# IMPLEMENTATION OF MARKER-ASSISTED SELECTION IN BC FORESTS: PERCEPTION SURVEY

by

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## Abstract

The iconic forests of British Columbia are deeply rooted in the lives of its inhabitants. Known for its lush green landscape and old growth trees, BC forests are home to over 1,300 plant and animal species, and provide a playground for recreational activities. The forest industry is a key contributor to the provincial economy. Over the last decade, the forest sector has experienced a number of challenges as a result of the global economic crisis, the US housing crash, changing markets, low-cost competitors, the strength of the Canadian dollar, and the mountain pine beetle epidemic. Since, the provincial and federal governments have made a commitment to transform the forest sector through innovation, enhanced environmental performance, and new markets. One such area of innovation has been in forest genomic technologies. Marker-assisted selection (MAS) is a biotechnological tool that allows desired traits to be flagged on the genome. This tool may assist tree breeders with the early selection of preferred genotypes, thus reducing the breeding cycle and more accurately and efficiently selecting for improved qualities. However, there is a poor understanding of perceived acceptability towards the adoption of this technology.

The objectives of this research were to investigate how the implementation of marker-assisted selection is perceived by forest stakeholders and First Nations in BC, and if this perception is dependent on the context of implementation. To accomplish these objectives, a mixed methods research approach was taken, employing semi-structured individual interviews, followed by a Likert scale questionnaire. Participants were categorized into four groups: government, industry, environmental non-governmental organizations (ENGOs), and First Nations.

The results of this analysis found that government and industry participants held positive perceptions towards MAS, supporting its use and continued research in BC. Both agreed that the advantages of MAS outweigh the disadvantages, frequently identifying its benefits in forest regeneration and to tree breeders. ENGOs and First Nations demonstrated a less favourable attitude towards MAS. Their attitudes lie between neutral and negative. Concerns were most strongly focused on environmental impacts, ecosystem degradation, and reduced genetic diversity; while identified benefits were specific to tree breeders and improved tree resiliency.

## Preface

This dissertation is an original intellectual product of the author, C. Nilausen, under the supervision of Dr. G. Bull. The research questions were identified by C. Nilausen and approved by her supervisor Dr. G. Bull and committee members Dr. N. Gélinas and Dr. R. Kozak. C. Nilausen led the design, collection of data, and analysis of this research. The methods and fieldwork reported in Chapters 3-6 were approved by the University of British Columbia's Behavioural Research Ethics Board (H13-00594).

This study was funded by Genome Québec, and falls within the larger SMarTForests Project led by J. MacKay and J. Bohlmann. The SMarTForests Project is a collaborative project between the University of British Columbia, the University of Alberta, and Université Laval; and sponsored by Genome Canada, Genome BC, Genome Québec, and Genome Alberta.

A version of Chapters 2 and 3 have been published in the Forestry Chronicle (Nilausen, C., Gélinas, N., Bull, G. (in press). Proposed Research on Social Perception of Marker-Assisted Selection and its Role in the Forests of British Columbia. *The Forestry Chronicle, 90*(5)). The project design and manuscript written for the published paper was completed by C. Nilausen. N. Gélinas and G. Bull were supervisory authors on this paper, and were involved in guidance and manuscript edits.

A version of Chapters 2, 3 and 4 has been published in SMarTForests Newsletter (Nilausen, C. (in press). From the Lab to the Forest. *SMarTForests Newsletter,* edition 3). The article written for publication was completed by C. Nilausen.

A version of Chapters 2 and 3 was published in BranchLines (Nilausen, C. (2013). Improving our Forests One Gene at a Time. *BranchLines, 24*(2), 7). This article written for publication was completed by C. Nilausen.

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## List of Abbreviations

AAC – annual allowable cut

aka – also known as

ANOVA – analysis of variance

BC – British Columbia

BREB – Behavioural Research Ethics Board

CEO – chief executive officer

$CO_2$ – carbon dioxide

CORE – Course on Research Ethics

DNA – deoxyribonucleic acid

ENGOs – environmental non-governmental organizations

EU – European Union

FLNRO – Ministry of Forests, Lands and Natural Resource Operations

FPAC – Forest Products Association of Canada

FRPA – Forest and Range Practices Act

GDP – gross domestic product

GE – genetic engineering

GM – genetic modification

GMO – genetically modified organism

$m^3$ – cubic metres

MAS – marker-assisted selection

Mb - megabyte

MPB – mountain pine beetle

NRCan-CFS – Natural Resources Canada-Canadian Forest Service

NSR – non-sufficiently restocked

SPSS – Statistical Package for the Social Sciences

TCPS2 – Tri-Council Policy Statement 2

US –United States

USD – American Dollars

## Acknowledgements

Firstly, I must begin by acknowledging and thanking my supervisor, Dr. Gary Bull. Thank you for encouraging me to change fields and pursue my interests from a new angle. The potential that you recognized allowed me to flourish in ways I didn't think possible. Your trust in my abilities and persistence in challenging me with additional roles and projects has left me confident in my skills and excited for a future with unknown opportunities. I'd also like to acknowledge my supervisory committee for providing immeasurable support throughout this study. Dr. Nancy Gélinas has provided so much support throughout the development and analysis of this project. By always asking critical questions, she challenged me to consider my work from various perspectives. I'd also like to thank Dr. Rob Kozak for his advice, guidance, and remarkably quick yet thoughtful replies to all my questions. I would like to thank Véronique Maltais for her support and collaboration on this project. It was such a pleasure working with someone that was as excited and passionate about the social context of this study as I was.

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*For my dearest friend and husband that has made this journey perfection*

# Chapter 1 Introduction

Historically, many rural communities in BC were founded and thrived on a healthy forest industry, providing quality wood domestically and internationally. Today, BC remains the world's leading supplier of softwood lumber, and has a $4 billion pulp and paper industry (Government of British Columbia, 2013b; Ministry of Forests Mines and Lands, 2010; Natural Resources Canada, 2013). Spanning across 60% of BC's 95 million hectares of land, these forests embody 16 biogeoclimatic zones and over 1300 forest-related plant and animal species. This lush green landscape is worldly known and is home to the coastal 'Great Bear Rainforest', one of the few remaining temperate rainforests on the planet.

In the last decade, the forest industry has experienced a number of challenges that resulted in a significant impact to the forest economy. From 2005 to 2009, the BC forest sector GDP fell 29.4% (Canadian Forest Service, 2013; Shu, 2012). This was a consequence of a decrease in demand for softwood lumber, a shift away from North American newsprint, an increase in competition by other forest product suppliers, and the increased strength of the Canadian dollar (Canadian Forest Service, 2013; Government of Canada, 2014; Ministry of Forests Mines and Lands, 2010).

In conjunction with these economic difficulties, BC forests have been plagued with a rampant mountain pine beetle (MPB) epidemic. Coupled with the absence of cold winter temperature, effective fire suppression over the last century has enabled a record-setting bark beetle infestation (Ministry of Forests Lands and Natural Resource Operations, 2012a). Starting in 1999 and rising exponentially, the projections are that by 2017, 58% (approximately 767 million cubic metres) of commercially valuable pine will be killed by the MPB (Ministry of Forests Lands and Natural Resource Operations, 2012a). As of March 2014, the MPB had infested over 18.6 million hectares of mature pine forests over the last 15 years (Ministry of Forests Lands and Natural Resource Operations, 2014a).

Furthermore, it is predicted that as the global climate continues to change, there will be increased incidences of wildfires, pests and diseases (Canadian Forest Service, 2013; Rank, 2013). To address these imminent issues, the Government of Canada has made a commitment to transform the forest sector. Through the development of innovative products, establishment of new markets, and a continued commitment to science-based sustainable forest management, this transformation aims to provide a promising future following a decade of struggles (Canadian Forest Service, 2013).

Natural Resources Canada-Canadian Forest Service (NRCan-CFS) has been investing resources in an effort to improve our understanding of Canada's forests. NRCan-CFS recognizes that it is imperative to better understand non-timber values, such as carbon storage and water purification, and make more informed forecasts of how these forests will change in the future (Canadian Forest Service, 2013). With increased knowledge, the forest sector can attempt to mitigate the effects of these anticipated changes, and make more informed decisions that support healthy forests and sustainable forest management practices (Canadian Forest Service, 2013). Through research projects, various initiatives, and collaborative partnerships, Canada is committed to understanding and adapting the forests in the face of climate change. For example, the Forest Products Association of Canada (FPAC) outlined in their Vision2020, three components to improve the future of the forest products industry. By setting goals for products, performance and people, FPAC suggested opportunities in bio-pathways and green transformation (Forest Products Association of Canada, 2014). Meeting the Vision2020 targets and ensuring the health and longevity of Canada's forests will require sustainably managed forests providing a steady supply of fibre to local mills, and innovation.

Forest genomic research is one area of innovation that the Canadian government has invested time and resources to help meet the ambitious goals of the Canadian forest sector. Through the 2009 and the 2012-2013 consultation process that included 115 key stakeholder representatives across Canada, two major opportunities offered by forest genomics were identified. Firstly, they found that marker technologies could be used to increase forest productivity in breeding by improving yields, quality, pest resistance, and lignocellulose quality for value-added products (Rank, 2013). And secondly, markers could improve forest health by identifying and tracking pests and pathogens (Rank, 2013). Accordingly, the Canadian government has supported genomic research by investing approximately $123 million since 2001 (Porth, Boyland, Ahmed, & Bull, 2014)

Forest genomic research is a rapidly expanding field that aims to improve forest productivity and health. Marker-assisted selection (MAS) is a type of genomic biotechnology that could serve as an additional tool to tree breeders. By allowing desired traits to be flagged on the genome, markers can be used for early selection of preferred genotypes, thus omitting the need to wait for a tree to reach maturity for those same traits to be expressed (Yanchuk, 2002). In contrast to genetic engineering (GE), MAS does not alter the original DNA. Rather, it identifies whether the desired trait(s) are being expressed, so that individuals with the best potential can be selected.

MAS has the potential to be a useful tool for forest management in BC by helping tree breeders address some of the current environmental and economic challenges facing the forest sector. However we have a poor understanding of the ‘social license’ breeders have in BC to have wider adoption of the technology.

The objectives of this study were twofold:

1. To determine how the implementation of forest genomic technologies, namely MAS, are perceived by stakeholders and First Nations in BC; and

2. To determine if that perception is dependent on the context of implementation.

The intent of this research study is to explore the social acceptability of a proposed alternative to traditional tree breeding methods (MAS). I will survey the perspectives of various stakeholders and First Nations groups that are key players in forest-related discussions.

# Chapter 2 Literature Review

In order to best understand the context and mechanisms that have led to forest genomic research in Canada, and subsequently the importance of perceived acceptability amongst stakeholders and First Nations in BC, a literature review was conducted. Section 2.1 provides an overview of biotechnology and more specifically marker-assisted selection. Section 2.2 presents the state of Canada's forests, with an emphasis on the forests of BC. Section 2.3 reviews the federal and provincial governments' responses to challenges faced by the forest sector. Section 2.4 describes the potential role of marker-assisted selection in the context of BC forests. Section 2.5 examines possible challenges and key considerations regarding the implementation of marker-assisted selection. Section 2.6 discusses attitudes and perceptions as they relate to genomics. Lastly, Section 2.7 summarizes the intent of this study.

## 2.1 Biotechnology and Marker-Assisted Selection

Although the field of biotechnology has been around for centuries, there has been considerable development since the late $20^{th}$ century. Biotechnology is defined as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (United Nations, 1992). Biotechnology encapsulates a wide variety of sectors including industrial biotechnology, such as household products, and health biotechnology, including drugs, vaccines, medical devices and therapies. Moreover, with a rapidly expanding population and ever changing climate, plant biotechnology has gained a lot of attention. In Canada, canola, corn, and soybeans crops have significantly improved their yields through plant biotechnology and pest control products (CropLife Canada, 2014). Plant biotechnology can be used to develop plants with a better response to heat, droughts, and floods; while also increasing yields without increasing cropped acreage. Currently, research and field studies are underway to address malnutrition in developing countries. For example Golden Rice aims to address vitamin A deficiency which leads to blindness in approximately 500,000 children per year (CropLife Canada, 2014). Wood is yet another vital resource for humans that will be impacted by climate change and a growing population. Although the history of tree breeding is relatively short compared to plant breeding, biotechnology in tree improvement may be an additional tool to supplement traditional practices.

Traditional tree breeding began in Canada in the early 1900s, with most tree improvement programs starting up in the second half of the 20$^{th}$ century (Zobel & Talbert, 1984). Tree improvement programs generally focus on growth rates (volume growth or yield), wood quality (form, fibre, lignin content, *etc*.), and adaptability (resistance to pests and diseases, abiotic stresses, *etc*.) (Gaston, Globerman, & Vertinsky, 1995; Sedjo, 2002). Although genetic gains through traditional tree breeding varies from 3-30% depending on the species in BC, these methods are expensive, long to complete, difficult to control, and lack selection precision for genotypes (British Columbia Ministry of Forests and Range, 2005; Gaston et al., 1995; Lee & Woolliams, 2013; Sedjo, 2002). Moreover, with the global demand for wood increasing by approximately 1.7% annually, it is estimated that the level of demand is exceeding what can be supplied, contributing to forest degradation (Fenning & Gershenzon, 2002). It is believed that the use of biotechnology on naturally slow-growing forests may be necessary in the attempt to meet the current demand, while minimizing degradation and unnecessary loss (Canadian Genome Centres, 2013; Fenning & Gershenzon, 2002; Harfouche et al., 2012; Kumagai, Culver, & Castle, 2010; Neale & Kremer, 2011; Rank, 2013).

Since the 1990s, biotechnology has been applied in forestry (Sedjo, 2002). Biotechnology in forestry can be categorized into three different groups: vegetation propagation, genetic engineering, and genetic markers (Yanchuk, 2002). Vegetation propagation is essentially the process of growing a new plant from a section of an existing plant. Vegetation reproduction in this manner can be achieved either through rooted cuttings or from somatic embryogenesis (embryonic plants are made from the non-reproductive tissue of a seed) (Hadley, Tanz, & Fraser, 2001). This process results in the production of clonal varieties (Yanchuk, 2002). Genetic engineering (GE), also known as genetic modification (GM), is the most commonly known form of biotechnology. It involves removing, modifying or adding genes to a DNA molecule, thereby altering the information that it contains (Keener, Hoban, & Balasubramanian, 2000). GM trees are thus those that have undergone manipulation at the DNA level, through mutagenesis, recombinant DNA techniques, or other (Snetsinger, 2010). The added genes can come from an individual within the same species, however they are usually taken from other species (Hadley et al., 2001). Lastly, genetic markers are DNA sequences that can either be part of a gene, the whole gene, a non-coding segment between genes, or an enzyme that is made by a gene (Hadley et al., 2001). These genetic markers are used to identify the location of genes within the genome that are responsible for the expression of a particular trait (Sedjo, 2002).

Marker-assisted selection (MAS), often referred to as “Smart Breeding,” is the process by which genetic markers are used for the indirect selection of desired traits, rather than the trait itself (Ashraf, Akram, & Foolad, 2012; Brumlop & Finckh, 2011). Markers tend not to have any biological effect, but rather can be thought of as notable and constant points of reference within the genome (Guimaraes, Ruane, Scherf, Sonnino, & Dargie, 2007).  Markers can be found within the desired gene or, more commonly, linked to a gene determining a trait of interest (Brumlop & Finckh, 2011; Guimaraes et al., 2007). Unlike genetic engineering, MAS does not alter the original DNA (Vogel & Van Aken, 2009); instead it uses genetic marker to identify naturally-occurring genetic variations among individuals, with the intent of selecting those with the best potential to meet desired criteria and objectives.

MAS is considered a “revolutionary” approach to traditional tree breeding as it allows breeders to select individuals based on their genotypes, rather than relying on their observable characteristics (phenotypes) (Boopathi, 2013a). The greatest strengths of molecular markers is the timeliness and efficiency for which individuals can be selected while maintaining the same level of breeding progress as conventional practices (Xu & Crouch, 2008). As many preferred traits are not observed until maturity, MAS eliminates this waiting period by allowing for the early selection of desired genotypes (Yanchuk, 2002). In trees, this is a significant amount of time. For example, *Picea glauca* (white spruce) achieves maturity at approximately 30 years of age (Forest Practices Branch, 2008). MAS can be performed at the seedling stage, thus reducing decades of time for breeders. "Once they are able to identify a genetic sequence that is always linked to disease resistance, for example, they can avoid testing every single offspring for this complicated trait – they just need to look for the marker with a rapid DNA test, and they know immediately whether or not which plants have the trait" (Vogel & Van Aken, 2009). MAS provides several other benefits to breeders, in that it can select for genes that demonstrate low heritability, have recessive alleles, and are difficult, expensive, or time exhaustive to determine phenotypically (Boopathi, 2013a; Brumlop & Finckh, 2011; Xu & Crouch, 2008). MAS also allows for gene pyramiding or combining multiple genes within the same breeding line, while having fewer unintentional losses and fewer selection cycles (Boopathi, 2013a; Xu & Crouch, 2008).

MAS could bring about a new era for the forest industry. Traditionally, tree breeders have relied on phenotypic traits to guide their breeding. When they came across a naturally occurring disease- or drought-resistant strain, they have taken those seeds and bred them in hopes of securing those genes in the offspring. This is very time intensive as breeders must often wait decades to see if the preferred trait was inherited. Moreover, if there are several traits that they hope to be inherited, then the process of cross-breeding can take several more generations, each requiring time for the seed to mature to an age where the presence of the desired trait can be adequately determined. MAS not only speeds up the selection process, but does so without being restrictive to early onset phenotypic characteristics. Regardless if a trait is controlled by a single or few genes (such as disease resistance), or is a complex quantitative trait that includes many genes (such as wood density), genetic markers provide a level of genomic information that is not achievable in conventional breeding practices. MAS can be used to review the DNA of thousands of individual trees so that the few with the best mix of preferred genes can be identified (Sedjo, 2002). Furthermore, MAS may be viewed by the public with more support than genetic engineering as breeders are not manually manipulating the genes, and thus all offspring inheritance occurs naturally (Vogel & Van Aken, 2009). It is also believed that genetic markers may be important in the assessment, conservation and use of diversity in germplasm and varieties (Brumlop & Finckh, 2011).

### 2.2 Canada and the Forests of British Columbia

Canada's vast forest landscape makes up 396.9 million hectares, amounting to 39% of its total land area (Canadian Forest Service, 2013). Differing from all other developed countries with a significant amount of forest cover, 90% of Canada's forestland is publically owned (Canadian Forest Service, 2013). Canada represents 10% of the world's forests, and 30% of the world's boreal forest (Canadian Forest Service, 2013). Contributing 1.1% to the GDP, Canada is the leading exporter of softwood lumber, newsprint and wood pulp (Canadian Forest Service, 2013).

Although the Canadian forest sector is now transforming, it follows a decade of struggles. Once a strong economy, the forest industry was greatly impacted by the U.S. housing crisis, the global economic recession, a transformation away from newsprint, an increase in low-cost competitors, and the strength of the Canadian dollar. Between 2005 to 2009, GDP dropped significantly (Canadian Forest Service, 2013). Moreover, the incidence of environmental challenges has increased in frequency and severity. Diseases, pests, wildfires, droughts, storms, and increases in temperature have impacted Canadian forest ecosystems (Canadian Forest Service, 2013). In 2011, Canada recorded 7,288 forest fires; and despite being consistent with the past 10-year average, many of these fires were reported to have had extreme behaviour (Canadian Forest Service, 2013).

The forests of British Columbia are no anomaly, but rather have followed much of the same trends and have been impacted by the same hardships affecting the rest of the country. Since Confederation and the Constitution Act of 1867, like the other westerly provinces, BC has been dominantly under the jurisdiction of their provincial government (95%) (Ministry of Forests Lands and Natural Resource Operations, 2014a). The forests of BC comprise 60% of BC's 95 million hectare land base, of which 83% is dominated by conifers (Ministry of Forests Mines and Lands, 2010). Sprawling over all 16 biogeoclimatic zones, forests over 140 years old make up 41% of BC's forests (Ministry of Forests Mines and Lands, 2010). Approximately 1,345 plant and animal species in BC rely to some degree on forests, and there are 49 native tree species to the province (Ministry of Forests Mines and Lands, 2010).

