant licensees the right to harvest volumes of timber (measured in cubic meters) from an area, often within which multiple licensees can operate. Area-based tenures, on the other hand, grant individual licensees nearly exclusive rights to harvest timber from a specified area.

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[24] Civil liability refers to resource professionals' liability for actions or decisions that may cause "harm" to another persons interests, as recognized under the law and by the courts.

[25] Such as the Forest License egulation, Community Tenures Regulation, Cut Control Regulation, and Woodlot License Regulation.

Tenures of either form can be replaceable or non-replaceable. Replaceable ones are generally 20-25 years long[26] and can be updated or renewed in order to provide investment security for the forest industry or in response to changing government policies (BC Ministry of Forests and Range, 2006a). Non-replaceable tenures are granted for a fixed term, often to meet specific short term objectives, such as salvaging pest infected timber. The majority of timber tenures in BC are long-term replaceable, volume-based tenures (British Columbia 2010).

Ninety six percent of the provincial timber harvest comes from two types of management units found across BC: timber supply areas (TSA) and tree farm license areas (TFL), of this 82% is from TSAs and 18% TFL areas (British Columbia 2010; BC MFLNRO 2011). A TFL is a type of area-based timber-harvesting license, typically granted to one agreement holder, such as a private company, working exclusively within a management unit. A TSA, on the other hand, supports multiple volume-based timber licenses within the management unit. Both types of management units are designated a timber harvest volume-limit, known as the annual allowable cut (AAC).

An important tenure obligation and a way in which the government generates revenue from licensee use of timber resources is stumpage. Stumpage is a fee paid by licensees to the government in exchange for harvesting timber on public land. It is the value of standing trees and in BC it represents a sum calculated from the amount of expected revenue from an efficient timber producer, with a reasonable margin for profit, less the expected cost of harvesting and delivering timber. Appraisals are conducted in order to determine stumpage rates and policies for doing so exist and apply to two broad regions in BC the coast and the interior. These policies are established by the MFRNRO Timber Pricing Branch and are available online[27].

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[26] The duration of a replaceable tenure depends on the type of tenure. For example, Community Forest Agreements can be up to 99 years, replaceable every 10, while a Forest License can be up to 25 years, replaceable every 5 to 10 years.
[27] http://www.for.gov.bc.ca/hva/manuals.htm

4.2.1. Impact on reforestation practices

Tenure obligations vary amongst the different tenure types and their associated levels of restriction affect licensee behavior and resource allocation in different ways. They ensure that tenure holders act in ways that are beneficial to society such as reforesting after harvesting or maintaining a steady flow of timber. Imposed tenure obligations come at a cost that can reduce the benefits that tenure holders can generate, resulting in reduced incentive to invest in activities such as silviculture (Luckert, 1991a). It has been found that the more restrictive a tenure obligation is, the more costly it becomes to a licensee, who is driven to maximize the return on investment on forest operations (Luckert 1991).

Tenure obligations are defined in the *Forest Act* and encompass rules for tenure duration, tenure transfers and exchanges, increases, additions, deletions, and reductions of tenure area, annual allowable cut, rates of harvesting, and payments to government (e.g., rent, stumpage fees, taxes, and penalties), as well as specifying the conditions for the suspension of tenure rights and license cancellations. Luckert and Haley (1993) have noted that because of the way in which costs and revenues from silviculture investments are realized by tenured firms in Canada, reforestation has sometimes been viewed as "just another cost of doing business," rather than a worthy investment. This is influenced by the tenure type as well as the way in which stumpage fees are determined.

In BC, there is no difference in stumpage fees for timber stands that have developed naturally, at no cost to a licensee, or stands that are the product of reforestation efforts and additional silvicultural investments (Luckert et al., 2011). This means that a licensee will likely not be able to recover the cost of additional expenditures from reforestation and subsequent stand maintenance (e.g. brushing, fertilizing, and pre-commercial thinning) (Luckert et al., 2011). This creates a very weak incentive for voluntary reforestation expenditures above what is required by law or for objectives other than merchantable timber production, such as forest health and resilience to cope with climate change.

The costs of mandatory forest regeneration after timber harvesting is accounted for to some extent in stumpage calculations in BC. These "silviculture allowances" are deductions in stumpage fees and are based on the average silvicultural costs for stands in the same ecological zone for the Interior Forest Region and for stands in the same district for the Coast Forest Region. In BC, this does not include expenditures beyond forest regeneration (Luckert et al., 2011). Licensees may try and avoid exceeding these allowances in order to reduce costs, especially during challenging economic times, which stifles investments in basic reforestation and encourages planting as cheaply as possible within permissible limits. In many instances, the allowances do not accurately reflect true costs. For example, extensive mortality of young samplings in recently regenerated stands may occur due to unusual frost events, heaving browsing, pests or diseases, or even drought spells. In these cases, true costs may exceed allowances, further promoting least cost approaches as general practice. Sometimes tenure holders end up growing timber at a loss in order to generate revenue through other activities such as wood processing and manufacturing, and in these cases, silviculture is seen as a cost of production rather than an investment (Luckert and Haley, 1993).

Luckert (1991a) and Zhang and Pearse (1996) have demonstrated a positive correlation between tenure security, including perceived security, and investments in silviculture. Tenure security refers to the reliability of long-term access to timber crops by licensees, and it varies depending on timber tenure type. They found that the greater the level of tenure security, the more likely firms are willing to make long-term investments and planning in their forestry operations. Zhang and Pearse (1997) provide empirical evidence of this effect on reforestation practices; they found that:

- Land that is not sufficiently restocked (NSR) occurs less frequently on private lands than on licensed public lands;
- Where NSR lands occur, they comprise a smaller proportion of harvested areas on private lands than on licensed lands;
- Operating companies more frequently regenerate harvested areas on their private lands than on their licensed public lands.

In their study, tenure security was defined in terms of tenure duration, renewability, exclusivity, government charges, scope for regulatory intervention, and perception by licensees and the courts. While they did not measure the relative importance of each of these, their findings indicate that holders of short-term, volume-based, and non-renewable tenures are probably the least likely to invest in innovative reforestation strategies, as the benefits of such actions may not be realized for decades to come. Rather, they will be more willing to take a least cost or minimum compliance approach to reforestation.

Between 1999 and 2009, the percentage of provincial timber volume in short-term tenures and medium-term tenures increased by 5% and 16%, respectively. This was primarily due to a reallocation of a significant portion of the ACC in 2003 to BC Timber Sales, woodlot licenses, community forest agreements, and First Nations tenures as part of the *Forest Revitalization Act*. Nevertheless, there have been no large and long-term forest tenures granted since 1990 (British Columbia, 2010). Additionally, nearly 82% of the provincial AAC has been apportioned to volume-based tenure holders with no long-term ties to an area. In other words, most timber available for harvesting in BC is held in tenures with relatively lower levels of "security" due to short durations and no exclusivity.

The ability to generate future revenue or recover costs from reforestation and silviculture investments is important for climate change adaptation. These are dependent in part on policies for calculating stumpage as well as tenure security. Disassociating silviculture investments and the direct benefits derived from them (such as improving the ability of the land to produce timber or enhancing resilience to disturbance events) removes incentives for tenure holders to allocate scarce resources to growing timber in novel ways (Luckert and Haley, 1993). This disconnect is likely even more prominent for volume-based tenures where several licensees operate across many different tracts of forest rather than exclusively within one area.

Climate change adaptation research promotes the establishment of diverse, healthy forests. These can be achieved in part through reforestation with diverse trees assemblages and additional silviculture treatments. However, if this means additional cost, beyond allowances, and with no guarantee that the resultant timber will be available to a licensee, there is little chance investments to accommodate climate change will occur with out some intervention. If, however, allowances can accommodate such actions and/or tenures are secure enough (e.g. exclusive access, long terms) to ensure access to future timber stocks produced through efforts today, licensees may be more inclined to implement such adaptations.

4.3. Forest Planning

4.3.1. Values and objectives

Since 2004, the *Forest Range and Practices Act* (FRPA) and associated legislation, such as the *Forest Planning and Practices Regulations* (FPPR), has been the primary legislation governing the management planning of British Columbia's forest. The Act and accompanying legislation are intended to uphold the various social, economic, and environmental forest values of the province through a results-oriented framework. While other provincial legislation[28] for the protection of forest resources and the environment exists, these two specifically cover planning and operational practices related to forest resources. Under the FRPA, tenure holders (licensees) are responsible for developing and implementing plans to meet objectives set by the government that seek to balance three main considerations (BC MFLNRO, 2011):

- Ensuring the sustainability of the timber supply.
- Providing adequate conservation and protection for non-timber resources.
- Giving appropriate weight to the economic interests of tenure holders.

The FRPA identifies eleven resource values for which government objectives may be set, regardless of the form of tenure; they are:

- Soils
- Visual quality
- Timber
- Forage and associated plant communities

[28] A comprehensive list can be found on the BC Ministry of Forests, Lands, and Natural Resource Operations website: http://www.for.gov.bc.ca/tasb/legsregs/

- Water
- Fish
- Wildlife
- Biodiversity
- Recreation resources
- Resource features
- Cultural heritage resources

Government objectives for these values come in the form of Legal Land Use Objectives (LUO) and Objectives Set by Government (OBSG) that are fairly broad, providing natural resource professionals the discretion to meet them the best way they see fit, within certain limits and standards of conduct. LOUs and OBSG vary regionally and locally across the province depending on the land-use planning history. They come in different forms and are derived from different sources, including (ILMB and MAL, 2008):

LUO, designated…

- in Higher Level Plans (HLP),[29]
- by the Minister responsible for the administration of the Land Act[30]
- by Ministers under the authority granted them by the FRPA's Government Action Regulations (GAR).[31]

OBSG…

- outlined in the Forest Planning and Practices Regulation (FPPR),[32]
- grand-parented from the Forest Practices Code.[33]

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[29] HLPs established under sections 3-5 of the *Forest Practices Code of BC Act* continue to have effect under the FRPA (ILMB and MAL, 2008).

[30] FRPA Section 1(1) defines government objectives as "a) objectives prescribed under section 149 (1) [of FRPA], or b) objectives established under section 93.4 of the *Land Act* by the minister responsible for the administration of the Land Act."

[31] The FRPA GAR grants the provincial ministers responsible for the *Wildlife Act, Forest Act,* and the *Land Act* the authority to establish certain types of objectives that must be met by licensees under the FRPA.

[32] Part 2 Division 1 of the FPPR identifies OSBG that must be addressed by licensees in their FSPs.

[33] Section 181 of FRPA identifies objectives from the *Forest Practices Code* that are still in effect.

4.3.2. Land use plans

Land use plans are an important part of BC's land and resource management strategy. They include Land and Resource Management Plans (LRMPs) and Sustainable Resource Management Plans (SRMPs) that provide strategic direction for more detailed regional or local natural resource management planning for government agencies, the private sector and, in some cases, nongovernment organizations. These integrated plans describe the vision, approach, broad goals, and objectives for public land use in BC such as timber exploitation, recreation, mining, and protected areas as well as strategic direction and priorities for sustainable natural resource management.

LRMPs are based on comprehensive negotiations completed in public and participatory consensus-seeking processes. They exist for a number of geographic regions in BC including large regions, sub-regions, watersheds, landscape units, coastal and marine areas. While LRMPs and their contents are not legally binding agreements, they provide significant insight into societal expectations, and as such can be made into law through one or more ministerial Land Use Orders.[34] SRMPs focus on issues and values at a more detailed level than LRMPs for smaller landscapes and watersheds.

4.3.3. Forest stewardship plans

The FRPA requires that licensees prepare a Forest Stewardship Plan (FSP) and Site Plan (SP) as well as obtain a Cutting Permit (CP) prior to harvesting or regenerating public land. Under the results-based FRPA framework, the FSP is the primary mechanism through which licensees define and submit their strategies (i.e. practices) or intended results (i.e. outcomes) to meet LUOs and OBSGs for government approval.[35] FSPs must also include information about the stocking standards, regeneration date, and free growing height that

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[34] For example, in 1996 the Ministers of Forest; Environment, Land and Parks; and Energy, Mines and Petroleum Resources signed an order making the Kamloops LRMP (KLRMP) a Higher Level Plan (KHLP) pursuant to section 1(1) of the *Forest Practices Code*. In 2006 the Minister of Agriculture and Lands declared an order for the mandatory implementation of the objectives in the KHLP under FRPA.

[35] Section 5 of the FPPR provides a definition for "result" and "strategy." Generally, a result is a description of measurable or verifiable outcomes, and a strategy is a description of measurable or verifiable practices that will be carried out in respect of a particular established objective.

may be utilized to meet tenure requirements for regenerating harvested areas. These are discussed in more detail in section 4.4.1.

FSPs are primarily intended as a means for licensees to demonstrate their stewardship commitments rather than their development activities. They are the only planning document a licensee must submit for government approval, and they do not have to indicate the specific location of intended cut blocks, roads, harvesting methods, or any other development activities; this type of information is found in Site Plans (SP). Approval of FSPs is usually conducted by a MFLNRO District Manager, or other government delegate, and is based on a number of criteria, including (BC MFR 2009):

- Consistency with timber harvesting rights granted under the form of tenure.
- Demonstration of consideration of public comments, including efforts to meet with First Nation groups affected by the plan.
- Specification of measurable or verifiable results or strategies for relevant government objectives.
- Specification of regeneration data, free-growing height, and stocking standards, and how they will apply.

Once an FSP is approved, it is valid for up to 5 years and the preparing licensee is legally bound and accountable to the commitments in them. A consequence of this is that FSPs tend to be written in legal jargon that can be difficult for a layman to understand and thereby challenging the public to read and comment on them.

After FSP approval, the FRPA requires licensees to prepare Site Plans (SP) prior to harvesting and road building. However, unlike FSPs, SPs do not need to be approved nor do they contain any legal obligations or commitments (Reader, 2006). Rather, the purpose of a SP is to make publicly available information about the development activities of a licensee, such as the approximate locations of cutblocks, how intended results or strategies apply to specific areas, and the stocking standards and soil disturbance limits that apply to specific areas. A Cutting Permit is also required for a licensee to exercise his/her tenured harvesting rights. It is the authority that permits the cutting and/or removal of timber from a particular area, and it is not intended for planning or plan enforcement.

4.3.4. Timber Supply Review

An Annual Allowable Cut (AAC) is a socially and scientifically informed decision of the maximum amount of timber than can be sustainably harvested while upholding social and environmental values. The *Forest Act* (section 8) mandates that the BC Chief Forester set an AAC for both TSAs[36] and TFLs no less than once every ten years.[37] In doing so, the Chief Forester must consider:

1) Forest composition and expected growth rates.
2) The expected re-establishment time following denudation.
3) Silviculture treatments.
4) Methods of timber utilization.
5) Rates of decay, waste, and breakage associated with harvesting.
6) Non-timber objectives.
7) Short and long term implications of alternative harvesting rates.
8) The economic and social objectives of the government.
9) Pests and disease and potential salvage programs.

A Timber Supply Review (TSR) is the process through which these considerations are made and evaluated, and it includes a preliminary analysis open for public review. AAC determinations are finally reported with a detailed rationale explaining all of the factors considered. AACs must be determined in such a way as to avoid adverse impacts on the ability of an area to supply timber in the short and long term. If an AAC is too high, it could result in long-term shortfalls of timber, and if it is too low, it could have immediate social and economic consequences (Snetsinger, 2008). Currently, the sum total AAC in TFLs and TSAs across the province is approximately 79 million cubic meters of timber (BC Ministry of Forests Lands and Natural Resource Operations, 2011a).

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[36] In the case of TSAs, the AAC is apportioned amongst the various licensees operating within it.

[37] According to the *Forest Act*, other management units must be assigned an AAC by Regional and/or District Managers of the BC Ministry of Forests, Lands, and Natural Resource Operations.

4.3.5. Impact on reforestation practices

The forest planning components of the BC forest management regime have important impacts on reforestation practices. Seven out of ten of the OBSG in the *Forest Planning and Practices Regulation* for non-timber forest values[38] include a provision to ensure that practices toward each do not "unduly reduce the supply of timber." For example, the objective for wildlife is,

> "*without unduly reducing the supply of timber from British Columbia's forests*, to conserve sufficient wildlife habitat in terms of amount of area, distribution of areas and attributes of those areas, for the survival of species at risk, the survival of regionally important wildlife, and the winter survival of specified ungulate species."

Under FPPR, this condition exists for objectives for the following values:

- Soils
- Wildlife
- Water, fish, wildlife and biodiversity within riparian areas
- Fish habitat in fisheries sensitive watersheds
- Water in community watersheds
- Landscape-level wildlife and biodiversity
- Stand-level wildlife and biodiversity

While such a constraint may not impact reforestation practices *per se*, it does put a limit on the use of reforestation as a tool to meet non-timber objectives toward these values, such as increasing the percentage of mixwood forest across a landscape to improve wildlife habitat. The FPRA does not explicitly define what it means to "unduly reduce the supply of timber," however the default standards for forest practices are based on those originally designed under the Forest Practices Code. The impact of FRPA on the timber supply cannot exceed 6%, including the impact of wildlife habitat areas, wildlife trees, ungulate winter

[38] Objectives for timber, visual quality, and cultural heritage resources under the FPPR do not have the constraint to not unduly impacting the timber supply.

ranges, old growth management areas, and management and protection of other non-timber resource values other than biodiversity (Province of British Columbia, 2004; BC Ministry of Forests Lands and Natural Resource Operations, 2008).

Sound forest management calls for the integration of forest value objectives (e.g. forest health, recreation, economic opportunities, social welfare, etc.). The introduction of climate change impacts and the research on vulnerability and adaptation adds weight to the importance of forest health objectives, as healthy forests are more resilient that unhealthy ones. The existing FRPA limits on the extent to which many non-timber objectives such as biodiversity, a critical component of forest health, can affect the timber supply places bounds on the ability to implement many climate change adaptation efforts, such as those recommended by Spittlehouse and Stewart (2003). In other words, climate change exacerbates the existing need to balance multiple forest objectives and FRPA places limits on that.

Other legal direction comes from Land Use Orders. These may directly or indirectly impact reforestation practices. For example, a legal order within the Kamloops LRMP area requires that licensees maintain or enhance habitat and forage production for moose and deer within specified special resource management zones. In some case, these zones overlap the timber harvesting land base where reforestation could play an important role in meeting such an objective.

Land use plans often indicate the agreed upon locations of various resource management zones and the acceptable activities that can take place within them. In a LRMP, this may include general resource, settlement resource, protection resource, and special resource management zones, each of which is spatially defined and made up of subdivisions, called landscape units, with provided strategic guidance for each. Where relevant, this includes guidance for forest practices in the form of not legally mandated objectives. Since these plans are developed through the coordinated and consensus seeking efforts of a variety of stakeholders, including the public, adherence to them on the part of forest licensees is an important part of their social license. In some cases, the policy within an LRMP goes beyond that required by law. For example, under the Kamloops LRPM, levels of low, intermediate, and high biodiversity emphasis have been assigned to each landscape units across the plan area. The plan states that these areas cannot impact more than 4% of the timber harvesting land base, even more limiting than the 6%.

Important factors that go into a Timber Supply Review and AAC determination are the assumptions about forest regeneration and growth rates on both managed and unmanaged stands. Regeneration and growth are influenced by stocking practices, silviculture systems, seed type, source, and availability (e.g., genetically improved selected seed), site productivity, regeneration delay, and mortality rates, amongst other factors. For a TSR, much of this information is obtained through analysis of forest conditions and existing practices so that projected timber flows accurately reflect the composition of the provincial timber harvesting landbase and the management practices taking place on it. For timber supply areas, this information is gathered from inventory data, however there may be a significant need for field work to ground truth remotely sensed inventory data (Iles, 2011; Moss, 2011). This level of verification is especially critical under climate change as its represents one level of uncertainty for which we have the capacity to address. This, of course, requires funding.

One criterion for the approval of licensee stocking standards is consistency with the Timber Supply Review so that timber flow projections are not put at risk (BC MFR, 2006a). Guidance from the MFLRNO states, "standards that are 'consistent' with the latest TSR should be considered to be 'acceptable'" (BC MFR, 2006a). Consequently, TSRs and stocking standards are linked in such a way that there is a two-way feedback between them (FREP, 2009). The MFLNRO does recognize the importance of innovation as societal values and management objectives change, and it is open, as a matter of policy, to accepting novel stocking standards provided they are accompanied with a sufficient and acceptable rationale. However, since approval is contingent upon being "similar to" or "exceeding" the standards applicable to the relevant practice assumptions in the TSR, there is an incentive to utilize standards that have been previously approved or that may increase timber flows, as opposed to other non-timber objectives.

The timber supply review process seeks to reflect current forest management practices and its influence on timber supplies and identify where improved information is required for future timber supply forecasts. It is the foundation for determining the AAC for the next ten years and its assumptions about forest practices serve as an important test for the approval of stocking standards. Under climate change it is important that these analyses are accurate with respect to assumptions about management objectives and ongoing forest practices, account for future risks posed by climate change, and provide some leeway for future adaptations including varying harvesting strategies, silviculture techniques, planting mixes, etc. Doing so could be facilitated through licensee requirements to consider climate change in their management strategies and reporting on any ongoing and planned adaptive actions. Alternatively, assumptions of climate vulnerabilities and risk could be built into the analysis potentially capturing the attention of licensees who would then be compelled to align with them. In this way, the timber supply analysis would effectively set some management goals toward which licensees would have to strive, as target tree species for harvesting and stocking standards are in part dependent on them.

4.4. Planting Standards

4.4.1. Stocking standards

Stocking standards are the prescriptions that licensees will use to ensure the regeneration of healthy, well-spaced, and acceptable species of trees required to establish a free-growing stand after harvesting or intermediate cutting. Stocking standards consist of information about the minimum and desired number of healthy, well-spaced trees of preferred and acceptable species per hectare. Preferred species are those that have been deemed ecologically suitable for a site with management activities aimed primarily at establishing them for conifer sawlog production. Acceptable species are also ecologically suitable, yet they may serve different objectives such as a value-added end products, biodiversity, or habitat objectives (BC Ministry of Forests, 2000).

The *Forest Planning and Practices Regulation* (FPPR section 26 and schedule 6) provides the content and criteria for stocking standard development and the factors the government considers for their approval. It stipulates that licensees they should consider government timber objectives[39] as well as other factors such as the silviculture system employed (i.e. even-aged or uneven-aged management) and forest health (MFR, 2006). It also lists the following factors that may be taken into consideration when developing stocking standards:

- The types of commercially valuable and ecologically suitable species that should be established and retained.
- The numbers and the distribution of healthy trees of a species that should be established.
- The characteristics, quantity and distribution of retained trees of a species required to ensure the area will remain adequately stocked.

The FPPR also permits the development of stocking standards for multiple cut blocks. The inclusion of these considerations and factors in the legislated direction provides flexibility for licensees to vary stocking standards according to species, planting density, distribution, and area. This means that stocking at the stand level can vary from what is in the FSP as long as collectively, the blocks do meet them.

The MFLNRO official responsible for approving FSPs, usually a District Manager, evaluates stocking standards during that process. To obtain approval, stocking standards must pass the tests outlined in the FPPR or include an adequate rationale if they do not (BC Ministry of Forests and Range, 2006b; BC Ministry of Forests Lands and Natural Resource Operations, 2011b). They are summarized here:

a) Initial High Level Test – an overview evaluation of the stocking standards to identify any missing information or issues that may affect approval. This includes a review to ensure that all circumstances and situations are covered (e.g. there are no missing representative stand types or silviculture systems), all identified objectives

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[39] i.e. maintain a commercially valuable timber supply in ways maintain competitive wood costs and that do not restrict the ability licensees to realize their rights.

in the FSP are addressed, that valuable species profiles are maintained or enhanced, and that standards are in a form that is measurable and verifiable.

b) Ecological Suitability Test – a comparison of stocking standards against the most up-to-date information regarding species suitability. The *Reference Guide to Forest Development Plan Stocking Standards*, used under the Forest Practices Code, is still a recommended starting point for this determination. Additional sources of information include recently published literature, research, or data regarding species acceptability. Consideration must also be given to primary, secondary, and tertiary species acceptability, which is based on silvicultural feasibility, reliability, and productivity and published in government guidebooks.

c) Forest Health Test – stocking standards must result in an area stocked with ecologically suitable trees that address immediate and long-term forest health issues. The emphasis for this test is species acceptability based on known/current health factors, with a focus on health risks posed to the maintenance of a continual supply of commercially valuable timber. The local Forest Health Strategy is an important source for information for determining species acceptability in this case.

d) Economically Valuable Supply of Timber – this test focuses on ensuring a supply of economically valuable timber into the future. Considering the uncertainty of future markets and economic benefits, the maintenance or enhancement of a mix of suitable species is considered a reasonable strategy by the government as it maintains options for long-term recovery of value and volume. Nevertheless, the proliferation of lower valued species is of importance for this test and consequently restrictions may be placed on the use of less acceptable species, such as broadleaves. The Timber Supply Review is seen as an information source for suitable species profiles.

e) Consistency with Timber Supply Review (TSR) – the intent of this test is to ensure that stocking standards do not have a strong potential to put at risk the trajectory of the future timber supply anticipated in the most recent TSR.

4.4.2. Free growing criteria

Under the *Forest and Range Practices Act* (sections 29 and 30) and the *Forest Planning and Practices Regulation* (sections 44–46), most forms of tenure require licensees to establish a "free growing stand." In other words, they must regenerate a harvested stand to a state of well-spaced trees that are healthy, are free of unacceptable levels of competition, have reached a minimum height, and can be expected to produce a commercially valuable crop (BC Ministry of Forests Lands and Natural Resource Operations, 2011c). This applies to most of the major forms of tenures including all Forest Licenses (volume-based) and Tree Farm Licenses (area-based).[40] The required strategies to ensure licensees achieve such stand conditions are the stocking standards, regeneration date, and free growing height specified in their FSPs. Free growing is the condition of a regenerated cutblock at which the legal and financial obligations for reforestation is passed from the licensee to the government; it is the point at which the government accepts liability over a regenerated stand (BC Ministry of Forests Lands and Natural Resource Operations, 2011c). Licensees can make a voluntarily declaration of free growing status for particular sites, and from that point the MOFLNRO has 15 months to make an assessment to verify this declaration or the area automatically reverts to the responsibility of the provincial government (Forest Practices Board, 2006). If no declaration is made, the licensee retains responsibility for the area, even after the free growing deadline has past.

The *Establishment to Free Growing Guidebook* developed under the *Forest Practices Code*, the 2011 version of the *Silviculture Surveys Procedure Manual – Regen. Delay, Stocking and Free Growing*, and district-level policies provide the primary guidance for the

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[40] FRPA Sections 29 and 30 require major license holders, timber sales manager, woodlot license holders, and non-replaceable license holders to meet conditions of a free growing stand.

establishment of free growing stands (BC Ministry of Forests Lands and Natural Resource Operations, 2011c).

Free growing status is determined by field surveys through an assessment of individual trees and the tree strata in a stand, not across the landscape as a whole. If an individual tree meets the following criteria, it can be considered free growing and contributing to the free growing status of the stand (Forest Practices Board, 2003; BC Ministry of Forests Lands and Natural Resource Operations, 2011c):

- A minimum number of healthy well-spaced trees of the preferred and acceptable species, but less than a maximum number allowed per hectare, established and distributed to meet objectives outlined in the SP, FDP[41], or FSP.
- Well-spaced.
- Free from damaging forest health agent incidences.
- Free from unacceptable damage.
- The required minimum height specified in the SP, FDP, or FSP or specified in the *Reference Guide for Forest Development Plan Stocking Standards* for the species and site series.
- Free from unacceptable brush and broadleaf tree competition.
- Established trees must be ecologically suitable to the site.
- The regenerated stand must be established for a minimum of five years (except for some high elevation zones, where the establishment period is eight years).

