A METHODOLOGY FOR ASSESSING THE ADAPTIVE CAPACITY OF THE FOREST SECTOR IN WESTERN NEWFOUNDLAND

by

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ABSTRACT

Climate change is and continue to be a major challenge that increases the adaptability requirements of the industrial sector in the future. Determining how much adaptive capacity is needed for sustainable development of the forest sector is a relatively new issue in Canada. This thesis uses the forest sector in Western Newfoundland as a case study to determine an appropriate method for adaptive capacity assessment. The case study used a modified Delphi method to elicit the opinion of local forest sector experts. The result revealed that evaluating adaptive capacity through the assessment of determinants is straightforward and feasible. This methodology is considered to be applicable in the other resource sectors and regions once determinants and data resources can be identified.

Keywords: climate change, adaptive capacity assessment, forest sector

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ABBREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
SFM	Sustainable Forest Management
CCFM	Canadian Council of Forest Ministry
CFS	Canadian Forest Service
SBW	Spruce budworm
R&D	Research and Development
LEED	Leadership in Energy and Environmental Design
CBFA	Canadian Boreal Forest Agreement
MOU	Memorandum of Understanding
MOA	Memorandum of Agreement
CRA	Collaborative Research Agreement
CNA	College of the North Atlantic
MUN	Memorial University of Newfoundland
FRI	Forest Resource Investment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada

CHAPTER 1 Introduction

Approximately 10% of the world's forest cover is located in Canada with 397 million hectares of forests and other woodlands (Williamson & Isaac, 2013). The vast forests constitute a world-class natural resource providing ecological, economic, social, and cultural benefits to all Canadians, including those who live in small northern communities and large urban centers (Williamson & Isaac, 2013).

Climate change scientists predict the rate and magnitude of climate change over the next 100 years will be unprecedented (Engle, 2011; Williamson & Isaac, 2013). Moreover, uncertainty with respect to climate change impacts on the forest sector will be much higher than uncertainty on the forest ecosystem alone. This is due to the fact that the forest ecosystem, forest management decisions, global markets, forest-based communities, public and common-property goods and services within the forest sector will be simultaneously influenced by the changing climate (Johnston et al., 2010). As a result of these cumulative and interacting effects, forest managers will no longer be able to predict future forest conditions with measurable risk rendering the selection of management options uncertain (Williamson & Isaac, 2013). Despite this uncertain decision environment, forest managers will still need to make decisions by developing new methods and approaches to deal with uncertainty and most importantly in formulating appropriate to minimize forest vulnerability.

This challenge is relatively new issue for Canadian forest management and requires new policies and management approaches (Williamson, Campagna, & Ogden, 2012). While prevention and mitigation are broadly deemed as the measures for sustainable management, adaptation is also another important means that has been widely studied in recent years. The majority of adaptation research has originated within the concept of vulnerability (Engle, 2011) that is defined as a function of exposure, sensitivity, and adaptive capacity (Williamson, Hesseln, & Johnston, 2010).

$$Vulnerability\ (V)\ =\ f\ (E, S, AC)$$

In this function, adaptive capacity has the potential of reducing the negative impacts on the environment, which leads to the reduction of vulnerability; therefore, before adaptation can proceed, an understanding of forest sector vulnerability is required (Williamson, Hesseln, & Johnston, 2010). Vulnerability is defined as "the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes" (Williamson, Campagna, & Ogden, 2012, p. 3). The vulnerability assessment approach has been applied not only by the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment report, but also for Canada's national assessment of climate change impacts (Lemmem et al., 2008). It is currently providing the basis for several forest and forest management-oriented climate change assessments in Canada (Johnston & Edwards, 2013). Because of the unique ways that adaptive capacity is shaped by human actions and the influences on both the biophysical and social elements of a system, it is considered to be critical for reducing vulnerability (Engle, 2011). Therefore, assessing adaptive capacity contributes to identifying and addressing an important aspect of vulnerability in forest-dependent socio-ecological systems. Moreover, it is also significant for developing policies to improve the adaptive capacity of forestry stakeholders by assisting them in identifying realistic adaptation options (Johnston et al., 2010). However, there has been no published research for the boreal forest to assess adaptive capacity towards climate change. Therefore, this study will examine the forest sector in Western Newfoundland as a case study to develop a methodological approach to assessing adaptive capacity.