British Columbia is the world's leading supplier of softwood lumber, with $11.6 billion in forest product exports in 2013, which equates to 34.8% of the province's total export value (Government of British Columbia, 2013a, 2013b; Ministry of Forests Lands and Natural Resource Operations, 2014a). The forest industry accounts for 3% of the provincial GDP, and in 2013 provided over 58,000 jobs (Council of Forest Industries, 2014; Ministry of Forests Lands and Natural Resource Operations, 2014a). These iconic forests support recreational activities and livelihoods, and provide sustenance to the people of the province.

Similarly to the rest of Canada, BC was deeply affected by the economic and environmental challenges faced over the last decade. The global economic crisis resulted in depressed prices and demand for wood. As the US is the largest lumber market for the province, BC was greatly impacted by the decline in US housing starts. Between 2005 and 2009, US housing starts were down 73% (Ministry of Forests Mines and Lands, 2010). Forest product exports dropped from $14.7 billion per year (average between 1996 and 2004) to $7.6 billion in 2009 (Ministry of Forests Mines and Lands, 2010). Rural forest-dependent communities in the interior of BC have been greatly impacted by job losses and mill closures since 2007 (Ministry of Forests Mines and Lands, 2010). Moreover, after decades of legal battles and conflicts over Aboriginal title and rights, First Nations are only now receiving economic benefits and opportunities to influence the forest sector.

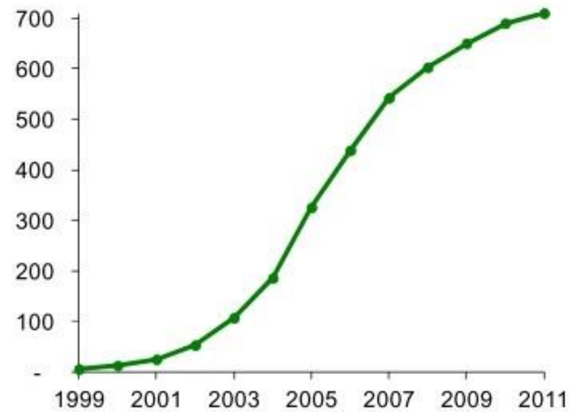


**Figure 1: Cumulative volume of merchantable pine affected by the mountain pine beetle since 1999 (in millions of cubic metres)(Ministry of Forests Mines and Lands, 2010)**

Environmentally, successful fire suppression has generated fuel buildup within the province. There is on average 1,908 wildfires burning approximately 141,092 hectares annually (Wildlife Management Branch, 2014). Over the last decade, 2009 was a particularly tough year for wildfires with 3,064 total fires, affecting 337,149 hectares (Wildlife Management Branch, 2014). However, the most significant challenge to forest health over the last decade has been the outbreak of the mountain pine beetle. Fire suppression and a lack of annual cold snaps have created optimal conditions for the MPB to thrive, prompting an outbreak of unprecedented historical record (Ministry of Forests Mines and Lands, 2010). Touted as the worst bark beetle infestation in North American history, by 2011 the MPB had killed an estimated 710 million cubic metres of pine (see Figure 1) (Ministry of Forests Lands and Natural Resource Operations, 2012a). This equates to 53% of all commercially valuable pine timber in the province (see Figure 2) (Ministry of Forests Lands and Natural Resource Operations, 2012a).

Although the spread of this epidemic is tapering off, as of March 2014, 18.6 million hectares had been infested by the beetle (Ministry of Forests Lands and Natural Resource Operations, 2014a).

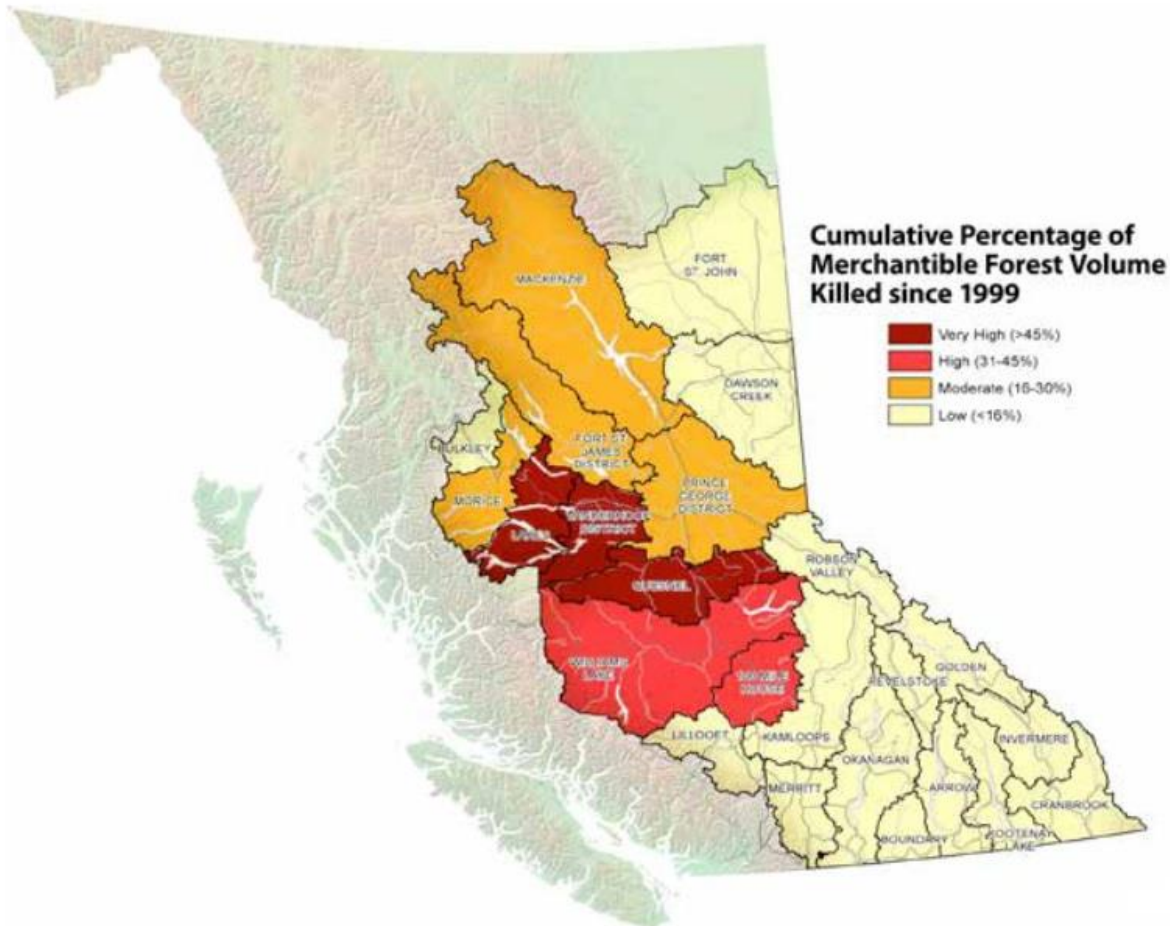


**Figure 2: Timber Supply Areas' cumulative impact of commercially valuable forest killed since 1999 (Ministry of Forests Lands and Natural Resource Operations, 2014a)**

Between the wildfires and the MPB outbreak, BC forests have become a net source of $CO_2$. It is predicted that it will take until 2020 for these forests to revert back to being a carbon sink (Ministry of Forests Mines and Lands, 2010). It is anticipated that the MPB will continue to impact the environment, the economy, and a large portion of the BC population (Ministry of Forests Lands and Natural Resource Operations, 2012a). Moreover, climate change will continue to affect forested areas by way of wildfires, pests, and overall reduction in forest health (Ministry of Forests Mines and Lands, 2010).

### 2.3 Government's Response to Forest Challenges

As climate change continues to impact the forests through fire, drought, disease and pest outbreaks, forest health and fibre supply will likely continue to be affected. The Canadian government has pledged to reinvent the forest sector by expanding to new markets, creating innovative products, and re-establishing their enduring commitment to sustainable forest management. In BC, exports to China have helped the forest product sector recover (see Figure 3). Although the US remains BC's largest market for softwood lumber exports, China, Japan, and Europe have been playing an increasingly important role (Government of British Columbia, 2013b).


**Figure 3: China has been a key driver in the recovery of BC forest product exports, although the US remains BC's largest export market (Ministry of Forests Lands and Natural Resource Operations, 2011)**

In BC, the provincial government has taken a number of steps to address the MPB epidemic. Through the formation of coalitions, partnerships, programs, research taskforces, and initiatives, BC has invested $917 million to address the issue of the MPB since 2001 (Ministry of Forests Lands and Natural Resource Operations, 2014a; Special Committee on Timber Supply, 2012). In 2008, following the 10th year of the outbreak, timber harvesting shifted to salvage logging of dead pine (Ministry of Forests Lands and Natural Resource Operations, 2012a). In 2009, the provincial annual allowable cut (AAC) increased to 88 million cubic metres (33% above the average 66 million cubic metres per year of the 1990s) to allow industry to salvage any merchantable timber and in an effort to contain the pest (Ministry of Forests Mines and Lands, 2010) (see Appendix A for more information on past and anticipated changes to the Provincial AAC).

In February 2012, an audit on the Ministry of Forests, Lands and Natural Resource Operations (FLNRO)'s management of timber was released. Within this report, the Auditor General criticised the Ministry for not adequately replanting parts of the forest damaged by wildfires, diseases and pests. The amendments made to the *Forest Act* in 1987 enforced that industry has a legal obligation to reforest areas allocated to them that are affected by harvesting, fire, pests, and diseases (Doyle, 2012; Ministry of Forests Mines and Lands, 2010). This requires industry to meet minimum height requirements for the stand within a 20 year period, and assumes at which point trees will continue to develop unimpeded by competing plants, shrubs, or neighboring trees (Doyle, 2012). Once trees have met these requirements, the stand is declared "free growing," and industry is able to return the land to the Crown. Any stewardship responsibilities that arise thereafter are under the care of the Ministry.

Conversely, since 2002 the government no longer has the same legal obligation to reforest areas affected by natural disturbances (Doyle, 2012). Nevertheless, it is expected that the government will act in the best interest of the public, which would include stewardship responsibilities that ensure present and long-term sustainability of future forests. Recognizing that not all areas affected by natural disturbances can be restocked due to limited accessibility and extent of the disturbance, the Ministry conducts ground surveys to determine which areas are suitable for replanting and which will be left to natural regeneration. The Auditor General concluded that there are large non-sufficiently restocked (NSR) areas, despite their suitability for silviculture investment (see Table 1) (Doyle, 2012). The report recommended that the Ministry establish long-term timber objectives that meet stewardship principles to ensure that the future timber supply is maintained or enhanced (Doyle, 2012). Noting that naturally regenerated stands tend to have lower timber volume per hectare and take longer to establish, the report raised concern that the Ministry is not taking advantage of the high productivity and genetic gain offered by nursery seeds, and the missed opportunity to influence species composition (Doyle, 2012).

**Table 1: Ministry's confirmed and estimated area within its responsibility that is suitable for replanting (Doyle, 2012)**

| | Hectares |
|---|---|
| Ministry-confirmed area of not satisfactorily restocked forest under its responsibility | 240,000 |
| Ministry's estimate of potential area suitable for replanting related to mountain pine beetle | 650,000 |
| Ministry's estimate of potential area suitable for replanting related to other disturbances such as wildfire | 200,000 |
| Current estimate of confirmed plus potential area suitable for replanting | 1,090,000 |

In August 2012, the Special Committee on Timber Supply submitted their report to the provincial government, outlining twenty recommendations over six key areas to address BC's mid-term timber supply. This committee was appointed by the Legislative Assembly of British Columbia, and tasked to review and advise the Ministry on how to attend to the loss of mid-term timber supply in the central interior affected by the MPB. Within the sections of *Forest Practices Consideration's*, *Other AAC-related Issues*, and *Forest Tenure Issues and Interests*, some of the suggestions put forth by the Committee to the Ministry were:

a) Ensure that the objective of growing more fibre and increasing net value is met by working with industry to support silviculture-related forest practice requirements (3.1a)
b) Either maintain or expand current funding for the tree improvement program (3.1b)

c) Formulate a strategy to re-engage the federal government to invest funds that will be used in response to the epidemic. These funds would be used to support planning and implementation programs at the federal, provincial, industry and partnership levels (3.2b)

d) Sufficient funding is allocated to support a five-year provincial inventory action plan, which outlines how the program will meet provincial priorities (4.1)

e) Gradually increase area-based tenures (5.1)

— (Special Committee on Timber Supply, 2012)

It is clear that the Special Committee on Timber Supply is emphasizing the need to increase fibre, invest in tree improvement programs, improve forest inventory, and shift to area-based tenures (see Appendix A for more information on tenure conversion). The Ministry responded in October 2012 with their report, *Beyond the Beetle: A Mid-Term Timber Supply Action Plan.* In this document, they specifically address each of the recommendations put forth by the Committee. They state that they will work with industry to review stocking standards, and that future forest health is of the highest priority (Ministry of Forests Lands and Natural Resource Operations, 2012b). They will also invest funds and collaborate with the Forest Genetics Council ensuring that new seedlings will be resilient against climate change, resistant to pests, and demonstrate high quality fibre (Ministry of Forests Lands and Natural Resource Operations, 2012b).

## 2.4 The Potential Role of Marker-Assisted Selection in BC

Genomic tools are being considered and are expected to play a more significant role in aiding BC re-establish their forests (Rank, 2013). For a province that relies on a healthy forest economy, is a key exporter to major developed nations, and is home to a rare and highly sought forest stand-type, the introduction of a new technology would only further its comparative advantage. Moreover, with the projected AAC levels expecting to drop from its current 64 million $m^3$ to 50 million $m^3$ by 2025, BC could benefit from a method where trees could grow faster, stronger, and healthier (Ministry of

Forests Lands and Natural Resource Operations, 2014b; Ministry of Forests Mines and Lands, 2010). To date, the greatest advancements and applications of MAS have been in crop plant varieties such as tomatoes, maize, rice, wheat, barley, soybeans, and potatoes (Boopathi, 2013b; Brumlop & Finckh, 2011). However, ongoing research in crops, forestry, livestock, fishery, and agro-forestry demonstrate the interest and suggest the potential range of applications of this genomic tool in the near future. In fact, since 2001 there has been $123 million invested in forest genomic research in Canada alone (Porth et al., 2014). Researchers across the Nation are working on projects to further genomics in Canada, including Genome BC, Genome Québec, Genome Canada, the University of British Columbia, the Université Laval, FPInnovations, the Canadian Food Inspection Agency and Natural Resources Canada (Natural Resources Canada, 2012). Moreover, MAS may also help the Ministry meet its objectives as outlined in their *Beyond the Beetle: A Mid-Term Timber Supply Action Plan.*

From an economic standpoint, MAS could help improve forest productivity. With a key softwood lumber market in the US, and expanding markets in China and Japan, BC remains the dominant source for softwood lumber exports in Canada (53.4%, 99.4%, and 93.7% respectively) (Council of Forest Industries, 2014). Shifting markets and new low cost competitors suggests that BC must consider alternative methods to the status quo to ensure lasting competitiveness. By providing breeders with an additional tool to select for wood quality traits, MAS could help breeders grow trees that demonstrate desired characteristics in a timelier fashion.

Environmentally MAS could help breeders achieve improved forest health. The devastation from the MPB and wildfires has left BC forests in a vulnerable state. With anticipated increases in average temperature and severity of environmental disturbances (Canadian Forest Service, 2013), MAS could aid breeders select with greater certainty seedlings that are resistant to droughts, pests and diseases. A healthy forest is also home to countless species, and thus necessary to maintain and sustain the ecosystem. Forests additionally absorb $CO_2$ and hence help regulate global carbon emissions. If breeders could select trees that demonstrate increased carbon sequestration, then the forests of BC could re-establish themselves as being a net carbon sink sooner; as well as help the province meet climate change targets in the future. Restocking our forests with trees that demonstrate resistance will help ensure the future stability, longevity, and health of BC's forests.

Socially, MAS could provide added security to a society that is dependent on forests. The forest sector provides approximately 58,000 jobs in BC, and studies have showed that 25 of 63 communities outside of the Greater Vancouver area receive 20-45% of their income from the forestry and tourism sectors (Ministry of Forests Lands and Natural Resource Operations, 2014a; Ministry of Forests Mines and Lands, 2010). With the onslaught of mill closures and job cuts in the sector, some rural communities are in a critical position. Breeders could use MAS to help select those seedlings used to replant in NSR areas, in areas affected by the MPB, or future harvested stands. If those seedlings are selected based on resistance, growth rates, and wood quality traits, then this could ensure a more reliable supply of timber in the future. And with a more secure supply of wood, mills can continue to operate, creating better job security to rural communities. Furthermore, a secure timber supply may attract investors to invest money in BC facilities (Ministry of Forests Lands and Natural Resource Operations, 2014a).

With advancements in genetic markers occurring each year, Natural Resources Canada and the non-for-profit Genome Canada have shown through their monetary investments that genomics in forestry is bounding with opportunity. It is believed that tree genomics research will lead to improved genomic selection, and serve as an additional tool to tree breeders in the selection of individuals for increased health and adaptability, growth rates, and wood quality (Kumagai et al., 2010).

## 2.5 Implementing MAS in BC

Since BC forests are nearly exclusively held under public title, any newly introduced tool or technology must comply with Provincial regulations before it can be readily implemented. A review of the literature indicates that there are no existing policies or regulations that specifically address the use of genetic markers within public forests. Hence, although MAS is not prohibited from being used within the province, there are also no policies that guide or define its use. This differs from other types of biotechnology, such as genetic modification. Under provincial policy (Section 5.1.8e of the Chief Forester's Standards for Seed Use), the commercial use of genetically modified trees on public land is prohibited (Research and Knowledge Management Branch, 2010). Since MAS is a diagnostic tool that is meant to assist tree breeders in the selection process, and does not involve any modification at the genetic level of an individual, its use is currently not restricted by provincial policy or regulation.

Economically speaking, breeders will only use diagnostic tools, like MAS, to supplement traditional tree breeding if they are cost effective (Yanchuk, 2002). Yanchuk (2002), senior scientist with the Tree Improvement Branch, stated that the financial costs of using this technology outweighed the additional genetic gains achieved. He argued that markers will likely only be used on commercially popular species such as pine and *Eucalyptus* species (Yanchuk, 2002).  But advancements in genome sequencing techniques and methodologies over the last decade have substantially reduced the costs of using these diagnostic tools (Resende et al., 2012). Prices have dropped from over $5,000 per sequenced Mb in 2001 to just over $0.10 per sequenced Mb in 2011 (Poland & Rife, 2012). In a study that examined genomic selection in Eucalyptus, it was estimated that progeny tests performed on 20,000 individuals would cost $51 USD per seedling (Resende et al., 2012). In terms of optimizing net present value, a study examining the potential of genetically improved white spruce trees in Quebec found that the optimal economic rotation age can be reduced by up to 9 years depending on the genetic improvement technique applied (Petrinovic, Gélinas, & Beaulieu, 2009). It is expected that genotyping costs will continue to come down and become more affordable (Resende et al., 2012), suggesting that in the future, economics will not be the key driver restricting its use in BC forests.

For a tool that is being designed for forest applications, social challenges will be the greatest hindrance in implementing MAS. In BC there are several important groups whose opinions must be heard in discussions surrounding the forests. Government and industry are the most obvious, as government is the legal owner of the land, and industry represents those forest companies, individuals, or other legal bodies, that acquire forest licences from the government which provide them with logging rights on a designated piece of land. Other relevant partners in forest-related discussions are environmental non-governmental organizations (ENGOs), and First Nations. The public is yet another important group; however their opinions were outside the scope of this study for reasons discussed later in this section.

Past conflicts over the last few decades in BC has emphasized the role and importance of including ENGOs and First Nations in forest-related discussions. History has demonstrated that the success in formulating new forest-related policies is hinged on the consultation and support by these two groups. The province received international attention in the late ‘90s and early 2000s when environmental groups launched a global campaign to bring awareness to the Great Bear Rainforest. In an effort to protect key ecological areas, environmentalists attacked companies that purchased wood from this region. This so-called ‘War in the Woods’ forced government and industry to work collaboratively with First Nations and ENGOs to reach a forested land-use management agreement that suited all parties.

Moreover a string of 190+ legal victories for First Nations over rights and title, including the recent land claim case where the Supreme Court of Canada ruled in favour of the Tsilhqot’in Nation (in

BC), has categorized First Nations as the true ‘Resource Rulers’ in Canada. BC has only 2 modern treaties that have been signed; with 43 Nations possessing agreements-in-principle (BC Treaty Commission, 2009). With an impressive and unprecedented rise in empowerment across Canada, government and industry recognize the need to engage and work collaboratively with First Nations in BC.