The regeneration date is an indication of how long after the commencement of harvesting a stand will have been stocked according to the standards indicated, and the free growing height is reached when the trees in a restocked stand are tall enough to escape competition from understory plants and other nearby trees. A regenerated stand must become free growing no later than 20 years after the commencement (also known as the "late free

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[41] FDP is a Forest Development Plan originally approved under the *Forest Practices Code.* They are similar to FSPs prepared under FRPA in that they include stewardship strategies, however they also include development plans.

growing date"), which is voluntarily declared by licensees (Forest Practices Board, 2006). Non-compliant licensees can argue a defense of having implemented due-diligence; however, if not accepted, the provincial government can impose administrative penalties (Forest Practices Board, 2003)[42].

4.4.3. Seed use

The *Forest and Range Practices Act* (section 31 and 169) and *Forest Planning and Practice Regulation* (section 43) control the use of tree seeds for regeneration under most forms of tenure in BC.[43] They enable the Chief Forester to set standards to regulate the sourcing, use, registration, storage, selection, and transfer of seed to be used in the establishment of free growing stands, according to stocking standards. Free growing stands established through artificial regeneration methods, such as tree planting, must consist of trees from a seedstock[44], or lot, that has been registered with the Tree Improvement Branch of the MFLRNO.[45]. Seed can be collected from natural stands or sourced from seed orchards from within and, in some case, outside of BC. In order to be eligible for registration and use, they must meet specific collection, genetic diversity, and physical quality requirements[46].

The BC Chief Forester, in the *Standards for Seed Use*, specifies these eligibility requirements as well as the methods for seedlot classification (e.g., on the basis of genetic worth and breeding performance), the minimum standards for seedlot storage, and the limits on seedlot transferability (e.g., use of a seedlot in a zone outside its zone of origin). The intent of these standards is to maintain the identity, adaptability, diversity and productivity of the Province's tree genetic resources (Snetsinger, 2005a). Seed transfer guidelines reflect a tradeoff among three principles (Ying and Yanchuk, 2006):

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[42] Though more typically, the late free growing date is amended to give the licensee more time to comply.

[43] The *Woodlot Planning and Practices Regulation* (section 32) regulates seed use for woodlot licenses, and those forest stands still subject to the *Forest Practices Code*, in accordance with the FRPA sections 191 and 192, must comply with its relevant regulations for seed use.

[44] According to FRPA definitions, "seed" includes any part of a forest tree represented, sold or used to grow a plant.

[45] All registry data is stored and managed online through the Seed Planning and Registry System (SPAR).

[46] Incidentally, genetically modified seed cannot be registered.

- Enhancing productivity.
- Minimizing biological risk of adaptation.
- Accommodating administrative planning realities and reforestation programs.

Seed planning is conducted to ensure that sufficient seed for the right species of the best quality from the right provenance is available for the establishment of free growing stands (BC Ministry of Forests Lands and Natural Resource Operations, 2011a). It can occur at a number of scales and includes activities such as seed procurement (seed supply agreements, trades, purchase), seed use (collection, selection, transfer) and seed deployment (results, strategies, timber supply assumptions) (BC Ministry of Forests Lands and Natural Resource Operations, 2011a).

A seed-planning zone is an area mapped with fixed boundaries within which seed material can be transferred without risking biological adaptability or productivity. The Chief Forester's seed transfer limits indicate how far the seed of a particular tree species can be planted from its location of origin as well as an acceptable elevation range. These limits reduce the risk of regeneration failure from maladaptation to climate, insects, disease, and other pests. The zones are generally updated as genetic traits for certain species are improved through breeding and new information becomes available from studies on the variation of adaptive traits across the landscape (e.g., growth form, phenology, cold and drought tolerance) (Johnson et al., 2004).

4.4.4. Impacts on reforestation practices

Regulations and policies for the establishment of free-growing stands are important because they ensure that harvested stands are regenerated. The policies that define free growing reveal a bias toward conifer crop trees and place limits on the presence of broadleaves (BC Ministry of Forests Lands and Natural Resource Operations, 2011c). This is based on the idea that competing broadleaves and other vegetation threaten the productivity of conifers. Consequently, after planting, licensees commonly remove all the young broadleaf trees, rather than risk non-compliance with standards for free growing (Simard et al., 2004). However, studies have shown that broadleaves can facilitate conifer growth and that their removal can even be deleterious to the remaining conifers (Simard and Hannam, 2000; Simard et al., 2004; Simard and Vyse, 2006). As such, free growing policies result in additional costs to licensees for treatments that are ineffective in many cases and that reduce the diversity, available habitat opportunities, and resilience of regenerated forests as well as any future economic potential from broadleaf trees (Simard and Vyse, 2006).

According to training and policy documents on stocking standard development and approval available through the MFLRNO[47], a variety of information sources, both old and new, are currently utilized in preparing and approving stocking standards throughout the province (MFLNRO n.d.; MFLNRO 2011). These documents emphasize the importance of innovation with respect to stocking, especially when it comes to addressing forest health issues. For example, a 2008 memorandum[48] from the BC Chief Forester and Assistant Deputy Minister of Operations regarding policy on the incorporation of mixed wood and broadleaf tree species into Forest Stewardship Plans reiterates the authority that the delegated decision maker responsible for approving stocking standards has for approving those plans that do not conform to conditions of the FPPR suitability criteria.

Nevertheless, there remains a bias for timber objectives in these documents, namely for the assurance of a sustainable flow of economically valuable timber. That same memorandum also states that consideration for the use of broadleaves should only be given in cases where they are intended to be actively managed as part of the future commercial timber supply. In cases where other objectives are intended (e.g., biodiversity, visual quality, nutrient cycling), broadleaves can be considered if their presence conforms to the criteria in Appendix 9 of the FPC *Establishment to Free Growing Guidebook*: "the crop tree is at least the required height above the broadleaf tree or other vegetation." In other words, they are acceptable only if they do not impede the ability of crop trees to grow, with this being based on a very narrow definition of competition, namely tree height. The free growing

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[47] This information is available through the following websites:
http://www.for.gov.bc.ca/hfp/silviculture/stocking_stds.htm#
http://www.for.gov.bc.ca/his/results/training/Stocking-Standards.htm

[48] File No. 195-40, available here: http://www.for.gov.bc.ca/hfp/silviculture/stocking_stds.htm#

guidebooks were originally "developed for the primary management objective of conifer sawlog production under an even-aged management system" (BC Ministry of Forests, 2000). However, in 2000, the guidebooks were expanded to include stocking standards for boreal broadleaves and for other objectives, such as for grizzly bear habitat and fire-maintained ecosystems. The revisions state that where forest plans specify different objectives, the free-growing guidelines, including stocking standards, may be modified.

One of the more readily used and important sources of information available for preparing stocking standards is *The Reference Guide to Forest Development Plan Stocking Standards*, it is essentially the basis for the test for ecological suitability. It lists preferred and acceptable species according to biogeoclimatic zones (BEC) for regions across the province and is intended as guidance for both the development and approval of stocking standards. Licensees can deviate from the guide if sufficient rationale is provided, although the timeframe for the review of novel stocking standards is unclear. This makes the choice to use species that are currently viewed as less acceptable, less reliable, or less productive or species that are not on the lists more challenging.

In 2009, the Forest and Range Evaluation Program (FREP)[49] conducted a study of stocking standards in the Coast, Northern Interior, and Southern Interior forest regions of BC and found that due to "time constraints, uncertainty over the process for supporting the development of new standards, and the uncertainty of what would be considered acceptable" by approving officials, stocking standards had not significantly changed in over 20 years (FREP, 2009). In fact, the FREP study found that the stocking standards examined from these three regions had been rolled over from those in previously approved forest development plans prepared under the *Forest Practices Code* that had been originally rolled over from those prepared by the Ministry of Forests and Range from more than two decades ago. This is disconcerting as objectives and values have certainly evolved since the

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[49] FREP is a program lead by both the BC Ministry of Forests, Lands, and Natural Resource Operations and the Ministry of Environment to assess the effectiveness of forest legislation in achieving stewardship objectives. More information can be found at http://www.for.gov.bc.ca/hfp/frep/

1980s. Since there is not a clear process with respect to the evaluation of novel or innovative stocking standards, there is a disincentive to prepare them as the process may become significantly delayed and with no guarantee of approval.

In addition, the BEC zone foundation for stocking standards becomes increasing irrelevant unless they are updated in some way to reflect changes in climate regimes and resultant plant species assemblages. In addition, none of the other tests for stocking standard approval take into account climate change. The ongoing research on climate change impacts to forest ecosystems should be somehow built into considerations of forest health, projections of timber supply, stocking standard approval guidelines so that licensees can begin to utilize reforestation as part of a provincial climate change adaptation strategy.

Regulations for seed use play an important role in ensuring the province is regenerated with trees of a minimum quality and diversity. This is important in terms of ecosystem health, forest productivity, and resilience. The Chief Forester's *Standards for Seed Use* place limits on licensee options for seedlot selection, although shifting species ranges and habitat suitability from climate change is testing the foundation of these limits. Nevertheless, the *Forest Planning and Practices Regulation* (section 43) allows for the approval of alternatives to any of the standards. Approval of these is based on the ability to demonstrate that alternatives are consistent with achieving the intent of the standards, i.e. to "maintain the identity, adaptability, diversity and productivity of the Province's tree gene resources" (Snetsinger, 2005b). The *Alternative Policy for the Chief Forester's Standard for Seed Use*[50] provides a process for licensees developing proposals for the use of alternative seed practices.

Currently, the MFLRNO is exploring the development of a Climate Based Seed Transfer System (BC Ministry of Forests Lands and Natural Resource Operations, 2011d). In addition, the ministry has recently expanded the elevation limits for seedlot transfers in general as well created three new zone for the transfer of Western Larch beyond its natural

[50] Alternative policy website: http://www.for.gov.bc.ca/code/cfstandards/policies/Alternatives_Policy_Signed.htm

range for use as a climate change adaptation strategy.[51] This provides more options for increasing the diversity of tree species in BC forests through reforestation efforts.

4.5. Summary

The BC forest management regime consists of numerous expectations derived from both the legal (compulsory planning, practices, and policy) and non-legal (guidance and social expectations) realm. Factors within each of these spheres have important implications for silviculture decisions and reforestation practices on the part of forest tenure holders in the province. Permeating the legal realm are requirements and expectations toward the maintenance of a continuous flow of merchantable timber over time, despite an expansion of forest values over the years and an increase in the importance of social and environmental principles. Nevertheless, the sustained production of timber has retained its status as the driving tenet or premise for forest management in British Columbia, affecting the ability to utilize innovative and alternative reforestation strategies toward non-timber objectives in managed public forests. This then limits the capacity to utilize reforestation and other strategies to adapt to climate change.

While there is currently a great deal of flexibility in the BC forest management regime for natural resource professionals to implement alternative management strategies, timber objectives clearly take precedence over others. This is evident in the following rules and policies steering forestry in BC:

- Forest tenures
- Timber supply review
- Forest stewardship plans
- Government objectives
- Stocking standards

[51] MFLNRO amendments to the Chief Forester's Standards for Seed Use for:
- Climate-based upward elevation changes can be found at http://www.for.gov.bc.ca/code/cfstandards/amendmentNov08.htm
- Western Larch can be found at http://www.for.gov.bc.ca/code/cfstandards/amendmentJun10.htm

- Free growing criteria
- Standards for seed use

Forest tenures are each associated with differing degrees of obligation and restriction, the costs of which affect licensee flexibility and their incentive to implement silviculture practice above minimum requirements. Reforestation is one such obligation and inaccurate assumptions of their cost in calculating silviculture allowances can increase the amount of stumpage licensees must pay to the government. This creates an incentive to take a least cost approach to silviculture, potentially stifling innovation to address climate change or any other objectives beyond the bottom line. This disincentive is likely even more significant for holders of short-term volume-based licenses that would have to incur costs without the prospect of receiving any of the long-term economic benefits. Those forms of tenure that ensure the greatest level of security over the longest periods of time (i.e. area-based long term renewable tenures) are more likely to provide the necessary assurance for licensees to invest in additional silviculture, thereby enhancing the adaptive capacity of the provincial forest management land base to cope with climate change.

The Timber Supply Review (TSR) is the process through which the Chief Forester determines the annual allowable cut, or harvest levels, for different management units across the province. Proposed stocking standards for reforestation are evaluated in part against consistency with the timber projections in the TSR. A result of this has been the reuse of stocking standards year after year, creating concern over the ability to meet evolving objectives (FREP, 2009).

The TSR must accurately reflect current forest practices with evidence from field-verified reviews and consider new threats to forest health in order to make the most informed calculations of timber flow and AAC determinations. Improved and long-term monitoring of regenerated stands, even after they have met free-growing standards, would increase the ability of a TSR to capture the impacts of changes in management or in the environment, provide more accurate projections of timber supply, and in turn spur the development of arguably more appropriate stocking practices (FREP, 2009).

In addition, criteria for the approval of stocking standards include a test for economic suitability, thereby placing a restriction on the acceptability of economically lower valued species. While this test is only one of five required for approval, similar caveats are embedded in others. For example, the "key focus" for the forest health test is the "risk posed to the maintenance of a supply of commercially valuable timber…" (BC Ministry of Forests and Range, 2006b). Additionally, these criteria should consider an evolving consideration of "ecological suitability" in light of changing patterns of temperature and precipitation and associated uncertainties. Clear criteria and a straightforward timeline for the evaluation of novel stocking standards toward non-timber objectives and guidance for the consideration of climate change would likely enhance the adaptive capacity of proactive tenure holders interested in reducing their vulnerability.

Forest values in British Columbia have evolved, but the legislation and policy that define the objectives toward those values have not. A clear bias toward timber production is evident in an important caveat present in the *Forest Planning and Practice Regulation* limiting the impact that many non-timber objectives can have on the timber supply. This stipulation hampers the capacity to meet non-timber objectives and inhibits the ability of natural resource professionals to integrate reforestation practices into a number of strategies that may reduce climate change vulnerability.

The *Forest and Range Practices Act* defines a "free growing" stand of trees as one consisting of commercially valuable species. This creates some important disincentives for alternative reforestation strategies toward non-timber objectives. Surveys for the determination of free growing overemphasize conifer crop trees and competition, which is narrowly defined using relative tree height rather than arguably more appropriate methods that rely on growth rates, tree vigour, and morphology. This has led to planting with primarily conifer species and over brushing[52] of broadleaves, thereby simplifying the forest rather than diversifying it.

[52] Brushing is the silviculture practice of removing unwanted and competing plants.

It has been demonstrated that standards for seed use, while rigid, can easily be changed to account for new information on the adaptability of certain tree genotypes and provenances and changes in climate suitability. The BC Ministry of Forests, Lands, and Natural Resource Operations is currently exploring the strategic incorporation of climate change into the seed transfer system and some policy changes have already been made. Seed zones as a whole have been broadened and the acceptable zones for the transfer of Western Larch seeds have been expanded to facilitate assisted migration efforts.

Reforestation in British Columbia is primarily a stand-level tool used for ensuring a sustained flow of timber. It is achieved primarily through licensee compliance with legislated requirements to regenerate harvested cutblocks to a free growing state in the cheapest and fastest way possible. British Columbians cannot expect to reduce the vulnerability of forest ecosystems and management to climate change under this kind of management framework and at this spatial scale. There is a need to redesign forest policies and rules so that they facilitate integrated strategies that balance multiple objectives in ways that minimize exposure and sensitivity to climate change impacts. These strategies must be implemented at multiple scales (small and large) in a coordinated fashion. This requires information, communication, leadership, direction, and planning processes that provide a space for the development of measurable landscape level objectives and targets toward which all licensees must strive.

Silviculture investments made by licensees that increase the social benefits provided by forests, such as enhancing climate change resilience, should be accounted for somehow when stumpage fees are assessed, so that licensees are not effectively penalized for doing so. Additionally, licensees should be able to directly benefit from long term silvicultural investments, such as secure access to timber in improved forest stands.

This chapter has presented critical elements of the BC forest management regime that have direct and indirect influences on reforestation decisions. These include forest management planning objectives, silvicultural costs and allowances, tenure security, criteria for meeting free growing requirements, stocking standard guidelines and approval criteria, and timber supply review assumptions about current practices and management objectives. The following chapter explores the importance of these elements to forestry practitioners in BC.

5. Adaptation and Reforestation Survey Results

The previous chapters present concepts of climate change, adaptation, and the role of reforestation in reducing climate change vulnerability of forest ecosystems. They also introduce elements of the BC forest management and policy regime that impact reforestation practices and explore how they may affect reforestation decisions. The survey results presented here build on those chapters through an initial scoping of the issues related to climate change adaptation as well as by testing many of the assumptions about policy influences. It does so through an examination of the opinions of a diverse range of experts from different fields as well as those directly involved in making and approving reforestation plans in BC: licensees and government approving officials. The responses are useful in building an understanding of the four research themes:

- Importance and acceptability of climate change and adaptive forest management.
- Barriers to implementing adaptive reforestation practices to address climate change.
- Incentives for implementing adaptive reforestation practices under climate change.
- Needs for implementing adaptive forestation practices under climate change.

The chapter begins with a presentation of the "Adaptation Survey" and then the "Reforestation Survey."

5.1. Adaptation Survey

The intent of the Adaptation Query survey was to record and analyze expert opinions and beliefs about climate change and the use of active adaptive forest management as a strategy for implementing alternative reforestation strategies under climate change in BC. Information from this survey was used toward an understanding of the first two themes, or objectives:

- Importance and acceptability of climate change and active adaptation forest management.
- Barriers to implementing adaptive reforestation practices to address climate change.

Results of this survey were also used to inform the development of the Reforestation Survey.

5.1.1. Respondent profile

Targeted participants included a diversity of individuals with experience in research or projects on the integration of climate change adaptation and forest management who attended the *Climate Change Adaptation and Sustainable Forest Management Workshop* (CCA-SFM)[53] that took place at the University of British Columbia's (UBC) Faculty of Forestry in Vancouver, BC, in February 2011. In total, all of the 111 attendees were contacted and 28 individuals completed the survey, representing 25.26% of those at the workshop[54].

Most of the respondents worked in British Columbia (75%), a few (14.3%) worked in Canada but not in BC, and the remaining 10.7% worked outside of Canada (n=28).

Nearly half (46.4%) of the respondents worked for a research or academic organization, 28.6% worked for a private company, 17.9% worked for the government, and 7.1% worked for a non-government organization (n=28).

Nearly forty percent (39.3%) of the respondents were involved in research, 28.6% in program or project development and implementation, 10.7% were delegated decision-makers, 3.6% in field operations, 3.6% in policy development, and 14.3% classified themselves as "other"[55] (n=28).

5.1.2. Descriptive statistics

The following sections are a summary of selected results of the Adaptation Query survey. They are presented in two sections 1) climate change and adaptive forest management, and 2) reforestation under climate change in British Columbia. Because of the large amount of

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[53] Workshop website: http://www.forestry.ubc.ca/cca-sfm-workshop/home.aspx

[54] Of the 111 workshop attendees, 58 opened and responded to some questions in the survey. Of this group, 28 answered every question.

[55] The "other" category consisted of students, an extension agent, and an "owner."

respondent agreement on many of the questions, numerical results have been translated in the following way to facilitate reading:

- Majority = 80% to 99.9%
- Most = 60% to 79.9%
- About half = 40% to 59.9%
- Several = 20% to 39.9%
- A few = 0.1% to 19.9%

Note that all the survey questions can be found in the Appendix.

Climate change and adaptive forest management

This section reports responses to survey questions about climate change as well as the use of active adaptive forest management (AAFM), one model for the management of ecosystems under conditions of uncertainty, such as that posed by climate change. Climate change and adaptation were presented in Chapter 2 and 3, and this section reveals some of the beliefs about these topics amongst the BC forestry community, especially of those that attended the CCA-SFM workshop at UBC.

For the purposes of the survey, AAFM was defined as *the explicit, purposeful, and systematic testing of forest management hypotheses on-the-ground (i.e. experimentation) to develop information, increase knowledge, and build understanding through monitoring and evaluation in order to reduce the vulnerability of both forest ecosystems and management. Fundamental to this is the cyclical integration of what is learned in planning and policy development to guide new action* (Stankey et al., 2005).

All of the of respondents felt that climate change will impact forest management over the next 50 years (n=41), and a majority (n=39) felt that humans have a responsibility to help forest ecosystems become more resilient to cope with climate change. When asked to individually rank forest values on their vulnerability to climate change, a majority of people felt that biodiversity is most vulnerable, most felt that water is the most vulnerable, and several felt that timber is the most vulnerable (n=38, respectively). Cultural and recreation/aesthetic values were seen as the least vulnerable to climate change.

Most respondents strongly agreed that forest managers should account for climate change impacts in their planning (n= 41) and felt that the ecological risks of AAFM are not too high to outweigh the benefits (n=38). Most respondents also agreed that the threat of climate change is sufficient to support an AAFM (n=41), the social risks of AAFM do not exceed the potential benefits (n=37), and that the economic risks of AAFM are not too high (n=39).

Respondents were presented with alternative forest management options under climate change, and they ranked each individually on a scale of preference. All of them felt that doing nothing is a least preferred alternative (n=38) and that implementing AAFM on a small spatial scale as pilot programs is a most preferred (n=41). Most respondents preferred implementation of AAFM on a large scale, and a few preferred a reactive approach to management under climate change, acting as events unfold.

In addition, a majority of respondents believed that some level of unintended negative impacts resulting from AAFM are acceptable, provided efforts are taken to mitigate them (n=39). Most respondents agree that the use of an integrated and coordinated planning system similar to that required for third party sustainable forest management certification would be an effective way to implement AAFM under climate change; several had neutral feelings and a few thought that it would not be an effective means (n=37).

Reforestation under climate change in British Columbia

This section reports responses to survey questions about current reforestation practices and the use of alternative reforestation methods to address potential climate change impacts. Chapter 3 discusses the importance of adaptation and how it can be implemented in the forest sector. Reforestation was identified as an integral part of any adaptive forest management strategy; however, several non-climate forces and conditions may affect the capacity for managers to utilize it toward climate impact related objectives. In this survey, these forces were presented to respondents as institutional, policy-related, organizational, economic, social and technical barriers that are potentially constraining to the use of alternative reforestation to address climate vulnerability in BC forestry. For the questions in this section, “alternative reforestation” was defined as *increasing tree species diversity and planting novel species mixes by forest tenure holders in BC.*

Institutional forces or barriers relate to overall forest objectives and the way in which management planning toward these is conducted in BC. Policy-related forces have to do with the direction and guidance that dictate how reforestation is conducted. Organizational barriers encompass how decisions are made as well as how information is generated and disseminated. Economic forces are those related to the way in which forests are valued financially, management is funded, and the merchantability of trees. Social forces relate to cultural values and public opinions, and technical forces have to do with the kinds of information needed for adaptive reforestation. There is certainly some overlap with respect to these, so it was useful for respondents to rank each potential barrier individually on a scale from least constraining to most constraining, regardless of the category.

Most respondents felt that current reforestation practices in BC do not sufficiently account for climate change, nor that they adequately promote ecosystem resilience (n=29). A majority felt that in light of future uncertainty, reforestation planning should account for climate change, as it is an important management tool for ensuring future habitat (n=32) and timber (n=33) quality and availability.

Overall respondents felt that the most important kind of constraints to licensee implementation of alternative reforestation strategies in BC are economic, followed by organizational and policy-related ones (Table 10). The least important are social and technical constraints.

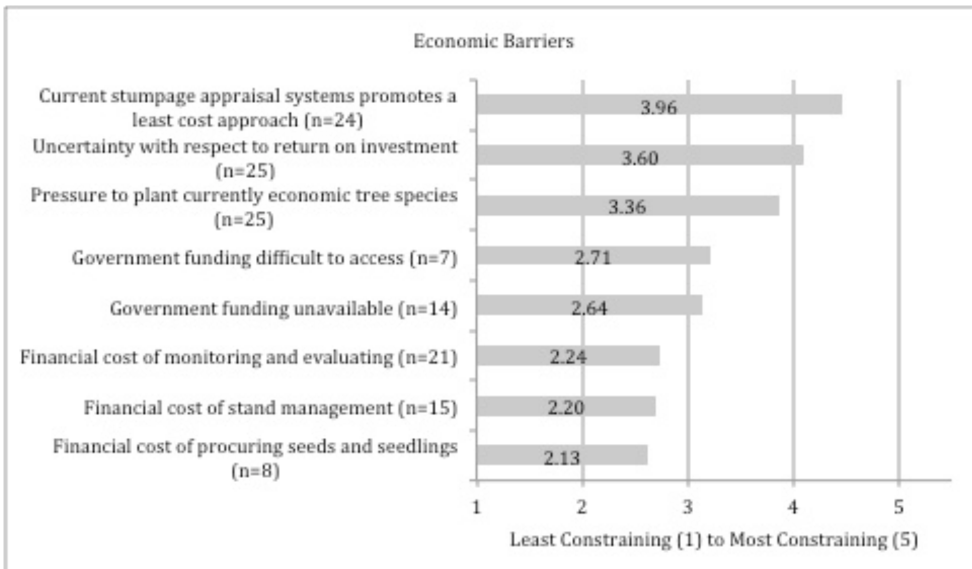
Table 10. Respondent opinions on the relative importance of several types of constraints on licensee implementation of alternative reforestation strategies in British Columbia (n=29).

Response	**Percentage**
Economic	44.8%
Institutional	17.2%
Policy-related	13.8%
Organizational	13.8%
Social	6.9%
Technical	3.4%

Economic barriers

Of the list of economic barriers presented to licensees with respect to the implementation of alternative reforestation strategies, respondents felt that the most constraining are the stumpage appraisal system, uncertainty with respect to return on investments, and pressure to plant currently economic tree species, respectively (Figure 2). The least constraining were the costs of procuring seeds and seedlings, stand management, and monitoring and evaluating forests stands.

Figure 2. Economic barriers to alternative reforestation. Mean of each ranking of the level of constraint posed by potential economic barriers to implementing alternative reforestations strategies under climate change in British Columbia.



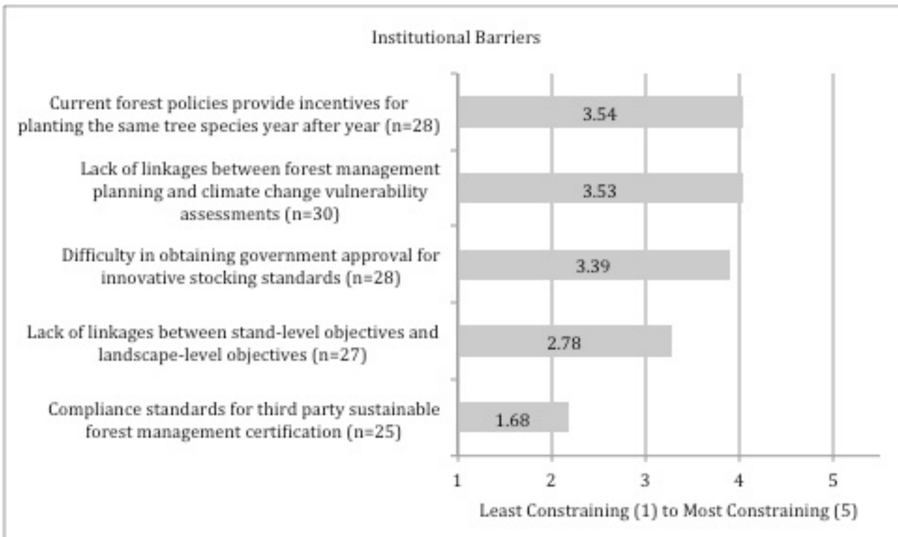
Other economic barriers that were not presented in the survey but were identified by the respondents include:

- The species/grade profile needed to support existing/planned milling infrastructure
- Cost of rehabilitation
- The stock market which encourages short term behaviours instead of long term investments
- Public rather than privately held land
- Responsibility for risk of failure
- Costs associated with plantation failure if wrong species selected or climate incompatibility

Institutional barriers

Of the listed institutional barriers to licensee implementation of alternative reforestation strategies, respondents felt that the most constraining are forest policies that provide incentives for planting the same tree species year after year, a lack of linkages between vulnerability assessments and forest management planning, and difficulty in obtaining government approval for innovative stocking standards (Figure 3). The least constraining was compliance standards for third party sustainable forest management certification:

Figure 3. Institutional barriers to alternative reforestation. Mean of each ranking of the level of constraint posed by potential institutional barriers to implementing alternative reforestations strategies under climate change in British Columbia.