In order to achieve this goal, an overview and analysis of various techniques for assessing adaptive capacity is necessary. The main objectives of this thesis are to;

1. define the most important determinants that make adaptation possible for the Forest Sector in Western Newfoundland under different climate change scenarios;
2. identify the most significant indicators for assessing these determinants across all the climate change scenarios; and
3. discuss the existing data resources or proxy methods for evaluating indicators of each determinant.

CHAPTER 2 Approaches to Assessing Adaptive Capacity

2.1 Adaptive Capacity

Before assessing adaptive capacity, understanding its definition and origin is particularly important. Engle (2011) describes adaptive capacity, by summarizing a few earlier studies, as “a requisite property for leadership and organizational success, for it maintains a repertoire of potential solutions to unforeseen problems and unpredictable variations, and allows for learning and adjustment despite the existence of its unalterable features” (Engle, 2011, p. 648). According to the IPCC, adaptive capacity pertains to “the ability of a system to adjust to climate change including climate variability and extremes to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (Williamson & Isaac, 2013, p. 3). The concept of “adaptation” originates from Darwin’s seminal work on natural selection and evolution, which includes mutation and adaptation (Engle, 2001). Even though definitions are somewhat different in various studies, the role that adaptation plays in the context of vulnerability is similar.

Canada's forest sector generally has a high potential to address forest management challenges through technical adaptations, due in part to the high education level of forest managers. However, aspects of technical and scientific capacity related specifically to climate change are generally low (Johnston et al., 2010). For example, Johnston et al. (2010, p. 7) mention how "forest managers, planners and policy-makers often feel ill-equipped to evaluate, plan or implement a possible course of action related to climate change". Yet, not all regions have the same level as the general level of Canadian forest sector's adaptive capacity. Different levels of adaptive capacity might occur because of the differences in requirements, preferences, costs of obtaining, developing, purchasing, creating or maintaining adaptive capacity assets, income, and relative prices of adaptive capacity assets and all other goods and services (Williamson, Hesseln, & Johnston, 2010). These differences in adaptive capacity can arise because of differences in demand, supply, and income. Therefore, the high or low level of adaptive capacity in a particular region does not necessarily mean that the region is relatively less or more vulnerable to climate change impacts compared to other systems (Williamson, Hesseln, & Johnston, 2010). For example, some segments of society face higher risks because of their location, their association with climate-sensitive environments, or their economic, political, and cultural characteristics. Therefore, impacts of climate change are expected to vary across Canada and this necessitates the need for regional and local vulnerability assessments (Johnston et al., 2010).

Although adaptive capacity assessment is most imperative on a regional level, there is often a lack of data to assess it (Lemmen et al., 2008). Information on climate change impacts is often unavailable at the temporal and spatial scales needed for planning and implementing, and general adaptation recommendations must be tailored for specific landscapes and operational conditions

(Johnston et al., 2010). Data for a specific region is often not currently sufficient for assessing local adaptive capacity. Johnston et al. (2010) suggests that “downscaling climate data and ecosystem modelling techniques could partially address the need for the information of adaptive capacity assessment” (p. 22).

2.2 Review of Assessment Methods

Williamson and Isaac (2013) present an overview of fourteen techniques and approaches (Table 1) used in adaptive capacity assessment. They are grouped into three broad categories: (1) description (including determinants and assets, indicators and mapping, properties, mobilization, case histories and proxies); (2) analysis (requirements, effectiveness and efficiency, equity, deficit); and (3) management (investing, reducing deficits, addressing inequalities, governance and institutions).

Table 1: Approaches for Assessing the Adaptive capacity of Sustainable Forest Management (SFM)

Description	**Analysis**	**Management**
Determinants and assets	Requirements	Investing
Indicators and mapping	Effectiveness and efficiency	Reducing deficits
Properties	Equity	Addressing inequalities
Mobilization	Deficit	Governance and institutions
Case histories and proxies		
Distribution		

Note. The information adapted from “Adapting sustainable forest management to climate change: An overview of approaches for assessing human adaptive capacity” (Williamson & Isaac, 2013).

In their report, a case study is provided to illustrate how to assess a specific aspect of adaptive capacity by combining approaches or technologies from different categories of methods. For example, in the case of assessing adaptive capacity by focusing on human capital, they adopt the determinants approach from the description group, the requirement-based approach from the group of analysis, and the investment approach in management group (Williamson, Isaac, 2013).