Another key challenge that could impede the implementation of MAS is its assumed relation to GE. Although GE is one of several techniques that fall under the biotechnology umbrella (which also includes MAS), the public has a misconception that genomics and GE are synonymous (Porth et al., 2014). The lack of knowledge surrounding GE, as well as public protests and media coverage has largely been one-sided and focused on the debate of genetically modified organisms (GMOs) (McHughen, 2007; Pardo, Midden, & Miller, 2002). This only further increases the likelihood that the public will equate genomics to this most commonly discussed form (Moshofsky, 2014). In a study conducted on 1,200 American consumers in 2004, researchers found that the public had very low knowledge on basic biology and agriculture (Hallman, Hebden, Cuite, Aquino, & Lang, 2004). These results are consistent with reported findings in the Eurobarometer study (INRA (Europe) - Ecosa, 2000); and it has since been argued that we cannot expect to gain meaningful results by asking consumers about biotechnology when they have a limited understanding of science (McHughen, 2007; Pardo et al., 2002). Constraints on time and budget, and recognizing that a larger educational component would be necessary to educate the public of the role and scope of biotechnological tools in forestry and Provincial silvicultural practices, policies, and regulations as they relate to the forestry sector, the general public was not included in this survey design.

## 2.6 Attitudes and Perceptions

Attitudes are dispositions or feelings generally towards abstract objects, and are comprised of cognitive and evaluative components. People use the information and knowledge about an object’s properties to form an affect or feeling towards said object. Opinions are the spoken or symbolic expression of these attitudes. Opinions and attitudes are often described in the context of a tree or a hierarchy model (Mcfarlane & Boxall, 2000; Pardo et al., 2002). General attitudes would be the stem, specific attitudes would be the branches, and opinions would be the leaves. New information that a person receives can have a greater rate of change over opinions than on the more stable attitudes.

In 2002, a study by Pardo *et al*. assessed and explored attitudes towards biotechnology in the European Union. They found that three cognitive structures were in play in framing more specific attitudes towards biotechnological applications. These were: technological optimism, the promise of biotechnology, and reservations toward biotechnology. Findings from this study revealed that the strongest predictor of positive perceptions of the benefits of biotechnology is if an individual believes in the promise of biotechnology (that biotechnology will improve the quality of life). The second strongest indicator was measured by an individual's perception of the impacts of new technologies on the quality of life (technological optimism). And lastly, being a member of the informed public was found to be the third significant predictor (ie: if an individual is generally interested in biotechnological discussions and understands basic biology and genetics). This study also found that people that had completed higher levels of education were positively correlated to positive perceptions of the benefits of biotechnological applications. Pardo *et al*. argued that an individual's belief in the promise of biotechnology or technological optimism will precede the individual's attitude regarding a specific application of biotechnology (2002). This study concluded that new information acquired through media reports is unlikely to change attitudes, but can overtime reinforce or erode this position.

Most of the literature investigating social perceptions and attitudes on genomics has focused on GE. There is an abundance of research that has assessed the perceptions of genetic modification in medical, agricultural, forest, and livestock applications. Interestingly, these studies have shown that attitudes regarding GE vary in different applications and contexts. For example in a study examining public attitudes towards genetic modification in the European Union, it was found that the public viewed GE in medical applications as useful (79%) and morally acceptable (71%); whereas GE in food was considered risky (60%) and morally unacceptable (70%) (Pardo et al., 2002). The Eurobarometer study reported similar findings, stating that participants only disagreed with modern biotechnology being applied in food production (INRA (Europe) - Ecosa, 2000).

In discussions that were restricted to one field of application, it has been found that different social groups have varying attitudes regarding genomics. In a recent study that assessed the acceptability of various forest management interventions in the context of climate change in rural forest-based communities, it was found that foresters, environmentalists, and business participants each perceived different adaptation strategies as being most favourable (Moshofsky, 2014). Foresters gave preference to local-based scenarios over assisted migration and forest genomic technologies; whereas environmentalists gave preference to scenarios that included mixed species, showing no significant difference between local or assisted migration strategies (Moshofsky, 2014).

## 2.7 Summary

Large monetary investments over the last decade, along with collaborative partnerships with various organizations across the country, have sparked interest over the potential of MAS, accelerating Canada as a leader in forest genomics (Kumagai et al., 2010).The application of MAS in BC forests could help the Province achieve increased health and adaptability, growth rates, and wood quality. However, before a new tool like MAS can be implemented, it is first necessary to survey social perceptions and ensure that not only is its use supported, but that it is applied in the appropriate context. Interviewing forest stakeholders and First Nations allows access to unquantifiable facts and provides a level of richness, depth and detail that is not achievable in quantitate research (Berg, 2007). Gaps in current knowledge that emerged from the literature review resulted in the research questions introduced in Chapter 1.

# Chapter 3 Methods

Following are the methods that were employed to address the research questions defined in Chapter 1. Section 3.1 presents the research design and rationale for employing qualitative research methods and semi-structured individual surveys supplemented with a quantitative questionnaire and an educational package. Section 3.2 discusses sampling methods and rationale for each social group included. Section 3.3 reviews the ethical implications and requirements in social science research when human subjects are used. Section 3.4 explores the methodological approaches taken in the interview and data analysis of this study.

## 3.1 Research Design and Rationale

Social science is the study of human thought and human behaviour with the aim of finding patterns of regularity within the social world (Babbie, 2010; Bernard, 2013). Within social science there are two common approaches that are employed by researchers: qualitative and quantitative. Qualitative research explores, describes, and explains nonnumerical data for the purpose of uncovering patterns of relationships and underlying meanings (Babbie, 2010). It is most commonly achieved through observations of or interviews with participants. Through these methods, researchers are able to uncover the understandings and perceptions of people; allowing them to assess unquantifiable facts about said individuals (Berg, 2007). Conversely, quantitative research involves the collection and analysis of numerical data. Each of these modes of research has their benefits and disadvantages. For instance, qualitative data may be rich in meaning but has been argued to be subjective, ambiguous, difficult to replicate, and restrictive in scope (Babbie, 2010; Bryman, 2004). Quantitative data on the other hand is easier to tabulate, compare, discuss, and allows for statistical analyses, yet black and white measurements may inaccurately or vaguely represent the grey social world (Babbie, 2010; Bryman, 2004). As encouraged by Onwuegbuzie and Leech (2005), in an effort to draw on the strengths of both types of data and minimize the weakness when reduced to one type of approach, this research study employed both quantitative and qualitative methods to address the research questions (Chapter 1).

For the qualitative inquiry, individual interviews were employed. Qualitative interviews in social science are essentially conversations that have a purpose (Berg, 2007). There are three main types of qualitative interviews: structured, semi-structured, and unstructured interviews. For this research study semi-structured interviews were chosen, as this method affords a balance of predetermined questions and topics that are typically asked in a systematic way, but gives the freedom to reorganize questions, be flexible with wording, and use probes for clarification when answers are unclear or could be elaborated (Berg, 2007).

Individual interviews were chosen over focus groups. Although focus groups have gained a lot of traction in social sciences since the 1980s and early 1990s, the comparative advantages/disadvantages of this method discouraged its use in this study. For example, focus groups may be cost effective and time saving, but are most effective with groups of 8-12 members and when participants are strangers (Fern, 1982). Moreover, issues with dominant participants controlling or leading the conversation can lead to peer pressure or biased information processing (Kaplowitz & Hoehn, 2001). Individual interviews on the other hand have been reported to generate 30-40% more ideas, that are of higher and more detailed-orientated quality (Fern, 1982).

In developing the interview guide for these semi-structured individual interviews, it was essential to create open-ended questions. Open-ended questions grant the participant the freedom to provide details and share stories when responding to the questions, allowing for a smooth and comfortable conversation to flourish. Each interview began with a few warm-up questions that were more general and socio-demographic in nature, so that participants felt more relaxed and natural with the interviewer. These were followed by questions that explored the participant’s familiarity with forest genomic tools, impression of and attitude towards MAS, perceived benefits and issues with the technology and foreseeable use of the tool (see Appendix B). Within the interview guide, most essential questions could be followed-up with a probing question if more information or clarity was needed from the respondent. Once the interview guide was created, three pre-tests were performed to ensure that question were in the right sequence, void of bias, and effectively addressed the research questions.

For the quantitative inquiry, a questionnaire was developed. The questionnaire was designed to cover topics of perceived interest, support, and usefulness of MAS in different contexts (see Appendix C). This questionnaire was designed using a Likert scale, giving participants the opportunity to rank their responses along a five-point scale from strongly agree to strongly disagree. The statements developed for the Likert scale complemented the questions designed for the qualitative interview, however were different enough to avoid overlap and repetition. A Likert scale was chosen for its ease of measurement in standardized response categories when determining the relative intensity of different issues (Babbie, 2010).

The questionnaire served two additional functions aside from the Likert scale. Firstly, it was an opportunity to collect socio-demographic information about the participant, such as age, gender, residence, and education. Participants were asked to circle the category that best described them. The questionnaire secondly served as a pre- and post-video knowledge comprehension test. For those participants unfamiliar with MAS, it was tested to see if their level of understanding improved after the video (described below). This technique is used to inform the interviewer that participants have at least the same relative understanding before beginning the interview process. Furthermore, in this study, the pre- post-test informed the interviewer which participants had *a priori* knowledge on the technology versus those who were being introduced to the technology.

An educational package was prepared for these interviews. It was expected that participants would range in their prior knowledge on MAS, so the educational package served as a way of ensuring that all participants at least knew what MAS is and how it can be used in forestry. The educational package consisted of a video that was originally prepared by Télé-Québec. This segment was part of a scientific series called Le Code Chastenay that aired on January 14$^{th}$, 2008 (see Appendix D for video script). Since this video was made in Quebec, it was originally in French. The production company gave permission to use this video in this research study, and allowed English voice-overlays, as long as the video was translated verbatim. Using iMovie and Samsung Voice Recorder, the video was converted into English for this study. The educational video was just over 11-minutes long.

### 3.2 Sampling of Social Groups

Purposive sampling was employed in this study. It was imperative that participants, or the companies/organizations that they worked with, were either involved in silviculture practices in BC, or that they actively participated in discussions that concerned silviculture practices in BC. It was also important that these individuals were well-versed in Provincial practices, policies, and regulations concerning forestry (see Appendix E for participant job titles). There are four main groups in the Province whose voices are typically involved in decisions concerning the forests: government, industry, First Nations, and ENGOs. For this reason, it was necessary to ensure each of these groups was represented in this study.

Government and industry are two important groups to this discussion as they are the anticipated potential end-users of MAS. The government is the regulator over silvicultural practices that take place on publicly owned forests. Individuals from various branches and departments within the Ministry of Forests, Lands, and Natural Resource Operations were invited to participate in this study.

Forest harvesting is generally performed by private forest companies. When grated forest tenure, these companies agree to a set of responsibilities, which generally include operational planning, reforestation, road building, strategic planning and inventory management (Ministry of Forests Lands and Natural Resource Operations, 2012c). Participants were sought from the top 10 biggest forest companies in BC in 2012, as well as the subcontracting companies that these larger companies hire for reforestation.

First Nations and ENGOs are two other key groups that are largely involved in forest-related discussions in BC. First Nations have been fighting with forest companies for decades as they try to protect Aboriginal and treaty rights. BC is one province that lacks settled treaties, and thus lacks certainty about Aboriginal rights and title (Luckert, Haley, & Hoberg, 2011). Nevertheless, the Courts have forced governments to include First Nations in the decision-making process and share economic benefits received from forestry (Luckert et al., 2011). For this study, individuals working in a forestry department at a Band office or work for a First Nations forestry company were invited to participate in this study.

Likewise, ENGOs have worked hard to establish a heard voice regarding the forests in BC. Through demonstrations, campaigns, and media, several major ENGOs have gained international attention for their efforts to protect the diversity and range of BC forests. Because of their active role in forestry, individuals from major ENGOs that have a focus on forests were invited to participate in this study.

Within the scope and context of this study, the general public was excluded. Findings from other genomic research studies revealed that the public has very low knowledge on basic biology and agriculture (Hallman et al., 2004; INRA (Europe) - Ecosa, 2000), and it has been argued that meaningful results from discussions on biotechnology with the public cannot be expected (McHughen, 2007; Pardo et al., 2002). Because of budget and time constraints, it was outside the scope of this study to create a larger educational package that would satisfactorily elevate the general publics' knowledge level on biology and crop science. Moreover, as it was decidedly important to survey those individuals that were active in silviculture practices and knowledgeable in forest policy and regulations, the views of the public were not surveyed.

### 3.3 Research Ethics

All research at the University of British Columbia that involves human participants must first seek approval by the Behavioural Research Ethics Board (BREB) before initial contact with any potential participants. BREB requires that all researchers involved in the study complete the Course on Research Ethics (CORE) which tests that researchers are aware and will adhere to the Tri-Council Policy Statement 2 (TCPS2). BREB also requires that the researcher submit the study's initial contact letter, research proposal, interview guide, consent forms, and questionnaire for ethics approval.

Once approved by BREB, I began the recruitment stage. All potential participants received an initial contact letter via mail (see Appendix F). Participants were invited to contact the researchers via telephone or email if they were interested in participating. A follow-up email was sent via email to those participants that had yet to respond to the original mailed letter. Interviews were scheduled with 25 individuals between July 30$^{th}$ and September 26$^{th}$ 2013. This sample size was deemed appropriate as the literature states that 15 to 20 interviews are usually required to achieve data saturation for themes in qualitative studies (Samure & Given, 2008).

Since the research was deemed low risk by BREB, and that participants spanned across the Province (see Figure 4), individual interviews took place at the participant's place of work. Once together, time was spent reviewing the consent form and answering any questions the participant may have had (see Appendix G). The consent form requested separate signatures for consent to freely participate in the study and for permission to be audio recorded. The participant was informed that their identity would be kept strictly confidential throughout the analysis and publishing of the data, and that all recordings would be stored securely under the guidelines of BREB.

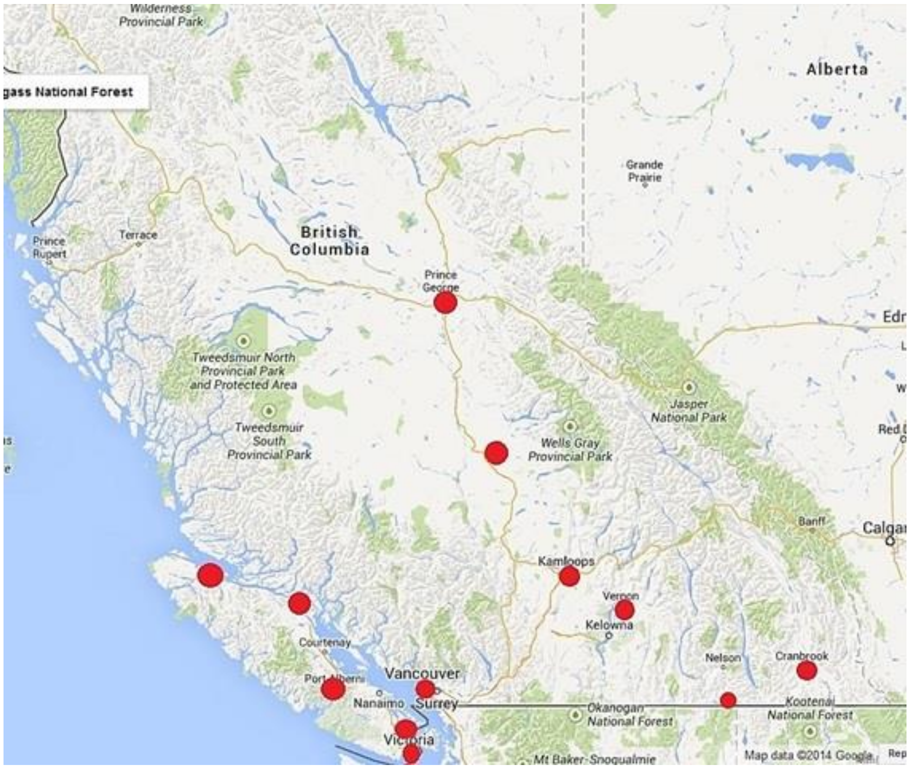


**Figure 4: Map of British Columbia indicating locations where interviews took place**

## 3.4 Methodological Approaches

### 3.4.1 Qualitative interviews and quantitative questionnaires

Each interview began by asking participants the first four questions as outlined in the interview guide (see Appendix B). Once the pre-video interview questions had been answered, the participant was given the questionnaire document (see Appendix C) and asked to answer the pre-video knowledge question and complete the 'respondent information' section. Participants then watched the 11-minute educational video, and answered the post-video knowledge question.

The interviewer then asked the second set of questions from the interview guide. Participants were given as much time as they wanted to go into as much detail as they wished for each of those questions. When clarity or further explanation was needed, they were prompted for it. Due to the nature of the semi-structured design, questions order switched on occasion, but all questions were asked of the participant. The interview was followed with the Likert scale questionnaire. Participants were given time to complete this survey (usually 5-10 minutes), upon which the interview was concluded.

### 3.4.2 Qualitative and quantitative data analysis

The first step in the qualitative data analysis was to prepare the data collected. Since interviews were audio recorded, each interview was first transcribed verbatim. This was performed using NVivo 10, which is a qualitative data software program. Next, each interview was coded for affect (*i.e.* positive, neutral, or negative first impression of MAS) or theme. Themes were identified by the frequency by which all participants made reference to a certain idea. If a single participant repeated an idea, it was not duplicated in the tally of references to that theme. Thus one reference was given per participant per idea. Queries were then performed by social group (*i.e.* government, industry, First Nations, and ENGOs), and thematic trends were noted. Relative frequencies were calculated by social group and by sample.

In the quantitative data analysis, responses from the questionnaire were inputted into a spreadsheet. Using Analysis ToolPak (an Excel add-in) and Statistical Package for the Social Sciences (SPSS), several tests were performed on the data. One-way Analysis of Variance (ANOVA) was calculated for each question, using alpha = 0.05. In order to effectively use ANOVA, there are four assumptions that must be met: each population is normally distributed, each population has the same variance, observations of a population are independent from the observations of other populations, and that observations are randomly selected from each population. Where the F critical value was smaller than the F stat value ($F_{stat} > F_{critical}$), a Bartlett's test was performed to ensure variances were equal.

Scheffé's Tests and confidence intervals were calculated to determine significant differences between social groups' responses. Lastly, a k-means cluster analysis was performed using 2 and 3 clusters.

# Chapter 4 Results

This chapter summarizes the results obtained from the research interviews. Section 4.1 highlights data collected on the sample population, including response rates and socio-demographic information. Section 4.2 reveals the results from the comprehension test. Section 4.3 presents qualitative and quantitative data that supports perceived acceptability towards the implementation of MAS in BC. Section 4.4 shows the perceived context (benefits, concerns, and usefulness) described by the participants for which the implementation of MAS is dependent.

## 4.1 Sample Population

Of the 62 contact letters that were sent inviting people to participate in this study, I received a 46.8% response rate. The group with the highest response rate was government (73.3%), and the lowest group response rate was ENGOs (26.7%) (see Figure 5). Potential interviewees contacted from government generally held roles as silviculture specialists, forest genetics specialists, or forest researchers. Industry participants generally assumed roles as silviculture coordinators, registered professional foresters, or forest managers. Invited First Nations participants were generally referral workers, CEOs, forest planners or forest consultants. And ENGOs typically held director or forest campaigner roles. Of the 29 respondents, I was able to schedule and complete interviews with 25 individuals.

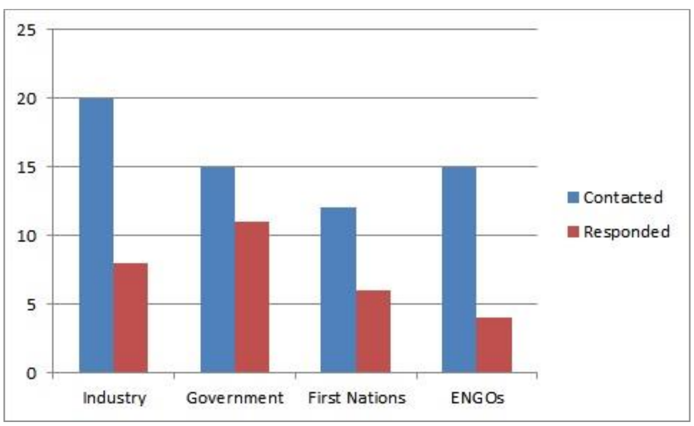


**Figure 5: Response rate for study by participant group**

Table 2 shows the distribution of participants by categorized group, gender, and residence. This sample was comprised of more males than females (18:7), which was anticipated as more males were initially contacted than females (41:21). Also, the majority of the sample was from rural communities in BC. Of the individuals that were interviewed, government was the largest group (9 participants), while ENGOs had the fewest participants (4).