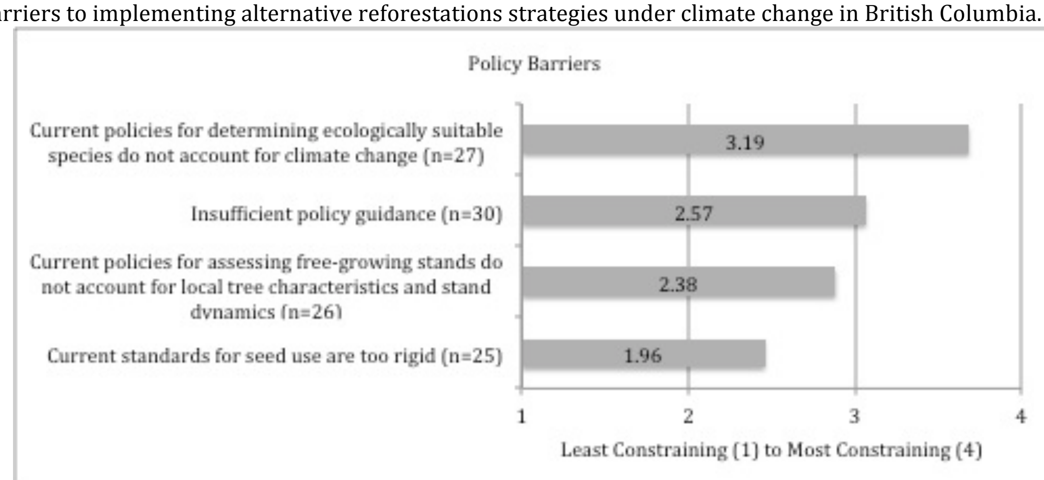
Other institutional barriers that were not presented in the survey but were identified by respondents include:

- A lack of landscape level forest objectives
- Risk averse financial policies within companies
- Stocking standard and acceptable tree species regulations
- Public ownership of land
- Seed transfer guidelines
- Tenure
- Implementation of professional reliance approach to forest management
- Current policy disincentives to plant a diversity of species
- Preference for status quo

Policy barriers

Of the listed policy barriers to licensee implementation of alternative reforestation strategies, respondents felt that the most constraining is a lack of consideration of climate change in policies that guide the determination of the most ecologically suitable species for reforestation (Figure 4). The least constraining was the chief forester's standards for seed use.

Figure 4. Policy barriers to alternative reforestation. Mean of each ranking of the level of constraint posed by potential policy barriers to implementing alternative reforestations strategies under climate change in British Columbia.



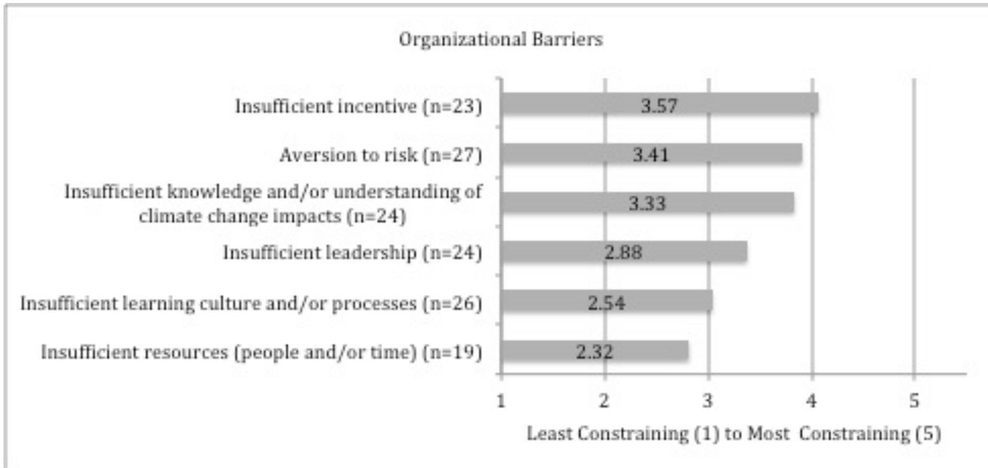
Other policy-related barriers that were not presented in the survey but were identified by respondents include:

- Stocking standards
- Free growing determination standards
- Policy making separated from management

Organizational barriers

Of the listed organizational barriers to licensee implementation of alternative reforestation strategies, respondents believed that the most constraining are insufficient incentive for licensee implementation of alternative reforestation strategies, followed by aversion to risk and insufficient understanding or knowledge of climate change impacts (Figure 5).

Figure 5. Organizational barriers to alterative reforestation. Mean of each ranking of the level of constraint posed by potential organizational barriers to implementing alternative reforestations strategies under climate change in British Columbia.

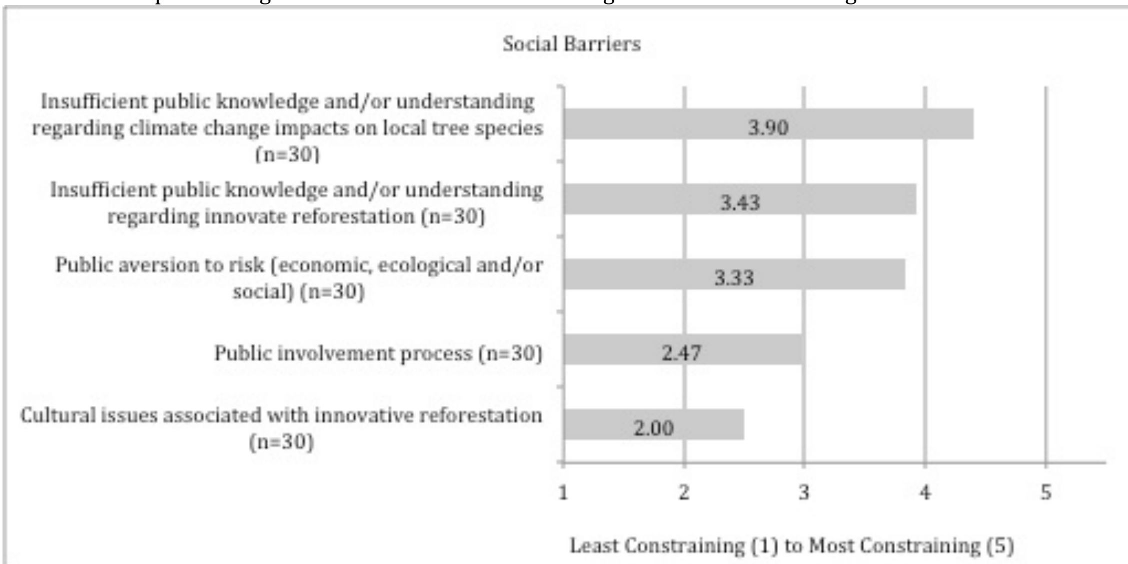


Another organizational barrier identified by one respondent was large tenures, although no explanation was given.

Social barriers

Of the listed social barriers to licensee implementation of alternative reforestation strategies, respondents felt a lack of public knowledge or understanding of climate change impacts are the most constraining (Figure 6). This may be because insufficient understanding sometimes translates to a lack of support for new ways of doing things as well as resistance to it. The least constraining were cultural issues associated with innovative reforestation.

Figure 6. Social barriers to alternative reforestation. Mean of each ranking of the level of constraint posed by potential social barriers to implementing alternative reforestations strategies under climate change in British Columbia.



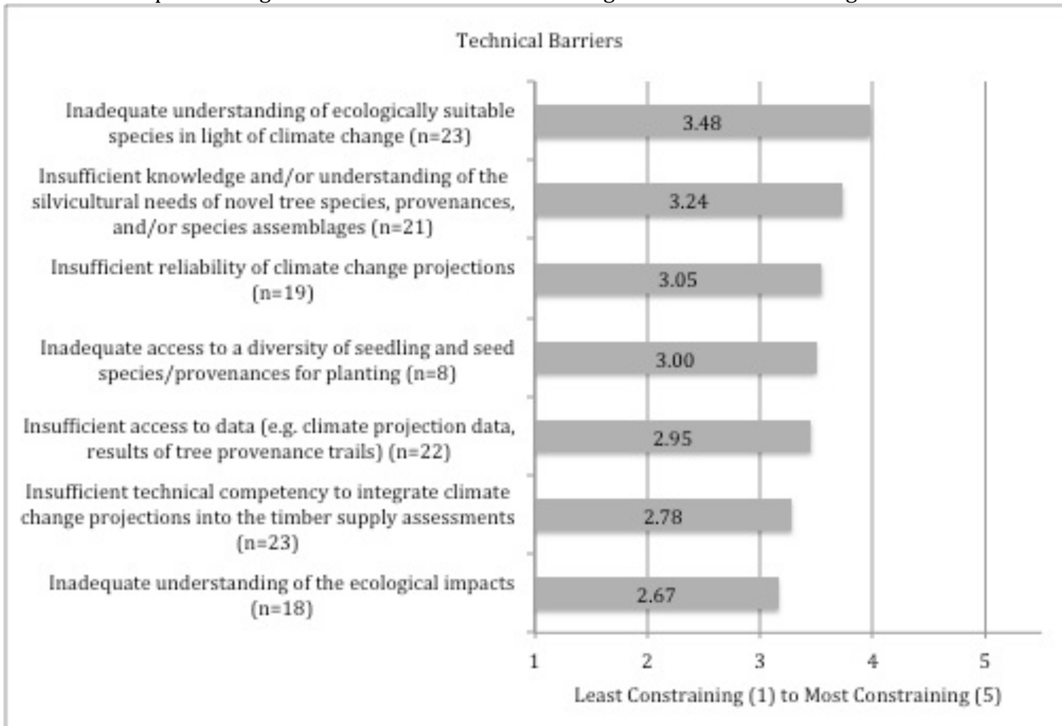
Other social barriers that were not presented in the survey but were identified by respondents include:

- Public disinterest
- Insufficient public knowledge about how climate change may affect people and their communities
- Insufficient public knowledge about how expectations may need to change
- Lack of trust

Technical barriers

Of the listed technical barriers to licensee implementation of alternative reforestation strategies, respondents indicated that the most constraining is an inadequate understanding of the ecological suitability of tree species in light of climate change, and the least constraining is an inadequate understanding of the ecological impacts of climate change (Figure 7).

Figure 7. Technical barriers to alternative reforestation. Mean of each ranking of the level of constraint posed by potential technical barriers to implementing alternative reforestations strategies under climate change in British Columbia.



Other technical barriers identified by respondents include:

- Uncertainty of the future ecosystem resilience
- Potential for disease and other 'surprises'
- Lack of knowledge of principles related to decision making under uncertainty
- Uncertainty as to the site-specific impacts of climate change

5.1.3. Summary

While the greatest number of respondents to this survey were from research organizations in BC, there was a fair representation from private companies and the government; however few were from nongovernment organizations. All respondents felt that climate change will impact forest management activities over the next 50 years. They also generally felt that humans and forest management, including reforestation practices, have a role to play in the reduction of climate change vulnerability and enhancement of ecosystem resilience. The top three forest values felt to be most at risk are biodiversity, water, and timber, respectively.

Almost all respondents felt that managers need to account for climate change and that active adaptive forest management is justified as a suitable means. As well, they felt that the benefits of adaptation are greater than social, ecological, or economic risks that may be associated with it. Respondents support small-scale systematic and planned experimentation of management strategies hypothesized to reduce forest ecosystem vulnerability from climate change. This support exists despite potential negative impacts that may occur as a result of the implementation of adaptations, since it has the potential to increase knowledge. Sustainable forest management planning with clear landscape-level objectives and measurable targets is also seen as being an effective means of implementing adaptive management.

Respondents indicated that current reforestation practices do not adequately promote ecosystem resilience in BC and that climate change considerations should play a larger role in reforestation practices. They also felt that reforestation will be especially important under climate change as a tool for maintaining biodiversity and implementing timber management and should therefore be included in forest planning.

Economic barriers are among the most important constraints to alternative reforestation, according to respondents. Especially constraining is the way in which tenure obligation allowances are calculated, as well as uncertainty, with respect to return on silviculture investments, including the costs of plantation failure and rehabilitation, should adaptations fail.

The next most important barriers were institutional ones, reflected by forest policies that incentivize planting the same species year after year, despite these not being specifically identified. In addition, there is support for a need to incorporate climate change vulnerability assessments in forest planning, including the development and approval of stocking standards.

Current forest policy barriers include established criteria for what is ecologically acceptable for planting and establishing a free-growing stand. Other barriers to alternative reforestation include social, organizational, and technical ones. Of these, especially important are insufficient public understanding of climate change impacts, risk aversion, lack of incentives, and a poor understanding of future ecological suitability and the silvicultural needs of novel species and assemblages.

While responses to this query cannot be generalized to all those involved in forest management in BC, they do represent the opinions of about half of the attendees of the *Climate Change Adaptation and Sustainable Forest Management Workshop*, many of whom have experience researching climate change and forestry issues and/or have first hand knowledge of forest management policy and practice in BC. The results identify a number of social, institutional, organizational, economic, technical, and policy-related barriers to the implementation alternative reforestation strategies in British Columbia.

The barriers identified in this survey are further explored in the Reforestation Survey which strives to understand how they affect decision-making. The next section presents the results of the Reforestation survey and explores in more detail the perspectives of timber tenure holders and government employees responsible for making and approving reforestation plans. It also identifies the needs, risks, and incentives for alternative reforestation strategies under climate change in BC, according to those groups.

5.2. Reforestation Survey Results

Results from the Adaptation Survey revealed a number of constraints on implementation of active adaptive forest management and the use of alternative reforestation strategies under climate change. This information was used to conduct the Reforestation survey.

The intent of this survey was to understand the impacts of *Forest and Range Practice Act* (FRPA) related policies and regulations on reforestation decisions in British Columbia (BC) and the factors that promote and constrain alternative reforestation strategies under climate change. The results presented here are from a self-administered electronic survey toward an understanding of each of the four research themes, or objectives namely:

- Importance and acceptability of climate change and active adaptation forest management.

- Barriers to implementing adaptive reforestation practices to address climate change in BC.
- Incentives for implementing adaptive reforestation practices under climate change in BC.
- Needs for implementing adaptive reforestation practices under climate change in BC.

5.2.1. Respondent profile

Targeted participants for the survey included timber tenure holders (licensees) and government employees with experience in the process of preparing or approving reforestation plans in BC. A solicitation for participation was sent to more than one hundred individuals via email and was placed in two electronic magazines, *Silviculture Magazine* and *Tree Planter*.[56] One hundred and twenty-nine people responded to the survey solicitation by opening the electronic survey hyperlink. Of these, 54 responded to the questions, for a response rate of 42%. The following tables show the break-down of respondents according to their work organization, position, and jurisdiction.

Table 11 Reforestation survey respondent profiles.

Type of Organization	Frequency	Percentage
Government	23	43.4%
Private Company	20	37.7%
Non-government Organization	9	17.0%
Research-Academic Organization	1	1.9%
Total	53	100%

[56] www.silviculturemagazine.com and www.treeplanter.com

Current Position within Organization	Frequency	Percentage
Program-project development and implementation	26	52.0%
Field operations	10	20.0%
Policy development	6	12.0%
Delegated decision-maker	6	12.0%
Researcher	2	4.0%
Total	50	100%

Jurisdictional Scale	Frequency	Percentage
Provincial	24	46.2%
District-Field Office	17	32.7%
Regional	7	13.5%
Municipal	4	7.7%
Total	52	100%

Possess a timber harvesting license or work for someone that does?	Frequency	Percentage
Yes	27	50.0%
No	27	50.0%
Total	54	100%

Type of License	Frequency	Percentage
Forest License, replaceable	8	29.6%
Community Forest Agreement	5	18.5%
Other	5	18.5%
Timber Sale License	3	11.1%
Forest License, non-replaceable	2	7.4%
Tree Farm License	1	3.7%
Forestry License to Cut	1	3.7%
Woodlot	1	3.7%
Private	1	3.7%
Total	27	100%

Responsible for Approving Forest Stewardship Plans	Frequency	Percentage
Yes	19	70.4%
No	8	29.6%
Total	27	100%

Independent variables

Respondents were classified into one of four groups (i.e. the independent variables) within two categories each (Plans and Licenses) to explore opinions on a number of questions from different perspectives.

Plans:

- Government Approvers (Govt Approvers or Approvers) – These respondents work for the government and approve forest stewardship plans. Out of all the respondents, 15 met these two criteria.
- Plan Makers (Makers) – These respondents possess a timber license or work for someone that does. Out of all the respondents, 27 respondents met this criterion.

These two groups are mutually exclusive. In other words, there are no Makers in the Approvers group and vice versa.

Licenses:

- Area-based Licenses (Area) – These respondents possess, or work for someone that possesses, an area-based forest license, including any one of the following: Tree Farm License, Community Forest Association License, Timber Supply License, Christmas Tree Permit, or private forest. Out of all the respondents, 10 met this criterion.
- Volume-based Licenses (Volume) – These respondents possess, or work for someone that possess a volume-based forest license, including any one of the following: Forest Licenses (replaceable or non-replaceable), Pulpwood Agreement, Forest License to Cut, or a Free Use Permit.[57] Out of all the respondents, 13 met this criterion.

These two groups are also mutually exclusive.

The Plans and Licenses independent variables were created because they represent the four main groups of actors with a direct stake in reforestation policy decisions in British Columbia. In simple terms, the actors include the licensees that make reforestation plans and the government officials that are charged, though the *Forest and Range Practices Act*, with approving them.

There are 475 major licenses across BC, each of which must prepare and submit reforestation plans in their FSPs for approval. Of these licenses, 32 are area-based and 443 are volume-based (BC MFLNRO, 2011). Additionally, there are 41 Ministry of Forest, Lands, and Natural Resource Operations district offices, each with at least one district manager, or other delegated decision maker, charged with approving FSPs and the reforestation plans within them (BC Ministry of Forests Lands and Natural Resource Operations, 2012). Area-based licenses and volume-based licenses are inherently different

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[57] Excluded from the "License" groups are those respondents with Community Salvage Licenses, as these can be either volume-based or area-based. The survey did not include an explicit question about whether or not one posses a volume-base or area-based license, instead it included a question about the kind of license.

forms of tenures with different tenure obligations and reforestation incentives. Table 12 depicts how all these groups are related to each other.

Table 12. Analytical matrix showing population sizes, sample sizes, and percentage of population represented by respondents for each of the four independent variables. Note that Area/Volume groups always represent Licensee Plan Makers and never represent Government Plan Approvers. This table does not include all survey respondents. In addition, Area and Volume-based groups are mutually exclusive.

Government Plan Approvers			**Licensee Plan Makers**			
Estimated Population	Sample	% Estimated Population Sampled		Population	Sample	% Population Sampled
41	15	37%	**Area-based**	32	10	31%
			Volume-based	443	13	3%

Dependent variables

The survey questions (dependent variables) were organized into seven different sections within the survey. These captured opinions and beliefs about:

- Stocking standards
- Free growing determination
- Stumpage appraisal
- Forest monitoring
- Climate change
- Alternative reforestation strategies, risks, barriers, and incentives

5.2.2. Descriptive statistics

The following sections present selected survey results for each of the four independent variables: Area-based Licensees (Area), Volume-based Licensees (Volume), Plan Approvers (Approvers), and Plan Makers (Makers). Results are presented

Note that all survey questions can be found in the Appendix.

Climate change and forest management

This section of the survey was intended to capture respondents opinions of climate change and the role of forest management in addressing vulnerability to its impacts. In general, there was a great deal of agreement across respondent groups and consistency between the results of this section of the survey with those of similar questions in Adaptation survey, presented in Chapter 5.1.2. An interesting question where some differences arose had to do with opinions about the adequacy of climate change projections for supporting adaptation, see Table 19.

Nearly all respondents in every group felt that climate and climate patterns in BC will change over the next 50 years (Table 13), that the greatest level of change will be with respect to extreme weather events (Figure 8), and that they will primarily have a medium to high impact on reforestation (Table 14).

Table 13. Importance of climate change. Percentage of respondents that feel that climate and climate patterns in BC will change over the next 50 years. Results are presented for each respondent group.

	All (n=54)	Area (n=9)	Volume (n=12)	Approvers (n=15)	Makers (n=24)
Yes	**94%**	**100%**	**92%**	**100%**	**96%**
No	6%	0%	8%	0%	4%
Total	100%	100%	100%	100%	100%

Figure 8. Extent of climate change. Comparison of the means of respondent group rankings on the extent they believe temperature, precipitation, and extreme weather will change over the next 50 years. Sample size varies for each variable-group combination. See Table 41 in the appendix for sample sizes and mean values.

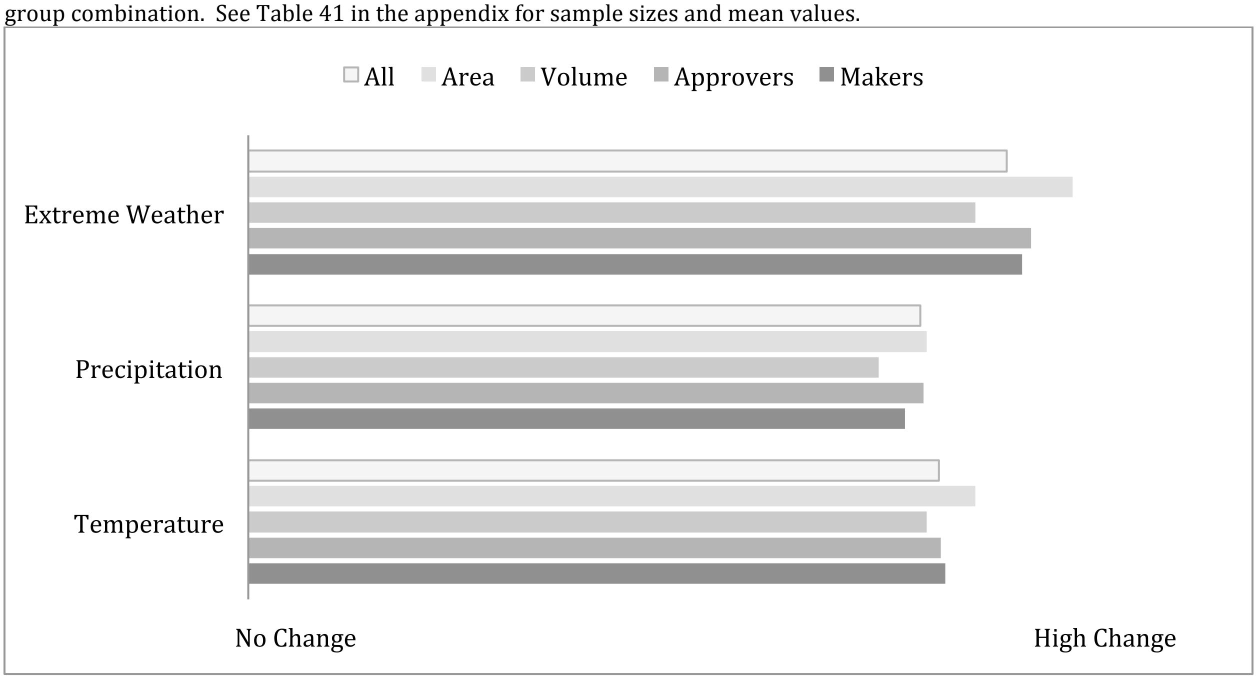


Table 14. Extent of climate change impacts on reforestation. Percentage of respondents that felt that climate change will impact reforestation practices over the next 50 years. Results are presented for each respondent group.

	All (n=55)	Area (n= 10)	Volume (n=12)	Approvers (n=15)	Makers (n=25)
Medium to High impact	**73%**	**90%**	**75%**	**67%**	**76%**
Low Impact	22%	10%	25%	33%	24%
No Impact	5%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Respondents in all groups strongly and almost completely agreed that humans have a responsibility to future generations to ensure forest ecosystems remain resilient to cope with climate change (Table 15). They also mostly agreed that forest managers need to account for climate change in their planning over one rotation (Table 16). However, beyond that, there was less agreement within groups (Table 17).

Table 15. Climate change and responsibility to future generations. Percentage of respondents who felt that humans have a responsibility to future generations to ensure forest ecosystems remain resilient to cope with climate change. Results are presented for each respondent group.

	All (n=54)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Strongly Agree	**54%**	**60%**	**62%**	**53%**	**56%**
Agree	43%	40%	38%	40%	44%
Neutral	2%	0%	0%	7%	0%
Disagree	0%	0%	0%	0%	0%
Strongly Disagree	2%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

Table 16. Climate change and forest planning over one rotation. Percentage of respondents who felt that forest managers need to account for climate change in their planning over one rotation. Results are presented for each respondent group.

	All (n=54)	Area (n=10)	Volume (n=13)	Approvers (n=14)	Makers (n=27)
Agree	**83%**	**80%**	**92%**	**86%**	**85%**
Neutral	9%	10%	0%	14%	4%
Disagree	7%	10%	8%	0%	11%
Total	100%	100%	100%	100%	100%

Table 17. Climate change and forest planning over more than one rotation. Percentage of respondents who felt that forest managers need to account for climate change in their planning over more than one rotation. Results are presented for each respondent group.

	All (n=54)	Area (n=9)	Volume (n=13)	Approvers (n=15)	Makers (n=26)
Agree	**52%**	**56%**	**38%**	**60%**	**50%**
Neutral	30%	11%	**38%**	27%	27%
Disagree	19%	33%	23%	13%	23%
Total	100%	100%	100%	100%	100%

Respondents in all groups overwhelmingly agreed that determining a tree species' ecological suitability for reforestation should incorporate information about plausible future climate change scenarios over the life of a stand (Table 18).

Table 18. Ecological suitability and climate change. Percentage of respondents that feel determining a tree species' ecological suitability for reforestation should incorporate information about plausible future climate change scenarios over the life of a stand. Results are presented for each respondent group.

	All (n=55)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Agree	**87%**	**90%**	**92%**	**87%**	**85%**
Neutral	7%	10%	0%	7%	7%
Disagree	5%	0%	8%	7%	7%
Total	100%	100%	100%	100%	100%

Overall, there were a mixed levels of agreement about whether current projections of climate change impacts are sufficient to support alternative reforestation strategies for the next planting cycle (Table 19). Government Approvers tended to feel that they are not sufficient, while Makers tended to feel that they are, indicating that there may be a slightly greater aversion to risk on the part of the government. When looking at the breakdown of Makers, an additional discrepancy is revealed: most Area-based licensees feel that climate projections are sufficient to support adaptation over the next planting cycle, whereas Volume-based licensees do not.

Regardless of feelings about climate projections, all groups mostly agreed that an active adaptive management approach is the best for implementing alternative reforestation strategies (Table 20). Additionally, respondents in all groups felt strongly that monitoring stands after they have reached free growing is very important under the uncertainty of climate change (Table 21).

Table 19. Climate change projections and alternative strategies. Percentages of respondents agreement with the statement "current projections of climate change impacts are sufficient to support alternative reforestation strategies for the next planting cycle." Results are presented for each respondent group.

	All (n=53)	Area (n=9)	Volume (n=13)	Approvers (n=14)	Makers (n=26)
Agree	38%	**67%**	38%	21%	**42%**
Neutral	21%	22%	15%	29%	19%
Disagree	**42%**	11%	**46%**	**50%**	38%
Total	100%	100%	100%	100%	100%

Table 20. Climate change and active adaptive management. Percentages of respondents that feel that an active adaptive management approach is the best approach for implementing alternative reforestation strategies. Results are presented for all respondent groups.