A number of other approaches are also discussed in the literature, and each one serving different purposes. A community capacity approach, for example, is more structured, and it has the advantage of going into more detail about the information, use, and depreciation of the various determinants that contribute to adaptive capacity, but there is a lack of a common definition of adaptive capacity in terms of which determinants are considered (Williamson, Hesseln, & Johnston, 2010). Among the literature that has been reviewed, most of them discuss the approach that assesses adaptive capacity through assessing its determinants. This approach has been defined as the "general approach" of adaptive capacity assessment in the study of Williamson, Hesseln, and Johnston (2010). The IPCC Third and Fourth Assessment reports also present this general approach to adaptive capacity assessment that relies on the assessment of its determinants (Williamson, Hesseln, & Johnston, 2010). A summary of the reviewed literature categorizes determinants for assessing adaptive capacity is presented as Table 2.

Table 2: Common determinants used in assessing adaptive capacity

Basic Determinants				
Economic Resources	Technology	Information and Skills (Knowledge capital)	Infrastructure	Institution
Optional Determinants				
Equity	Social (and human) capital	Risk management	Cultural capital	Natural capital

Basic determinants used in all of these studies implies that they are the fundamental elements which cannot be ignored for assessing adaptive capacity, while optional determinants may not be necessary for all regions because some of them are not being applicable in some areas. However, assessing only basic determinants is not sufficient, and optional determinants are needed to develop a more comprehensive understanding of the adaptive capacity. The drawbacks of this approach are discussed by Williamson, Hesseln, and Johnston (2012). There is no recognition of interrelations between determinants or no systematic assessment to evaluate the optimal mix of determinants or analysis; and there is an inconsistency in their application and lack of comparability across studies due to a lack of consensus about determinants of adaptive capacity. However, as Edwards et al. (2015) suggest adaptive capacity assessments rely largely on interviews, discussions, and surveys. Thus this problem can be addressed at a regional scale by collecting information from forestry experts and identifying the most important determinants. When compares to other methods, this general approach of assessing adaptive capacity has broader applicability, and is practical, straightforward, and intuitive. It leads to assessment and measurement approaches that are feasible, and tractable for policy analysis (Williamson, Hesseln, & Johnston, 2012).

According to the literature, there are multiple ways to assess adaptive capacity. However, since neither of these methods is perfect, applying only one of them might lead to misunderstanding of the current level of adaptive capacity. As Williamson and Isaac state in their report (2013, p.1), "There is no single right way to assess adaptive capacity; therefore, it is impossible to set out a step-by-step procedure for such an assessment". For the forest sector in Western Newfoundland, assessing its adaptive capacity is particularly important, because the economic growth of the province relies on the forest sector with thousands of people employed in industries such as pulp and paper production, sawmilling, and forest management. Climate change will inevitably be a major challenge that increases the adaptability requirements of the Western Newfoundland forest sector in the future.

Through reviewing the adaptive capacity assessment literature, it is reasonable to conclude that a combination of assessment methods is required to develop a comprehensive understanding of the adaptive capacity. For the case of Western Newfoundland, the "general approach" of adaptive capacity assessment can be used in combination with the two other approaches. They are indicators and proxy methods. Indicators in the adaptive capacity context are defined by Williamson and Isaac (2013), as "measures that can be reported either spatially or temporally. Relevant indicators may be based on determinants or assets that are known to contribute to adaptive capacity" (p. 6). Data for indicators can be collected by research or can be obtained from existing sources (Williamson & Isaac, 2013). As they state in their report that "overall adaptive capacity is a condition or state of being that is intangible and difficult to quantify" (p.7), thus proxy measures may serve as compensation in the assessment process. Proxy measures are used when indicators method with the existing data resources can't be applied in a practical way. They have been commonly used in environmental management situations as proxies are relatively easy to create and operationalize (Gregory et al. 2012). For example, years of working with environmental issues can be used as a proxy for the experience of environmental managers. Whereas it is often impossible to estimate someone's experience because experience cannot be estimated. This measure is potentially effective as a proxy if it can be assumed that the period of time of devoting oneself to the environmental issue is related to gaining experience for that person.