**Table 2: Distribution of participants by categorized group, gender, and residence**

| | Male | Female | Rural | Urban | Total |
|---|---|---|---|---|---|
| *# of industry participants* | 5 | 1 | 5 | 1 | 6 |
| *# of government participants* | 7 | 2 | 9 | 0 | 9 |
| *# of First Nation participants* | 3 | 3 | 5 | 1 | 6 |
| *# of ENGO participants* | 3 | 1 | 0 | 4 | 4 |

The mean, median, and mode age category across the sample fell within the 51-60 age group (Figure 6). However, the average age of industry and ENGO participants fell in the 41-50 age group. The First Nations' group had an equal distribution of representation from the age categories 41-50 and 51-60.

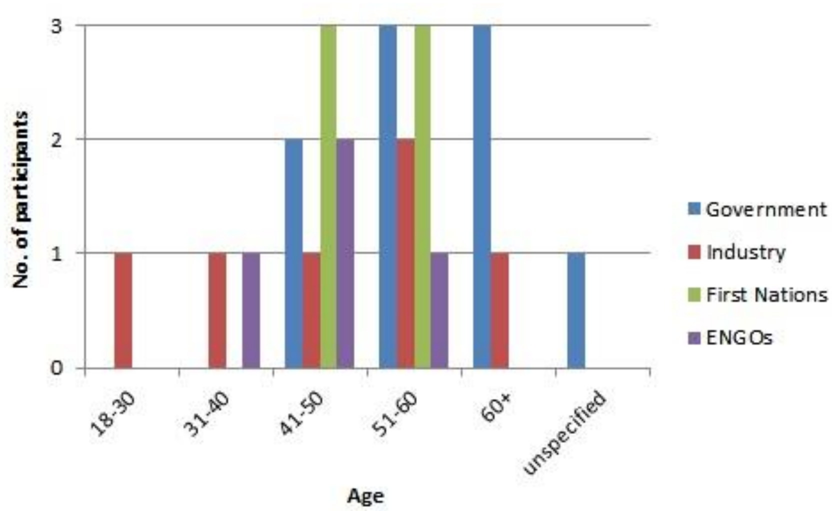


**Figure 6: Distribution of participant's age by categorized group**

Of the four groups, government had the highest level of average education, with the majority of the sample from that group having earned a Master's Degree, and the minimal level of education earned was a Bachelor's Degree (Figure 7). There was an equal representation in the number of participants that had completed a Bachelor's Degree and a Master's Degree in this sample.

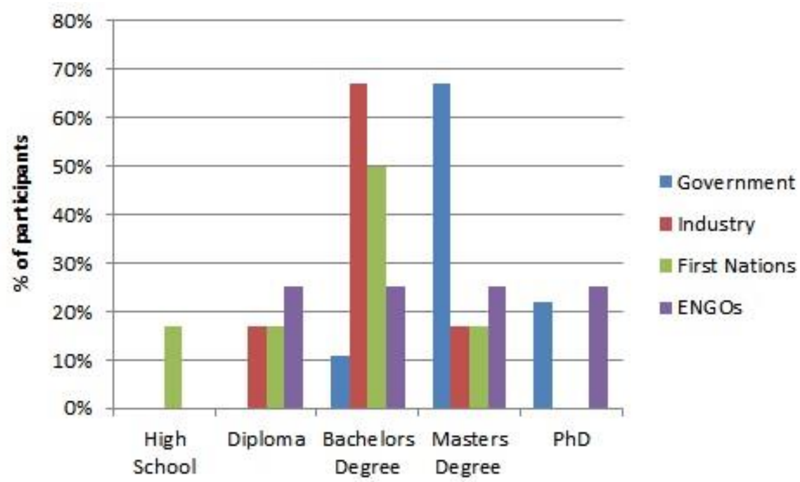


**Figure 7: Distribution of education level obtained represented as a proportion of members within each group**

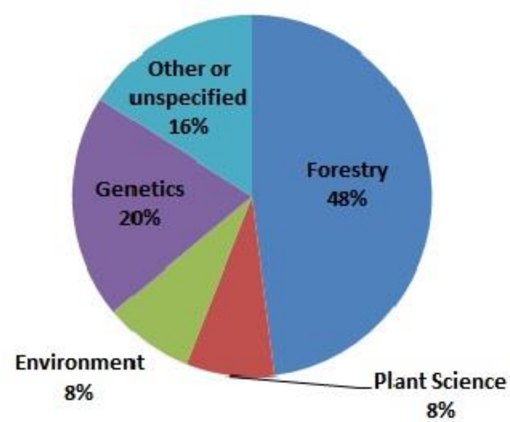


**Figure 8: Distribution of sample's areas of academic specialization**

Figure 8 shows the distribution of academic specialization of the sample. The majority of participants had a background in forestry; followed by a background in genetics. All participants that indicated their academic disciplines were from the sciences. There were two participants that did not specify their specialized academic discipline.

## 4.2 Comprehension Test

Across all groups, the educational video improved participant's understanding of MAS. Figure 9 shows that the number of people that answered the post-video question correctly versus the pre-video question. It is necessary to note that the pre- and post-video question was exactly the same (see Appendix C).

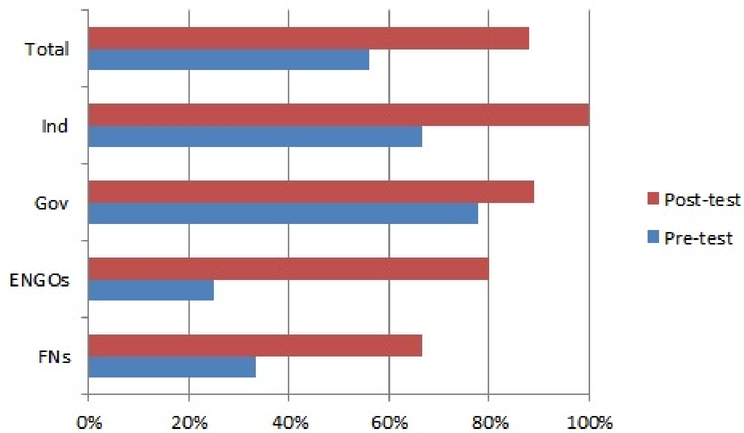


**Figure 9: Distribution of correct answers to the pre- and post-video question, represented by proportion of categorized group**

In the qualitative interviews, participants were asked if they were familiar with MAS. Of the 25 participants, 44% confirmed that they were familiar (7 participants) or were somewhat familiar (4 participants) with MAS (Figure 10). All those that said they were familiar with MAS answered the pre-video question correctly (28% of total sample), and did not change their answer following the video. Of the participants that said they were somewhat familiar with MAS, all answered the post-video question correctly.

There were 14 participants who stated that they were not familiar with MAS. On the questionnaire, 5 of these participants guessed the correct answer to the pre-video question. Following the video, 11 of the participants that were originally unfamiliar with MAS (78.6%) answered the post-video question correctly. Of the 3 that answered incorrectly, they all chose response ‘C.’

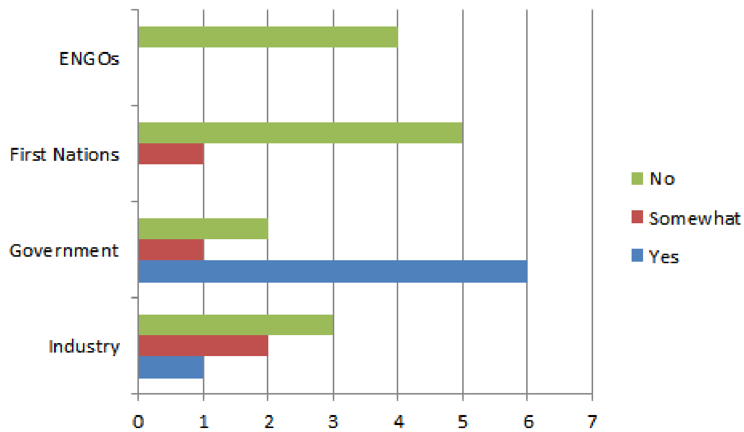


**Figure 10: Participant familiarity with MAS a priori interviews**

## 4.3 Research Question 1 Results

The scope of the first research question was to examine the perception of stakeholders and First Nations on the implementation of forest genomic technologies, namely MAS, in BC. In this section, the results obtained from the qualitative interviews and those collected in the quantitative questionnaire are reported separately.

### 4.3.1 Qualitative data collected in response to research question 1

In the qualitative interviews, participants were asked to report their first impression of MAS. Table 3 shows that the majority of participants had a positive first impression. Industry demonstrated the highest level of initial impression, with all members reporting it to be positive. The only group that reported a negative first impression was First Nations.

**Table 3: Participants' first impression of MAS represented as a proportion of members within a group, and as a sample population total**

| | Positive | Neutral | Negative |
|---|---|---|---|
| Industry | 100.0% | | |
| Government | 77.8% | 22.2% | |
| First Nations | 16.7% | 50.0% | 33.3% |
| ENGOs | 50.0% | 50.0% | |
| **Total** | **64.0%** | **28.0%** | **8.0%** |

Participants were also asked to share their organization's attitude regarding the use of genomic technologies (in general) in the forest of BC. From Table 4, it can be seen that there was a diversity of answers that needed to be accommodated, as some participants were either unsure of their organization's attitudes, stated that their organization held no attitudes regarding genomic technologies in the forests, or deemed that attitudes depended on the context of which the tool would be applied. Although the highest reported organizational attitude was positive, neither First Nations nor ENGO participants indicated a positive or neutral attitude. First Nation participants were divided between 'negative', 'none or unsure,' and 'depends'. One First Nation participant said, "[…] they are not being consulted so their attitude may be that they 'don't know,' because no one is coming and talking to them about it. […] There's a gap in communication – it's not happening. And there is not knowledge or awareness by the communities, by the First Nations."

ENGOs were split between 'none' and 'depends on context.' One participant indicated that as long as the scale, thoroughness of research and consequences were investigated, and an assurance that they were not selecting too narrow of a band of markers (to maintain genetic diversity), then they would not have a problem with the use of genomic technologies. Another participant indicated that as far as they knew, colleagues were only unanimously opposed to GMOs.

Industry participants were divided between 'positive,' 'neutral' and 'unsure' of their organizations' opinions. Government participants expressed positive attitudes regarding genomic technologies. One participant stated, "We are open, and as I said we are contributing to the research today with the view that we will potentially utilize it ourselves."

**Table 4: Organization's attitude (as reported by participant) regarding genomic technologies in BC forests, represented as a proportion of each group and as a sample population total**

| | Positive | Neutral | Negative | None or Unsure | Depends on Context |
|---|---|---|---|---|---|
| Industry | 50.0% | 16.7% | | 33.3% | |
| Government | 88.9% | 11.1% | | | |
| First Nations | | | 33.3% | 33.3% | 33.3% |
| ENGOs | | | | 50.0% | 50.0% |
| **Total** | **44.0%** | **8.0%** | **8.0%** | **24.0%** | **16.0%** |

Table 5 reflects participant responses when asked to describe their organization's expected attitude regarding the use of MAS in BC. Government respondents unanimously reported positive attitudes. One government participant replied:

> "There's no problem with it. All we're doing is – it's just another tool to support our activities and field tests. So I don't think there'd be any objection in using marker-aided selection. It is not what a lot of the public thinks. It's not witchcraft or anything. You're just identifying specific genes; but you aren't doing anything with them really. You're just multiplying them. […] If it helps, then they'll be supportive."

Industry also highly reported positive attitudes regarding the implementation of MAS. Indeed, only one industry participant indicated that they were 'unsure' about their company's opinion regarding MAS usage in BC. From the responses heard in the interviews, industry would support the use of this tool in the field, however would like to see complementing policies defining its use and trials demonstrating its effectiveness in the field.

**Table 5: Organization's attitude (as reported by participant) regarding the use of MAS in BC forests, represented as a proportion of each group and as a sample population total**

| | Positive | Neutral | Negative | None or Unsure | Depends on Context |
|---|---|---|---|---|---|
| Industry | 83.3% | | | 16.7% | |
| Government | 100.0% | | | | |
| First Nations | | 33.3% | 50.0% | | 16.7% |
| ENGOs | | 25.0% | 25.0% | 25.0% | 25.0% |
| **Total** | **56.0%** | **12.0%** | **16.0%** | **8.0%** | **8.0%** |

ENGO participants were equally split between 'neutral,' 'negative,' 'no opinion,' and 'depends.' Generally, ENGOs discussed that their organizations would not have much to comment on this tool as its use would be very specific. If however, this tool could be potentially harmful for adaptability in light of climate change, or reduced diversity across the stand, then they would not be supportive of its use.

First Nation participants largely fell in the 'neutral' or 'negative' attitude category. Some claimed that members of their community would not entertain the idea of using this tool, while others noted the potential of the tool. In general, First Nations claimed that there is a gap in knowledge and communication between communities and those who develop new technologies for the forests. In order for that gap to be closed, trials need to be performed and First Nations must be informed – this is the only way to establish trust with the community.

### 4.3.2 Quantitative data collected in response to research question 1

Within the questionnaire, participants were asked to rank their responses to various question by using a five-point Likert scale (from 1 – strongly agree, to 5 – strongly disagree). There are four basic assumptions used in ANOVA (Section 3.4.2). For this study, it has been assumed that each population was normally distributed. Observations collected in this study were independent of each other, and a

Bartlett's test was used to ensure population variances were equal (an alpha value = 0.05). Lastly, since purposive sampling was employed in this study, observations were not randomly selected from each population. Thus, the findings described below may not be generalizable to the entire population.

When participants were asked whether they agreed that the advantages of MAS outweighed the disadvantages, there was a significant difference in responses between industry and government, and ENGOs (Figure 11). A significant difference exists between the ranked means (7.94 > 3.10). A Scheffé's Test revealed that there was a significant difference between government and ENGOs, and that industry demonstrated a significant difference in responses compared to ENGOs and First Nations.

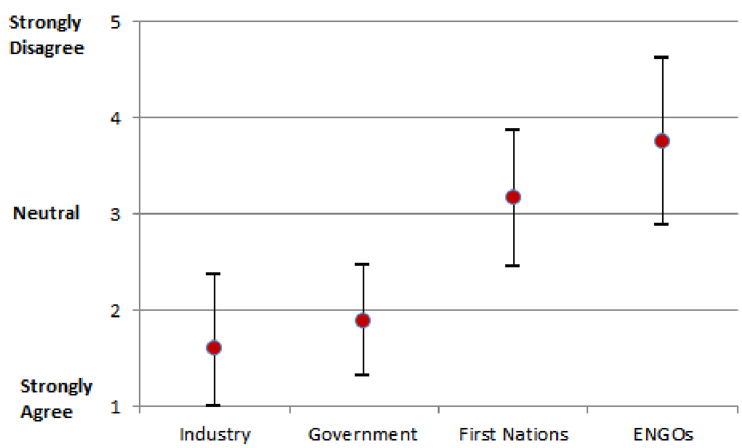


**Figure 11: Mean level of agreeance and 95% confidence interval by group to the statement that the advantages of MAS outweigh the disadvantages**

Participants were then asked to rate their level of agreeance to the statement, "my attitude towards the use of MAS in the forests of BC is positive" (Figure 12). A significant difference exists between the ranked means (20.56 > 3.07). A Scheffé's Test indicated that industry and government differed significantly in responses from First Nations and ENGOs.

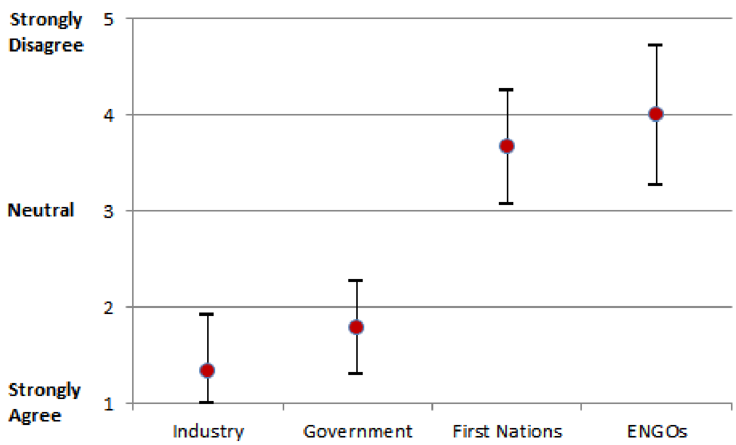


**Figure 12: Mean response and 95% confidence interval by group to the statement that the participant had a positive attitude towards the use of MAS in the forests of BC**

Next, participants were asked to rank their support in the continued investigation and research in genomic technologies (Figure 13). A significant difference exists between the ranked means (7.82 > 3.07). A Scheffé's Test revealed that government mean responses were significantly different than ENGO mean responses, and that industry mean responses were significantly different than ENGO and First Nation mean responses.

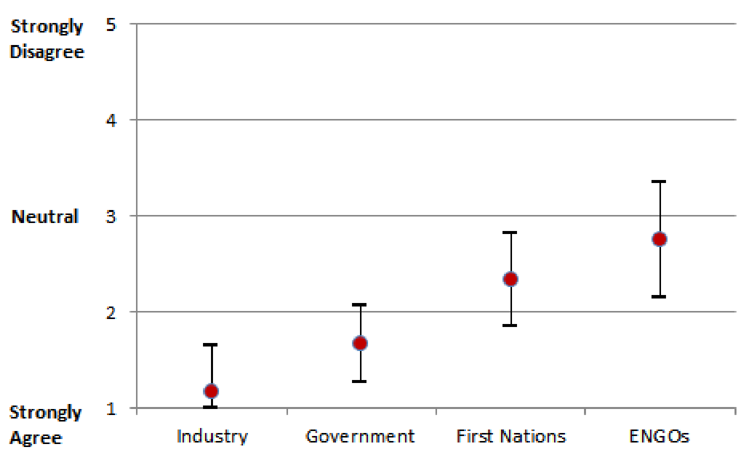


**Figure 13: Mean response and 95% confidence interval by group to the statement that the participant supports the continued investigation and research in genomic technologies**

Lastly, participants were asked to rank their personal support in the implementation of MAS in BC forests (Figure 14). Note that this differs from the qualitative question that asked them to discuss the expected opinion of their organization towards the implementation of MAS in BC forests. For this question, the assumption that variances are equal between populations was violated. However, the results were indicative of differences between industry and government responses when compared to First Nations and ENGO responses.

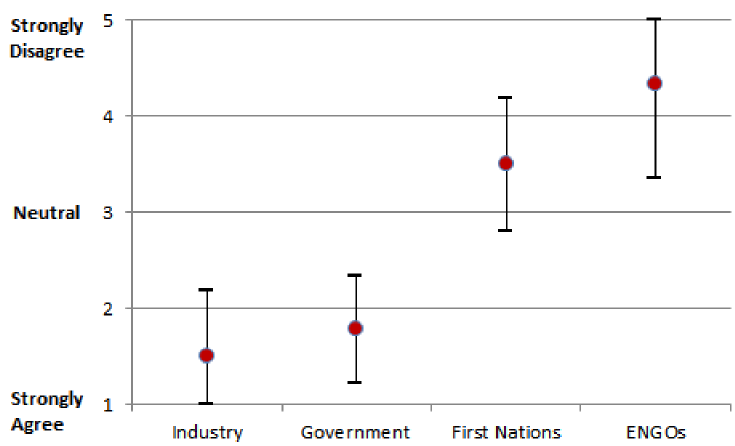


**Figure 14: Mean response and 95% confidence interval by group to the statement that the participant supports the implementation of MAS in BC forests**

## 4.4 Research Question 2 Results

The aim of the second research question was to determine if participants' perception of MAS was dependent on the context that it was implemented. In this section, the results obtained from the qualitative interviews and those collected in the quantitative questionnaire were reported separately.

### 4.4.1 Qualitative data collected in response to research question 2

In the qualitative interviews, participants were asked to discuss the perceived benefits, concerns, and usefulness of MAS as a tool to supplement traditional tree breeding methods. Table 6 represents the identified benefits that were stated in the interviews. Across all groups, using MAS to select for desired traits was the most frequently identified benefit. Other notable benefits that were popular among all groups were that MAS would be time saving, that it would be an additional tool to tree breeders, and that it would improve screening capacity.