	All (n=53)	Area (n=9)	Volume (n=13)	Approvers (n=15)	Makers (n=26)
Agree	**79%**	**78%**	**92%**	**87%**	**85%**
Neutral	15%	11%	8%	13%	8%
Disagree	6%	11%	0%	0%	8%
Total	100%	100%	100%	100%	100%

Table 21. Climate change and forest monitoring. Percentages of respondents that feel that monitoring reforested stands after they have reached a free growing state is very important under the uncertainty of climate change. Results are presented for each respondent group.

	All (n=54)	Area (n=9)	Volume (n=13)	Approvers (n=15)	Makers (n=28)
Strongly Agree	**54%**	**78%**	**46%**	**53%**	**58%**
Agree	31%	11%	38%	40%	27%
Neutral	13%	11%	15%	7%	12%
Disagree	2%	0%	0%	0%	4%
Strongly Disagree	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

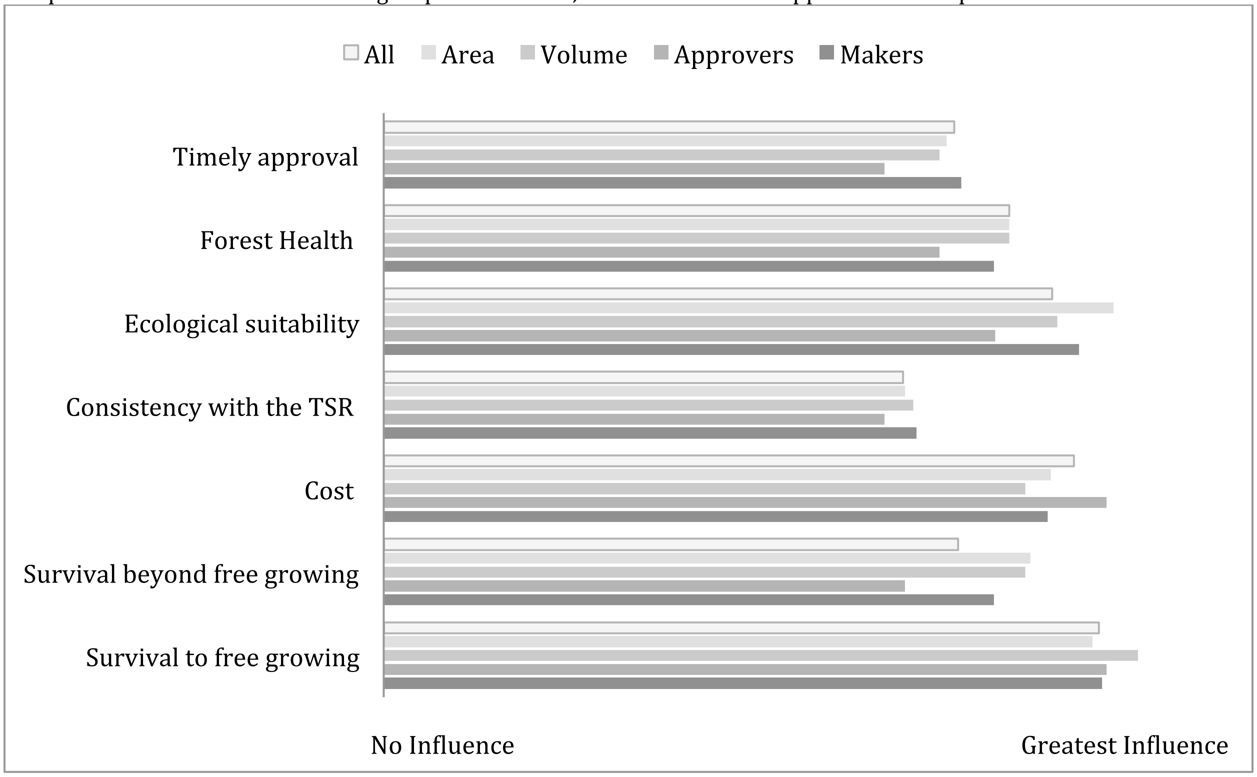
Stocking standards

Stocking standards are essentially reforestation prescriptions and are the foundation of any reforestation strategy to address climate change in BC. The choice of stocking standards by licensees is influenced by a number of things including ecological suitability, survivability, cost and consistency with government direction and guidance, many of which factor into their approvability by the provincial government. In addition, the results-based *Forest and Range Practices Act* was intended to provide professional foresters the discretion to develop stocking standards most suited to local conditions, even though they may deviate from established government guidelines. This section reports the importance of these factors to respondents for the development and approval of stocking standards. Overall, there was a great deal of agreement in opinions across the independent variable groups; however a question about stocking standard approval criteria revealed some differences in the opinions between Makers and Approvers, see Figure 10.

Influences on licensee stocking standard decisions

In this section, respondents were asked to individually rank potential influences on a scale from no influence to greatest influence. "Survival to free-growing" and "cost" were seen as two of the most influential factors on stocking standard development by a majority of respondents all groups, except Area-based licensees, of which most ranked "ecological suitability" as having a higher influence (Figure 9). "Consistency with the timber supply review" had the lowest mean rank for all groups. Table 33 in the Appendix contains the frequencies for all groups.

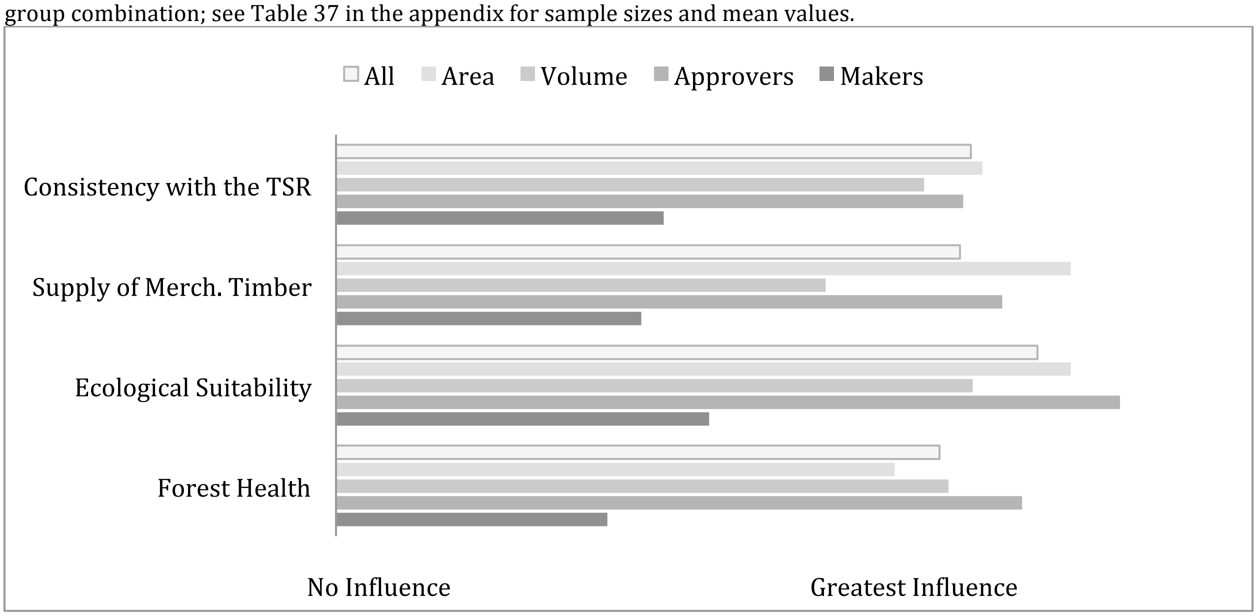
Figure 9. Mean rank of influences on stocking standards. Comparison of the means of respondent group rankings on the influence of a number of criteria for licensee decisions about tree species and planting densities for stocking standards. Sample size varies for each variable-group combination; see Table 34 in the appendix for sample sizes and mean values.



Stocking standard approval criteria

In this section, respondents were asked to individually rank stocking standard approval criteria on a scale from no influence to greatest influence. Of the criteria presented, rankings across groups were generally consistent, except Makers, who consistently ranked each criteria lower (Figure 10). This may be driven by Volume-based licensees and their low ranking for “supply of merchantable timber” relative to that of Area-based licensees, who saw it as more influential. See Table 35 in the appendix for the response frequencies for each of these groups.

Figure 10. Mean rank of stocking standard approval criteria. Comparison of the means of respondent group rankings on the influence of a number of criteria for government approval of stocking standards. Sample size varies for each variable-group combination; see Table 37 in the appendix for sample sizes and mean values.



In another related "agree or disagree question," a majority of Approvers (80%, n=15) and most of the Makers (72%, n=25) agreed that approval of stocking standards is based primarily on the ability to sustain merchantable timber volumes over time. For Makers, this was driven primarily by the responses of Area-based Licensees, all of which also agreed (n=9). Volume-based Licensees were evenly split in their agreement (n=12). See Table 36 in the appendix for the response frequencies for each of these groups.

Professional reliance and stocking standards

For these questions, respondents were asked to individually rank their level of agreement (from strongly disagree to strongly agree) with statements about stocking standard approval. Most Makers (59%, n=27) felt that approval of stocking standards does not adequately take into account understanding of local conditions by the professional forester, while most Approvers (87%, n=15) felt that is does. See Table 38 in the appendix for the response frequencies for each of these groups.

In addition, all Approvers agreed (n=15) that the government is generally willing to approve alternative stocking standards when sufficient rationale is provided. However, most Makers disagreed with that (63%, n=27). Interestingly, half of the Area-based Licensees (50%, n= 10) felt that the government is willing to approve alternatives, compared to only 8% of Volume-based Licensees (n=13) See Table 39 in the appendix for the response frequencies for each of these groups.

Free growing determination

Licensees are compelled by the BC forest management regime to establishing trees to a state of free growing on a harvested forest stands. Once a free growing determination has been made, the responsibility and liability of that stand is passed to the BC government. As such, there is a great incentive for licensees to achieve this, and the government criteria for this determination likely has a strong influence on reforestation decisions and therefore, climate change adaptation.

Most respondents in all groups felt that the free growing policy promotes reforestation with "the most commercially valuable tree species" or "the fastest growing species." See Table 40 in the appendix for response frequencies and the other options. In addition, a majority of respondents agreed that achieving free growing obligations is the main consideration for reforestation decisions by licensees (Table 22).

Table 22. Free-growing obligation and licensee decisions. Percentage of respondent agreement with the statement that "achieving free growing obligations is the main consideration for reforestation decisions by licensees." Results are presented for each respondent group.

	All (n=58)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Agree	**90%**	**100%**	**77%**	**93%**	**85%**
Disagree	10%	0%	23%	7%	15%
Total	100%	100%	100%	100%	100%

Stumpage appraisal

Chapter 4 discusses why silviculture in BC is seen by licensees primarily as a cost of doing business rather than a worthy, long term investment. This may be a consequence of tenure security issues (i.e. exclusive long term access to management units, or lack thereof) in concert with the way in which forests are valued in BC. Currently, silviculture allowances (i.e. stumpage fee reductions for licensee silviculture obligations), only cover licensee reforestation efforts, and do not account for incremental silviculture such as fertilizing, brushing, or pre-commercial thinning.

Not surprisingly, a majority of respondents in each group agreed that the stumpage appraisal system promotes a least cost approach to reforestation (Table 23).

Table 23. Stumpage appraisal and reforestation decisions. Percentage of respondent agreement with the statement that "the stumpage appraisal system promotes a least cost approach to reforestation." Results are presented for all respondent groups.

	All (n=55)	Area (n=7)	Volume (n=13)	Approvers (n=15)	Makers (n=24)
Agree	**76%**	**71%**	**85%**	**80%**	**79%**
Disagree	24%	29%	15%	20%	21%
Total	100%	100%	100%	100%	100%

Forest monitoring

Forest monitoring is critical under climate change, and this includes monitoring stands that have been declared free growing, as it is anticipated that they will continue to grow well until the next harvest cycle. If health issues arise as climate change unfolds, they must be known so that appropriate actions can be taken, mistakes avoided, and lessons learned; this requires monitoring.

Adequacy of forest monitoring

A majority of respondents in each group felt that monitoring of forest stands after they have reached a state of free growing is inadequate (Table 24).

Table 24. Adequacy of forest monitoring. Percentage of respondent agreement with the statement "there is adequate monitoring of reforested stands after they have reached a free growing state." Results are presented for all respondent groups.

	All (n=57)	Area (n=9)	Volume (n=13)	Approvers (n=15)	Makers (n=26)
Agree	11%	0%	0%	13%	0%
Neutral	14%	0%	23%	13%	19%
Disagree	**75%**	**100%**	**77%**	**73%**	**81%**
Total	100%	100%	100%	100%	100%

Responsibility for monitoring

Most respondents in each groups felt that provincial government should be responsible for monitoring forest stands after they have been declared free growing. Several respondents from each group, except Approvers, also felt that it should be a shared responsibility between the government and licensees (Table 25).

Table 25. Responsibility for forest monitoring. Percentage of respondent opinions on where the responsibility of forest monitoring lay, after licensees have met free growing obligations. Results are presented for all respondent groups.

	All (n=56)	Area (n=10)	Volume (n=12)	Approvers (n=14)	Makers (n=26)
Provincial government	**64%**	**80%**	**67%**	**86%**	**69%**
Tenure holder	9%	0%	17%	7%	12%
Shared responsibility	27%	20%	17%	7%	19%
Total	100%	100%	100%	100%	100%

A majority of respondents in all groups felt that provincial government should be responsible for the cost of monitoring after free growing obligations have been met (Table 26).

Table 26. Cost of forest monitoring. Percentage of respondent opinions on where the responsibility of the cost of forest monitoring lay, after licensees have met free growing obligations. Results are presented for all respondent groups.

	All (n=55)	Area (n=9)	Volume (n=12)	Approvers (n=14)	Makers (n=25)
Provincial government	**80%**	**89%**	**100%**	**93%**	**84%**
Tenure Holder	5%	0%	0%	7%	4%
Other	15%	11%	0%	0%	12%
Total	100%	100%	100%	100%	100%

Strategies, risks and barriers of alternative reforestation

This section of the survey was intended to capture opinions about the extent of alternative reforestation strategies that are appropriate for BC and the risks and barriers to them.

All groups mostly agree that under climate change, alternative reforestation strategies for forest resilience are best planned across a landscape, as opposed to on a stand-by-stand basis (Table 27).

Table 27. Scale of adaptive reforestation. Percentages of respondents that feel that under climate change, alternative reforestation strategies for forest resilience are best planned across a landscape, as opposed to on a stand-by-stand basis. Results are presented for all respondent groups.

	All (n=55)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Agree	**69%**	**60%**	**62%**	**87%**	**59%**
Neutral	15%	20%	15%	7%	15%
Disagree	16%	20%	23%	7%	26%
Total	100%	100%	100%	100%	100%

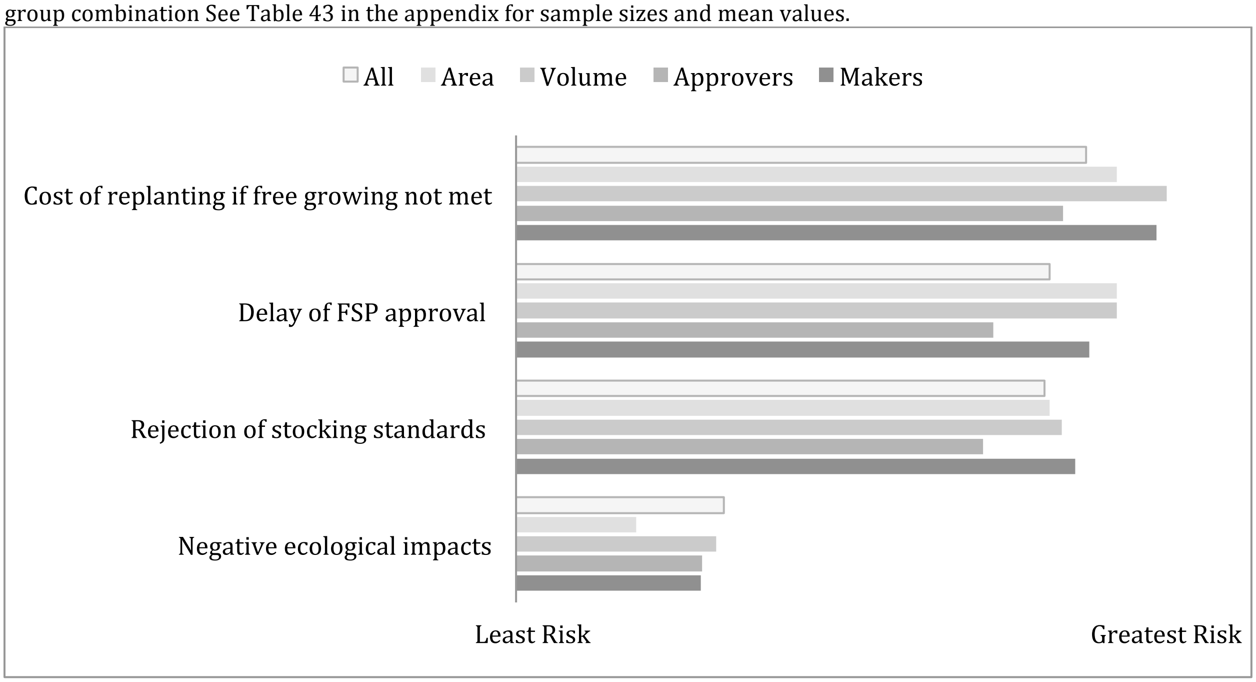
Makers felt that licensees carry most of the risk associated with alternative reforestation while Approvers felt that the government does (Table 28). This is somewhat unsurprising as each group felt that they carried most of the burden of risk.

Table 28. Alternative reforestation and risk perception. Percentage of respondents' opinions on where the risks associated with implementing alternative reforestation strategies lay. Results are presented for all respondent groups.

	All (n=54)	Area (n=9)	Volume (n=13)	Approvers (n=15)	Makers (n=26)
Currently, the government takes on most of the risk	**28%**	22%	8%	**53%**	15%
Currently, licensees take on most of the risk	**28%**	**44%**	**62%**	7%	**46%**
Currently, risks are shared equally	24%	11%	15%	13%	15%
I do not agree with any of these statements	20%	22%	15%	27%	23%
Total	100%	100%	100%	100%	100%

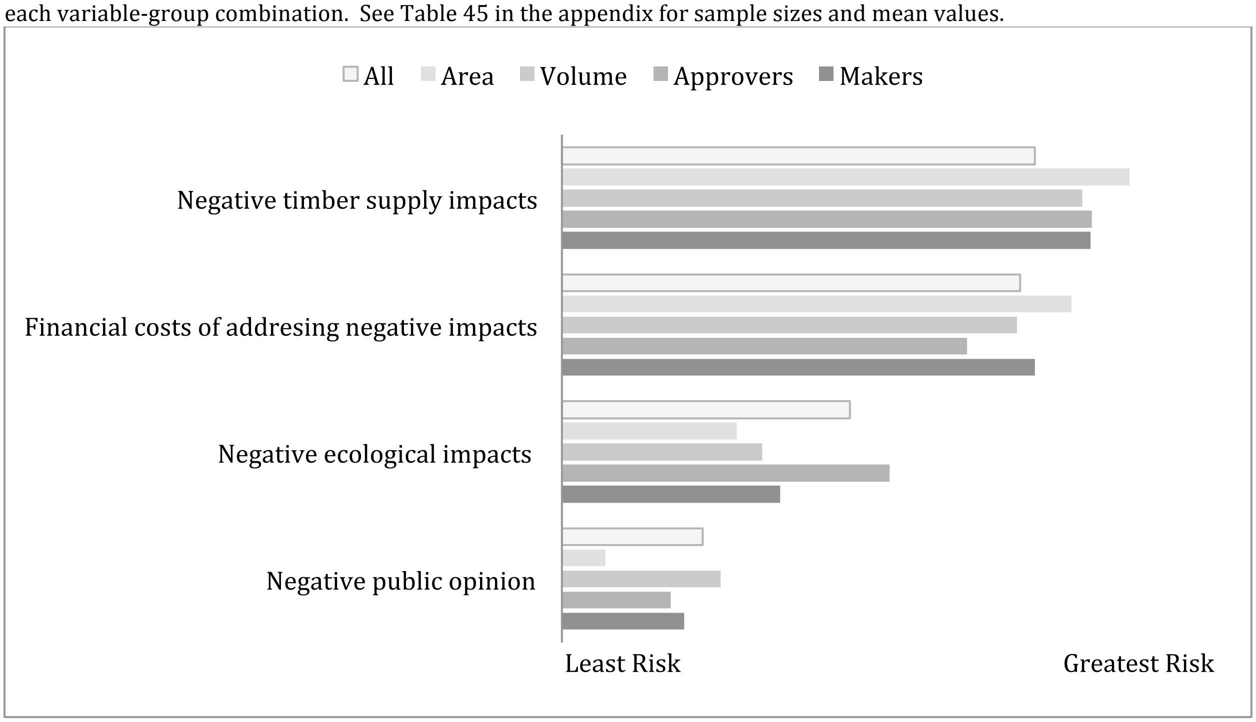
Makers felt that the "costs of replanting" are a greater risk to licensees than did Approvers, and the same was true between Volume-based Licensees and Area-based Licensees, respectively (Figure 11). This is consistent with the previous question about risk perception. Overall, "negative ecological impacts" were seen as the least risk to licensees by all groups. See Table 42 in the appendix for response frequencies.

Figure 11. Alternative regeneration risks to licensees. Comparison of the means of respondent group rankings of several risks to licensees with respect to implementing alternative reforestation strategies. Sample size varies for each variable-group combination See Table 43 in the appendix for sample sizes and mean values.



Generally, most respondents in all groups felt that “the financial costs of addressing negative impacts” and “negative impacts to the timber supply” are the greatest risks to the government with respect to implementing alternative reforestation plans (Figure 12). “Negative ecological impacts” was seen as the least risky factor by respondents in all groups. See Table 44 in the appendix for response frequencies.

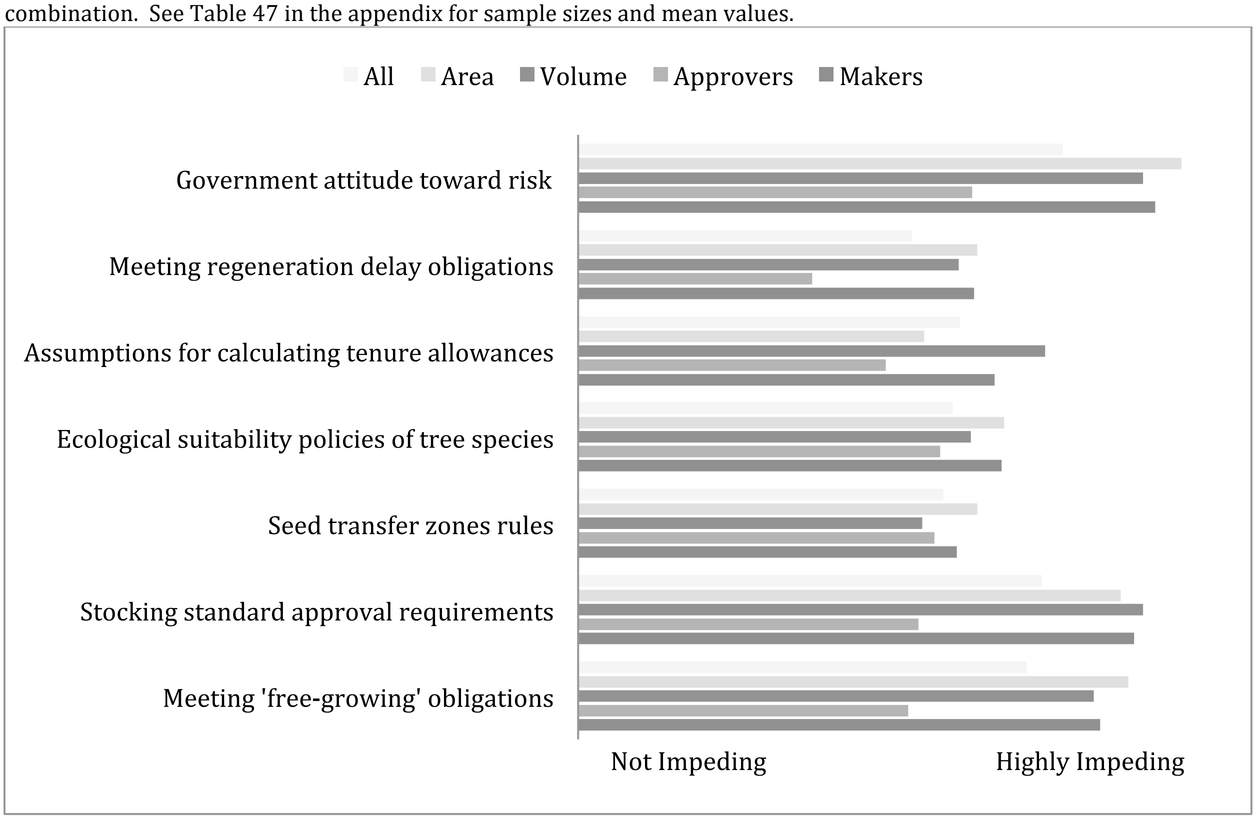
Figure 12. Alternative regeneration risks to the government. Comparison of the means of respondent group rankings of several risks to the government with respect to implementing alternative reforestation strategies. Sample size varies for each variable-group combination. See Table 45 in the appendix for sample sizes and mean values.



The most impeding barriers to licensee implementation of alternative regeneration strategies according to All respondents was “government attitude toward risk” (Figure 13). This barrier also carried the greatest weight for respondents within each of the independent variable groups. “Seed transfer rules” and “conditions for meeting regeneration delay requirements” were ranked as the least impeding over all.

The greatest differences arose between Makers and Approvers, especially with respect to opinions about “government attitude toward risk,” “meeting regeneration delay obligations,” assumptions for calculating tenure obligation allowances” (which encompass silviculture allowances discussed in Chapter 4), “meeting free growing oblations,” and “stocking standard approval requirements.” In each case, Makers saw them as being much more impeding than did Approvers. See Table 46 in the appendix for response frequencies.

Figure 13. Alternative regeneration barriers. Comparison of the means of respondent group rankings of several barriers to licensee implementation of alternative reforestation strategies. Sample size varies for each variable-group combination. See Table 47 in the appendix for sample sizes and mean values.