In summary, defining what determinants contribute to adaptive capacity of Western Newfoundland forest sector will be the first step of the assessment. However, determinants of adaptive capacity could be various depending on different ecosystems (Keskitalo et al., 2011). Almstedt and Reed (2013) state that, "As ecosystems and social-cultural systems vary between planning landscapes, specific criteria may also vary at different scales or across contexts" (p.672). Therefore, the data of local condition is required. Many studies have proved that experts who are living or working in forest sector have relatively high knowledge of the forest, and they have the sensitive insight of local forest management in the context of climate change (Ogden & Innes, 2009; McDaniels et al., 2012). Therefore, gathering information from the experts to define important determinants of adaptive capacity in Western Newfoundland is crucial for the whole study. This information will show the significant factors that affect the adaptive capacity, and filter other irrelevant elements for the assessment process, and eventually get the methods for adaptive capacity assessment in Western Newfoundland.

CHAPTER 3 Methodology

3.1 Climate Change Scenarios

Climate change scenarios are used in this study in order to make sure the assessment method is applicable under different climate conditions for the forest sector in Western Newfoundland. The necessity of using scenarios has been stated in one of the reports of the Canadian Council of Forest Ministry (CCFM) that "Scenarios provide crucial information to address how, given an uncertain future for Canadian forests, forest managers and others can be ensure that adaptation will be effective in a range of possible future outcomes. Scenarios therefore offer a way to explore future uncertainty, assess the range of possibilities, and develop flexible adaptation plans for the continued sustainability of Canada's forest systems" (Price &

Isaac, 2012, p.1). The scenarios were developed in conjunction with the thesis committee, based on current IPCC projections (Figure 1).

Current (Status Quo)	Moderate Change	High Change
➢ **Composition/Structure** • Normal Boreal Forest mix ➢ **Disturbances** • Hemlock Looper/SBW • Windthrow • Little Fire • Some diseases • Few invasives ➢ **Forest Management** • Current Climate/Precip. • Current Winter Season • Current Road Access • Std. Silviculture	➢ **Composition/Structure** • Stressed Boreal Forest mix ➢ **Disturbances** • Increase in pests • No Change in Windthrow • Moderate Fire increase • Increase in diseases • Few invasives ➢ **Forest Management** • Increase Temp./Precip. • Shorter Winter Season • Road Access more limited • More silviculture Challenges • Increased competition	➢ **Composition/Structure** • Changed Forest (> temp. spec.) ➢ **Disturbances** • More increase in pests • Increase in Windthrow • Sign. increase in Fire • More diseases and invasives ➢ **Forest Management** • Sign. increase Temp./Precip. • Shorter/Wetter Winter Season • Road Access difficult (to manage) • Need different silviculture Practice

Figure 1: Climate Scenarios and Types of Impacts.

3.2 Study Area

Western Newfoundland includes three main ecoregions of the island of Newfoundland: Western Newfoundland Ecoregion, Northern Peninsula Ecoregion, and Strait of Belle Isle Ecoregion (Figure 2). Even though it adjoins to the coast and its altitude is various, the condition of this region contributes to forest growth because it is characterized by a humid climate with a relatively short frost period. Besides, the soils of this region are nutrient due to the enrichment of humus, making it ideal vegetation for the growth of Fir forest (Meades & Moores, 1989). The western region is defined as the continuous region depicted in Figure 2.