**Table 6: Identified benefits of MAS, represented as the relative proportions by group and of the total sample population, calculated using relative frequencies**

| Identified Benefits | Industry | Government | First Nations | ENGOs | Total |
|---|---|---|---|---|---|
| Forest regeneration benefits | | | | | |
| 1. Selection of traits | 83.3% | 88.9% | 100.0% | 100.0% | 92.0% |
| Industry focused traits | | | | | |
| General | 50.0% | 66.7% | 66.7% | 50.0% | 60.0% |
| Wood quality/density | 16.7% | 55.6% | | 25.0% | 28.0% |
| Improve forest resilience | | | | | |
| Climate change adaptation | 66.7% | 33.3% | 50.0% | 25.0% | 44.0% |
| Pests/diseases | 66.7% | 44.4% | | 25.0% | 36.0% |
| Maintain/improve forest ecosystem | | | | | |
| Faster growing trees | 16.7% | 22.2% | 33.3% | 25.0% | 24.0% |
| Knowledge from genes | 33.3% | | 33.3% | | 16.0% |
| Forest industry specific benefits | | | | | |
| 2. Useful for plantations | | | 33.3% | 50.0% | 16.0% |
| 3. Cost effective | 16.7% | 11.1% | 16.7% | | 12.0% |
| Reduce fill planting | 16.7% | 11.1% | 16.7% | | 12.0% |
| Reduce brushing | | 11.1% | 16.7% | | 8.0% |
| Reduce treatment | | 11.1% | | | 4.0% |
| Achieve free-to-grow sooner | 16.7% | | | | 4.0% |
| Tree breeder benefits | | | | | |
| 4. Time saving | 100.0% | 100.0% | 50.0% | 25.0% | 76.0% |
| 5. Additional tool to breeders | 66.7% | 66.7% | 16.7% | | 44.0% |
| 6. Increase screening capacity | 16.7% | 77.8% | 16.7% | | 36.0% |
| Other benefits | | | | | |
| 7. Reduce pressure | | 11.1% | | 50.0% | 12.0% |
| 8. First Nation values | | | 16.7% | | 4.0% |
| 9. Carbon storage | | | 16.7% | | 4.0% |

Among industry participants, the most frequent benefits identified were that MAS would be time saving, that it would help tree breeders, and that it had an ability to select for desired traits to improve forest resilience and industry specific traits. Unique to the group, participants stated that it would allow a company to reach free-to-grow status sooner, hence that a company would be able to return the land to the Crown and be relinquished of any legal obligations defined by the tenure licence sooner.

Government participants also mentioned most frequently that benefits of MAS include timeliness, an additional tool to tree breeders, and its ability to select for industry focused traits. Exclusively to this group, government participants voiced that MAS could reduce treatments (*i.e.* sprays). One participant described the cost-effectiveness of MAS as follows:

> "It's going to be perhaps a cheaper way of selection rather than doing all these trials and maintaining these sites over the years; say three decades. Right now it costs money to put those trials in: you have to pay the planters, find the sites, prepare the sites, and then you may have to maintain those sites and measure them over the years. Brushing and treatment is also expensive. So I don't know, it could be cost saving as well."

First Nations uniquely specified that MAS could be used to select trees that would have greater carbon sequestration capacity. They also revealed that it could be used to maintain First Nation values. For example, it could be used to improve breeding of medicinal plants and food plants that are culturally and economically important to First Nations.

Lastly, all ENGOs identified that MAS would be helpful in selecting trees based off their desired traits. This group further discussed its potential ability to reduce pressure from natural forests. Participants explained that agreements or moratoriums could be established so that certain areas could be allocated to forestry-related uses, and other areas could be conserved and protected.

Table 7 highlights the perceived concerns that were identified through the qualitative interviews. Of all the concerns that were identified, impacts to genetic diversity and increased susceptibility/reduced resiliency were the two most commonly identified issues by all groups (48% and 44% respectively). Other issues that were described with notable relative frequency across all groups were that MAS could have unknown impacts to ecosystems, that the tool is expensive to use with unknown additional training and facility costs, that public and First Nations perceptions may be negative, and that it is difficult to predict which traits will be desired by the industry 50 years from now.

**Table 7: Identified concerns of MAS, represented in relative proportions by groups and by the total sample population, calculated using relative frequencies**

| Identified Concerns | Industry | Government | First Nations | ENGOs | Total |
|---|---|---|---|---|---|
| Unknown Impacts | | | | | |
| 1. Impacts to genetic diversity | 50.0% | 22.2% | 50.0% | 100.0% | 48.0% |
| 2. Increase susceptibility / reduce resiliency | 33.3% | 11.1% | 66.7% | 100.0% | 44.0% |
| 3. Impacts to ecosystem | | | 83.3% | 100.0% | 36.0% |
| 4. Impact from breeding with wild populations | | | | 25.0% | 4.0% |
| Issues with technology | | | | | |
| 5. Expensive to use (technology, facility and/or training) | 16.7% | 55.6% | 33.3% | | 32.0% |
| 6. Unsure which traits will be desired in future | 33.3% | 22.2% | 16.7% | 25.0% | 24.0% |
| 7. Expensive to develop tool | | 44.4% | | | 16.0% |
| 8. Exploitation of industry desired traits | | | 33.3% | 50.0% | 16.0% |
| 9. Genes don't determine all phenotypes | 16.7% | 22.2% | 16.7% | | 16.0% |
| 10. Traits of interest involve many genes | | 33.3% | | | 8.0% |
| Implementation issues | | | | | |
| 11. Perception by public and/or First Nations | 50.0% | 33.3% | 16.7% | | 28.0% |
| 12. Need for policy defining usage | 16.7% | 11.1% | | 25.0% | 12.0% |
| 13. Does not replace field tests | 33.3% | 11.1% | | | 12.0% |

Uniquely to government participants, it was discussed that MAS and marker technologies in general have been very expensive to develop. Also, many traits of interest involve many genes, which would be inherently more difficult to select for using markers. Government and industry participants were the only two groups that expressed that markers technologies do not replace field tests, and that progeny testing and identifying superior trees will still need to occur.

Although participants were not specifically asked in the qualitative interviews to report which traits MAS could be helpful in selecting, participants routinely identified said traits. Table 8 demonstrates that 44% of all participants articulated that MAS could be used in the selection of volume/growth/productivity traits, while 36% expressed its potential use in resistance/resilience against pests and diseases, and general forest management traits. Government was the only group that identified wood density as a selectable trait, while government and industry were the only two groups to identify its use in comparing relatedness and genetic gain among individuals and species.

**Table 8: Traits that MAS could be useful in selecting for, represented as a proportion of each group and by the total sample population, calculated by using relative frequencies**

| Selection of traits | Industry | Government | First Nations | ENGOs | Total |
|---|---|---|---|---|---|
| Volume/growth/productivity | 50.0% | 33.3% | 50.0% | 50.0% | 44.0% |
| Resistance/resilience | 50.0% | 33.3% | 16.7% | 50.0% | 36.0% |
| General forest management | 50.0% | 11.1% | 66.7% | 25.0% | 36.0% |
| Wood quality | 50.0% | 33.3% | | 25.0% | 28.0% |
| Fibre/structural strength/straighter | | 33.3% | 16.7% | 25.0% | 20.0% |
| Climate change adaptation | 16.7% | 33.3% | 16.7% | | 20.0% |
| For industry specific traits | 33.3% | | 16.7% | 50.0% | 20.0% |
| Wood density | | 33.3% | | | 12.0% |
| Compare relatedness/genetic gain observed | 16.7% | 22.2% | | | 12.0% |

### 4.4.2 Quantitative data collected in response to research question 2

Figure 15 demonstrated the mean responses by each group when considering the usefulness of MAS in the defined context. Respondents displayed similar views in three of the scenarios: increasing timber production, increasing timber quality, and adding value to wood products. In all three cases, mean participant responses within groups fell between ‘strongly agree’ to ‘neutral.’ In each of these scenarios, industry showed the highest level of agreeably (most closely to ‘strongly agree’), closely followed by government. First Nations were the least agreeable in these three cases (most closely to ‘neutral’). There was no statistically significant difference in participant grouped responses for ‘increasing conservation areas’ or for ‘rehabilitating sites and/or degraded sites.’

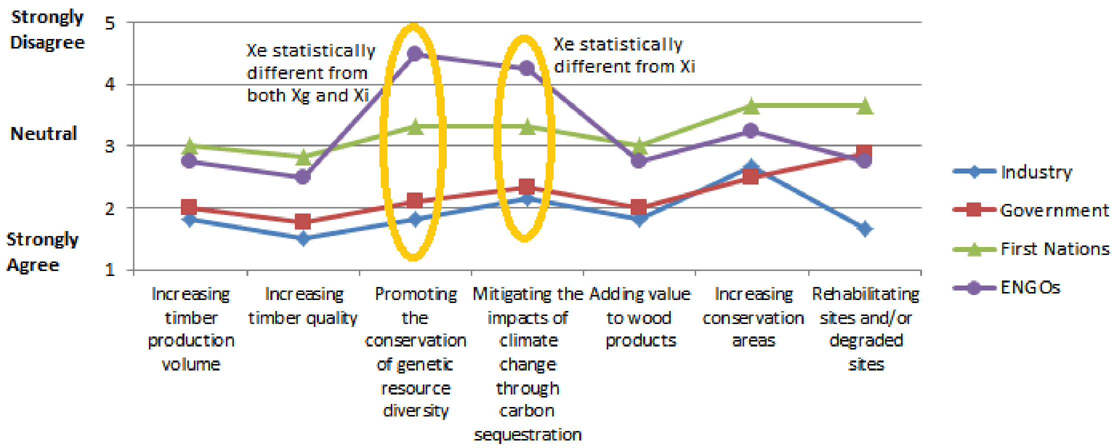


**Figure 15: Mean response by group for usefulness of MAS as a tool if used in a forest management framework in BC. Circles denote significant differences revealed through ANOVA and Scheffé's Tests (alpha = 0.05). Notes indicate statistically significant differences that exist with Xi, Xg, Xf, and Xe denoting mean scores for Industry, Government, First Nations, and ENGOs respectively.**

There was a significant difference in ranked mean for 'promoting the conservation of genetic resource diversity' (6.69 > 3.07). A Scheffé's Test revealed that there was a significant difference between ENGOS, and government and industry. There was also a significant difference in ranked mean for 'mitigating the impacts of climate change through carbon sequestration' (3.50 > 3.07). Interestingly, the Scheffé's Test and confidence intervals did not reveal where the significant difference lay. As the null hypothesis was rejected, at least one contrast must exist, thus the significant difference lies between the two most extreme means (Maxwell & Delaney, 2004). In this case, industry and ENGO group means were significantly different.

## 4.5 K-Means Cluster Analysis

A k-means cluster analysis was performed using SPSS. Although trials were completed using 2, 3 and 4 clusters, no apparent trends or patterns appeared using the socio-demographic information collected. This is likely a result of the small sample size. Nonetheless, it can be stated that attitudes did not seem to have a discriminating power, or that patterns of responses seem to be similar across all groups.

# Chapter 5 Discussion

A number of interesting findings emerged in this study, contributing to the existing knowledge on societal perceptions of forest genomic technologies. This research surveyed the perceptions of three forest stakeholder groups and First Nations in British Columbia, exploring perceptions on implementing MAS in BC forests, and in which context implementation might be most favourable.

Section 5.1 explores the first research question results, which was to examine how stakeholders and First Nations perceive the implementation of forest genomic technologies, namely MAS, in BC. Section 5.2 explores the second research question results, which considers whether perception of MAS is dependent on the context in which it is applied.

## 5.1 Attitudes and Perceptions of MAS in BC Forests

Section 5.1.1 examines the attitudes and perceptions by group, as they were uncovered through the qualitative interview. Section 5.1.2 reviews the quantitative results and finally, section 5.1.3 considers these findings as they relate to the academic literature.

### 5.1.1 Qualitative results

The strength of employing qualitative research methods is that it accesses unquantifiable facts from the individuals that are observed or interviewed (Berg, 2007). Survey research provides a level of richness, depth, and detail that is not achievable in quantitative research. Through conversations with participants, researchers are able to uncover the views of others through an exclusive lens that was shaped uniquely through the participant’s individual experiences (Rubin & Rubin, 2005). In this study, the variations in perceptions regarding the implementation of MAS in BC forests were assessed across four social groups.

Preceding the interviews, 56% of the participants had no prior knowledge of MAS, and another 16% stated that they were only somewhat familiar with the technology. After participants were shown the informative video on MAS, they were asked to share their first impressions about the technology. This question revealed that the majority of participants held positive first impressions (64%), while only 8% of participants stated that their first impressions were negative. This was an interesting finding when compared to the responses of subsequent questions.

For instance, when participants were asked to discuss their organization's anticipated attitude regarding the use of general genomic technologies in the forests of BC, the level of positive and neutral responses decreased (positive responses reduced approximately by a third, and neutral responses reduced by approximately two-thirds), while negative responses remained constant, as compared to first impressions. In this case, participants responded with greater frequency that they were either unsure of their organization's attitudes, that their organization held no attitude towards genomics, or that it depended on the context. Furthermore, when asked to discuss their organization's anticipated attitude regarding the specific use of MAS in the forest of BC, participants responded with higher levels of positive, neutral, and negative attitudes when compared to general genomic technologies.

It is not surprising that a respondent would have higher reported levels of uncertainty when asked to share the attitudes of their affiliated organization. One participant commented, "You know we have – any organization has a lot of people who have different morals." Another participant warned that they could not adequately answer the question having not had the opportunity to talk to all of their colleagues about said idea before. Unless it is a topic that is readily discussed within an organization, it would be difficult to predict the position that would be taken by that organization (or the opinions of the individuals that make up that organization). This could explain the difference in responses received between the "first impression" question, and the subsequent questions about anticipated attitudes regarding genomics and MAS.

Nonetheless, it was striking that participants were more willing to rate their organization's expected attitude regarding MAS with greater certainty than genomic technologies in general. Indeed, industry and government responded with elevated levels of positive attitudes (depressing all neutral opinions and half of the unknown opinions). Similarly, ENGOs and First Nations displayed decreased uncertainty (represented by unknown and context dependent opinions), increasing their neutral and negative attitudes. When considering the total sample population, it was revealed that organizational attitudes towards MAS received higher proportions of positive, neutral, and negative attitudes (20%, 33%, and 50% respectively), compared to general genomics.

Review of the interviews indicated that government and industry expected their organization to be more open and receptive to the use of MAS, rather than genomics in general, because it specifically did not involve any manipulation of DNA (*ie*: differs from GE). "I think that it's positive. It's not genetic modification, and we recognize the difference." GE is a controversial topic in the media in the context of food, plants, and forestry; and both government and industry participants explicitly recognized that MAS is simply an identification tool.

Interviews with ENGOs and First Nations revealed that these two groups had different motives to explain their responses. ENGOs were generally more concerned about the potential ecological implications of this specific tool. They expressed their concern of whether its use could potentially harm a tree's ability to adapt to climate change and/or reduce overall genetic diversity. Other ENGOs communicated that a tool of this nature is not something their organization would readily weigh-in on. "[…] it is a very specific technique, and we'll probably not follow it very closely; just on a high level."

First Nations took a more social stance. Some participants were concerned about how their community and/or elders would respond to the tool. “They won’t like it. My mother-in-law wouldn’t even entertain this. She would say, ‘no, we don’t want anything to do with it.” Another participant replied, “I don’t know. I think it would probably be mixed, from ‘absolutely no way,’ to ‘tell me more about it,’ to ‘huh?’” A third participant explained that historical relationships with government and industry have left a profound gap in communication with communities. Although those relationships have been improving, this participant felt that geneticists and researchers are not adequately consulting and accommodating when proposals could impact Aboriginal rights and title.

> “So for instance, a different but I think similar issue is that they are doing species migration with trees […] and these are geneticist and researchers, and the Chief Forester. And they aren’t talking to First Nations about it. […] I don’t know if First Nations know about it. There’s a gap in the communication – it’s not happening. And there is not knowledge or awareness by the communities, by the First Nations.”

This participant felt that until this gap was narrowed, there would be a continued level of distrust towards the research community.

### 5.1.2 Quantitative results

Since the early 1990s, social science researchers have more frequently used quantitative data analysis to supplement and support qualitative analysis. This ‘mixed-method’ approach allows researchers to collect and analyze qualitative and quantitative data within the same study. Quantitative data analysis provides a level of measurement, causality, generalization, and replication that is arguably not achievable in qualitative data collection (Bryman, 2004). In this study, participants completed a quantitative questionnaire, requiring each individual to explicitly express their degree of agreeance to a variety of questions.

For the quantitative questions that addressed the first research question, it was found in all cases that industry and government reported views that were supportive of the use and continued research of MAS; whereas First Nations and ENGOs were less supportive, lending more to a neutral or negative stance. In all cases, industry mean responses were highest in agreeance (most closely to strongly agree) whereas ENGO mean responses were always the lowest level of agreeance among groups. Government mean responses were always most closely adjacent to industry, while First Nation mean responses were always most closely similar to ENGOs.

Industry and government participants agreed that the advantages of MAS outweighed the disadvantages. Likewise, their attitude towards the use of MAS in BC was positive, and both groups agreed that they supported the implementation of MAS in BC forest. In all the above stated scenarios, average responses were ranked between ‘strongly agree’ and ‘agree’ by both groups.

Conversely, First Nations and ENGOs’ average responses tended towards a disagreeable position. Both First Nations and ENGOs indicated they disagreed with the statement that the advantages of MAS outweighed the disadvantages. In this case, First Nation average responses fell more closely towards a neutral stance, whereas ENGOs fell more closely towards ‘disagree.’ Both First Nations and ENGOs disagreed with the statement that their attitude towards the use of MAS in BC forests was positive. When asked to indicate their support for the implementation of MAS, First Nations were split equally between ‘neutral’ and ‘disagree,’ while ENGOs had an average response that fell between ‘disagree’ and ‘strongly disagree.’

Lastly, although all four groups generally agreed that they supported the continued investigation and research of genomic technologies, industry and government felt more strongly. Both industry and government responses fell between ‘strongly agree’ and ‘agree.’ Differently, First Nation and ENGO responses fell between ‘agree’ and ‘neutral.’

### 5.1.3 Key findings

Generally speaking, industry and government demonstrated more favourable attitudes towards genomic technologies and MAS. Both the qualitative and quantitative data endorse the notion that both groups are strongly supportive about the continued investigation and the future use of MAS in BC forests. Between the two groups, government was more favourable in their attitudes regarding genomics and MAS. This was expected as government has been investing and collaborating on genomic projects (such as AdapTree and SMarTForests) with the University of British Columbia. Moreover, the Tree Improvement Branch within the Ministry of Forests, Lands, and Natural Resource Operations has a number of researchers currently working on molecular marker projects.

Surprisingly, industry displayed higher levels of average agreeance and support of MAS compared to government in the quantitative questionnaire; however there was no statistically significant difference in responses between these two groups. It is possible that government was more conservative in their responses on the questionnaire, because as a group they are more informed about the technology. In the interviews, government participants stated a number of times that although they are eager to use this tool, they require more conclusive evidence of its efficiency and effectiveness before they will fully endorse it. Government participants may have been more cognisant to make statements like this because they are aware of the slow progress that has been made in this field; which is consistent with the literature, stating frequently that MAS remains an unfulfilled promise that lags behind expectations (Boopathi, 2013b; Grattapaglia, 2008; Guimaraes et al., 2007; Xu & Crouch, 2008).

First Nations and ENGOs demonstrated less favourable attitudes towards MAS and genomic technologies, than industry and government. First Nations had stronger negative attitudes than ENGOs in the qualitative interviews, while ENGOs tended to disagree more strongly to the statements in the quantitative questionnaire. Although this trend emerged in the quantitative data, there was no statistically significant difference in responses between these two groups. And in spite of each groups' views, both generally supported the continued research and investigation in genomics.

ENGOs generally held an indifferent attitude towards MAS, stating that they would only be concerned if it reduced genetic diversity. This infers that support could be gained by ENGOs if they were further informed about the technical details of MAS, and how its use is not anticipated to reduce genetic diversity any more than traditional tree breeding techniques (Brumlop & Finckh, 2011). First Nations' support could also be improved. The interviews revealed that First Nation communities are often excluded from technological and forest management discussions, particularly by geneticists and researchers. Participants stressed that communities would need field trials to gain support for this tool, but that relationship building with communities would be equally necessary. Currently there remains a lack of trust with the research community, which stems from a legacy of disengagement, lack of consultation, and minimal communication by government and industry. Improving these relationships could enable more open discussions around new tools, technologies and methods to be used in forest management.