Incentives and policies for climate change adaptation

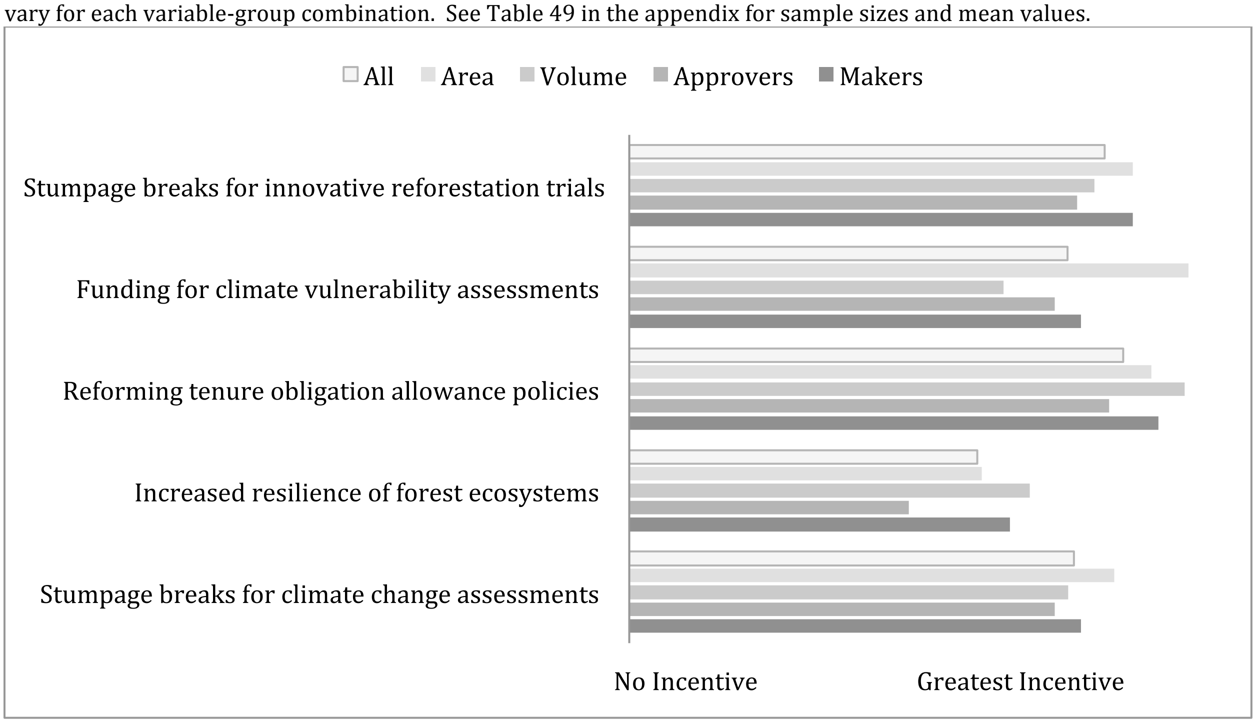
Respondents were presented with some incentive and policies alternatives to encourage climate change adaptation, including the use of reforestation to reduce vulnerabilities. They ranked each of the proposals independently of one another along an incentive scale.

Incentives

Results indicate little differences between the groups’ responses with the exception of “increased forest resilience,” which, more Makers saw as being a great incentive than did Approvers. Interestingly, a majority of Approvers felt this would provide low (53%) to no incentive (40%, n=15) for adaptation. Nevertheless, all of the other incentives were mostly ranked as providing at least a great incentive, see Table 48 in the appendix for response frequencies.

All groups mostly felt that "reforming tenure obligation allowance policies" provides the greatest level of incentive, followed by "stumpage breaks for innovative reforestation" (Figure 14). Area-based Licensees ranked "funding for climate change assessments" as the greatest incentive, well above any other group.

Figure 14. Mean rankings of climate change adaptation incentives. Comparison of the means of respondent groups' rankings of several incentives to licensee consideration of climate change in their reforestation strategies. Sample sizes vary for each variable-group combination. See Table 49 in the appendix for sample sizes and mean values.



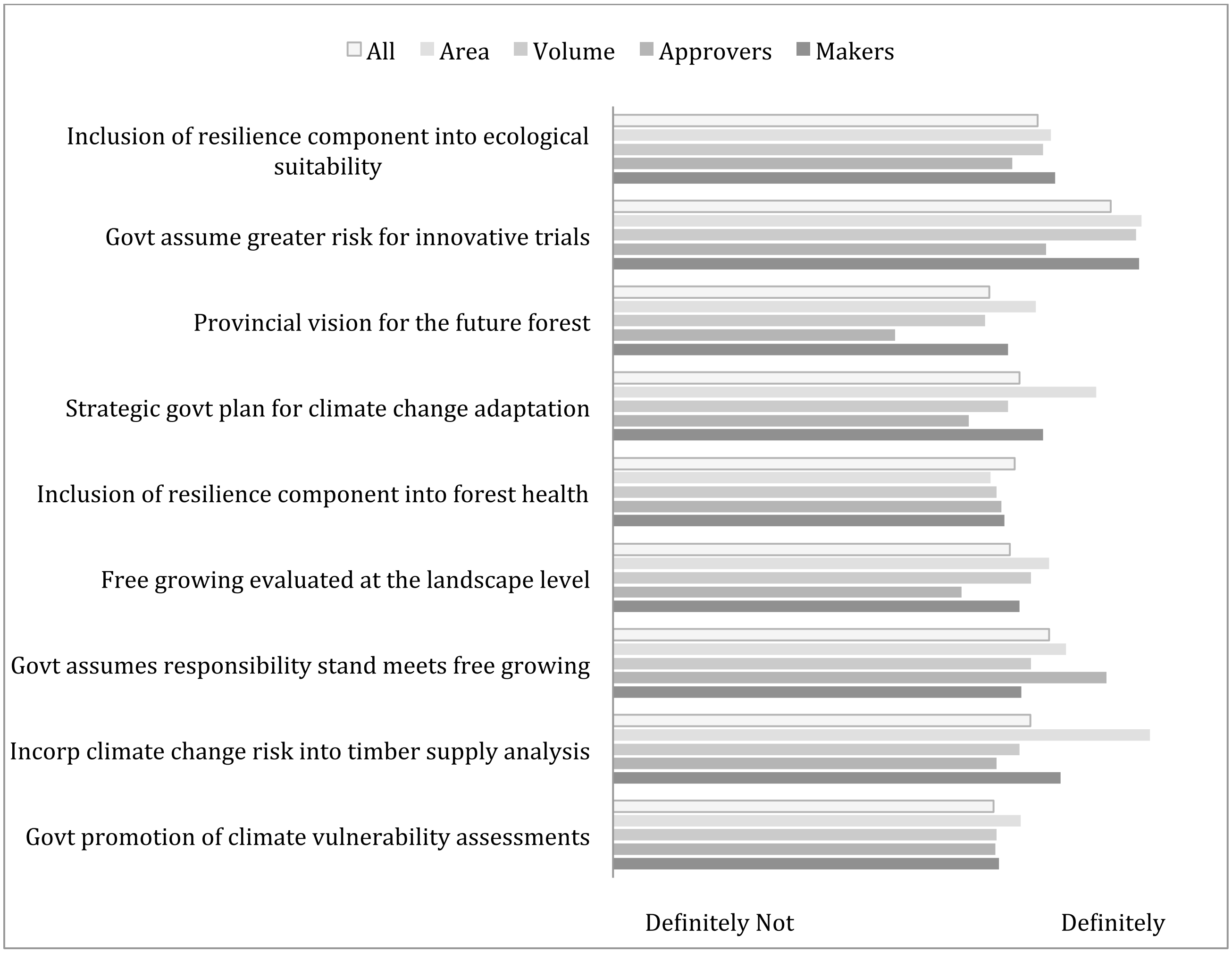
Policies

All of the policies presented will "probably" encourage licensees to consider climate change in their reforestation strategies, according to All respondents, with the exception of "government promotion of climate vulnerability assessments" and "a provincial vision for the future forest." These were ranked lowest by all groups. See Table 50 and Table 51 in the appendix for response frequencies and mean rankings. The greatest differences between groups varied, depending on the policy alternative.

Approvers felt that "government assumes responsibility of ensuring stands meet free growing determination criteria" is the policy most likely to encourage consideration of climate change in reforestation strategies. Whereas Makers felt that "government assumes a greater portion of the risks associated with innovative reforestation trials" is the most likely to encourage such considerations (Figure 15). Interestingly, Makers ranked development of a "provincial vision for the future forest" as much more likely to promote adaptation than did Approvers (Figure 15).

Area-based Licensees put the greatest weight on "incorporation of climate change risk into the timber supply analysis" and "government assuming a greater risk for innovative trials." They ranked "inclusion of resilience component into forest health" as the least likely consider climate change in their reforestation strategies (Figure 15). Volume-based Licensees felt that "government assuming a greater responsibility of the risks associated with innovative reforestation trials" is most likely to encourage climate change consideration on the part of licensees. The least likely was a "provincial vision for the future forest" (Figure 15).

Figure 15. Mean rankings of climate change adaptation policies. Relative weight of respondent group rankings on the probability that several hypothetical policies will encourage consideration of climate change by licensees in their reforestation strategies. Sample size varies for each variable-group combination See Table 51 in the appendix for sample sizes and mean values.



5.2.3. Data Exploration

Selecting statistical tests

Data exploration revealed that non-parametric statistical tests should be performed because they are distribution free and do not assume that a sample is from a normally distributed population. They may be used with nominal and ordinal data, are useful with small samples, and many are able to produce probability statements regardless of the distribution of the population from which the sample is randomly drawn (Norcliffe 1977).

The most appropriate inferential statistics for analysing the independent variables were:

- Pearson's Chi-Square test – to test differences between the distributions of two independent variables. The null hypothesis (H_0) is that there is no difference in the distributions.
    - For ordinal or nominal data
- T-test – to determine differences in the mean responses between two independent variables. The null hypothesis (H_0) is that there is no difference in the means.
    - For interval data
- For all of these tests, the level of significance (alpha α) was set at 0.05. If $p \leq 0.05$, the null hypothesis was rejected.

When comparing the mean values of two groups for two categories, such as for a 'yes' or 'no' type questions (dichotomous variables), it was possible to use a Fishers exact test. This test was also useful for cases when one of the categories had an expected frequency less than 5 in a Chi-square analysis.

- Fisher's exact test – to determine differences in the mean responses between two independent variables. The null hypothesis (H_0) is that there is no difference in the means.
- The level of significance (α) was set at 0.05. If $p \leq 0.05$, the null hypothesis was rejected.

Variable grouping

To better understand each of the respondent groups' opinions on a number of issues, several related variables were combined to form an opinion scale. This was done to increase the robustness of the inferential statistical tests by increasing the number of observations for those variables with low response frequencies.

Cronbach reliability test

A Cronbach reliability test was conducted for each variable grouping to identify consistency among values; for example, if respondents answered "high" to one question in the group, did they generally answer "high" to the others in the group? This helped determine the utility and appropriateness of grouping certain variables (Bland and Altman, 1997). For comparing groups, a Cronbach alpha value of ≥ 0.7 was acceptable. This means that means that those groupings with an alpha ≥ 0.7 could be grouped acceptably and further explored using statistical tests to discover differences, or lack thereof, between independent variables (Area, Volume, Maker, Approver). Those groupings that met the 0.7 criterion are listed below:

- FORESTER - Opinions about the importance the government places on the professional judgement of foresters in stocking standards approval (combined variables Q5 and Q6).[58]
- Interpretation - the higher the mean, the more strongly respondents felt about the importance the government places on the professional judgement of foresters during stocking standards approval.
- IMPACTS - Opinions on the extent of climate change and its impacts (combined variables Q17_1 to Q17_3 and Q18).
- Interpretation - the higher the mean, the greater the level of change in climate that respondents expected will occur.
- IMPORTANCE - Opinions on the importance of addressing climate change (combined variables Q19 to Q22).
- Interpretation - the higher the mean, the more respondents felt that climate change should be accounted for in forest management.
- CONSTRAINTS - Opinions about the level of constraint posed by several forest policies to licensee implementation of alternative reforestation strategies (combined variables Q30_1 – Q30_7).
- Interpretation - the higher the mean, the more respondents felt that current forest policies impede the implementation of alternative reforestation strategies by licensees.

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[58] Q# refers to the variable number as coded for SPSS. Variable names and their respective codes can be found in the survey in the appendix.

- INCENTIVES - Opinions about the ability of several incentives to encourage licensee consideration of climate change in their strategies for reforestation (combined variables Q31_1 – Q31_5).
- Interpretation - the higher the mean, the more respondents felt that licensees will be encouraged to consider climate change in their reforestation strategies through the implementation of listed incentives.
- GOVERNMENT - Opinions about the ability of several policy changes to encourage licensee consideration of climate change in their strategies for reforestation (combined variables Q32_1, Q32_2, and Q32_4 to Q32r_9).
- Interpretation - the higher the mean, the more respondents felt that implementing a number of policy changes will encourage licensees to consider climate change in their strategies for reforestation.

The mean responses of each of the independent variables for each variable grouping can be found in Table 29 (Plans: Approvers, Makers) and Table 30 (License: Area, Volume); their interpretation follows.

Table 29. Cronbach reliability test for Plans. Presented are mean responses of Makers and Approvers for each variable grouping that scored a Cronbach alpha ≥ 0.7.

	Plans	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Importance	Approvers	15	4.01	0.48	0.12
	Makers	27	4.00	0.54	0.10
Constraints	Approvers	14	2.12	0.58	0.16
	Makers	26	2.97	0.51	0.10
Incentives	Approvers	15	2.44	0.59	0.15
	Makers	27	2.76	0.53	0.10
Forester	Approvers	15	4.10	0.47	0.12
	Makers	27	2.54	0.95	0.18
Impacts	Approvers	15	2.88	0.69	0.18
	Makers	27	2.93	0.59	0.11
Government	Approvers	13	2.44	0.35	0.10
	Makers	26	2.84	0.53	0.10

Table 30. Cronbach reliability test for License. Presented are mean responses of Area and Volume for each variable grouping that scored a Cronbach alpha ≥ 0.7.

	License	N	Mean	Std. Deviation	Std. Error Mean
Importance	Area	10	4.03	0.64	0.20
	Volume	13	4.02	0.37	0.10
Constraints	Area	9	3.07	0.58	0.19
	Volume	13	2.89	0.44	0.12
Incentives	Area	10	2.86	0.57	0.18
	Volume	13	2.66	0.57	0.16
Forester	Area	10	2.90	1.07	0.34
	Volume	13	2.27	0.83	0.23
Impacts	Area	10	3.13	0.47	0.15
	Volume	13	2.79	0.63	0.17
Government	Area	10	3.01	0.50	0.16
	Volume	13	2.74	0.53	0.15

Interpretation of the means:

- FORESTER - Approvers/Area felt more strongly that the government places importance on the judgement of the professional forester in stocking standard approval than did Makers/Volume.
- IMPACTS - Makers/Area felt that a greater level of climate change will occur than did Approvers/Volume.
- IMPORTANCE - Approvers/Area felt more strongly that climate change should be accounted for in forest management than did Makers/Volume.
- CONSTRAINTS - Makers/Area felt more strongly that current forest policies impede the implementation of alternative reforestation strategies by licensees than did Approvers/Volume.
- INCENTIVES - Makers/Area felt more strongly that licensees will be encouraged to consider climate change in their reforestation strategies through the implementation of listed incentives than did Approvers/Volume.
- GOVERNMENT - Makers/Area felt more strongly that implementing a number of listed policy changes will encourage licensees to consider climate change in their reforestation strategies than did Approvers/Volume.

These variable groupings were analyzed further using t-test, see "Inferential Statistics," below.

5.2.4. Inferential statistics

Makers and approvers

Fisher's Exact Tests

After running a chi-square test to compare the distributions of responses for the Plans category (i.e. Makers and Approvers) for each of the dependent variables, none of the cross tabulations completely met the required assumption for a chi-square test that no more than 20% of the cells has an expected frequency less than 5. Consequently, some variable categories were combined to reduce the number of cells with expected frequencies less than 5, produce a 2x2 crosstabulation, and conduct a Fisher's exact test. Results of these revealed statistical differences ($p \leq 0.05$) in the distribution of some responses between Makers and Approvers (Table 31).

There was a significant difference between Makers and Approvers in their opinions about the risks of alternative regeneration. More Makers felt that the cost of having to replant, should a novel plantation fail to meet free-growing requirements, is a "greatest risk." Additionally, Makers primarily saw negative ecological impacts of alternative reforestation as a "least risk."

With respect to barriers, significantly more Makers felt that conditions for meeting free-growing obligations "impedes to highly impedes" alternative reforestation strategies than did Approvers. Most Approvers felt that it is "not impeding to somewhat impeding." In addition, nearly all Makers felt that stocking standard approval requirements are "impeding to highly impeding," whereas significantly more Approvers felt that it is not. The government's attitude toward risk was also an important barrier to adaptation from the perspective of Makers with significantly more who saw it as "impeding to highly impeding."

Significantly more Makers felt that if the government assumes a greater responsibility over the risks associated with alternative reforestation, it will "probably to definitely" encourage consideration of climate change when licensees prepare their reforestation strategies.

Table 31. Fisher's exact test. Presented are those cases where p ≤ 0.05 and the null hypothesis (that there is no difference in the distributions) was rejected.

Category	Variable[59]	Value	Frequency	Approvers	Makers	Fisher's Exact Sig (2-sided) p
Risks	Q28_3. Cost of replanting if free growing isn't met n=21	Greatest Risk	Count	4	13	0.012
			Percent	50.0%	100.0%	
		Least Risk	Count	4	0	
			Percent	50.0%	0.0%	
	Q29_2. Negative ecological impacts n=36	Greatest Risk	Count	6	4	0.053
			Percent	50.0%	16.7%	
		Least Risk	Count	6	20	
			Percent	50.0%	83.3%	
Barriers	Q30_1. Conditions for meeting free-growing obligations n=41	Impeding to highly impeding	Count	5	21	0.006
			Percent	33.3%	80.8%	
		Not impeding to somewhat impeding	Count	10	5	
			Percent	66.7%	19.2%	
	Q30_2. Stocking standard approval requirements n=42	Impeding to highly impeding	Count	5	26	0.000
			Percent	33.3%	96.3%	
		Not impeding to somewhat impeding	Count	10	1	
			Percent	66.7%	3.7%	
	Q30_7. Government attitude toward risk n=41	Impeding to highly impeding	Count	7	25	0.000
			Percent	46.7%	96.2%	
		Not impeding to somewhat impeding	Count	8	1	
			Percent	53.3%	3.8%	
Incentives	Q32_7. Provincial vision for the future forest n=41	Probably to definitely	Count	2	15	0.008
			Percent	13.3%	57.7%	
		Definitely not to probably not	Count	13	11	
			Percent	86.7%	42.3%	
			Percent	73.3%	100.0%	
		Definitely not to probably not	Count	4	0	
			Percent	26.7%	0.0%	

[59] Variable names and their respective codes can be found in the survey in the appendix.

T-test

The means for each of the variable groupings (described in the "Variable Grouping" section above) for the independent variables Makers and Approvers are reported in Table 29. T-tests of these revealed significant differences ($p \leq 0.05$) between the means for three sets of grouped variables: CONSTRAINTS (Approvers, mean=2.122, sd=0.582; Makers, mean=2.969, sd 0.5112; $p < 0.001$), FORESTER (Approvers, mean= 4.1000, sd=0.4006; Makers, mean=2.537, sd=0.9500; $p<0.001$), and GOVERNMENT (Approvers, mean= 2.440, sd=0.3468; Makers, mean=2.835, sd=0.52546; p=0.019). This means that there are statistically significant differences between Plan Makers and Plan Approvers for these variables. The interpretation is as follows:

- FORESTER
    - Approvers felt more strongly that the government places importance on the judgement of the professional forester in stocking standard approval than did Makers.
- CONSTRAINTS
    - Makers felt more strongly that current forest policies impede the implementation of alternative reforestation strategies by licensees than did Approvers.
- GOVERNMENT
    - Makers felt more strongly that implementing a number of listed policy changes will encourage licensees to consider climate change in their reforestation strategies than did Approvers.

For those variables groupings not listed above (i.e. IMPACTS, IMPORTANCE, INCENTIVES), there were no statistical differences between the mean responses of Approvers and Makers.

Area and volume-basedlLicenses

Fisher's exact tests

For Area and Volume, none of the cross tabulations met the required assumption for a chi-square test that no more than 20% of the categorical variables has an expected frequency less than 5. So, it was concluded that some variables groups should be combined. Results of a Fisher's exact test on these revealed that there were more similarities between the responses of Area and Volume than between Makers and Approvers, although some statistical differences were present (Table 32).

These differences were related to stocking standard approval and incentives. Specifically, all Area-based licensees felt that approval of stocking standards is based primarily on their ability to sustain merchantable timber volumes over time; volume-based licensees were split in their opinions about this. In addition, most Area-based licensees felt that the provision of additional funding for climate vulnerability assessments would be a great incentive to get licensees to account for climate change in their reforestation plans, whereas Volume-based licensees felt that it was not a very good incentive.

Table 32. Summary of results of Fisher's Exact test for several variables. Presented are those cases where $p \leq 0.05$ and the null hypothesis (that there is no difference in the distributions) was rejected.

Category	Variable	Value	Frequency	Area	Volume	Fisher's Exact Sig (2-sided) p
Stocking Standards	Q3. Approval primarily based on sustaining a supply of merchantable timber n=21	Agree	Count	9	6	0.019
			Percent	100.0%	50.0%	
		Disagree	Count	0	6	
			Percent	0.0%	50.0%	
Incentives	Q31_4. Funding for climate vulnerability assessments n=22	Great to greatest incentive	Count	8	5	0.031
			Percent	88.9%	38.5%	
		No to low incentive	Count	1	8	
			Percent	11.1%	61.5%	

T-test

T-tests revealed no significant differences in the mean responses for any of the variable groupings between Area and Volume-based Licensees. The mean scores for each independent variable can be found in Table 30.

5.2.5. Summary

Reforestation survey respondents were separated into four groups whose opinions are thought to be informative for understanding perspectives on forest policy implementation and climate change adaptation. These include the opinions of government officials that approve reforestation plans and the area and volume-based forest licensees that prepare them. Sampling methods and response rates prevent making generalizations from these samples to the larger population of licensees and government approving officials across British Columbia.

Generally, there were few differences among the responses of each group. This may suggest a level of consensus of opinion about certain issues, presenting a stronger case for making policy changes or leaving them alone. The differences of opinion that did arise were primarily between government employees that approve reforestation plans (Approvers) and licensees (Makers), especially with respect to self-perceptions of risk exposure, and the levels of constraint posed by a number of potential climate change adaptation barriers. Essentially, the government and licensee respondents each felt that they carry more of the risk associated with alternative reforestation strategies. Licensees tended to feel that a the level of constraint posed by a number of institutional characteristics and policies that affect reforestation are greater than did government plan approvers.

The strongest levels of agreement among all groups occurred for questions about:

- The importance of climate change and the role of forest management in adaptation.
- The influences on the selection and approval of stocking standards.
- Government levels of acceptable risk and their impact on reforestation practices.

Nearly all respondents felt that the climate is changing and that extreme weather events will be a major factor with respect to impacts on reforestation practices, which are anticipated to be greatly affected. They saw humans as having a responsibility to future generations to ensure forest ecosystems remain resilient to cope with climate change and that forest managers should account for it in their planning over at least the next planning cycle. Beyond that time frame, there was less agreement. Respondents also felt that the determination of ecological suitability for trees used in reforestation should consider plausible scenarios of climate change. In terms implementation, an active adaptive management approach was seen as ideal, requiring enhanced forest monitoring from current levels, including that of stands that have been declared free-growing. There was a strong indication that management strategies are most effective when they are coordinated at landscape scales rather than done in a stand by stand piece meal fashion.

The development of stocking standards seems to be primarily driven by the ability of a forest stand to reach a state of free growing, in addition to costs. In terms of approval, ecological suitability criteria for stocking standards was seen as having the greatest influence, although all criteria (consistency with the timber supply analysis, forest health, and supplying merchantable timber over time) were important. Despite this, responses to other questions indicate that there may be a bias in the approval process toward sustaining merchantable timber supplies. Since guidelines for preferred and acceptable species are based on ecological suitability as well as productivity, this situation is not a contradiction. In other words, there is room within current government guidelines for licensees to plant fast growing merchantable tree species that are thought to be ecologically suitable. However, since current research has shown that some preferred species may not actually be suitable in places, then stocking guidelines should be examined and adjusted based on the latest science (see chapter 4). Results also demonstrate agreement among groups that policies for determining silviculture allowances promote a least cost approach to reforestation, rather than one based on management objectives. This presents an opportunity to encourage silviculture investments that will enhance ecosystem resilience to cope with stresses.

Overall, respondents felt that the government's aversion to risk is one of the most impeding barriers to utilizing reforestation to address climate change, an integral tool for forest management adaptation. This stems primarily from the risk of having to pay to addressing negative impacts, whatever they may be, as well as reductions in the timber supply. This, however, is apparently affecting the approval of stocking standards that are different from the business as usual approach, which, in places, may not reflect what is best in terms of long term forest resilience.

Currently the risk of plantation failure lies on licensees who must achieve free growing criteria before the responsibility over a stand is passed back to the government. This regulation has certainly worked and ensured that forests are regenerated promptly. However, the policies that support it may not ensure an acceptable quality of forest to survive beyond free growing, an adequate level of biological diversity, or the ability to cope with climate change. In addition, many licensees agreed that the current criteria for free growing inhibits alternative approaches. These policies should ensure stands are regenerated with an acceptable assemblage of species in a manner that will provide sufficient diversity for the broader ecosystem to cope with future climate impacts, in addition to other objectives. Respondents agreed that there should be a more even distribution of the risks and costs associated with reforestation investments. In fact, licensees indicated that if the government were to assume a greater level of the risk associated with reforestation, it would very likely encourage them to build climate change into their planning. Additionally, reforming policies for determining silviculture allowances was seen as being a useful incentive to promote adaptation.

There is a suggestion that current reforestation policies tend to promote the use of the most commercially valuable and fastest growing species, rather than a balanced approach, and licensees felt more strongly than government respondents that these policies impeded the use of alternative reforestation strategies. According to licensees, implementing some policy changes as well as providing additional incentives will encourage adaptation on their part. This includes stumpage breaks for innovative reforestation trials. Area-based licensees also felt that the provision of some funds for climate vulnerability assessments would encourage adaptations as well as including elements of climate change risk into the timber supply analyses.

Other results from this study include mixed opinions about whether stocking standards and free growing criteria promote ecosystem resilience, indicating a need for improved monitoring, a lack of understanding of resilience, and/or disinterest. In addition, most licensees felt that stocking standard approval does not adequately take into account local knowledge of professional foresters and that even when sufficient rational is provided, the government is still unwilling to approve them. In addition, it seems that government respondents placed less importance overall on the judgement of professional foresters than did licensees. Furthermore, there is some evidence that the government may be more willing to approve alternative stocking standards for area-based licenses compared to volume-based ones. Seed use standards were not seen as a great barrier to alternative reforestation.

In sum, the results of this survey reveal that there is a recognition amongst the forest management community in BC that climate is changing and that something should be done. Additionally, the following may be important barriers and risks to the use of reforestation to reduce climate change vulnerability of BC forests:

- Risk aversion on the part of the provincial government
- The criteria for stocking standard approval
- The criteria needed for a declaration of free growing
- Costs of plantation failure

The following may be useful incentives to encourage climate change adaptation and promote the use of reforestation for reducing climate impact vulnerabilities:

- Developing a provincial vision for future forests in light of climate change
- Government assuming a greater amount of the risk associated with reforestation
- Incorporating climate change risk into the timber supply analysis process°
- Providing stumpage breaks for innovative reforestation efforts

- Financial support for incremental silviculture, for example, through improvements in how silviculture allowances are calculated

The implications of these results as well as some recommendations are discussed in the following chapter.

6. Discussion and Conclusions

6.1. Introduction

This study sought to describe how climate is changing in British Columbia, identify forms of adaptation that can take place within the forest sector, and explore elements of the *Forest and Range Practices Act* that may facilitate or inhibit the use of reforestation as part of an adaptation strategy. The Adaptation and Reforestation Queries provided a logical framework for understanding climate change, adaptation and the four research themes:

- Importance and acceptability of climate change and active adaptation forest management.
- Barriers to implementing adaptive reforestation practices to address climate change in BC.
- Incentives for implementing adaptive reforestation practices under climate change in BC.
- Needs for implementing adaptive reforestation practices under climate change in BC.

The results of the two surveys reveal a number of adaptive capacity issues related to the use of alternative reforestation strategies in BC to address climate change issues. These are discussed after a brief summary of climate change in British Columbia and the need for adaptation in forest management.

6.2. Climate Change

Numerous factors interact in BC to create great spatial and temporal diversity in climate and weather that contribute to the appreciable ecological diversity of the province. This includes its topography; the dynamic oceanic, continental, and arctic air masses that circulate through it; and large-scale atmosphere-ocean patterns such as the El Niño-Southern Oscillation and the Pacific Decadal Oscillation. A consequence of these is a broad range of inherent climate variability across BC, making it somewhat challenging to determine what is within a normal range and what constitutes change. Nevertheless, historical and contemporary observations reveal some significant changes in air temperature and precipitation patterns with provincial and regional trends that will continue to have important ecological and socio-economic impacts. Therefore, it is prudent to understand the change and impacts that have occurred and that may occur in order to mitigate and adapt to them within the BC forest sector. The rapid expansion and proliferation of the mountain pine beetle impacting about 17.5 million hectares of forest land demonstrates the importance of this.

Observations show that warming in BC has been occurring at a rate more than one and a half times faster than the average global rate for the last hundred years (+1.5°C between 1900–2004), a factor partially attributed to its high northern latitude. Warming has occurred differentially across spatial and temporal scales with minimum temperatures increasing faster than maximum temperatures, resulting in a reduction in the daily temperature range. The greatest warming has been occurring in the winter and spring months in the northern and southern-interior regions of the province. Precipitation trends in the province are just as variable as global ones. Generally, there has been an increase in precipitation across the province over the last century (+22% from 1900 to 2004), which is consistent with trends in the Pacific Northwest as a whole. There has also been a rise in the number of both extreme wet and extreme dry events. However, there is great spatial and seasonal variability. The greatest increases have occurred in the interior plateau region and northern coast during the summer months. The greatest decreases in precipitation have occurred in the last 50 years and have been especially notable in the interior and eastern regions of the province during the winter months.

Global and regional climate models project continued warming in British Columbia through the 21st century. The range of projections is great for both the middle and end of the 21st century; nevertheless, even the lowest projections, +1.2°C on average for the 2050s, are still cause for concern in terms of impacts. By the end of the 21st century, warming may even be as high as 4°C on average across the province. The province as a whole will likely continue to get wetter; however, finer scale modelling reveals variability, especially across seasons. Southern BC is expected to get much drier during the summer months, and the northern regions are projected to receive a greater increases in precipitation in the winter than the rest of the British Columbia. There is a higher degree of uncertainty for projections of precipitation than for temperature.

A major concern with climate change is the consequential effect on the frequency and intensity of extreme weather events. In Canada, the number of areas experiencing extreme dry and extremely wet summer conditions has increased, and in the southwest of the country there has been a significant increase in the percentage of heavy summer rainfall. In BC, there have been fewer extreme cold days and nights, fewer frost days, more extreme warm nights and days, and longer frost-free periods. In addition, there have been more precipitation days, although no consistent changes in its extremes.

Climate is an important determinant of forest ecosystem structure, function, and process. It is one of three fundamental elements (climate, vegetation, and soils) that make up the biogeoclimatic ecosystem classification system (BEC) used widely in forestry in British Columbia and the framework upon which natural resource management and much forest policy in the province is based. Understanding climate variability and change is therefore very important for understanding impacts on forest ecosystems, management, and their resultant policy implications.

As a result of 20th century global warming, there is evidence of a pole-ward migration of suitable species habitat ranges as well as upward shifts in elevation. In addition, it is having impacts on phenology, species lifecycles, growth rates, and natural disturbance events such as storms, droughts, fire, disease and insect outbreaks. Future novel climates may result in species assemblages and forest dynamics in places unlike any ecologist has ever seen. This raises questions about the implications for forest values, societal expectations, and the role of forest management. As forest ecosystems change, humans are left with the option to do nothing or adapt. In many places in BC, doing nothing is the only option. However, in places where humans can have an influence, it is in societies best interest to adapt in order to enhance resilience and reduce vulnerability as well as seize opportunities to maintain forest values for current and future generations.

6.3. Adaptation

Adaptation is one response to unavoidable climate change. Specifically, it entails taking action to reduce the vulnerability of a system impacted by climate-related stresses such as rising temperatures, altered ecosystem productivity, floods, and forest fires. It also includes taking advantage of any opportunities that climate change may present. The scale and timing of impacts are influenced by the nature of climate change (e.g., change in means, variability, or extremes of climate factors) and in turn dictate the appropriate adaptive response. Adaptation can occur in a number of ways, and in human-natural systems, such as forestry, it can be anticipatory and planned. A few examples from forestry include alternative methods of gene management, forest protection, forest regeneration, silviculture management, forest operations, non-timber resource management, and protected area management. Identifying appropriate adaptations requires an understanding of the vulnerability to the impacts of future climate stimuli, including the capacity to adapt, as well as knowledge of place, local goals and values. Implementation requires an adaptive approach best facilitated by flexible institutions that provide additional incentives as needed, encourage the acquisition of skills to work under conditions of uncertainty, incorporate lessons iteratively into policy and management, and disseminate them as information is gained through action.

In the British Columbia forest sector, climate change assessments have been under way since at least 2005, when the Future Forest Ecosystems Initiative (FFEI) was launched. However, it has not been until relatively recently that the adaptive capacity of the forest management framework has begun to be addressed. To date, there remains a critical need in the British Columbia forestry sector for adaptation-policy assessments that can bridge the gap between research on impacts and vulnerability and the operationalization of adaptive actions. This disparity is evident in the literature, is recognized by research organizations, and has been discussed at climate change workshops and conferences throughout the province. An assessment of the adaptive capacity of the BC forest management framework is critical for the development of institutional processes that are flexible enough to facilitate adaptation and evolve as societal values change and as new knowledge on the direction of climate change and its impacts is developed.

It is important to have public forest policies that support dynamic management activities to continue to meet societal expectations as ecosystems are impacted or that can also evolve as we learn more about what is realistic and adjust our expectations. Climate change puts into question traditional forest management objectives, such as restoration, meriting a dialogue with the broader BC community about the desired condition and function of BC's future forests. However, the fast rate of climate change in the Pacific Northwest requires the implementation of actions now that will reduce vulnerability in the long run.

An understanding of how public forest management decisions are influenced by the policies and rules currently in place will shed light on the effect they have on the capacity of timber tenure holders and other forest managers to adapt to climate change. This study initiates such an assessment. It utilizes reforestation in BC to ground an exploration of the influence of the *Forest and Range Practices Act* and associated legislation and regulations on licensees' ability to implement adaptation recommendations. It answers specific questions about the influence of a number of components of the BC forest management framework on decisions made by the actors responsible for managing the public forests of British Columbia.

6.4. Reforestation and Climate Change

Reforestation is an important tool that can be used to achieve desired future forest conditions. Under climate change, any combination of the following actions may help increase forest resilience, reduce management vulnerabilities, and create opportunities to maintain forest values under climate change:

- Utilizing planting stock from a mixture of provenances/genotypes that grow well under a range of conditions.
- Enhancing forest recovery after disturbances with adapted trees and plant communities.

- Utilizing drought-tolerant tree genotypes.
- Managing tree densities, species compositions, and forest structure (e.g. avoiding overstocking and balancing age classes).
- Minimizing habitat fragmentation.
- Maintaining habitat connectivity in a varied and dynamic landscape.
- Identifying and planting better suited tree species.
- Promoting mixed-species forests.

In and of themselves, these practices are not unconventional, however, there is an indication of a lack of coordination in BC and opportunities for management practices to enhance forest ecosystem resilience to cope with climate change and other stressors on public land. However, before these actions are employed by licensees, some goals related to desired conditions of the future forests of BC should be in place with an accompanying set of policies that provide direction, guidance, and incentives to facilitate the use of these activities creatively toward objectives to meet them. Policies that encourage cost sharing, risk distribution, and lesson learning within and across organizations are critical under the uncertainty of climate change impacts. In other words, the capacity to adapt to climate change depends on a flexible system of forest governance with clearly defined goals that is informed by and responsive to research and that facilitates coordinated and regular planning to meet a number of social, environmental and economic objectives, making adjustments as needed.

In BC, a number of laws, regulations, policies, and other guidance encapsulated by the *Forest and Range Practices Act* regime influence how decisions are made and the manner in which management activities are implemented, including:

- Tenure obligation adjustments
- Timber supply review analysis
- Forest stewardship plans
- Land use plans
- Stocking standards
- Free growing determination

- Standards for seed use

These components of the BC forest management regime directly and indirectly affect decisions about reforestation including the source of seeds and plants used in reforestation, the kind of species planted and their location, planting densities, the timing of planting, the amount of money invested in planting and follow-up treatments after planting, amongst others. After an examination of the limitations of this study, the outcomes of each of the four research objectives are discussed.

6.5. Study Limitations

This study was an exploration of the influence of the BC forest management framework on the capacity of timber tenure holders to use reforestation to adapt to climate change. It did not test any explicit hypothesis; rather, it followed a logical sequence of steps in an investigation designed to inform future research endeavours and even policy making. Nevertheless, some elements of the research design may be improved to reduce sample error, coverage error, and measurement error, and perhaps statistically extrapolate results to the larger populations they may represent. This includes narrowing the scope of the investigation to one or two specific questions, narrowing the population criteria, randomizing the sampling process, and utilizing several methods of data collection other than electronic surveys distributed via email. The use of focus groups may be an efficient means of exploring these issues. They provide a space for a variety of responses and opinions, rather than limiting participants to one of several categories selected by the researcher.

6.5.1. Adaptation survey

The Adaptation Query was not designed to randomly sample any population. Instead, participants at a conference about integrating climate change adaptation and sustainable forest management were targeted for their professional expertise on the subject. It was known beforehand that many of the conference attendees were actively involved in climate change and forest management research and their opinions would be useful for informing this study. However, not all of the participants were necessarily experienced in these fields, there were also students and other interested groups. The results of the Adaptation survey are useful for building an understanding of the important issues related to climate change adaptation in forest management, but they are not representative of any population other than perhaps those that attended the workshop. Nevertheless, many of the participants were indeed experts in this burgeoning field and the survey provided another avenue for them to share their insight. These lessons were incorporated into the reforestation survey, which is the central focus of the discussion and conclusions.

6.5.2. Reforestation survey

The Reforestation survey targeted individuals with experience preparing and approving reforestation plans in British Columbia. This is an immeasurable population that spans generations of individuals with experience working within any one of several dominant forestry paradigms and institutional frameworks that have existed in BC in the past. This study did not explicitly state that it intended to capture opinions of contemporary forest policies and regulations, although the jargon and policy names utilized implied it. It is possible, though unlikely, that some respondents were confused.

Since there was no discrete target population, but broad participant criteria, efforts to obtain study participants were not random. Individuals were recruited through personal contacts, networking, and publicly available information on the Internet, really anyone that had some experience in the area of study. As such, the opinions of some groups such as First Nations Woodland and Tree Farm Licensees are likely underrepresented.

Some of the survey questions may be construed as biased. For example, question 3: "approval of stocking standards is based primarily on the ability to sustain merchantable timber volumes over time; agree or disagree?" As an exploratory study, there is some leeway to pose galvanizing questions. They provide an opportunity to get straight to the point and begin to understand how people feel about certain topics and what areas could be further invested. Nevertheless, all of the questions were identified either through the adaptation survey, literature reviews, or through conversations with practicing professionals and researchers in BC forestry, and the ones selected for use are the ones that surfaced time and time again.

Some questions had respondents rank each dependent variable (e.g. criteria for stocking standard approval, influences on stocking standard decisions) along a scale (e.g. no influence to greatest influence) independently of each other, as opposed to ranking them against each other. Since many of the variables in these cases were ranked at almost the same level, the latter method would have more clearly revealed the more salient influences/criteria.

Additionally, it would have been interesting to include a question about the region where respondents work to understand opinions from the different coastal and interior forestry contexts. These regions consist of different forest types, topography, and climates and represent distinct industrial and economic realities, as well as have their own silvicultural needs and ecological challenges. Opinions about influences on reforestation decisions from each of these regions may be very different.

6.6. Alternative Reforestation Strategies Under Climate Change

This section discusses the results of the reforestation survey within the context of the research objectives which include building an understanding of research themes.

6.6.1. Theme 1 - Importance and acceptability of climate change and active adaptive forest management

The results of this study indicate that people that prepare and approve reforestation plans in BC feel that climate change is occurring and that humans have a responsibility to ensure forests are resilient to cope with those impacts. Both licensees and government employees are anticipating changes in temperature, precipitation, and extreme weather events as a result of climate change and expect that the impacts from these will affect forest management over the next 50 years. As a consequence, a majority from both groups also think that managers need to account for climate change in their planning over the next planning cycle. Despite this, there are mixed feelings about whether or not the currently available projections of climate change are sufficiently reliable to support the implementation of reforestation strategies that are different to those currently recommended in government documents. In addition to perceptions about the reliability of climate change projections (or perhaps the utility of them), many on both sides of reforestation planning (plan makers and approvers) agreed that there are several additional barriers, discussed in the following sections.

6.6.2. Theme 2 - Barriers to implementing adaptive reforestation practices to address climate change

Risk is one of the greatest barriers to trying new reforestation strategies. Not surprisingly, both licensees and the government felt that they would each carry most risk associated with implementing novel stocking standards. Risks could include ecological fall out, plantation failure, not meeting free-growing criteria, reductions in merchantable timber volumes, delays in plan implementation, or even rejection of management plans. All of these cost money and time to both licensees and the government and, consequently, pose some very important impediments to climate change adaptation.

The most important barriers to licensees are the costs associated with having to replant if free growing requirements are not met. This makes sense considering that all respondent groups overwhelmingly agreed that meeting free growing obligations is the main consideration for licensees developing stocking standards. If this is the most important factor, then adjusting the criteria for free growing determination presents an opportunity for climate change adaptation. As discussed in Chapter 4, other research has concluded that these criteria promote the use of fast growing conifer species in many places and are actually reducing stand diversity, which is the opposite of what climate change demands.

Both licensees and government employees that approve reforestation plans felt that the approval of stocking standards is primarily based on the ability to sustain merchantable timber volumes over time. The existing criteria for the approval of stocking standards is supposed to represent a balance of several important factors including forest health, ecological suitability, consistency with projections of the timber supply, and the provision of a supply of economically valuable timber. If there is an imbalance, this needs to be addressed. Interestingly, most volume-based licensees felt that the government is not willing to authorize novel stocking standard proposals even when a rationale is provided, and most area-based licensees felt that it is willing. It seems that area-based licensees are receiving more leeway for innovation than volume-based ones. If this is true, and depending on the reasons, this could support arguments for increasing the proportion of area-based tenures in BC.

With the introduction of the *Forest and Range Practices Act*, registered forest professionals have been given the discretion to apply their expertise and local knowledge to forest management in order to ensure provincial forest objectives are met. According to licensees that participated in this study, understanding of local conditions is not adequately accounted for in the approval process. In order for licensees to utilize reforestation as part of a climate change strategy, the government must be willing to trust the rationale of professionals about the best course of action, regardless of the form of tenure. Risk aversion is one of the most important impediments to climate adaptation innovation.

The approval process for stocking standards and forest stewardship plans is an important crux in the results-based framework for forest management in BC, as any attempts to be innovative can be hampered here. Approval issues could also be the consequence of insufficient capacity on the part of those responsible for approving plans. This could be in terms of technical/scientific expertise to understand and evaluate their content, time to properly review and assess them, or even to fund someone to look at them closely. Another more likely reason is aversion to risk. Once a forest stewardship plan, which contains the proposed stocking standards, is approved, the government becomes accountable if the plan is implemented as stipulated. In other words, by approving a plan, the government assumes responsibility for it.

Another reason for stocking standard rejection is that they may not meet the five key tests: 1) initial high level test 2) ecological suitability test 3) forest health test 4) supply of economically valuable timber test, and 5) consistency with the timber supply review. However, as discussed in Chapter 4, these tests and other stocking standards policy and guidance documents, demonstrate a bias toward timber objectives. Additionally, the ecological suitability test is based on stocking guidelines that offer a menu of historically preferred and acceptable species according to biogeoclimatic (BEC) zones that are based on a static climate. However, as demonstrated by the new science-based policy for the assisted migration of western larch, suitable habitats are changing with time and what is considered preferred today may not even be acceptable in the future.

Tenure obligation adjustments could be another impediment to innovation and the use of novel reforestation strategies to address climate change. As discussed in chapter 4, these are cost allowances provided to licensees for meeting their tenure obligations, such as replanting harvested stands. Currently, however, the calculation for this allowance may not always reflect the true costs of reforestation as they are overly broad and cannot capture site-specific challenges or additional costs incurred as a result of disturbance events, the patterns of which are expected to be altered as climate continues to change. This provides very little incentive for a tenure holder to spend money on anything other than on what is necessary to meet tenure obligations. Licensees are very likely not willing to innovate with species assemblages, provenances or other stocking methods that cost more upfront, especially if they cannot afford it. Two ways of addressing this would be to either give them the money to make the investments for the greater good or give them the assurance they too will benefit, say from healthy vigorous forests with ample timber, by providing adequate tenure security. A majority of both the government and licensee (area and volume-based) groups that participated in this study agreed that the cost assumptions built into the obligation adjustments have a direct influence on reforestation choices and the way they are currently set up promotes choices that are based on solely on minimizing cost. Prescriptions for reforestation should be the most likely to achieve established and measureable stand-level targets that contribute to landscape level objectives for desired future forest conditions. They should be founded on science and not solely by the desire to meet legal obligations as cheaply and as fast as possible.

6.6.3. Theme 3 - Incentives for climate change adaptation

This study has also identified a number of potential incentives to encourage the consideration of climate change on the part of BC timber tenure holders in their reforestation strategies. According to licensees, the ones with the greatest potential are reforming the way in which tenure obligation adjustments are calculated and providing stumpage breaks for innovative reforestation trials. While reimbursement for novel reforestation practices would certainly increase the chances that licensees try them out, reimbursements may be likened to unfair subsidies and would have to be carefully considered so as not to breach the terms of the existing softwood lumber agreement between the United States and Canada.

Area-based licensees put greater weight on the probability that incorporating climate change risk into timber supply analyses will encourage climate change considerations by licensees. One way this could be manifest is through projections of fire, insect outbreaks, and other disturbances and the impact they may have on timber volumes over time, expressed as probabilities. Alternative scenarios of climate change and impacts coupled with various management actions could be evaluated in the timber supply review process and a series of recommendations on the best ways of achieving established objectives could be made by the BC Chief Forester. This would in turn provide more space for developing and approving alternative stocking standards.

Most volume-based licensees felt that government acceptance of more risk associated with novel management strategies would encourage climate change adaptation on the part of licensees. Creating ways of sharing the risks associated with climate change adaptation will be an important part of any effort to increase adaptive capacity in the province. A vast majority of forests in BC are public and while tenure holders hold much of the responsibility for their management, it is ultimately the government's job to ensure that is done well. Under the present levels of future uncertainty, licensees cannot be expected to bear the entire burden of risk. It is the government's role to ensure sound management takes place, and this includes both facilitating novel management and sharing the risk. Doing so will help ensure licensees return healthy forests back to the province.

6.6.4. Theme 4 - Needs for implementing adaptive reforestation practices in BC

There was a general neutrality and lack of agreement among licensees and government employees about whether or not current reforestation practices adequately promote ecosystem resilience, and this is an indication of any one or combination of things. There is either a poor understanding of resilience, there is little concern or interest in concepts of resilience, and/or there is a lack of data available about the condition of forest stands post free growing. All of which are disconcerting and should be addressed. With respect to data availability, inventory information is critical if the province intends to learn from past management to improve forest practices and increase its ability to manage under conditions of uncertainty, as monitoring is a fundamental component of adaptive management. However, both government and licensee respondents overwhelmingly felt that current post-free growing monitoring efforts are inadequate. Implementing novel management strategies to enhance forest resilience and reduce climate vulnerability will require regular data collection from sample plots across the province, as the background climate will change differentially in places and management will vary locally. According to study participants, paying for and implementing monitoring after reaching 'free to grow' should be the responsibility of the provincial government. Since, however, it is the licensees' responsibility to ensure stands meet free growing criteria, perhaps they too could be responsible for establishing monitoring plots on their licensed areas up until that point. Another strategy, to ensure sampling precision, would be for the MFLNRO to establish ground-based sampling plots across the province and where they fall on licensed areas, it would be the licensees' responsibility to disclose information about management practices in those units. Then the MFLNRO would collect and use this information to conduct research. In this way there would be a record of forest inventory data as well how that inventory is changing as a result of management. Control plots, representative of the population of forest stands in an area, could be set up on sites that are off limits to harvesting or other management actions.

Fortunately, much of this work has already been done. The province has previously established a number of Permanent Sample Plots (PSPs) across BC to understand how stands of trees change with time to inform the development of growth and yield models. In addition, several natural resource ministries have established research plots in BC as well as ecosystem, wildlife habitat, and species inventories. Canada's National Forest Inventory – British Columbia Program has a number of ground and aerial plots across BC. All of these should be utilized as part of a provincial-scale monitoring program for assessing climate change impacts and identifying effective management practices to address them. Unfortunately, is unclear that these important sources of data are being maintained or adequately utilized to produce the kind of information necessary for a reliable monitoring program, a sentiment supported by both government and tenure-holding participants of this study.

An issue that has surfaced through this research is the need for balanced landscape level management objectives that are measurable. Currently, the eleven FRPA value objectives put too much weight on timber, limiting the ability of lower level plans to achieve broader objectives, such as reducing climate vulnerability and developing resilient forests. Currently in BC, forest management planning occurs primarily at the stand level, and there are no requirements to balance objectives at scales beyond those in a Forest Stewardship Plan. The Land and Resource Management Plans are primarily an expression of the goals of local stakeholders for natural resource use. They are non-binding high level plans that indicate zones, objectives, and strategies for natural resource exploitation such as recreation, timber extraction, mining, water, etc. They do not have measurable targets or attempt to integrate licensee strategies or provide a means for coordinated and strategic implementation. Forest Stewardship Plans are primarily a means through which the government can hold individual licensees accountable for their stewardship commitments; it is therefore not a strategic plan (BC Ministry of Forests and Range, 2009). Sustainable Forest Management plans in BC are required only as part of a voluntary forest certification process.[60] They are guided by LRMPs and in turn guide the development of FSPs where applicable. In places where SFM plans do not exist, there is no coordination of licensee strategies and activities toward landscape level goals, especially important for timber supply areas where several licensee may be operating.

6.7. Conclusions

Sound forest management requires that a strategy be set, with clear goals, objectives, and measureable targets that maintain multiple values toward which managers can strive and measure progress. The uncertainty of future climate and associated impacts on forest

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[60] Under voluntary, market-based schemes, players in BC forest industry can obtain third party verified certification for their forestry operations and tenured land in exchange for developing and implementing Sustainable Forest Management Plans in accordance with the specified standards from one of several accredited organizations.

ecosystems demands this kind of coordinated approach at the landscape-level. Uncertainty requires that we think about what we want, the desired conditions of the future forests across BC. This includes defining the landscape level functions that are deemed important and the forest structure, species, age classes, and arrangements required to maintain those functions. Since the ecological suitability of many species is put into question by climate change, promoting species diversity is likely a better approach than not. Once these objectives have been established, active adaptive forest management can be employed as part of the SFM framework to deliberately test hypotheses about the ability of a number of reforestation actions to meet the objectives under changing conditions over time. In this way we can learn to manage while managing to learn. Achieving this does not necessitate revamping major components of the current institutional framework for forest management in British Columbia. Rather a common goal for healthy resilient forest and incremental reform of a number of policies to facilitate action toward that goal would be greatly beneficial and increase the capacity for climate change adaptation.

Reforestation in British Columbia is governed through a number of policies and regulations encompassed within the *Forest and Range Practices Act*. Reforestation practices are currently assessed at the stand-level and without landscape-level objectives and targets, so it is unclear how they are affecting forest resilience to cope with climate change. Once these objectives have been determined regionally, some subtle changes to the way existing policies are designed may help facilitate the use of reforestation for objectives other than timber production, such as climate change adaptation. These include the determination criteria for free growing, the key tests used for stocking standard approval, tenure obligations, and FRPA value objectives. Aversion to risk is also one of the biggest barriers to implementation of any novel management practice. Currently licensees and the provincial government each feel that they carry most of the burden of risk with respect to reforestation. Finding ways to distribute this risk would provide more incentives for adaptation. Climate change also demands that the province improve its forest monitoring program, as it is currently inadequate to support adaptive management.

The findings of this study are in accordance with the recent Auditor General's recommendation to the MFLNRO with respect to industry stewardship. Current industry restocking activities are the result of a motivation to comply with tenure obligations as soon as possible in order to reduce financial liability and risks. This study concludes that this is the consequence of a set of reforestation policies that encourage the use of a narrow range of planting options that are based on oversimplified concepts of ecological resilience and a primary objective of ensuring sustainable timber volumes. This hampers the ability to utilize innovative and alternative reforestation strategies toward non-timber objectives in managed public forests, including the capacity to utilize reforestation and other strategies to adapt to climate change.

6.7.1. Recommendations

Climate change adaptation - To balance uncertainty, risk aversion, and a need for action, implement climate change adaptation efforts at the stand level under a carefully planned active adaptive management approach with clear landscape-level objectives and measurable targets. This would involve testing various management actions under "real" forest conditions (as opposed to controlled research plots) hypothesized to reduce forest ecosystem vulnerability, identifying new information, and utilizing it to inform future management and policy decisions. A similar design using areas designated for adaptive management is described in the Northwest Forest Plan established for federal lands of Washington, Oregon, and northern California, in the United States. There is evidence of support for this kind of approach in BC since it has great potential to increase knowledge where great uncertainty exists.

Forest planning - Land and Resource Management Plans, Sustainable Forest Management Plans for certification, and other regional plans have already been developed for the province. These can serve as the basis for regional discussions with licensees, perhaps at the forest district level, for the development of management plans that describe the goals and objectives for those regions or some other logical area designation like watersheds. These discussions should consider climate change vulnerability and the latest research on adaptation. Numerous projects funded through the Future Forest Ecosystem Scientific Council have already created information and processes related to vulnerability and adaptation, and this information should be disseminated for use in forest management planning. In this way, the forest stewardship plans of every licensee, area or volume-based, that falls within a forest district forest, or other designated area, can be developed through a climate change lens and geared toward meeting regional landscape level targets. Approval of stocking standards, free growing, and rationale for novel management can be assessed based on those objectives as well as public input on those plans. Another important issue with respect to objectives is the current FRPA limitation on the extent to which objectives affect the timber supply. Perhaps a better provision is that objectives do not unduly affect the function and diversity of the forest management landbase.

Objectives set by government – Remove the limits on timber supply impacts that may result from achieving other non-timber objectives. The appropriate balance between FRPA values should occur locally and be based on landscape-level objectives. Perhaps a more appropriate limitation is on the impact of any objective on forest resilience rather than timber supply.

Forest tenures – Tenures with more security, such as area-based ones, are more likely to result in silvicultural investments toward the reduction of climate vulnerability, especially in combination with rewards or other incentives for innovation. Increase the proportion of area-based tenures to increase tenure security and connect long term benefits of incremental silviculture to the licensees that pay for and implement it.

Timber supply review – This process should incorporate climate-related risks such as droughts, insect outbreaks, fire, etc. Another approach could be to dedicate a certain percentage of the timber harvesting landbase to an adaptive management designation where licensees are encouraged to implement alternative reforestation and other practices to reduce vulnerability.

Forest stewardship plans – should include measureable stand level targets toward landscape level objectives. The intent here is to have reforestation and other management actions within FSPs evaluated against regionally relevant objectives, requiring coordination amongst all licensees in an area. This would enhance the relevance of local forest knowledge held by forest professionals and increase opportunities for innovation.

Stocking standards – approval process for stocking standards should be improved so that risks are more evenly distributed between the licensees that steward public forests while utilizing them and the government that is responsible for ensuring they are well managed on the part of the public.

all key criteria should be reevaluated through a climate-change lens to provide space for the development of standards that reduce climate vulnerability and/or take advantage of opportunities presented by climate change.