The results gathered from the qualitative interviews indicated that all participant groups had more defined attitudes towards MAS than genomic technologies in general. Analysis of the interviews suggests that the specificity of MAS permitted participants to consider its potential implications more acutely. This may have warranted a stronger opinion about their organizations' expected perceptions towards MAS, leaving more cautious responses for the more blanket and abstract ideas like genomic technologies in general.

## 5.2 Perception in the Context of Implementation

Section 5.2.1 examines the perceived benefits as identified by each group. Section 5.2.2 explores each group's perceived concerns about MAS, and Section 5.2.3 discusses the perceived usefulness of MAS in the context of various forest management frameworks.

### 5.2.1 Perceived benefits of MAS

Through a qualitative analysis of the interviews, several perceived benefits of MAS were identified. Among all groups, its ability to select for desired traits was the most frequently reported. In fact 23 of the 25 participants specified this benefit at least once in their interview. Most of the traits that were identified by all groups were general industry-focused traits (60% of all participants); however improving forest resiliency was also of great interest. In fact, 44% of participants articulated its potential ability to help in climate change adaptation, and 36% stated its potential use against pests and diseases. In both cases (climate change adaptation and pest/disease resistance), industry discussed these two benefits with the highest frequency among groups.

A second benefit that was identified by all groups was that MAS would be time saving in the tree breeding process. In this case 19 of the 25 participants referred to this benefit in their interview. Two other notable benefits of MAS that were identified by participants were that it would be an additional tool and increase the screening capacity for tree breeders. Government and industry emphasized that MAS would not replace field trials and provenance testing, but its ability to speed up the screening process, both in the selection stage and in future mitigation efforts, would be useful.

> "In the conventional way, I'm producing trees that may be planted 15 years from now, and then are in the ground for another 50 years. So I'm producing trees that aren't harvested for 65-70 years. So having these tools – if all of a sudden a Douglas

> fir pine beetle appears on the horizon, I think very quickly you use the technology and screen these other trees and deploy those."

An interesting benefit suggested was that MAS could relieve pressure off other stands. Here it was described that if this tool could be used to increase timber production in a given area (*ie:* produce a greater amount of cubic metres of wood), when met with a well-designed policy or moratorium other areas could be conserved from harvest. This is because a company would theoretically be able to reach their maximum harvestable volume within a smaller area; hence other areas could be protected from harvest. Moreover, ENGOs argued further that industry desires a certain level of wood quality, so if this tool could achieve that level elsewhere, this may relieve pressure off of old-growth stands.

Approximately a quarter of the participants identified that MAS could be used to produce faster growing trees, which would improve the forest ecosystem. Regenerating a stand in a more timely fashion could be beneficial for wildlife habitat by reducing wildlife corridors. "Well I see an advantage of trees growing faster after clearcutting or logging, because it's good cover for wildlife, and good for streams."

### 5.2.2 Perceived concerns of MAS

The qualitative interviews revealed concerns that were categorized as: unknown impacts, issues with the technology, and implementation concerns. Of all identified concerns, unknown impacts were the most frequent. Careful inspection of this category reveals that it could have been classified as environmental concerns. The three most frequently reported concerns within this set were: impacts to genetic diversity, increased susceptibility (or reduced resiliency), and impacts to ecosystems. Each of these is generally related to decreased diversity. However, according to Brumlop & Finckh, MAS can actually be used to broaden the genetic base of species, ensuring that diversity is maintained or improved (2011). Several published articles discuss how MAS has the potential to increase genetic variation by more easily incorporating wild seeds into breeding programs, compared to traditional breeding (McCouch, 2004; Vogel & Van Aken, 2009; Xu & Crouch, 2008).

Interview queries showed that 'impacts to the ecosystem' concerns were discussed largely in the context of reduced species diversity across the landscape. This specifically included reduced ecological diversity and ecosystem degradation resulting from intensive forest management.

> "Out in the broader forest the issue remains: is it inherently reducing the overall diversity of the whole forest because you aren't taking all the warts and pimples. And we don't know for sure if they are valuable in ensuring the forest is healthy as a whole or not. And what role they might play in the evolution of the forest. […] With this kind of program, you could weed all that stuff out over time, [but] you don't know what you are losing, and it might be too late."

ENGOs and First Nations were further concerned that MAS would facilitate the application of monocultures or plantations following harvest. However, this concern cannot be applied exclusive to MAS and genomic tools, but rather to any harvested area that is subjected to intentional reforestation. Concerns of this nature can be (and have been) addressed by regulations set by the provincial government. The Forest and Range Practices Act (FRPA) outlines stocking standards under Section 26. This regulation requires that stands are restocked "with ecologically suitable species that address immediate and long-term forest health issues on the area." Chief Forester Jim Snetsinger elaborated in the 2009 memorandum on "Guidance on Tree Species Composition at the Stand and Landscape Level" that developed stocking standards should be mindful of existing species diversity, species vulnerability due to climate change, potential risks of insects and diseases, and maintenance of natural diversity at the forest level." Nonetheless, future implementation regulations designed to outline the scope of MAS usage should include species diversity requirements to address these concerns.

When comparing relative proportions of identified environmental concerns, ENGOs and First Nations demonstrated particularly high levels of frequency. It was not surprising that ENGOs expressed high levels in this category as environmental organizations are typically in the business of identifying and voicing these sorts of concerns. Moreover, First Nation cultural values and traditional practices are strongly connected to the forest. First Nation communities in BC are continually fighting land-use plans with government and industry, to ensure a healthy forest ecosystem is maintained for social, environmental and economic benefits.

Government had the strongest economic concerns. Although First Nations and industry recognized the expense in using this tool, no other group discussed the expense of developing such a tool. This monetary cost involved in using MAS was described in terms of the price to acquire and apply this technology, to undergo training on how to perform and interpret trials, and to invest in a facility to perform these tests. Government has already invested a substantial amount of money and resources into the research and development of MAS. It is thus not surprising that government participants spoke of their eagerness to see if the final deliverables will meet the initial promised aspects and if the advantages will be there. This concern has likewise been addressed in the literature, stating that MAS will not be applied unless genetic gains can offset the cost of using the technology (Petrinovic et al., 2009; Yanchuk, 2002). In Eucalyptus, studies have already shown that the breeding cycle is halved when early-selection methods are employed (Resende et al., 2012). And the economic rotation age in genetically improved white spruce can be reduced by up to nine years (Petrinovic et al., 2009). Porth *et al.* recognized that the cost of producing seedlings is higher when genotyping is employed, however will be offset by increased volume, reduced timeframe, and the production of higher value products (in press). Nonetheless, to date little of the genomics budget has been spent towards economic analysis (Porth et al., in press). This concern should be addressed in future forest genomic research in Canada.

Another interesting outcome of the interviews was that government, industry and First Nations emphasized their concerns on public and First Nation perception towards MAS. Perception concerns were strictly focused on mistaking MAS for GE. This concern is supported by various studies done over the last 15 years that have assessed public perception towards GE and GMOs, and the lack of public distinction from genomics. In studies done in the US and the European Union (EU), it was found that the public was generally uninformed about GE and genomic technologies, and their current applications (Hallman et al., 2004; Heuvel, Renes, Gremmen, Woerkum, & Trijp, 2007; INRA (Europe) - Ecosa, 2000; McHughen, 2007; Pardo et al., 2002). It was frequently reported that negative perceptions towards biotechnology are not based on objective knowledge but rather shaped by protest groups and media, or from distrust with big business companies in the US (namely Monsanto), and regulatory agencies in the EU (Hall, 2007; McHughen, 2007; Pardo et al., 2002). Despite these views, the limited knowledge held by the public regarding biotechnology means that a flow of new and factual information can erode previous opinions over time (Pardo et al., 2002). Indeed, in a study by Heuvel *et al.* respondents that initially associated genomics more closely to GE than conventional breeding, changed their views following explanations of each type of biotechnology, ultimately ranking genomics more closely to conventional breeding and deeming incomparable with GE (2007). These two studies suggest that public awareness on biotechnology (and forest genomic technologies more specifically) could and should be improved to mitigate this concern.

Predicting what characteristics will be desired from trees 30, 50, or 80 years from now is a challenge identified by all groups. Several participants mentioned that it is difficult to predict how future pests, diseases and climate will impact the forest. “What’s going to be the issue 30-35 years from now? Assuming that we can predict and therefore select for all the things that might be dormant genetically, or not considered important [today].” Another participant said, “there is nothing in marker-assisted selection that provides any reassurance that a population adapted to today's climate will be adapted in 60, 70, 80 years." Government participants also addressed the uncertainty of future markets, and the difficulty in planning for the forest sector's future needs.

> "I'm not convinced that wood density is still as important as lots of people think. We've been wrestling with that whole subject for 30 years now. And we still don't get, to me, satisfactory responses from the industry people. They can't tell us what they want 30-40 years from now. They just want wood. Fibre."

Although predicting and selecting for the 'right' traits is difficult (if not impossible), it is not a limitation of MAS. Rather it is a limitation of breeding strategies in general – especially in trees which naturally develop and evolve over long timeframes.

Lastly, some participants voiced the need for a well-defined policy to parallel the introduction of this tool to ensure responsible usage. Government, ENGO and industry participants all recommended that percentage limitations should be set for the proportion of a stand that employs this type of seed selection. Currently, there are standards set by the Chief Forester for seed use in the province. These standards regulate where orchard seeds and wild seeds can be planted and how diverse the parents need to be. Updating policies or regulations to define how MAS can be applied would promote its responsible usage.

### 5.2.3 Perceived usefulness of MAS

All participant groups reportedly agreed that MAS could be useful in the context of increasing timber production volume, increasing timber quality, and adding value to wood products. It is not surprising that positive responses were received for these uses as the interviews revealed that 60% of all participants identified that MAS could be beneficial in the selection of industry-focused traits. Similarly, all participant groups shared a neutral stance towards the potential role of MAS in the context of increasing conservation areas and rehabilitating sites and/or degraded sites. These findings are consistent with the identified benefits, as less than a quarter of participants discussed its use in selecting traits that would improve the forest ecosystem, and only 12% of all participants made reference to its use in relieving pressure off other stands.

ENGOs had a significantly different position than government and industry in the context of promoting the conservation of genetic resource diversity. While ENGOs disagreed with this statement, government and industry agreed that MAS could be useful in this case. Again, this is likely because ENGOs are unfamiliar with the technical details of tree breeding and are unaware that MAS is not expected to reduce the genetic diversity any further than traditional breeding practices (Brumlop & Finckh, 2011).

Lastly, industry and ENGOs demonstrated significantly different opinions regarding the usefulness of MAS in mitigating the impacts of climate change through carbon sequestration. While industry agreed with this statement, ENGOs disagreed. As with the previous scenarios, these results are consistent with the analysis of reported benefits. In fact, 66.7% of industry participants had identified that MAS could be used in climate change adaptation, compared to only 25% of ENGO participants.

## 5.3 Connections to the Literature

The conclusions made in the 2002 Pardo *et al*. study discussed in Section 2.6 can be translated to the findings from this research project. Here, government and industry were found to have positive perceptions towards the implementation of MAS in BC. Conversely, ENGOs and First Nations exhibited less favourable attitudes towards the use of MAS in BC forests (lying between neutral and negative). Their strongest concerns were focused on the potential implications to diversity, and unknown environmental impacts.

As a sector that utilises a wide range of progressive technologies, it may be assumed that government and industry generally have a favourable attitude towards technology. This technological optimism may further influence their more specific attitudes towards the promise of biotechnology. If these assumptions hold true, according to the proposed model in Pardo *et al*. (2002) then these two cognitive structures could be influencing their more specific positive attitudes toward biotechnology applications (such as MAS). Furthermore, government and industry participants entered this research study with the highest levels of prior knowledge on MAS (77% and 50% respectively), while First Nations and ENGOs were mostly unaware of MAS (83.3% and 100% respectively). According to Pardo *et al.* being part of the informed public can influence an individual's attitude towards specific biotechnological applications (such as MAS).

Unfortunately, the Pardo *et al.* model does not inform us what variables significantly influence reservations towards biotechnology. They concluded that traditional demographic and educational indicators were not useful in explaining perceived concerns (Pardo et al., 2002). However, I would argue from the findings in this research study, that unfamiliarity with not only specific biotechnologies, but with more general scientific understanding of biology and genetics, has played some role in influencing participant's attitudes. This idea is supported by an American study, that concluded that it was unsurprising that respondents were uncertain about GM technology when they had little informed knowledge or awareness (Hallman et al., 2004).

Several studies and reports have discussed the negative public perception towards biotechnology, and how this perception has not been formed on objective knowledge (Heuvel et al., 2007; INRA (Europe) - Ecosa, 2000; McHughen, 2007). In fact, the media has arguably played a large role in influencing people's opinions, often presenting high credibility sources against non-scientific yet charismatic opponents (McHughen, 2007). News reports often counter arguments supported by scientific data with proponents that believe something is safer, healthier or 'better.' But by not identifying to the audience that the belief is unsupported by factual evidence, viewers may assume that both arguments are equally credible and legitimate (McHughen, 2007).

### 5.4 Successful Implementation

I argue that it would be invaluable for advocates of forest genomic technologies and applications to develop an educational package to increase forest stakeholders and First Nations' knowledge, and reduce misconceptions, towards forest biotechnology. This educational information needs to be easily accessible by all groups. It is imperative that it is structured in layman's terms (void of scientific jargon), and assumes that the viewer has minimal *a priori* scientific understandings. Furthermore, this educational tool must not come across as a marketing ploy. Hence, it needs to be unbiasedly informing; portraying the strengths, weaknesses, and limitations of using molecular markers in a forest context. The educational tool should also present the potential benefits and concerns of MAS from a social, environmental and economic context. This video should also be specific to the forests of BC, and include clips with relevant forest representatives. According to other public perception surveys on biotechnology, scientific academics, consumer organizations, and environmental organizations are considered trusted sources of information by the public (INRA (Europe) - Ecosa, 2000; McHughen, 2007). I would thus argue that gaining support (and possibly collaboration in development) of this education tool from the government, academia, First Nations, ENGOs, and industry would provide a level of assurance and confidence to forest stakeholders and First Nations. This may include the Ministry of Forests, Lands and Natural Resource Operations, the University of British Columbia, the BC First Nations Forestry Council, Greenpeace BC, ForestEthics, Canfor, West Fraser Timber, and Tolko Industries.

To address the concerns that were raised around exploitation, reduced genetic diversity, and impacts to the ecosystem, this tool should be supplemented with a well-designed and well-defined policy framework. This could set limitations and define proportions of MAS usage in reforestation and forest management regimes, as well as regulate monocultures by setting standards that require multi-species compositions. Furthermore, forest certification schemes may need to be modified to set standards for MAS usage in a management unit. This due diligence prior to implementation will assure all parties that cautious and thoughtful consideration was employed. This is particularly necessary as humans prescribe an emotive value to forests and trees (Hall, 2007). Trees are significant to human culture and values, and have played a role in human history, mythology, and identity (Hall, 2007). Indeed, they are the only plant or crop in which a vast portion of the population ascribe moral value (Burke, 2001).

MAS is a promising tool that could help improve forest productivity and forest health, but to do so, selection of markers must be chosen on a broader basis than economic significance (such as wood quality and fibre characteristics). Resilience against pests and diseases, and climate change adaptability are also important in a sustainable forest management regime. MAS may help the provincial forest sector deliver an unmatchable timber product and increase production abilities, but it should also be used to support healthy forests.

For MAS to be readily adopted and used in BC, it needs to be economically viable and requires social support. Genomic research is constantly evolving, and marker technologies in Canada are approaching a reality. Economic investments over the last dozen years have supported research and development; reducing the gap between economic costs and genetic gains. This study has shown that government and industry are supportive of the future implementation of MAS in BC forests. And with increased evidence that MAS will not reduce genetic diversity, ENGOs will likely take a neutral stance and remain at arm’s length. Thus of the forest-related groups surveyed in this study, gaining First Nations support will be pivotal. Field trials, consultation, and community engagement will likely be important components to attaining this support.

# Chapter 6 Conclusions and Recommendations

The forests of BC represent a key pillar to the provincial identity. Worldly-known, these forests play an important role socially, environmentally, and economically. As all three contexts have experienced a number of challenges over the last decade, the government has considered genomic tools to address these issues and improve forest health and forest productivity. This study surveyed three forest stakeholder groups and First Nations in BC with an aim of assessing their perception on the implementation of forest genomic technologies (namely marker-assisted selection), and examining if this perception is dependent on the context of implementation.

Through research interviews, government and industry were found to have positive perceptions towards the implementation of MAS in BC. Displaying support for its use and continued research, both groups identified its benefits in forest regeneration. ENGOs and First Nations demonstrated less favourable attitudes towards MAS, generally ranging between neutral and negative positions. Although both groups recognized the usefulness of MAS as a tool to support the forest industry, both showed concerns that it could have unknown environmental impacts, such as increased susceptibility, impacts to genetic diversity, and impacts to the ecosystem (including reduced biodiversity, ecosystem degradation, and monocultures). Among all groups, participants found that MAS allowed for the selection of preferred traits (notably for industry desired traits, climate change adaptation, and pest/disease resiliency), and that it would be time saving to tree breeders.

Drawing from the results of this study and its connections to the literature, an appropriate setting must be established before MAS can be successfully implemented in BC. This would include increased forest stakeholder and First Nation awareness and knowledge of biotechnology and its applications, a well-defined policy that addresses the limitations of its usage, and strengthening engagement and consultation with First Nations. If this road is adequately paved, a promising future for genomic technologies in the forests of BC may exist.

# Chapter 7 Limitations and Further Research

There were several limitations in this study. Firstly, the sample size was quite small. Since individual interviews were preferred for this study over focus groups, compounded by tight deadlines for data collection and a conservative budget, it was not possible to expand this study to include a larger sample size. Although the number of interviews exceeded the recommended sample size necessary to reach thematic saturation in qualitative research methods (15-20 participants) (Samure & Given, 2008), it was restrictive in the quantitative data analysis.

There were two additional limitations in the context of the sample. Firstly, since it was deemed important that participants were familiar with silvicultural practices, provincial standards, and forest policies and regulations, a purposive sample was employed. Although this is an acceptable method of sampling in qualitative research, it lacks an ability to be widely generalizable (Berg, 2007). Another limiting factor of this sample was that public opinions were excluded due to budgetary and time constraints. Moreover, the results from several other research studies indicated that the public has very low knowledge on basic biology and agriculture (Hallman et al., 2004; INRA (Europe) - Ecosa, 2000), and it has been argued that meaningful results from discussions on biotechnology with the public cannot be expected (McHughen, 2007; Pardo et al., 2002). As purposive sampling was used to restrict participation to individuals with a certain range of knowledge, the public's opinions were outside the scope of this study.

Lastly, another limitation of this study was that it used an educational video that was outdated and not relevant to BC. Since this video was originally designed for a Quebec television series, the images, locations, researchers, and language was Quebec-centric. Although it was converted to English for the purpose of this study, it would have been more interesting and relevant had this video been central to the forests of BC. Moreover, since the video was originally produced and aired in 2008, the estimations and research progress that was captured in the film was dated.

## References

Ashraf, M., Akram, N. A., & Foolad, M. R. (2012). Marker-Assisted Selection in Plant Breeding for Salinity Tolerance. In S. Shabala & T. A. Cuin (Eds.), *Plant Salt Tolerance* (Vol. 913, pp. 305–333). Totowa, NJ: Humana Press. doi:10.1007/978-1-61779-986-0

Babbie, E. (2010). *The Practice of Social Research* (12th ed.). Belomon, CA: Wadsworth Cengage Learning.

BC Treaty Commission. (2009). Quick Facts. *BC Treaty Commission*. Retrieved May 08, 2014, from http://www.bctreaty.net/files/quickfacts.php

Berg, B. L. (2007). *Qualitative Research Methods for the Social Sciences* (6th ed., p. 384). Boston: Pearson Education Allyn & Bacon.

Bernard, H. R. (2013). *Social Research Methods - Qualitative and Quantitative Approaches* (2nd ed., p. 788). Los Angeles, Calif.: SAGE Publications.