- Concepts of ecologically suitable species should be reevaluated.
- Forest health considerations should include climate change impacts.
- Timber supply analyses should account for risks associated with climate impacts.

Ecological Suitability - update what may be considered ecologically suitable in light of climate change. This also require improvements in monitoring as many, including participants of this study, are unsure whether current government guidelines for stocking standards are adequately promoting ecosystem resilience.

Species compositions across the province will be altered with climate change and provide opportunities for the development of alternative forest products and sources of timber and fiber. Greater consideration should be given to species that may be currently uneconomical.

Free growing criteria – broadening criteria for declaring stands free growing to ensure stands are not only reforested promptly but also facilitate reforestation strategies toward the development of resilient, healthy and vigorous forests over the long term. These criteria should be based on science and principles of ecology and climate change resilience. They also should be simple enough to understand and measure. In addition, risk should be more evenly shared by the government and licensees as climate will affect forest regeneration, growth, development, and health and therefore the ability to achieve free growing status.

Standards for seed use – should continue to be updated as provenance trials and climate projections provide more information.

Monitoring – the provincial monitoring programs should be improved and geared toward understanding how forests are changing over time and how management affects them.

Plots should be designed to be representative of populations of forest stands and not solely for use in growth and yield modelling.

Professional judgment - When forest professionals provide rationale for new stocking standards, their rationale should be measured against established landscape level forest objectives, concepts of climate change adaptation and the reduction of vulnerability, not against issues of liability or single purpose management objectives, such as timber.

6.7.2. Future work

Some additional research would produce information that is useful for decision-making with respect to reforestation strategies moving forward and would increase the capacity of forestry practitioners and policy makers to address climate change, for example:

Costs and benefits of various alternative reforestation strategies (e.g. mixed species forests, mixture of provenances, variable densities) - these should include the necessary silviculture treatments (e.g. thinning) to establish well spaced and healthy stands. It should also account for risks in its analysis of cost (e.g. an increase in the susceptibility of a stand to insects, disease, and water stress)

Influence of BC's tenures on reforestation and other silvicultural practices - this should expand the existing research on the effect of the length of tenure terms and renewability to include the effect of area-based vs. volume-based tenures.

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Appendix

Adaptation Survey and Variable Codes

Policies for adaptation of forestry in British Columbia

Section 1: Opinions and beliefs about climate change and adaptive forest management.

Active adaptive forest management is one model for the management of forest ecosystems under conditions of uncertainty, such as that posed by climate change. For the purposes of this questionnaire, it is defined as the explicit, purposeful, and systematic testing of forest management hypotheses on-the-ground (i.e. experimentation) to develop information, increase knowledge, and build understanding through monitoring and evaluation in order to reduce the vulnerability of both forest ecosystems and management. Fundamental to this is the is the cyclical integration of what is learned into planning and policy development to guide new action.

Q1 1. Climate change will impact forest management over the next 50 years.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Q2 2. Humans have a responsibility to help forest ecosystems become more resilient to cope with climate change.

○ 1 Strongly Agree

○ 2 Agree

- 3 Neutral
- 4 Disagree
- 5 Strongly Disagree
- 6 Unsure

Q3 3. Forest managers need to account for climate change impacts in their management or planning.

- 1 Strongly Agree
- 2 Agree
- 3 Neutral
- 4 Disagree
- 5 Strongly Disagree
- 6 Unsure

Q4 4. The threat of climate change is not yet sufficient to promote active adaptive forest management.

- 1 Strongly Agree
- 2 Agree
- 3 Neutral
- 4 Disagree
- 5 Strongly Disagree
- 6 Unsure

Q5 5. The ecological risks of active adaptive forest management are too high and outweigh the benefits that might occur as a result.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral
- ○ 4 Disagree
- ○ 5 Strongly Disagree
- ○ 6 Unsure

Q6 6. The social risks of active adaptive forest management are too high and outweigh the benefits that might occur as a result.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral
- ○ 4 Disagree
- ○ 5 Strongly Disagree
- ○ 6 Unsure

Q7 7. The economic risks of active adaptive forest management are too high and outweigh the benefits that might occur as a result.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral
- ○ 4 Disagree
- ○ 5 Strongly Disagree

○ 6 Unsure

Q8 8. Rank the following actions regarding forest management under climate change.

From most preferred (1) to least preferred (5)

- ○ 1 Do nothing
- ○ 2 Continue with current practices.
- ○ 3 Implement a program of active adaptive forest management at a small spatial scale in isolated settings as pilots.
- ○ 4 Implement a program of active adaptive forest management at a large scale across the landscape.
- ○ 5 Adapt to climate change in a reactive manner, responding as events unfold.

Q9 9. Rank the following forest values in your jurisdiction on their vulnerability to climate change.

From most vulnerable (1) to least vulnerable (5)

- ○ 1 Biodiversity
- ○ 2 Timber
- ○ 3 Culture
- ○ 4 Recreation/Aesthetics
- ○ 5 Water

Comments (optional)

Q10 10. Rank the following forest values in your jurisdiction on their importance to you.

From most important (1) to least important (5)

- ○ 1 Biodiversity
- ○ 2 Timber
- ○ 3 Culture
- ○ 4 Recreation/Aesthetics
- ○ 5 Water

Comments (optional)

Section 2: Priorities and responsibilities for implementing active adaptive forest management on public land in British Columbia (BC)

Q11 11. Which of the following statements best describes your opinion about the financial costs of implementing active adaptive forest management on public land in BC?

- ○ 1 The provincial government should pay
- ○ 2 Timber harvest licensees should pay
- ○ 3 Local communities should pay
- ○ 4 Non-government interest groups should pay.
- ○ 5 All beneficiaries should share the financial costs
- ○ 6 Other, please specify: ____________________other
- ○ 7 N/A

Comments (optional)

Q12 12. Which of the following statements best describes your opinion about the type of organization responsible for monitoring and evaluating active adaptive forest management on public land in BC?

- ○ 1 Provincial government should be responsible
- ○ 2 Timber harvest licensees should be responsible
- ○ 3 Local communities should be responsible
- ○ 4 Non-government interest groups should be responsible
- ○ 5Monitoring and evaluation should be a multistakeholder participatory effort
- ○ 6 Other, please specify: ____________________

○ 7 N/A

Comments (optional)

Q13 13. Innovative forest management methodologies on public land in BC should be approved by the government prior to implementation.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q14 14. Monitoring and evaluation programs for active adaptive forest management on public land in BC should be developed and overseen by a multi-stakeholder board.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q15 15. It is widely understood that negative feedback, or unintended impacts, can produce valuable lessons and are important for learning.

With which of the following statements about the impacts of active adaptive forest management do you most agree?

○ 1 Unintended negative impacts are unacceptable because some of them may cause irreversible damage.

○ 2 Some level of unintended negative impacts are acceptable, provided every effort is taken to mitigate them after they take place.

○ 3 Only foreseeable, relatively minor negative impacts are acceptable.

○ 4 Unintended impacts are acceptable because the potential for gains in information, knowledge, and understanding are great.

○ 5 Other, please specify: ____________________

○ 6 N/A

Comments (optional)

Q16 16. The use of an integrated and coordinated planning system similar to that required for third party sustainable forest management certification would be an effective way to implement active adaptive forest management.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Section 3: Opinions and beliefs about innovative reforestation in post-harvested timber stands in British Columbia (BC).

Climate change may have a significant impact on the ability of certain tree species in areas throughout BC to regenerate naturally or become established after planting. This has important implications not only for timber but also species habitat quality and availability. Therefore, some studies recommend increasing the diversity of tree species and tree species mixes for post timber-harvest reforestation as a way to conserve biodiversity, promote economic and ecological resilience, and increase adaptive capacity to climate change.

Q17 17. In light of future uncertainty with respect to climate impacts on species habitats, reforestation is, or will be, an important management tool for ensuring future habitat quality and availability.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral
- ○ 4 Disagree
- ○ 5 Strongly Disagree
- ○ 6 Unsure

Comments (optional)

Q18 18. Currently in BC, reforestation is used as a tool for biodiversity management.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q19 19. Reforestation is an important management tool for ensuring future timber quantity and quality, so planning must account for future climate.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q20 20. Current reforestation practices in BC sufficiently account for climate change.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q21 21. Current reforestation practices in BC adequately promote ecosystem resilience.

○ 1 Strongly Agree

○ 2 Agree

○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Comments (optional)

Q22 22. Rank the social constraints of increasing tree species diversity and planting novel species mixes by timber harvesting licensees in BC during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Public aversion to risk (economic, ecological and/or social).
- ○ 2 Insufficient public knowledge and/or understanding regarding innovate reforestation.
- ○ 3 Insufficient public knowledge and/or understanding regarding climate change impacts on local tree species.
- ○ 4 Public involvement process.
- ○ 5 Cultural issues associated with innovative reforestation.

Q22A Are there other social constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

○ 1 No

○ 2 Yes (please specify) ____________________other

○ 3 Unsure

Comments (optional)

Q 23 23. Rank the institutional constraints of increasing tree species diversity and planting novel species mixes by timber harvesting licensees in BC during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Lack of linkages between forest management planning and climate change vulnerability assessments.
- ○ 2 Current forest policies provide incentives for planting the same tree species year after year.
- ○ 3 Difficulty in obtaining government approval for innovative stocking standards.
- ○ 4 Lack of linkages between stand-level objectives and landscape-level objectives.
- ○ 5 Compliance standards for third party sustainable forest management certification.

Q23A Are there other institutional constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

○ 1 No

○ 2 Yes (please specify) ____________________other

○ 3 Unsure

Comments (optional)

Q24 24. Rank the top 5 economic constraints of timber-harevesting licensees in BC to increase tree species diversity and plant novel species mixes during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Government funding unavailable.
- ○ 2 Government funding difficult to access.
- ○ 3 Uncertainty with respect to return on investment.
- ○ 4 Current stumpage appraisal systems promotes a least cost approach.
- ○ 5 Pressure to plant currently economic tree species.
- ○ 6 Financial cost of procuring seeds and seedlings.
- ○ 7 Financial cost of stand management.
- ○ 8 Financial cost of monitoring and evaluating.

Q24A Are there other economic constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

○ 1 No

○ 2 Yes (please specify) ____________________other

○ 3 Unsure

Comments (optional)

Q25 25. Rank the organizational constraints of timber-harvesting licensees in BC to increase tree species diversity and plant novel species mixes during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Aversion to risk.
- ○ 2 Insufficient leadership
- ○ 3 Insufficient knowledge and/or understanding of climate change impacts.
- ○ 4 Insufficient incentive.
- ○ 5 Insufficient resources (people and/or time).
- ○ 6 Insufficient learning culture and/or processes.

Q25A Are there other organizational constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

○ 1 No

○ 2 Yes (please specify) ____________________other

○ 3 Unsure

Comments (optional)

Q26 26. Rank the top 5 technical constraints of timber-harvesting licensees in BC to increase tree species diversity and plant novel species mixes during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Insufficient reliability of climate change projections.
- ○ 2 Insufficient access to data (e.g. climate projection data, results of tree provenance trails).
- ○ 3 Inadequate access to a diversity of seedling and seed species/provenances for planting.
- ○ 4 Insufficient knowledge and/or understanding of the silvicultural needs of novel tree species, provenances, and/or species assemblages.
- ○ 5 Insufficient technical competency to integrate climate change projections into the timber supply assessments.
- ○ 6 Inadequate understanding of ecologically suitable species in light of climate change.
- ○ 7 Inadequate understanding of the ecological impacts.

Q26A Are there other technical constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

- ○ 1 No
- ○ 2 Yes (please specify) ____________________other
- ○ 3 Unsure

Comments (optional)

Q27 27. Rank the policy-related constraints of timber-harvesting licensees in BC to increase tree species diversity and plant novel species mixes during reforestation.

From most constraining (1) to least constraining (5)

- ○ 1 Insufficient policy guidance.
- ○ 2 Current standards for seed use are too rigid.
- ○ 3 Current policies for assessing free-growing stands do not account for local tree characteristics and stand dynamics.
- ○ 4 Current policies for determining ecologically suitable species do not account for climate change.

Q27A Are there other policy constraints you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

- ○ 1 No
- ○ 2 Yes (please specify) ____________________other
- ○ 3 Unsure

Comments (optional)

Q28 28. What is the most important kind of constraint you think might inhibit timber harvesting licensees from increasing tree species diversity and planting novel species mixes in BC during reforestation?

- ○ 1 Social
- ○ 2 Institutional
- ○ 3 Economic
- ○ 4 Organizational
- ○ 5 Technical
- ○ 6 Policy-related

○ 7 Unsure

Q29 29. Please list at least 2 incentives for organizations to implement policies that promote increasing diversity of tree species and species assemblages during reforestation in BC.

You may add more if you wish.

1.

2.

3.

4.

Comments (optional)

Section 4: Opinions and beliefs about increasing flexibility in the use of old-growth management areas (OGMAs) in British Columbia (BC).

The need for reserves to provide habitat elements for a range of plants and animals will not change in the future, yet climate change is threatening to alter the character of existing reserves, often reducing the amount of habitat or even changing species composition. Therefore, some studies recommend the maintenance of flexibility with respect to large habitat reserves, such as Old Growth Management Areas (OGMAs), so that some can be moved if species shift their use of habitats.

30. In light of future uncertainty with respect to climate change impacts on large habitat reserves, flexibility in their delineation is an important management tool for biodiversity conservation.

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

31. OGMAs are the most effective landscape-level tools for meeting biodiversity objectives and providing abundant wildlife habitat in BC.

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

32. Currently in BC, there is sufficient integration of OGMAs, a landscape-level tool for wildlife habitat and biodiversity, with stand-level tools (e.g. wildlife tree retention).

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

33. Currently in BC, there is sufficient integration of OGMAs with other landscape-level management tools for wildlife habitat and biodiversity (e.g. Ungulate Winter Ranges).

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

34. If a natural disturbance (e.g. fire or insect outbreak) destroys an OGMA, it is OK to open that area for reforestation and future timber harvesting if a replacement OGMA is established in a currently in-tact harvestable area.

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

35. If projected climate change threatens the ability of an OGMA to meet its objectives, it is OK to open that area for reforestation and future timber harvesting if a replacement OGMA is established in a currently in-tact harvestable area.

○ Strongly Agree

○ Agree

○ Neutral

○ Disagree

○ Strongly Disagree

○ Unsure

Comments (optional)

36. Rank the top 5 social constraints of shifting OGMAs from one location to another in BC.

From most constraining (1) to least constraining (5)

1
- ○ Public aversion to risk (economic, ecological and/or social).
- ○ Insufficient public knowledge and/or understanding regarding the purpose of OGMAs.
- ○ Insufficient public knowledge and/or understanding regarding climate change impacts on local forests (including OGMAs).
- ○ Public involvement process.
- ○ Cultural issues associated with existing OGMAs.
- ○ Public aversion to change.

2
- ○ Public aversion to risk (economic, ecological and/or social).
- ○ Insufficient public knowledge and/or understanding regarding the purpose of OGMAs.
- ○ Insufficient public knowledge and/or understanding regarding climate change impacts on local forests (including OGMAs).
- ○ Public involvement process.
- ○ Cultural issues associated with existing OGMAs.
- ○ Public aversion to change.

3 ○ Public aversion to risk (economic, ecological and/or social).

○ Insufficient public knowledge and/or understanding regarding the purpose of OGMAs.

○ Insufficient public knowledge and/or understanding regarding climate change impacts on local forests (including OGMAs).

○ Public involvement process.

○ Cultural issues associated with existing OGMAs.

○ Public aversion to change.

4 ○ Public aversion to risk (economic, ecological and/or social).

○ Insufficient public knowledge and/or understanding regarding the purpose of OGMAs.

○ Insufficient public knowledge and/or understanding regarding climate change impacts on local forests (including OGMAs).

○ Public involvement process.

○ Cultural issues associated with existing OGMAs.

○ Public aversion to change.

5 ○ Public aversion to risk (economic, ecological and/or social).

○ Insufficient public knowledge and/or understanding regarding the purpose of OGMAs.

○ Insufficient public knowledge and/or understanding regarding climate change impacts on local forests (including OGMAs).

○ Public involvement process.

○ Cultural issues associated with existing OGMAs.

- ○ Public aversion to change.

Are there other social constraints you think might inhibit the flexibility to shift OGMAs from one location to another?

- ○ No
- ○ Yes (please specify) ______________________
- ○ Unsure

Comments (optional)

37. Rank the institutional constraints of shifting OGMAs from one location to another in BC.

From most constraining (1) to least constraining (5)

1
- ○ Lack of linkages between OGMA delineation and climate change vulnerability assessments.
- ○ Current forest policies promote the fixed placement of OGMAs.
- ○ Difficulty in obtaining government approval.
- ○ Government lacks the necessary resources (time and/or people).
- ○ Lack of a strategic planning process to integrate landscape-level habitat objectives with stand-level timber objectives.

2
- ○ Lack of linkages between OGMA delineation and climate change vulnerability assessments.
- ○ Current forest policies promote the fixed placement of OGMAs.
- ○ Difficulty in obtaining government approval.
- ○ Government lacks the necessary resources (time and/or people).

- ○ Lack of a strategic planning process to integrate landscape-level habitat objectives with stand-level timber objectives.

3
- ○ Lack of linkages between OGMA delineation and climate change vulnerability assessments.
- ○ Current forest policies promote the fixed placement of OGMAs.
- ○ Difficulty in obtaining government approval.
- ○ Government lacks the necessary resources (time and/or people).
- ○ Lack of a strategic planning process to integrate landscape-level habitat objectives with stand-level timber objectives.

4
- ○ Lack of linkages between OGMA delineation and climate change vulnerability assessments.
- ○ Current forest policies promote the fixed placement of OGMAs.
- ○ Difficulty in obtaining government approval.
- ○ Government lacks the necessary resources (time and/or people).
- ○ Lack of a strategic planning process to integrate landscape-level habitat objectives with stand-level timber objectives.

5
- ○ Lack of linkages between OGMA delineation and climate change vulnerability assessments.
- ○ Current forest policies promote the fixed placement of OGMAs.
- ○ Difficulty in obtaining government approval.
- ○ Government lacks the necessary resources (time and/or people).
- ○ Lack of a strategic planning process to integrate landscape-level habitat objectives with stand-level timber objectives.

Are there other institutional constraints you think might inhibit the flexibility to shift OGMAs from one location to another?

○ No

○ Yes (please specify) ______________________

○ Unsure

Comments (optional)

38. Rank the economic constraints of shifting OGMAs from one location to another in BC.

From most constraining (1) to least constraining (5)

1 ○ Financial costs to government of negotiations.

○ Financial costs to timber harvest licensees of negotiations.

○ Government reluctance to invest the necessary human resources.

○ Short-term economic impact of changes to the timber harvestable land-base.

○ Financial costs of research to validate a shift.

2 ○ Financial costs to government of negotiations.

○ Financial costs to timber harvest licensees of negotiations.

○ Government reluctance to invest the necessary human resources.

○ Short-term economic impact of changes to the timber harvestable land-base.

○ Financial costs of research to validate a shift.

3 ○ Financial costs to government of negotiations.

○ Financial costs to timber harvest licensees of negotiations.

○ Government reluctance to invest the necessary human resources.

○ Short-term economic impact of changes to the timber harvestable land-base.

○ Financial costs of research to validate a shift.

4 ○ Financial costs to government of negotiations.

○ Financial costs to timber harvest licensees of negotiations.

○ Government reluctance to invest the necessary human resources.

○ Short-term economic impact of changes to the timber harvestable land-base.

○ Financial costs of research to validate a shift.

5 ○ Financial costs to government of negotiations.

○ Financial costs to timber harvest licensees of negotiations.

○ Government reluctance to invest the necessary human resources.

○ Short-term economic impact of changes to the timber harvestable land-base.

○ Financial costs of research to validate a shift.

Are there other economic constraints you think might inhibit the flexibility to shift OGMAs from one location to another?

○ No

○ Yes (please specify) ______________________

○ Unsure

Comments (optional)

39. Rank the organizational constraints to the provincial government of shifting OGMAs from one location to another in BC.

From most constraining (1) to least constraining (5)

1 ○ Aversion to risk.

○ Insufficient leadership.

○ Insufficient knowledge and/or understanding of climate change impacts.

○ Insufficient incentive.

○ Insufficient resources (people and/or time).

○ Insufficient learning culture and/or processes.

2 ○ Aversion to risk.

○ Insufficient leadership.

○ Insufficient knowledge and/or understanding of climate change impacts.

○ Insufficient incentive.

○ Insufficient resources (people and/or time).

○ Insufficient learning culture and/or processes.

3 ○ Aversion to risk.

○ Insufficient leadership.

○ Insufficient knowledge and/or understanding of climate change impacts.

○ Insufficient incentive.

○ Insufficient resources (people and/or time).

○ Insufficient learning culture and/or processes.

4 ○ Aversion to risk.

○ Insufficient leadership.

○ Insufficient knowledge and/or understanding of climate change impacts.

○ Insufficient incentive.

○ Insufficient resources (people and/or time).

○ Insufficient learning culture and/or processes.

5 ○ Aversion to risk.

○ Insufficient leadership.

○ Insufficient knowledge and/or understanding of climate change impacts.

○ Insufficient incentive.

○ Insufficient resources (people and/or time).

○ Insufficient learning culture and/or processes.

Are there other organizational constraints you think might inhibit the flexibility to shift OGMAs from one location to another?

○ No

○ Yes (please specify) ____________________

○ Unsure

Comments (optional)

40. Rank the technical constraints of shifting OGMAs from one location to another in BC.

From most constraining (1) to least constraining (5)

1 ○ Insufficient reliability of climate change projections.

○ Insufficient reliability of climate change vulnerability assessments.

- ○ Inadequate forest inventory data.
- ○ Insufficient technical competency to integrate climate change projections into forest management planning.

2
- ○ Insufficient reliability of climate change projections.
- ○ Insufficient reliability of climate change vulnerability assessments.
- ○ Inadequate forest inventory data.
- ○ Insufficient technical competency to integrate climate change projections into forest management planning.

3
- ○ Insufficient reliability of climate change projections.
- ○ Insufficient reliability of climate change vulnerability assessments.
- ○ Inadequate forest inventory data.
- ○ Insufficient technical competency to integrate climate change projections into forest management planning.

4
- ○ Insufficient reliability of climate change projections.
- ○ Insufficient reliability of climate change vulnerability assessments.
- ○ Inadequate forest inventory data.
- ○ Insufficient technical competency to integrate climate change projections into forest management planning.

Are there other technical constraints you think might inhibit the flexibility to shift OGMAs from one location to another?

- ○ No
- ○ Yes (please specify) ____________________

○ Unsure

Comments (optional)

41. Are there current policy-related constraints you think might inhibit the flexibility to shift OGMAs from one location to another in BC?

○ No

○ Yes (please specify) ____________________

○ Unsure

Comments (optional)

42. What is the most important kind of constraint you think might inhibit the flexibility to shift OGMAs from one location to another in BC?

○ Social

○ Institutional

○ Economic

○ Organizational

○ Technical

○ Policy-related

○ Unsure

43. Please list at least 2 incentives for organizations to implement policies that promote flexibility in the delineation of OGMAs in BC.

You may add more if you wish.

Section 5: Experience

Q44 44. What is your current position within your organization?

○ 1 Program/project development and implementation

○ 2 Policy development

○ 3 Researcher

○ 4 Field operations

○ 5 Delegated decision-maker

○ 6 Other (please specify) ____________________other

Q45 45. For which of the following types of organizations do you work?

○ 1 Government

○ 2 Non-government Organization

○ 3 Research/Academia

○ 4 Private Company

○ 5 Other (please specify) ____________________other

Q46 46. At what jurisdictional scale do you work?

○ 1 Federal

○ 2 Provincial/State

○ 3 Regional

○ 4 District/Field Office

○ 5 Municipal

○ 6 Other (please specify) ____________________ other

Q47 47. Where is your organization based?

○ 1 British Columbia (BC)

○ 2 Pacific Northwest (United States and/or Canada)

○ 3 Canada (outside of BC)

○ 4 Outside of Canada

Excluded 48. Are you aware of any research or projects experimenting with species habitat and/or reserves within an adaptive managment framework (active or otherwise) in BC?

○ No

○ Yes (please specify) ____________________

Q49 49. Are you currently aware of any forest managers and/or companies experimenting with reforestation within an adaptive management framework (active or otherwise) in BC?

○ 1 No

○ 2 Yes (please specify) ____________________other

Q50 50. Are you aware of any government policies in BC (past or present) for implementing some form of adaptive forest management (active or otherwise)?

○ 1 No

○ 2 Yes (please specify) ____________________other

Please provide any additional comments you would like in the space below. Thank you.

Reforestation Survey Questions and Variable Codes

Reforestation Policy Under Climate Change in British Columbia

Section 1: Current reforestation practices and policy implementation in BC.

Definitions

Hover the mouse cursor over each word to reveal its definition.Alternative stocking standardsForest health Free growingProfessional reliance ResilienceStocking standardsTenure obligation adjustment

Stocking Standards

Q1 1. Rank the weight of the following influences on licensee decisions about tree species and planting densities for stocking standards.

(note: values can be repeated; e.g. more than one variable can be valued as "greatest influence")

	1 Greatest Influence	2 Great Influence	3 Low Influence	4 No Influence	5 Unsure
Q1_1 Survival to free growing.	○	○	○	○	○
Q1_2 Survival beyond free growing.	○	○	○	○	○
Q1_3 Cost.	○	○	○	○	○
Q1_4 Consistency with the Timber Supply Review.	○	○	○	○	○
Q1_5 Ecological suitability.	○	○	○	○	○

Q1_6 Forest Health.	○	○	○	○	○
Q1_7 Timely approval.	○	○	○	○	○

Q2 2. Rank the weight of the following criteria on government approval of stocking standards.

	1 Greatest Influence	2 Great Influence	3 Low Influence	4 No Influence	5 Unsure
Q2_1 Forest health.	○	○	○	○	○
Q2 _ 2 Ecological suitability.	○	○	○	○	○
Q2_3 Supply of merchantable timber over time.	○	○	○	○	○
Q2_4 Consistency with Timber Supply Review.	○	○	○	○	○

Q3 3. Approval of stocking standards is based primarily on the ability to sustain merchantable timber volumes over time.

○ 1 Agree.

○ 2 Disagree.

○ 3 Unsure.

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree	6 Unsure
Q4 4. Government	○	○	○	○	○	○

guidelines for stocking standards adequately promote ecosystem resilience.

Q5 5. Approval of stocking standards adequately takes into account understanding of local conditions by the professional forester.	○	○	○	○	○	○
Q6 6. The government is generally willing to approve alternative stocking standards when sufficient rationale is provided.	○	○	○	○	○	○

Comments About Stocking Standards

Section 2: Free Growing

Q7 7. With which of the following statements about the influence of the free growing policy on licensees do you most agree?

○ 1 It primarily promotes reforestation with the most ecologically suitable species.

○ 2 It primarily promotes reforestation with the fastest growing species.

○ 3 It primarily promotes reforestation with the most commercially valuable tree species.

○ 4 It primarily promotes reforestation with species most likely to ensure an adequate supply of timber volumes over time.

○ 5 It primarily promotes a balanced consideration reforestation with the most ecologically suitable species, consistency with the timber supply review and forest health.

- ○ 6 I do not agree with any of these.
- ○ 7 Unsure.

Q8 8. Achieving free growing obligations is the main consideration for reforestation decisions by licensees.

- ○ 1 Agree.
- ○ 2 Disagree.
- ○ 3 Unsure.

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree	6 Unsure
Q9 9. The free growing policy ensures regenerated stands are resilient.	○	○	○	○	○	○

Comments About Free Growing

Section 3: Stumpage Appraisal

Q10 10. The stumpage appraisal system promotes a least cost approach to reforestation.