Boopathi, N. M. (2013a). Marker-Assisted Selection. In *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits* (pp. 173–186). Tamil Nadu: Springer India. doi:10.1007/978-81-322-0958-4

Boopathi, N. M. (2013b). Success Stories in MAS. In *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits* (pp. 187–192). Tamil Nadu: Springer India. doi:10.1007/978-81-322-0958-4

British Columbia Ministry of Forests and Range. (2005). *Tree Improvement in British Columbia* (p. 6). Victoria. Retrieved from http://www.fgcouncil.bc.ca/brochure-tree-improve-05.pdf

Brumlop, S., & Finckh, M. R. (2011). *Applications and potentials of marker assisted selection ( MAS ) in plant breeding* (p. 178). Bonn, Germany: Bundesarnt fur Naturschutz (BfN), Federal Agency for Nature Conservation. Retrieved from http://www.bfn.de/0502_skripten.html

Bryman, A. (2004). *Social Research Methods* (2nd ed., p. 592). Oxford: Oxford University Press.

Burke, S. W. (2001). Responding to new trees and to the issues at hand: The insistute of forest biotechnology. In S. H. Strauss & H. D. Bradshaw (Eds.), *Proceedings of the First International Symposium on Ecological and Societal Aspects of Transgenic Plantations* (pp. 62–69). Washington: Oregon State University. Retrieved from www.fsl.orst.edu/tgerc/iufro2001/eprocd.pdf

Canadian Forest Service. (2013). *The State of Canada's Forests: Annual Report 2013. Natural Resources Canada* (p. 62). Ottawa. Retrieved from http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/35191.pdf

Canadian Genome Centres. (2013). *A Canadian Forest Sector Genomics Strategy: Using Canadian Strengths to Address Sector Challenges*.

Council of Forest Industries. (2014). Economics & Statistics: The Economic Contribution of BC Forest Industry. Retrieved May 01, 2014, from http://www.cofi.org/bc-forest-industry/economics-statistics/

CropLife Canada. (2014). Helping solve the world's challenges. Retrieved July 22, 2014, from http://www.croplife.ca/agriculture-today/helping-solve-the-worlds-challenges

Doyle, J. (2012). *An Audit of the Ministry of Forests, Lands and Natural Resource Operations' Management of Timber*. Victoria.

Fenning, T. M., & Gershenzon, J. (2002). Where will the wood come from? Plantation forests and the role of biotechnology. *Trends in Biotechnology*, *20*(7), 291–6. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12062973

Fern, E. F. (1982). The Use of Focus Groups for Idea Generation: The Effects of Group Size, Acquaintanceship, and Moderator on Response Quantity and Quality. *Journal of Marketing Research*, *19*(1), 1–13. Retrieved from http://www.jstor.org/stable/3151525

Forest Practices Branch. (2008). Tree Species Compendium. *The Ministry of Forests, Lands, and Natural Resource Operations*. Retrieved June 24, 2014, from http://www.for.gov.bc.ca/hfp/silviculture/Compendium/WhiteSpruce.htm

Forest Products Association of Canada. (2014). *Vision2020 Report Card: 2010 to 2012 - Pathways to prosperity for Canada's forest products sector* (p. 28). Ottawa. Retrieved from www.fpac.ca/images/uploads/Vision2020_ReportCard_2014.pdf

Gaston, C., Globerman, S., & Vertinsky, I. (1995). Biotechnology in forestry: Technological and economic perspectives. *Technological Forecasting and Social Change*, *50*(1), 79–92. doi:10.1016/0040-1625(94)00084-A

Government of British Columbia. (2013a). Exports by Province: Annual Data. The Province of British Columbia. Retrieved from http://www.bcstats.gov.bc.ca/StatisticsBySubject/ExportsImports/Data.aspx

Government of British Columbia. (2013b). Trade and Invest British Columbia - Forestry. *Province of British Columbia*. Retrieved July 04, 2014, from http://www.britishcolumbia.ca/export/industry-sectors/forestry.aspx

Government of Canada. (2014). Industry. *Natural Resources Canada*. Retrieved April 23, 2014, from http://www.nrcan.gc.ca/forests/industry/13305

Grattapaglia, D. (2008). Perspectives on genome mapping and marker-assisted breeding of eucalypts. *Southern Forests: A Journal of Forest Science*, *70*(2), 69–75. doi:10.2989/SOUTH.FOR.2008.70.2.2.530

Guimaraes, E. P., Ruane, J., Scherf, B. D., Sonnino, A., & Dargie, J. D. (2007). *MARKER-ASSISTED SELECTION: Current Status and Future Perspectives in Crops, Livestock, Forestry and Fish* (p. 494). Rome: Food and Agriculture Organization of the United Nations.

Hadley, M. J., Tanz, J. S., & Fraser, J. (2001). *Biotechnology: Potential Applicationsin Tree Improvement* (pp. 1–12). Vancouver.

Hall, C. (2007). GM technology in forestry: lessons from the GM food "debate." *International Journal of Biotechnology*, *9*(5), 436–447. doi:10.1504/IJBT.2007.014270

Hallman, W. K., Hebden, W. C., Cuite, C. L., Aquino, H. L., & Lang, J. T. (2004). *Americans and GM Food: Knowledge, Opinion and Interest in 2004* (p. 25). New Brunswick. doi:RR-1104-007

Harfouche, A., Meilan, R., Kirst, M., Morgante, M., Boerjan, W., Sabatti, M., & Scarascia Mugnozza, G. (2012). Accelerating the domestication of forest trees in a changing world. *Trends in Plant Science*, *17*(2), 64–72. doi:10.1016/j.tplants.2011.11.005

Heuvel, T., Renes, R. J., Gremmen, B., Woerkum, C., & Trijp, H. (2007). Consumers' images regarding genomics as a tomato breeding technology: "maybe it can provide a more tasty tomato." *Euphytica*, *159*(1-2), 207–216. doi:10.1007/s10681-007-9474-7

INRA (Europe) - Ecosa. (2000). *The Europeans and Biotechnology: Eurobarometer 52.1* (p. 94).

Kaplowitz, M. D., & Hoehn, J. P. (2001). Do focus groups and individual interviews reveal the same information for natural resource valuation? *Ecological Economics*, *36*(2), 237–247.

Kayne, D. (2014). Canfor has concerns with area based tenure process. *World of Wood*. Retrieved May 08, 2014, from http://www.canfor.com/media-center/world-of-wood-blog/world-of-wood-blog/2014/04/12/canfor-has-concerns-with-area-based-tenure-process

Keener, K., Hoban, T., & Balasubramanian, R. (2000). Biotechnology and its applications. *The North Carolina Cooperative Extension Service*. Retrieved April 24, 2014, from http://www.ces.ncsu.edu/depts/foodsci/ext/pubs/bioapp.html

Kumagai, K., Culver, K., & Castle, D. (2010). Public-Private Research Collaborations in Canadian Forestry Genomics: Knowledge Management and Innovation. *The Integrated Assessment Journal*, *10*(1), 63–77.

Lee, S., & Woolliams, J. (2013). *Novel Tree Breeding* (p. 27). Edinburg.

Luckert, M. K., Haley, D., & Hoberg, G. (2011). *Policies for sustainably managing Canada's forests: tenure, stumpage fees, and forest practices* (p. 214). Vancouver: UBC Press.

Maxwell, S. E., & Delaney, H. D. (2004). *Designing experiments and analyzing data: a model comparison perspective* (2nd editio.). Mahwah, N.J.: Lawrence Erlbaum Associates.

McCouch, S. (2004). Diversifying Selection in Plant Breeding. *PLoS Biology*, *2*(10), 1507–1512. doi:10.1371/journal.pbio.0020347

Mcfarlane, B. L., & Boxall, P. C. (2000). Factors Influencing Forest Values and Attitudes of Two Stakeholder Groups: The Case of the Foothills Model Forest, Alberta, Canada. *Society & Natural Resources*, *13*(7), 649–661. doi:10.1080/08941920050121927

McHughen, A. (2007). Public perceptions of biotechnology. *Biotechnology Journal*, *2*(9), 1105–1111. doi:10.1002/biot.200700071

McWilliams, J., & McWilliams, J. (2011). Silviculture: The Dilemma. *Silviculture Magazine*, 24–25. Retrieved from http://www.silviculturemagazine.com/sites/silviculturemagazine.com/files/issues/2011104006/Summer 2011_0.pdf

Ministry of Forests Lands and Natural Resource Operations. (2011). *2011/12 Annual Service Plan Report* (p. 49). Retrieved from www.gov.bc.ca/for/

Ministry of Forests Lands and Natural Resource Operations. (2012a). *A History of the Battle Against the Mountain Pine Beetle: 2000 to 2012* (p. 12). Ministry of Forests, Lands and Natural Resource Operations. Retrieved from http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs2012_2/519896/pine beetle response brief history may 23 2012.pdf

Ministry of Forests Lands and Natural Resource Operations. (2012b). *Beyond the Beetle: A Mid-Term Timber Supply Action Plan* (p. 19).

Ministry of Forests Lands and Natural Resource Operations. (2012c). *Timber Tenures in British Columbia - Managing Public Forests in the Public Interest* (p. 17). Retrieved from http://www.for.gov.bc.ca/ftp/HTH/external/!publish/web/timber-tenures/timber-tenures-2012.pdf

Ministry of Forests Lands and Natural Resource Operations. (2014a). *Discussion Paper: Area-Based Forest Tenures* (p. 14). Victoria.

Ministry of Forests Lands and Natural Resource Operations. (2014b). Forest Analysis. Retrieved from http://www.for.gov.bc.ca/hts/aactsa.htm

Ministry of Forests Mines and Lands. (2010). *The State of British Columbia's Forests, third edition* (p. 323). Victoria. Retrieved from www.for.gov.bc.ca/hfp/sof/index.htm#2010_report

Moshofsky, M. M. (2014). *Climate Change, Forests, and Communities: Identifying the Range of Acceptable Human Interventions in Forested Ecosystems*. The University of British Columbia.

Natural Resources Canada. (2012). *The State of Canada's Forests: Annual Report 2012* (p. 56). Ottawa.

Natural Resources Canada. (2013, October 17). Canadian Forest Service: Statistical Data - British Columbia. *Government of Canada*. Retrieved July 04, 2014, from http://cfs.nrcan.gc.ca/statsprofile/overview/bc

Neale, D. B., & Kremer, A. (2011). Forest tree genomics: growing resources and applications. *Nature Reviews Genetics*, *12*(2), 111–122. doi:10.1038/nrg2931

Pardo, R., Midden, C., & Miller, J. D. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, *98*(1), 9–24. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12126802

Petrinovic, J. F., Gélinas, N., & Beaulieu, J. (2009). Benefits of using genetically improved white spruce in Quebec: The forest landowner's viewpoint. *The Forestry Chronicle*, *85*(4), 571–582. doi:10.5558/tfc85571-4

Poland, J. A., & Rife, T. W. (2012). Genotyping-by-Sequencing for Plant Breeding and Genetics. *The Plant Genome*, *5*, 92–102. doi:10.3835

Porth, I., Boyland, M., Ahmed, S., & Bull, G. (2014). Forest Genomics Research and Development in Canada: Priorities for Developing an Economic Framework. *The Forestry Chronicle*.

Rank, D. (2013). *Forest Sector: Challenges, Genomic Solutions* (p. 36). Retrieved from http://www.genomecanada.ca/en/sectorstrategies/

Research and Knowledge Management Branch. (2010). Forest Genetics Section: Biotechnology. *Province of British Columbia*. Retrieved April 30, 2014, from http://www.for.gov.bc.ca/hre/forgen/projects/biotechnology.htm

Resende, M. D. V, Resende, M. F. R., Sansaloni, C. P., Petroli, C. D., Missiaggia, A. a, Aguiar, A. M., … Grattapaglia, D. (2012). Genomic selection for growth and wood quality in Eucalyptus: capturing the missing heritability and accelerating breeding for complex traits in forest trees. *The New Phytologist*, *194*(1), 116–28. doi:10.1111/j.1469-8137.2011.04038.x

Rubin, H. J., & Rubin, I. S. (2005). *Qualitative Interviewing: the Art of Hearing Data* (2nd editio., p. 291). Thousand Oaks, CA: SAGE Publications Ltd.

Samure, K., & Given, L. M. (2008). Data Saturation. In L. M. Given (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods* (pp. 196–197). Los Angeles, Calif.: SAGE Publications.

Sedjo, R. A. (2002). Biotechnology for Planted Forests: An Assessment of Biological , Economic and Environmental Possibilities and Limitations. In T. Swanson (Ed.), *The Economics of Managing Biotechnologies* (pp. 71–95). Kluwer Academic Publishers.

Shu, J. (2012). *2011 Economic State of the B.C. Forest Sector* (p. 43). Retrieved from www.for.gov.bc.ca/ftp/het/external/!publish/web/economic-state/Economic-State-of-BC-Forest-Sector-2011.pdf

Special Committee on Timber Supply. (2012). *Growing Fibre, Growing Value* (p. 70).

United Nations. (1992). *Convention on Biological Diversity* (p. 30). Rio de Janeiro.

Vogel, B., & Van Aken, J. (2009). *Smart Breeding - Marker-Assisted Selection: A non-invasive biotechnology alternative to genetic engineering of plant varieties* (p. 28). Amsterdam, the Netherlands.

Xu, Y., & Crouch, J. H. (2008). Marker-Assisted Selection in Plant Breeding: From Publications to Practice. *Crop Science*, *48*(2), 391–407. doi:10.2135/cropsci2007.04.0191

Yanchuk, A. D. (2002). The role and implications of biotechnology in forestry. *Food and Agriculture Organization of the United Nations*, *Unasylva*(30), 18–22.

Zobel, B., & Talbert, J. (1984). *Applied Forest Tree Improvement* (p. 505). New York: Wiley.

# Appendix A: Notes

## Volume-based versus area-based tenures

The conversion of volume-based tenures to area-based tenures has been a topic of conversation for years. In Canada, forest licensing agreements with private companies take the form of "Crown forest tenures." These tenure agreements give exclusive harvesting rights to private companies, while requiring payments to be made to the government. The fees collected by the government are most commonly in the form of stumpages. Tenure agreements include forest management responsibilities, which vary according to the nature of the tenure agreement assigned. BC's two major tenure agreements (Tree Farm Licences (aka area-based) and Forest Licences (aka volume-based)) are both allocated price competitively to the highest bidder (Luckert et al., 2011). Although the rest of Canada typically allocates area-based tenures, BC uniquely favors volume-based tenures (see Table 9) (Ministry of Forests Lands and Natural Resource Operations, 2014a).

**Table 9: Distribution of tenure type by percentage in BC (Ministry of Forests Lands and Natural Resource Operations, 2014a)**

| Tenure Type | Percentage of Harvest |
|---|---|
| Volume-based (forest licences, non-replaceable forest licences, etc.) | 60 per cent |
| BC Timber Sales – timber sale licences | 20 per cent |
| Area-based licences (tree farm licences, community forest agreements, woodlot licences, First Nations woodland licences) | 20 per cent |

The volume-based tenure system of BC has been criticized as one of several factors contributing to the degradation of BC forests. With significant areas affected by fire and the MPB, the government must increase funds and improve inventory to address NSR areas, and forests with poor health, quality and resiliency (McWilliams & McWilliams, 2011). It has been argued that the conversion of volume- to area-based tenures will result in greater investments in silviculture and a higher level of forest management as the tenure holder will have increased security and be the direct beneficiary of silviculture investments (Ministry of Forests Lands and Natural Resource Operations, 2014a). The added security of tenure and timber supply, as outlined in the Ministry's Discussion paper, could:

a) Help companies increase their competitiveness and attract investors;
b) Provide stability to workers and communities that rely on a healthy forest industry;
c) Allow neighbouring mills to invest in equipment to match timber characteristics;
d) Encourage a licensee to share costs with the government for improved inventory and growth and yield information;
e) Improve operational planning, access planning, stewardship, and predictability of the timber supply;
f) Improve licensee's relationship with local communities and First Nations

— (Ministry of Forests Lands and Natural Resource Operations, 2014a)

In spite of these discussions and the announcement made by Minister Steve Thomson for a public engagement process, Canfor provided good arguments against the conversion to area-based tenures. On April 12, 2014, CEO Don Kayne submitted a letter addressing Canfor's concerns regarding the conversion. He argued that it is a fallacy that areas-based tenures would improve stewardship: "It is economics that drives low levels of intensive silviculture with the 60- to 80-year rotations we have in the interior, not the form of tenure." He continues that meaningful consultation results from informed public support and not from narrow opportunities for public consultation. Moreover, the lack of reliable inventory compounded by the impact from the MPB will make it very difficult to assign area-based tenures, likely resulting in unbalanced allocations, disadvantaging some companies over others (Kayne, 2014). As Canfor is the largest forest company in BC, its public aversion to converting volume-based tenure has largely squashed any plans for a changeover in the near future.

## Changes to the AAC

With the record-breaking mountain pine beetle infestation that broke out in BC in 1998, the provincial government has had to adjust the AAC in response. In 2008, there was a conversion from timber harvesting to salvage logging of dead pine (Ministry of Forests Lands and Natural Resource Operations, 2014a; Special Committee on Timber Supply, 2012). In an effort to salvage any merchantable timber and to contain the pest, the government increased the AAC to 88 million cubic metres in 2009 (33% above the average 66 million cubic metres per year of the 1990s) (Ministry of Forests Mines and Lands, 2010). It is expected that by 2025, the BC timber supply will be reduced to 50-60 million cubic metres per year, and will stay there for several decades, until the forests can recuperate from the epidemic (see Figure 16) (Ministry of Forests Mines and Lands, 2010). The long-term sustainable harvest level for BC is estimated at 70 million cubic metres per year, and forecasts estimate that this will be achievable by 2075 (Ministry of Forests Mines and Lands, 2010).

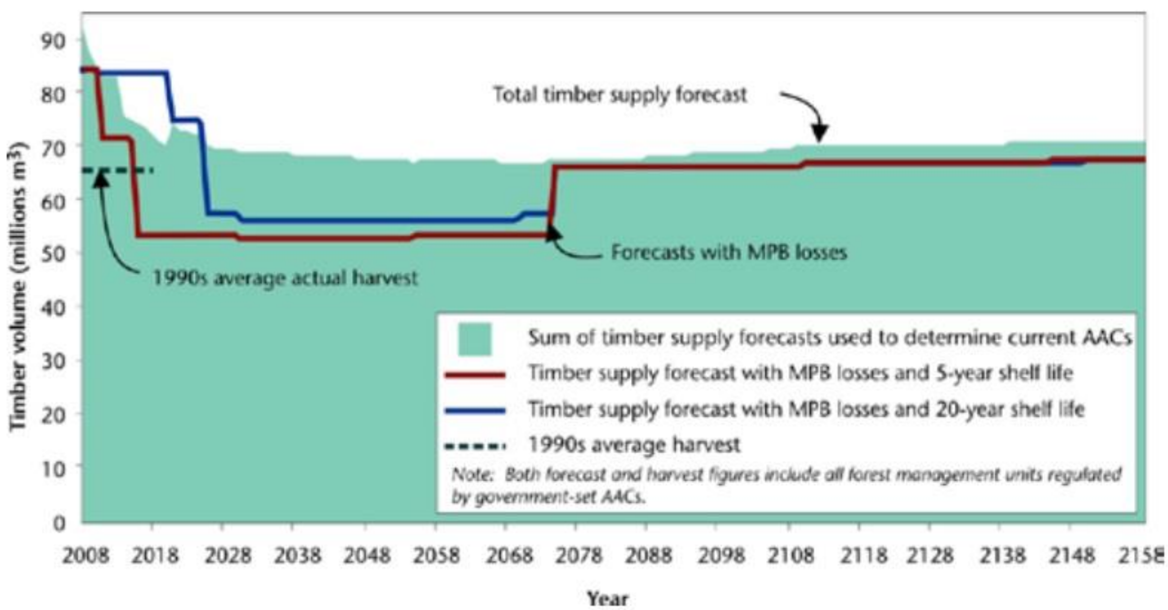


**Figure 16: Long-term forecast of BC's timber supply under three different scenarios (Ministry of Forests Mines and Lands, 2010)**

# Appendix B: Interview Guide

**INTERVIEW GUIDE:**

Implementation of Marker-Assisted Selection in BC Forests: Perception Survey

**Part A: Pre-Video**

1) Can you tell me briefly about your experience in the forest sector?
   Probe: Organizations; duration; interests

2) What organization do you represent now and what is your role?
   Follow-up: what role do you have in silviculture?

3) What is the scope of activities of this organization?
   Probe: Mission; objectives

4) What is your familiarity with forest genomics? [Novice, intermediate, expert]
   Follow-up: What is your familiarity with marker-assisted selection?