- ○ 1 Agree.
- ○ 2 Disagree.
- ○ 3 Unsure.

Q11 11. Cost assumptions built into calculations for tenure obligation adjustments directly influence licensee choices for reforestation.

- ○ 1 Agree.
- ○ 2 Disagree.
- ○ 3 Unsure.

Comments About Stumpage Appraisal

Section 4: Monitoring

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree	6 Unsure
Q12 12. Currently, reforestation practices adequately promote ecosystem resilience.	○	○	○	○	○	○
Q13 13. There is adequate monitoring of reforested stands after they have reached a free growing state.	○	○	○	○	○	○

Q14 14. Monitoring after free-to-grow should be the responsibility of...

- ○ 1 The provincial government
- ○ 2 The forest tenure holder (i.e. licensee)
- ○ 3 Other, please specify: ____________________

○ 4 Unsure

Q15 15. The cost of monitoring after free-to-grow should be the responsibility of...

○ 1 The provincial government

○ 2 The forest tenure holder (i.e. licensee)

○ 3 Other, please specify: ______other

○ 4 Unsure

Comments About Monitoring

Section 5: Climate change in British Columbia.

Importance of climate change

Q16 16. Do you feel that the climate and climate patterns in BC will change over next 50 years?

- ○ 1 Yes
- ○ 2 No
- ○ 3 Unsure

Q17 17. To what extent do you think the climate in BC will change over the next 50 years?

	1 High change	2 Medium change	3 Low change	4 No change	5 Unsure
1 Precipitation	○	○	○	○	○
2 Temperature	○	○	○	○	○
3 Extreme weather events (e.g. droughts and storms)	○	○	○	○	○

Q18 18. To what extent do you think such changes will impact reforestation practices over the next 50 years?

- ○ 1 High impact
- ○ 2 Medium impact
- ○ 3 Low impact
- ○ 4 No impact
- ○ 5 Unsure

Comments on the importance of climate change

Alternative reforestation under climate change.

Definitions

Hover the mouse cursor over each word to reveal its definition. Active adaptive managementAlternative stocking standardsFree growingProfessional relianceRegeneration delay ResilienceStocking standardsTenure obligation adjustment

Section 6: Importance of climate change

	1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree	6 Unsure
Q19 19. Humans have a responsibility to future generations to ensure forest ecosystems remain resilient to cope with climate change.	○	○	○	○	○	○
Q20 20. Forest managers need to account for climate change in their planning over one rotation.	○	○	○	○	○	○
Q21 21. Forest managers need to account for climate change in their planning over more than one one rotation.	○	○	○	○	○	○
Q22 22. Determining a tree species' ecological suitability for reforestation should incorporate information about plausible future	○	○	○	○	○	○

climate change scenarios over the life of a stand.						
Q23 23. Current projections of climate change impacts are sufficient to support alternative reforestation strategies for the next planting cycle.	○	○	○	○	○	○
Q24 24. An active adaptive management approach is the best approach for implementing alternative reforestation strategies.	○	○	○	○	○	○
Q25 25. Monitoring reforested stands after they have reached a free growing state is very important under the uncertainty of climate change.	○	○	○	○	○	○

Comments about the importance of climate change

Section 7: Alternative reforestation strategies, risks, and barriers

Q26 26. Under climate change, alternative reforestation strategies for forest resilience are best planned across a landscape, as opposed to on a stand-by-stand basis.

- ○ 1 Strongly Agree
- ○ 2 Agree
- ○ 3 Neutral

○ 4 Disagree

○ 5 Strongly Disagree

○ 6 Unsure

Q27 27. With which of the following statements about the risks associated with implementing alternative reforestation strategies do you most agree?

○ 1 Currently, the government takes on most of the risk.

○ 2 Currently, forest licensees take on most of the risk.

○ 3 Currenlty, risks are shared equally between the government and licensees.

○ 4 I do not agree with any of these statements.

○ 6 Unsure.

Q28 28. Rank the following risks to licensees with respect to implementing alternative reforestation strategies.

From greatest risk (1) to least risk (5)

(note that only one value can be selected for each variable and each value can only be used once. i.e. there can only be one "greatest risk," etc.. A true ranking)

	1	2	3	4	5
1 Delay of Forest Stewardship Plan approval.	○	○	○	○	○
2 Rejection of stocking standards.	○	○	○	○	○
3 Cost of having to replant if free growing requirements aren't met (e.g. if trees don't survive).	○	○	○	○	○
4 Negative ecological impacts.	○	○	○	○	○

Q29 29. Rank the following risks to the government for implementing innovative reforestation strategies.

From greatest risk (1) to least risk (4)

(note that only one value can be selected for each variable and each value can only be used once. i.e. there can only be one “greatest risk,” etc.. A true ranking)

	1	2	3	4
1 Negative public opinion.	○	○	○	○
2 Negative ecological impacts.	○	○	○	○
3 Negative timber supply impacts.	○	○	○	○
4 Financial costs of addresing negative impacts.	○	○	○	○

Q30 30. Rank the following   barriers to licensee implementation of alternative regeneration strategies.

	1 Highly impeding	2 Impeding	3 Somewhat impeding	4 Not impeding	5 Unsure
1 Conditions for meeting "free-growing" obligations.	○	○	○	○	○
2 Stocking standard approval requirements.	○	○	○	○	○
3 Seed transfer zones rules.	○	○	○	○	○
4 Policies for determining ecological suitability of tree species for reforestation.	○	○	○	○	○
5 Assumptions for calculating tenure obligation allowances in	○	○	○	○	○

stumpage appraisal.					
6 Conditions for meeting regeneration delay obligations.	○	○	○	○	○
7 Government attitude toward risk.	○	○	○	○	○

Comments about alternative reforestation strategies, risks, and barriers

Section 8: Incentives

Q31 31. Rank the following incentives on their ability to encourage licensees to consider climate change in their strategies for reforestation.

	1 Greatest Incentive	2 Great Incentive	3 Low Incentive	4 No Incentive	5 Unsure
1 Stumpage breaks for climate change vulnerability assessments.	○	○	○	○	○
2 Increased resilience of forest ecosystems.	○	○	○	○	○
3 Reforming tenure obligation allowance policies.	○	○	○	○	○
4 Funding for climate vulnerability assessments.	○	○	○	○	○
5 Stumpage breaks for innovative reforestation	○	○	○	○	○

trials.

Q32 32. Rank the following hypothetical policies on the probability they will encourage consideration of climate change by licensees in their reforestation strategies.

	1 Definitely	2 Probably	3 Probably Not	4 Definitely Not	5 Unsure
1 Government promotion of climate vulnerability assessments for all forest management planning.	○	○	○	○	○
2 Incorporating climate change risk into the Chief Forester's timber supply analysis.	○	○	○	○	○
3 Government assumes responsibility of ensuring a stand meets free growing after licensee meets regeneration delay obligations.	○	○	○	○	○
4 Free growing evaluated at the landscape level (as opposed to block by block).	○	○	○	○	○
5 Inclusion of a resilience component into the forest health criteria for stocking standard approval.	○	○	○	○	○
6 Strategic government plan for climate change adaptation in	○	○	○	○	○

forestry.					
7 Provincial vision for the future forest.	○	○	○	○	○
8 Government willingness to assume greater amount of risk for innovative trials.	○	○	○	○	○
9 Inclusion of a resilience component into the ecological suitability criteria for stocking standard approval.	○	○	○	○	○

Comments About Incentives

Experience and background.

Q33 33. What is your current position within your organization?

- ○ 1 Program/project development and implementation
- ○ 2 Policy development
- ○ 3 Researcher
- ○ 4 Field operations
- ○ 5 Delegated decision-maker
- ○ 6 Other (please specify) ____________________other

Q34 34. For which of the following types of organizations do you work?

- ○ 1 Government
- ○ 2 Non-government Organization
- ○ 3 Research/Academia
- ○ 4 Private Company
- ○ 5 Other (please specify) ____________________other

Q35 35. At what jurisdictional scale do you work?

- ○ 1 Federal
- ○ 2 Provincial/State
- ○ 3 Regional
- ○ 4 District/Field Office
- ○ 5 Municipal
- ○ 6 Other (please specify) ____________________other

Q36 36. Where is your organization based?

○ 1 British Columbia (BC)

○ 2 Pacific Northwest (United States and/or Canada)

○ 3 Canada (outside of BC)

○ 4 Outside of Canada and the Pacific Northwest.

Q37 37. Do you posses a timber harvest license or work for someone that does?

○ 1 Yes

○ 2 No

Q38 38a. What type of forest license (timber tenure) do you or your organization possess?

○ 1 Tree Farm License

○ 2 Community Forest Agreement

○ 3 Timber Sale License

○ 4 Forest License (replaceable)

○ 5 Forest License (non-replaceable)

○ 6 Pulpwood Agreement

○ 7 Forestry License to Cut

○ 8 Free-Use Permit

○ 9 Community Salvage License

○ 10 Christmas Tree Permit

○ 11 Other ____________________other

Any last comments?

Q39 39b. Are you responsible for approving forest stewardship plans and/or stocking standards or work for a department that is?

- ○ 1 Yes
- ○ 2 No

Any last comments?

Reforestation Survey Results

Stocking standards

Influences on licensee stocking standard decisions

Rank the weight of the following criteria on licensee decisions about tree species and planting densities for stocking standards (responses in Table 33 and Table 34):

- Survival to free growing
- Survival beyond free growing
- Cost
- Consistency with the Timber Supply Review (TSR)
- Ecological Suitability
- Forest Health
- Timely Approval

Table 33 Frequency of ranked stocking standard influences. Results are presented for All respondents.

	No Influence	Low Influence	Great Influence	Greatest Influence	Total
Survival to free growing (n=58)	2%	3%	45%	**50%**	100%
Survival beyond free growing (n=57)	9%	32%	**35%**	25%	100%
Cost (n=58)	3%	10%	38%	**48%**	100%
Consistency with the TSR (n=57)	5%	**49%**	37%	9%	100%
Ecological suitability (n=58)	2%	12%	**50%**	36%	100%
Forest Health (n=57)	2%	19%	**56%**	23%	100%
Timely approval (n=57)	12%	21%	**47%**	19%	100%

Table 34. Means of ranked influences on stocking standard decisions. Results are presented for each respondent group.

	All	Area	Volume	Approvers	Makers
No Influence (1), Low Influence (2), Great Influence (3), Greatest Influence (4)					
Survival to free growing	**3.43**	3.40	**3.62**	**3.47**	**3.44**
n	58	10	13	15	27
Survival beyond free growing	2.75	3.10	3.08	2.50	2.93
n	57	10	13	14	27
Cost	3.31	3.20	3.08	**3.47**	3.19
n	58	10	13	15	27
Consistency with the TSR	2.49	2.50	2.54	2.40	2.56
n	57	10	13	15	27
Ecological suitability	3.21	**3.50**	3.23	2.93	3.33
n	58	10	13	15	27
Forest Health	3.00	3.00	3.00	2.67	2.93
n	57	10	13	15	27
Timely approval	2.74	2.70	2.67	2.40	2.77
n	57	10	13	15	27

Stocking standard approval criteria

Rank the weight of the following criteria on government approval of stocking standards (responses in *Table 35* and *Table 36*):

- Consistency with the Timber Supply Review (TSR).
- Ecological suitability.
- Supply of merchantable timber over time.
- Forest health.

Table 35. Frequency of ranked stocking standard approval criteria. Percentage of respondent rankings of the influence of a number of criteria for government approval of stocking standards. Results are presented for all respondents.

	No Influence	Low Influence	Great Influence	Greatest Influence	Total
Forest Health (n=57)	4%	12%	**60%**	25%	100%
Ecological Suitability (n=57)	2%	5%	46%	**47%**	100%
Supply of Merch. Timber (n=57)	2%	14%	**54%**	30%	100%
Consistency with the TSR (n=56)	2%	11%	**57%**	30%	100%

Table 36. Mean rank of stocking standard approval criteria. Means of respondent rankings of the influence of a number of criteria for government approval of stocking standards. Results are presented for each respondent group.

	All	Area	Volume	Approvers	Makers
No Influence (1), Low Influence (2), Great Influence (3), Greatest Influence (4)					
Forest Health N	3.05 57	2.90 10	3.08 12	3.33 15	1.92 26
Ecological Suitability N	**3.39** 57	**3.50** 10	**3.17** 12	**3.67** 15	**2.27** 26
Supply of Merch. Timber N	3.12 57	**3.50** 10	2.67 12	3.27 15	2.04 26
Consistency with the TSR N	3.16 56	3.20 10	3.00 12	3.13 15	2.12 26

Approval of stocking standards is based primarily on the ability to sustain merchantable timber volumes over time (responses in Table 37).

Table 37. Frequency of stocking standard approval and merchantable timber criteria. Percentage of respondent agreement with the statement that "the approval of stocking standards is based primarily on the ability to sustain merchantable timber volumes over time." Results are presented for all respondent groups.

	All (n=56)	Area (n=9)	Volume (n=12)	Approvers (n=15)	Makers (n=25)
Agree	**77%**	**100%**	**50%**	**80%**	**72%**
Disagree	23%	0%	**50%**	20%	28%
Total	100%	100%	100%	100%	100%

Professional reliance and stocking standards

Approval of stocking standards adequately takes into account understanding of local conditions by the professional forester (responses in Table 38).

Table 38. Professional reliance and stocking standards. Percentage of respondent agreement with the statement that "approval of stocking standards adequately takes into account understanding of local conditions by the professional forester." Results are presented for all respondent groups.

	All (n=59)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Agree	**49%**	**50%**	23%	**87%**	30%
Neutral	14%	0%	15%	7%	11%
Disagree	37%	**50%**	**62%**	7%	**59%**
Total	100%	100%	100%	100%	100%

The government is generally willing to approve alternative stocking standards when sufficient rationale is provided (responses in Table 39).

Table 39. Alternative stocking standards and forester rationale. Percentage of respondent agreement with the statement that "the government is generally willing to approve alternative stocking standards when sufficient rationale is provided." Results are presented for all respondent groups.

	All (n=59)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Agree	**56%**	**50%**	8%	**100%**	30%
Neutral	12%	0%	15%	0%	7%
Disagree	32%	**50%**	**77%**	0%	**63%**
Total	100%	100%	100%	100%	100%

Free growing determination

Influence of free growing policies on reforestation

With which of the following statements about the influence of the free growing policy on licensees do you most agree? The policy primarily promotes reforestation with…(responses in Table 40)

- Species most likely to ensure an adequate supply of timber volumes (timber volume)
- The most commercially valuable species (valuable species)
- The most ecologically suitable species (ecologically suitable)
- The fastest growing species (fastest growing)
- A balanced consideration of ecological suitability, consistency with the Timber Supply Review, and forest health (balanced)

Table 40. Frequency of agreement about influence of free growing. Percentage of respondent agreement with statements about the influence of the free growing policy on licensee reforestation decisions. Results are presented for all respondent groups.

	All (n=59)	Area (n=10)	Volume (n=13)	Approvers (n=15)	Makers (n=27)
Timber volume	12%	0%	15%	20%	7%
Valuable species	**37%**	30%	**31%**	**47%**	26%
Ecologically suitable	10%	10%	15%	7%	11%
Fastest growing	27%	**50%**	15%	27%	**33%**
Balanced	8%	10%	15%	0%	15%
I do not agree with any of these statements	5%	0%	8%	0%	7%
Total	100%	100%	100%	100%	100%

Climate change and alternative reforestation

To what extent do you think climate in BC will change over the next 50 years? (responses in Table 41)

Table 41. Extent of climate change. Means of respondents' rankings of the amount of change respondents feel that precipitation, temperature, and extreme weather will undergo over the next 50 years. Results presented are of all respondent groups.

	All	Area	Volume	Approvers	Makers
No Change, (1), Low Change (2), Medium Change (3), High Change (4)					
Temperature n	2.85 53	3.00 10	2.80 10	2.86 14	2.88 24
Precipitation n	2.77 53	2.80 10	2.60 10	2.79 14	2.71 24
Extreme weather n	**3.13** 53	**3.40** 10	**3.00** 10	**3.23** 14	**3.19** 24

Strategies, risks and barriers of alternative reforestation

Rank the risks to licensees on the following factors with respect to implementing alternative reforestations strategies (responses in Table 42 and Table 43).

Delay of Forest Stewardship Plan (FSP) approval

Rejection of stocking standards

Cost of having to replant if free growing requirements are not met (e.g. if trees don't survive)

Negative ecological impacts

Table 42. Frequency of licensee risk rankings for alternative regeneration. Percentage of rankings of several risks to licensees with respect to implementing alternative reforestation strategies. Results are presented for all respondents.

	Scale: Least Risk (1) - Greatest Risk (5)				
	1	2	3	4	5
Delay of FSP approval (n=42)	2%	10%	**36%**	24%	29%
Rejection of stocking standards (n=47)	2%	4%	36%	**43%**	15%
Cost of replanting if free growing not met (n=52)	6%	8%	23%	23%	**40%**
Negative ecological impacts (n=52)	31%	**50%**	8%	8%	4%

Table 43. Mean ranks of licensee risks for alternative regeneration. Means of respondents' rankings of several risks to licensees with respect to implementing alternative reforestation strategies. Results are presented for all respondent groups.

	All	Area	Volume	Approvers	Makers
	Scale: Least Risk (1) - Greatest Risk (5)				
Negative ecological impacts	2.04	1.60	2.00	1.93	1.92
N	52	10	12	14	26
Rejection of stocking standards	3.64	3.67	3.73	3.33	3.79
N	47	9	11	12	24
Delay of FSP approval	3.67	**4.00**	4.00	3.38	3.86
N	42	9	12	13	22
Cost of replanting if free growing not met	**3.85**	**4.00**	**4.25**	**3.73**	**4.20**
N	52	10	12	15	25

Rank the following risks to the government for implementing innovative reforestation strategies (responses in Table 44).

- Negative public opinion
- Negative ecological impacts
- Negative timber supply impacts
- Financial costs of addressing negative impacts

Table 44. Frequency of alternative regeneration risks to the government. Percentage of rankings of several risks to the government for implementing alternative reforestation strategies. Results are presented for all respondents.

	Scale: Least Risk (1) - Greatest Risk (4)			
	1	2	3	4
Negative public opinion (n=48)	**63%**	23%	2%	13%
Negative ecological impacts (n=47)	21%	**43%**	19%	17%
Negative timber supply impacts (n=48)	2%	13%	**52%**	33%
Financial costs of addressing negative impacts (n=50)	6%	22%	28%	**44%**

Table 45. Mean ranking of alternative regeneration risks to the government. Means of respondent rankings of several risks to the government with respect to implementing alternative reforestation strategies. Results are presented for all respondent groups.

	All	Area	Volume	Approvers	Makers
	Scale: Least Risk (1) - Greatest Risk (4)				
Negative public opinion n	1.65 48	1.20 10	1.73 11	1.50 14	1.56 25
Negative ecological impacts n	2.32 47	1.80 10	1.92 12	2.50 12	2.00 24
Financial costs of addressing negative impacts n	3.10 50	3.33 9	3.08 12	2.86 14	3.17 24
Negative timber supply impacts n	**3.17** 48	**3.60** 10	**3.38** 13	**3.43** 14	**3.42** 26

Rank the following barriers to licensee implementation of alternative regeneration strategies (responses in Table 46 and Table 47).

- Conditions for meeting "free-growing" obligations
- Stocking standard approval requirements
- Seed transfer zone rules
- Policies for determining ecological suitability of tree species for reforestation
- Assumptions for calculating tenure obligation allowances in stumpage appraisal
- Conditions for meeting regeneration delay obligations
- Government attitude toward risk

Table 46. Frequency of alternative regeneration barriers. Percentage of rankings for several barriers to licensee implementation of alternative regeneration strategies. Results are presented for all respondents.

	Not Impeding	Somewhat Impeding	Impeding	Highly Impeding
Meeting 'free-growing' obligations (n=52)	12%	27%	**31%**	**31%**
Stocking standard approval requirements (n=53)	15%	15%	**34%**	**36%**
Seed transfer zones rules (n=52)	17%	**42%**	35%	6%
Ecological suitability policies of tree species (n=52)	19%	**37%**	35%	10%
Assumptions for calculating tenure allowances (n=46)	26%	**28%**	26%	20%
Meeting regeneration delay obligations (n=54)	**35%**	30%	26%	9%
Government attitude toward risk (n=53)	11%	17%	28%	**43%**

Table 47. Mean ranking of alternative regeneration barriers. Means of respondent group rankings of several barriers to licensee implementation of alternative reforestation strategies. Results are presented for all respondent groups.

	All	Area	Volume	Approvers	Makers
Scale: Not Impeding (1), Somewhat Impeding (2), Impeding (3), Highly Impeding (4)					
Meeting 'free-growing' obligations	2.81	3.44	3.23	2.07	3.27
n	52	9	13	15	26
Stocking standard approval requirements	2.91	3.40	3.54	2.13	3.48
n	53	10	13	15	27
Seed transfer zones rules	2.29	2.50	2.15	2.23	2.37
n	52	10	13	13	27
Ecological suitability policies of tree species	2.35	2.67	2.46	2.27	2.65
n	52	9	13	15	26
Assumptions for calculating tenure allowances	2.39	2.17	2.92	1.93	2.61
n	46	6	13	14	23
Meeting regeneration delay obligations	2.09	2.50	2.38	1.47	2.48
n	54	10	13	15	27
Government attitude toward risk	**3.04**	**3.78**	**3.54**	**2.47**	**3.62**
n	53	9	13	15	26

Incentives for climate change adaptation

Rank the following incentives on their ability to encourage licensees to consider climate change in their strategies for reforestation (responses in Table 48 and Table 49).

- Stumpage breaks for climate change vulnerability assessments
- Increased resilience of forest ecosystems
- Reforming tenure obligation allowance policies
- Funding for climate vulnerability assessments
- Stumpage breaks for innovative reforestation trials

Table 48. Frequency of rankings of climate change adaptation incentives. Percentage of rankings of several incentives on their ability to encourage licensees to consider climate change in their strategies for reforestation. Results are presented for all respondents.

	No Incentive	Low Incentive	Great Incentive	Greatest Incentive
Stumpage breaks for climate change assessments (n=54)	17%	22%	**41%**	20%
Increased resilience of forest ecosystems (n=54)	22%	**52%**	22%	4%
Reforming tenure obligation allowance policies (n=52)	13%	13%	**38%**	35%
Funding for climate vulnerability assessments (n=54)	17%	26%	**37%**	20%
Stumpage breaks for innovative reforestation trials (n=54)	15%	9%	**54%**	22%

Table 49. Mean rankings of climate change adaptation incentives. Means of respondent rankings of the ability of several incentives to encourage licensees to consider climate change in their strategies for reforestation.. Results are presented for all respondent groups.

	All	Area	Volume	Approvers	Makers
Scale: No Incentive (1), Low Incentive (2), Great Incentive (3), Greatest Incentive (4)					
Stumpage breaks for climate change assessments	2.65	2.89	2.62	2.53	2.69
n	54	9	13	15	26
Increased resilience of forest ecosystems	2.07	2.10	2.38	1.67	2.27
n	54	10	13	15	26
Reforming tenure obligation allowance policies	**2.94**	3.11	**3.31**	**2.86**	**3.15**
n	52	9	13	14	26
Funding for climate vulnerability assessments	2.61	**3.33**	2.23	2.53	2.69
n	54	9	13	15	26
Stumpage breaks for innovative reforestation trials	2.83	3.00	2.77	2.67	3.00
n	54	9	13	15	26

Rank the following hypothetical policies on the probability they will encourage consideration of climate change by licensees in their reforestation strategies (responses in Table 50 and Table 51)

- Government (govt) promotion of climate vulnerability assessments for all forest management planning
- Incorporating climate change risk into Chief Forester's timber supply analysis (TSR)
- Free-growing determined at the landscape level (as opposed to block by block)
- Inclusion of a resilience component into forest health criteria for stocking standard approval

- Strategic government plan for climate change adaptation in forestry
- Provincial vision for the future forest
- Government willingness to assume greater amount of risk for innovative trials
- Inclusion of a resilience components into ecological suitability criteria for stocking standard approval

Table 50. Frequency of rankings of climate change adaptation policies. Percentage of rankings on the probability that sseveral hypothetical policies will encourage consideration of climate change by licensees in their reforestation strategies. Results are presented for all respondents.

	Definitely Not	Probably Not	Probably	Definitely
Govt promotion of climate vulnerability assessments (n=54)	9%	**41%**	39%	11%
Incorp climate change risk into timber supply analysis (n=51)	4%	29%	**53%**	14%
Govt assumes responsibility stand meets free growing (n=54)	13%	20%	31%	**35%**
Free growing evaluated at the landscape level (n=51)	14%	24%	**49%**	14%
Inclusion of resilience component into forest health (n=53)	8%	32%	**47%**	13%
Strategic govt plan for climate change adaptation (n=52)	10%	29%	**44%**	17%
Provincial vision for the future forest (n=53)	13%	**40%**	32%	15%
Govt assume greater risk for innovative trials (n=54)	2%	7%	**50%**	41%
Inclusion of resilience component into ecological suitability (n=53)	4%	25%	**58%**	13%

Table 51. Mean rankings of climate change adaptation policies. Means of respondents' rankings of the probability that sseveral hypothetical policies will encourage consideration of climate change by licensees in their reforestation strategies. Results are presented for all respondent groups.

	All	Area	Volume	Approvers	Makers
Scale: Definitely Not (1), Probably Not (2), Probably (3), Definitely (4)					
Govt promotion of climate vulnerability assessments	2.52	2.70	2.54	2.53	2.56
n	54	10	13	15	27
Incorporation of climate change risk into TSR	2.76	**3.56**	2.69	2.54	2.96
n	51	9	13	13	26
Govt assumes responsibility stand meets free growing	2.89	3.00	2.77	**3.27**	2.70
n	54	10	13	15	27
Free growing evaluated at the landscape level	2.63	2.89	2.77	2.31	2.69
n	51	9	13	13	26
Inclusion of resilience component into forest health	2.66	2.50	2.54	2.57	2.59
n	53	10	13	14	27
Strategic govt plan for climate change adaptation	2.69	3.20	2.62	2.36	2.85
n	52	10	13	14	26
Provincial vision for the future forest	2.49	2.80	2.46	1.87	2.62
n	53	10	13	15	26
Govt assume greater risk for innovative trials	**3.30**	3.50	**3.46**	2.87	**3.48**
n	54	10	13	15	27
Inclusion of resilience component into ecological suitability	2.81	2.90	2.85	2.64	2.93
n	53	10	13	14	27

Variable groupings

Several combinations of dependent variables were explored to develop an opinion scale. These are listed below using the variable codes[61] used in SPSS (e.g. Q5r) along with the Cronbach alpha value (α) for each combination.

- Q5r, Q6r (α = 0.745)
- Q17r_1 to Q17r_3, Q18r (α = 0.868)

[61] A list of variable names and their codes can be found the following section of this appendix.

- Q19r to Q22r (α =0.722, if Q21r is removed)
- Q30r_1 to Q30r_7 (α =0.762)
- Q31r_1 to Q31r_5 (α =0.783)
- Q32r_1 to Q32r_9 (α = 0.767, if Q32r_3 is removed)

Those combinations listed above with α ≥ 0.7 were deemed acceptable groupings and were labelled and recorded, see below:

- Forester=mean(Q5r Q6r).
- Impacts=mean(Q17r_1 to Q17r_3 Q18r).
- Importance=mean(Q19r to Q22r).
- Constraints=mean.6(Q30r_1 to Q30r_7).
- Incentives=mean(Q31r_1 to Q31r_5).
- Government=mean.7(Q32r_1 Q32r_2 Q32_4 to Q32r_9).

The mean value of each of these variable groupings for each of the independent variables (Area, Volume, Approver, Maker) as well as their interpretation can be found in Chapter 5, section "Variable Groupings.