***Elevate/ensure understanding – Watch educational package video***

**Part B: Post-Video**

5) What is your first impression of marker-assisted selection? [Positive/negative]

6) What advantages, if any, do you perceive in the use of MAS in forestry?
   Probe: Explain.

7) What issues, if any, do you perceive in the use of MAS in forestry?
   Probe: Explain.

8) Specifically, what use, if any, would MAS be to you and your organization?
   Probe: Potential benefits/costs?

9) Given that MAS is a genomic tool, what is your organization's attitude about the use of genomic tools in the forests of BC?
   Follow-up: What do you expect your organization's attitude will be about the use of MAS in BC?

# Appendix C: Questionnaire

**QUESTIONNAIRE**
Implementation of Marker-Assisted Selection in BC Forests: Perception Survey

Department of Forest Resources Management
2nd Floor, Forest Sciences Centre
2045 - 2424 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-3482 Fax: (604) 822-9106
(604) 822-4935

*Please complete both sides of the following questionnaire and submit it back to your interviewer, Chelsea Nilausen, within a week following your interview.*

**Pre-Video:**

Marker-Assisted Selection is:

A) A technique used to transfer genetic material between organisms
B) A technique used to assess whether specific genes have been passed from parent to offspring
C) A technique used to accelerate tree breeding
D) B & C
E) Don't know

**Respondent Information:**

| | | | | | |
|---|---|---|---|---|---|
| ***Name of Participant:*** | | | | | |
| ***Age*** | 18-30 years | 31-40 years | 41-50 years | 51-60 years | 60+ years |
| ***Gender*** | Male | Female | | | |
| ***Residence*** | Urban | Rural | | | |
| ***Education*** | High School | Diploma | Bachelor's Degree | Master's Degree | PhD |
| ***If applicable, please state discipline of study*** | | | | | |

**Post-Video:**

**Marker-Assisted Selection is:**

A) A technique used to transfer genetic material between organisms
B) A technique used to assess whether specific genes have been passed from parent to offspring
C) A technique used to accelerate tree breeding
D) B & C
E) Don't know

| Questions on Marker-Assisted Selection: | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| 1) Generally speaking, I think that the following institutions ***would*** be interested in implementing marker-assisted selection in BC… | | | | | |
| (a) Provincial government | 1 | 2 | 3 | 4 | 5 |
| (b) Forest industries | 1 | 2 | 3 | 4 | 5 |
| (c) Environmental groups | 1 | 2 | 3 | 4 | 5 |
| (d) First Nations | 1 | 2 | 3 | 4 | 5 |
| (e) Private landholders | 1 | 2 | 3 | 4 | 5 |
| (f) Municipal government | 1 | 2 | 3 | 4 | 5 |
| 2) Generally speaking, I think that the following institutions ***should*** be interested in implementing marker-assisted selection in BC… | | | | | |
| (a) Provincial government | 1 | 2 | 3 | 4 | 5 |
| (b) Forest industries | 1 | 2 | 3 | 4 | 5 |
| (c) Environmental groups | 1 | 2 | 3 | 4 | 5 |
| (d) First Nations | 1 | 2 | 3 | 4 | 5 |
| (e) Private landholders | 1 | 2 | 3 | 4 | 5 |
| (f) Municipal government | 1 | 2 | 3 | 4 | 5 |
| 3) I think that the advantages of MAS outweigh the disadvantages | 1 | 2 | 3 | 4 | 5 |
| 4) My attitude towards the use of MAS in the forests of BC is positive | 1 | 2 | 3 | 4 | 5 |
| 5) I support the continued investigation and research in genomic technologies | 1 | 2 | 3 | 4 | 5 |
| 6) I support the implementation of MAS in BC forests | 1 | 2 | 3 | 4 | 5 |
| 7) I think that MAS, if used in a forest management framework in BC, could be a useful tool for… | | | | | |
| (a) increasing timber production volume | 1 | 2 | 3 | 4 | 5 |
| (b) Increasing timber quality | 1 | 2 | 3 | 4 | 5 |
| (c) Promoting the conservation of genetic resource diversity | 1 | 2 | 3 | 4 | 5 |
| (d) Mitigating the impacts of climate change through carbon sequestration | 1 | 2 | 3 | 4 | 5 |
| (e) Adding value to wood products | 1 | 2 | 3 | 4 | 5 |
| (f) Increasing conservation areas | 1 | 2 | 3 | 4 | 5 |
| (g) Rehabilitating sites and/or degraded stands | | | | | |

# Appendix D: Educational Video Script

**SCRIPT: Dialogue for Educational Video – translated from *le Code Chastenany* on Télé Québec**

Narrator:
31:48 The forest occupies almost half the territory of Quebec. It constitutes one of the principle engines of the economy. The forest industry is seeking a way to be more productive. What it wants is two by fours that are straight, resistant and dense in fibre. This is possible because all of these characteristics exist naturally in certain trees.

Narrator:
32:18 Over decades, scientists have been trying to improve the forest by selecting the best trees, and crossing them with one another.

Jean Beaulieu:
32:26 We take the best trees. The best trees that we have found in the natural forest or from the plantations that we have established, and then we cross them, to obtain the offspring, with the purpose that these trees are on average better than the previous generation.

Narrator:
32:46 Jean Beaulieu works for the Canadian Forest Service. In the field of forest genomics, he is one of the pioneers.

Jean Beaulieu:
32:53 White spruce trees for example, have both sexes on the same tree. So, the male sex is the pollen. That yellow pollen that we find on our cars in the spring; that is the male sex part of the tree. There are also small flowers that become cones. That flower is female. Once we have obtained those seeds, then we have a set of parents. And we'll cross a mother and father seed, and we use those seeds to establish a new plantation.

Narrator:
33:24 We hope that this new plantation is better than the previous. But this traditional method of breeding to improve the forest is also very limiting. The problem is the time.

Jean Beaulieu
33:35 So what we want to evaluate is the quality of the wood, the density of the wood, the length of the fibres-- It requires that the tree has reached a certain dimension which takes decades to develop before we can see what it is able to do. For certain characteristics, it requires that we wait 20 or 30 years before we are actually capable to evaluate the tree.

Narrator:
33:51 Twenty years is long. Too long. So in comes into play 'genomics'.

Narrator:
33:58 Thanks to genomics, we are able to determine which descendants are the most promising, even as a small seedling. The improvement of the forest will be able to occur at record speed.

Jean Bousquet:
34:07 Twenty years is a chunk of time too long to wait. With the use of genetic markers that allows us to predict 50% of the genetic value in just a couple days, there is an enormous gain to be had.

Narrator:
34:19 Jean Bousquet is a co-director of the Arborea Project at the University of Laval. His objective is to improve white spruce trees.

Jean Bousquet:
34:27 We are able to tell with fast diagnostic tests, in the span of just a couple days, you can evaluate the genetic lineages on their adaptation, their growth, the formation of the wood-- So that we can better identify the natural diversity so that you have the power to better identify the trees that satisfy the needs of man and the needs of our forests.

Narrator:
34:49 Arborea is one of the most important research projects in the world on forest genomics.

Jean Bousequet:
34:54 The Arborea project's final goal is to accelerate the identification of a variety of trees so that we can provide tools for tree planters and tree breeders, and to dedicate a certain percentage of the plantation territory to improvements.

Narrator:
35:12 The other co-director of the project is Jean Mackay, forest geneticist. He has the difficult task of cataloging the genome of the white spruce.

John Mackay
35:23 The genome essentially compares to that of a dictionary or a catalogue. It is a vast document with a lot of information.

Narrator:
35:33 The genome in fact is an assembly of genes of a species. In 2007, John Mackay attained his objective.

John Mackay:
35:40 We estimate that we have done the inventory on approximately 26 thousand genes of the spruce genome. Obviously there are always some that are missing in the inventory, and maybe those are genes that are important, so we continue to do gene research.

Jean Bousquet:
35:58 We can't see if there are patterns or see tendencies with 20 thousand genes. We have to have more powerful informative tools and more powerful statistical tools to help us sort these thousands of genes.

Narrator:
36:14 This glass slide contains a good portion of the 26 thousand genes of the white spruce. Each of these small boxes contains hundreds of genes. For John Mackay, this glass slide represents five years of work.

John Mackay:
36:28 With genomic tools today, we have overcome barriers and have knocked down doors that were closed until now.

Narrator:
36:36 The researcher can now focus on what these genes do and identify what contributes to makes these trees perform better.

John Mackay:
36:43 The goal is to have trees that are better adapted to our conditions of growth, and that can also respond to the demands of our forest industry; for example by delivering wood of the best quality.

Jean Bousquet:
36:56 For example these three right here are very specific to the population of the Gaspésie

John Mackay:
37:01 We did a large number of samples, of tissues, of cells, of trees in different physiological conditions to recover all of the genes that are found there.

Narrator:
37:11 The genes are essentially the same from one tree to the next, except in some very small sections. These tiny differences are called genetic markers.

Jean Bousquet:
37:21 My role, with my team, is to go and identify the fine variations that exist among trees. Those that differ one tree from another.

Narrator:
37:32 It is these markers that interest the researchers. These markers will tell if the spruces have the researched characteristics.

John Mackay:
37:40 So, certain forms of a gene will be present in the trees in low densities, while other forms will be present in high densities.

Narrator:
37:50 Other markers can identify those trees that are resistant to the cold or against certain insects. Researchers of the Aborea project have undergone several experiments in the Valcartier forest which is found a few kilometers away from the laboratory. At the center of their research, with the aim to improve spruce trees, they complete progeny tests. In this greenhouse there are a thousand trees that were all obtained from the same two parents. By comparing their markers, their fine genetic differences, researchers try to identify those that grow straight, strong and fast. But reforestation is more than the production of two by fours-- let's think of the urban forest or where the tree plays an ecological role.

Jean Bousquet:
38:33 For example an ecologist could tell you what's the CO2 or the carbon fixation. And we are always currently talking about it, about the level of climatic heating and capturing of carbon, because this is also important.

Narrator:
38:45 Eventually the researchers will be able to provide genetic material kits that will respond to the diverse demands of the industry

Jean Bousquet:
38:52 We are talking about kits, small kits of markers that we will be able to deliver to the tree planters or tree breeders, and they will be able to use those to accelerate the rate of selection

Narrator:
39:02 Do these tools give them a recipe to super spruces? Would we prefer to re-plant forests with clones?

Jean Bousquet:
39:09 Since the beginning we established certain values that are linked to the Arborea project and linked to the results that we have found. One of those values was genetic diversity of future plantations, because the diversity here is the basis of adaptation. What we are trying to avoid is to plant a tree that we have cloned into tens of thousands of samples, and then this tree be sensitive to climatic factors or to insects, at which point we would then lose everything. We would lose everything all at once. We can’t allow this to happen in Quebec-- within the forests or with plantations that take 30-50 years to grow

Narrator:
39:47 With the genetic markers of Arborea it will be possible to know in the first year if the young seedling will be a tree that is big, straight, and strong.

John Mackay:
39:57 In twenty years we are expecting that the large majority of re-planted trees in Quebec will be in a selection process and production of seedlings. A large majority of these seedlings could be selected with the tools that we develop today.

Jean Beaulieu
40:20 It’s a dream that all young geneticists have had over the years to accelerate the cycles of improvement. Listen, since I have worked in the industry we have achieved two cycles of improvement. In 30 years I could have done 10 cycles, and increased the value of the forests that we constitute, maybe the industry today wouldn’t be in such bad shape.

-----------------------------------40:48 ENDS-----------------------------------------------------------------

[Table-top discussion between Chastenay and Veronique]

Chastenay
40:55 Veronique, in this case we are talking about trees that have been genetically modified. Are these the trees that we call GMOs?

Veronique
41:02 No, we shouldn’t mix up the two. There has been experiments conducted where we have created GMO trees in Canada--

Chastenay
41:09 --So we have taken a gene from one species and inserted it into the gene of another tree and let it grow

Veronique
41:14 Yes, but in the case of Aborea, the researchers really wanted to distinguish this type of research. Here they identify the best genes of white spruce to create a spruce that is better; that is improved.

Chastenay
41:25 Do we think that we can apply this technique to other trees than the spruce?

Veronique:
41:29 Yes, presently the Aborea project is part of an international consortium on forest genetics. For example, in BC we are trying to do the same kind of work on black spruce, which is a species that is very important to Quebec. We think of doing the same work with larch, white pine, and in fact, all the species that are important to the industry.

Chastenay:
41:47 And these identification kits of the best trees will be available for the people in the field when?

Veronique:
41:54 First, we are currently testing and we think that within a few years, maybe three or four--

Chastenay:
42:00 --Yes we are still in the middle of research

Veronique:
42:02 Yes, in three/four years we will have the kits ready for the improvers of the forest. Here for us, in Quebec, it is the people of the ministry of natural resources that do the replanting.

Chastenay:
42:11 Let’s simply hope that they have the same concern to conserve the biodiversity that the researchers, who said it best in their reports, we have to conserve different types of trees in our forest.

------------------------------------------- 42:21 ENDS --------------------------------------------------------

# Appendix E: Participant Job Titles

| Participant Group | Job Title |
|---|---|
| Government | Silviculture specialist |
| Government | Silviculture specialist |
| Government | Forest genetics manager |
| Government | Forest geneticist |
| Government | Forest geneticist |
| Government | Molecular and tree geneticist |
| Government | Branch director |
| Government | Seed policy officer |
| Government | Program manager |
| ENGOs | Organization director |
| ENGOs | Forest and climate campaigner |
| ENGOs | Terrestrial campaign director |
| ENGOs | Senior Science and policy advisor |
| Industry | Senior silviculturist |
| Industry | Silviculture consultant |
| Industry | Operations forester |
| Industry | Operations forester |
| Industry | Forest investment account coordinator |
| Industry | Seed orchard supervisor |
| First Nations | Band office president |
| First Nations | Aboriginal coordinator |
| First Nations | First Nations advisor |
| First Nations | Natural resources referral worker |
| First Nations | Planning forester |
| First Nations | Aboriginal resource advisory CEO |

## Appendix F: Letter of Initial Contact

Department of Forest Resources Management
2nd Floor, Forest Sciences Centre
2045 - 2424 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-3482 Fax: (604) 822-9106
(604) 822-4935

July 19, 2013

Dear _________,

Chelsea Nilausen, a Master of Science student at the University of British Columbia, is currently working on her graduate thesis project entitled 'Implementation of Marker-Assisted Selection in BC Forests: Perception Survey.' The purpose of this work is to assess if and how genomic technologies are considered as a forest management tool, if the application of genomic technologies in forestry is viewed as invasive and if this perception is context-dependent, and whether linked issues can facilitate or impede large-scale implementation of genomics-derived diagnostic tools in tree breeding.

The experience and perspectives of individuals and organizations with a vested interest in provincial forestry are invaluable to providing a forum for informed decision-making. As a stakeholder in this area, you are invited to offer your knowledge by participating in this research. Specifically, your participation would involve one one-hour interview at your office, where you would answer various open-ended questions and a short questionnaire (5-10 minutes) in reflection of your views and opinions. The intention of this survey is to explore the perceived costs and benefits, potential use, and recommendations for the integration of this genomic technology within tree breeding in British Columbia. Your participation is voluntary.

We would greatly appreciate you taking the time to share your knowledge on these ideas. We understand that you and your organization are quite busy and would be happy to work around your schedule.

If you would like to confirm your willingness to participate, or have any questions or comments regarding this research study, please contact Chelsea Nilausen.

Thank you for your consideration,

Sincerely,

Chelsea Nilausen
M.Sc. Student, Co-Investigator
Forest Resource Management
The University of British Columbia
Email: xxx

Gary Q. Bull
Ph.D., Professor, Principal Investigator
Forest Resource Management
The University of British Columbia
Email: xxx

# Appendix G: Consent Form

**CONSENT FORM**
Implementation of Marker-Assisted Selection in BC Forests:
Perception Survey

Department of Forest Resources Management
2nd Floor, Forest Sciences Centre
2045 - 2424 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-3482 Fax: (604) 822-9106
(604) 822-4935

**Overview of Study Team:**

This research falls within the SMarTForest project, funded by Genome Canada and co-funders, and is under the responsibility of the Principal Investigator, Dr. Gary Q. Bull, professor with the Department of Forest Resource Management (Dept. of FRM) at the University of British Columbia (UBC) and Co-Investigator Chelsea Nilausen, an MSc student with the Dept. of FRM at UBC. This research is part of Ms. Nilausen's graduate thesis project, which will be accessible to the public upon submission.

Chelsea Nilausen, MSc student
Phone number: xxx.xxx.xxxx
Email: xxx

Gary Q Bull, PhD, professor
Phone number: xxx.xxx.xxxx
Email: xxx

**Nature of the Project**

The objective of this project is to assess if and how genomic technologies are considered as a forest management tool, if the application of genomic technologies in forestry is viewed as invasive and if this perception is context-dependent, and whether linked issues (such as the type of forest management regime(s)) can facilitate or impede large-scale implementation of genomics-derived diagnostic tools in forestry and in particular tree breeding.

**Role of the Participant**

You are being invited to take part in this research study because your organization has a stake in silvicultural practices in BC forestry. This study will help us learn more about the perception of genomic technologies in the province. If you agree to take part in this study, your participation will consist of answering several questions, both orally and through a questionnaire. It is expected that the interview will take approximately one hour, and the questionnaire approximately 5-10 minutes of your time. With your permission, your interview will be audio recorded. Your participation is voluntary and you are free to withdraw at any time.

Interview Topics:

- General information about your affiliated organization
- Your perception on the use of genomics in forestry
- Consideration of genomic technologies as a forest management tool
- Support for this tool by current forest governance
- Implementation possibilities

You *may* be contacted again for further information and questions following your interview, if necessary. The results of this study will be reported in a graduate thesis and may also be published in journal articles and books.

**Voluntary Participation and Opting Out**

Your involvement in this research project is voluntary. You can end your participation without consequence and without justification of your decision at any point before, during or after the process. We do not think that there is anything in this study that could harm you. You will not be exposed to any physical, cultural, social or psychological risks. Your responses will be codified and your identity kept confidential on all published findings. Your shared opinions and attitudes will be generalized with those collected from other interviews. It is anticipated that findings from this study may be beneficial to your organization and others that have a vested interest in the forest industry of BC.

**Confidentiality and Data Management**

All information and data gathered will be confidential. The following measures will be taken to assure confidentiality:

- Participants will not be identified by name in any reports of the completed study;
- Data collected will be codified, and only Ms Nilausen and Dr Bull will have access to the code and names;
- Audio recording, questionnaires and transcript of the interview will be stored safely on a password protected computer or locked filling cabinet, in an alarmed office at UBC; only Ms Nilausen and Dr Bull will have access to these documents
- Audio recordings, transcripts of interviews, questionnaires, and consent forms will be kept on file with the Principal Investigator (Dr Gary Q. Bull) within the University for 5 years, and will be thereafter destroyed;
- Only global and depersonalized information and analysis results will be published;
- The results may be published in scientific journals and/or on the project website

**Contact for Information about the Study**

If you have any questions or concerns regarding the research or your involvement, please contact one of the study leaders. The names and contact information are listed at the top of the first page of this form.

**Complaints or Criticisms**

If you have any concerns about your rights as a research subject and/or your experiences while participating in this study, you may contact the Research Subject Information Line in the UBC Office of Research Services at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598.

**Participant Consent and Signature Page**

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative impact to you. Your signature below indicated that you have received a copy of this consent form for your own records, and that you consent to participate in this study.

I, the undersigned ____________________________ grant freely to participate in the research project entitled "Implementation of Marker-Assisted Selection in BC Forests: Perception Survey." I am acquainted with the consent form and I understand the purpose and nature of the research project. I understand that this study requests that I participate in an interview and complete a questionnaire.

____________________________________ Date: __________________________

Participant Signature

I give permission to have my interview audio recorded. I am aware that the audio recording will only be used as a data collection tool, and my identity will be kept confidential in all published data. I am aware that my audio recordings will be safely and securely stored at the University of British Columbia for five years; after which Dr Gary Q. Bull will destroy them. I am aware that through the analysis process of this project, only Ms Chelsea Nilausen and Dr Gary Q. Bull will have access to my recordings.

____________________________________ Date: __________________________

Participant Signature

We plan to publish results around June 2014. If you desire to receive a summary, please include your email address:

_____________________________________________________

I, the interviewer, have explained the goals and the nature of the project to the participant. I have answered all questions to the best of my knowledge and I have verified the participant understands.

_____________________________________ Date: __________________________

Co-Investigator/MSc student signature

*Your collaboration is extremely important to this research and we thank you for your participation.*