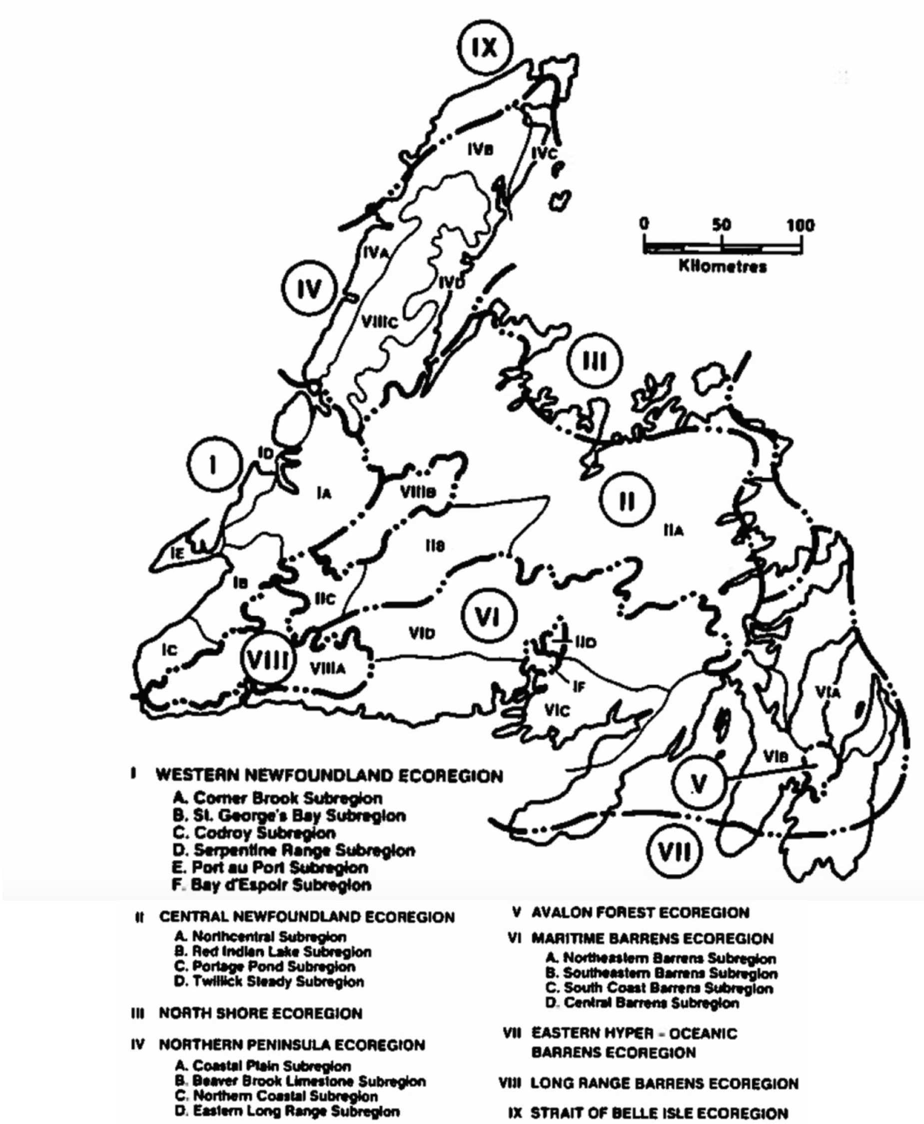

Figure 2: Map of Newfoundland with the study area marked as IX, IV, I (Meades & Moores, 1989).

Beckley (1995) states that “a predominant assumption among many academics, policy makers, and laypersons is that economic and social well being are closely linked” (p.261). As mentioned in Chapter 2, the economic growth of Western Newfoundland relies partly on the forest sector; in other words, social well-being is tied closely to the forest sector in Western Newfoundland. However, the global demand of paper is decreasing due to the use of electronic devices, and as a result, the forest sectors have been declining since 2005. This situation is much more serious in the province of Newfoundland and Labrador (Wernerheim & Long, 2010). With thousands of people employed in industries such as pulp and paper production, sawmilling, and forest management in Newfoundland, the decreased demand of paper will inevitably be a threat to the well-being of the society as a whole.

3.3 Research Design

A recent report commissioned by the Canadian Council of Forest Ministers provided a literature review of determinants and methods used to assess adaptive capacity (Williamson & Isaac, 2013). The determinates and methods used in the study were chosen and refined from this report. The main drawbacks of using these pre-define approaches is the inconsistency and incomparability across studies due to a lack of consensus about important determinants of adaptive capacity. Therefore, the delphi method (Okoli & Pawlowski, 2004) was considered to be an effective method for addressing this knowledge gap. A comparison of traditional survey and Delphi method is shown in Okili and Pawlowski's study (Table 3).

Table 3: Comparison of traditional survey and Delphi method (Okoli & Pawlowski, 2004)

Evaluation Criteria	**Traditional Survey**	**Delphi study**
Summary of procedure	The researchers design a questionnaire with questions relevant to the issue of study. There are numerous issues concerning validity of the questions they must consider to develop a good survey. The questionnaire can include questions that solicit quantitative or qualitative data, or both. The researchers decide on the population that the hypotheses apply to, and selects a random sample of this population on whom to administer the survey. The respondents (who are a fraction of the selected random sample due to non-response by some) fill out the survey and return it. The researchers then analyze the usable responses to investigate the research questions.	All the questionnaire design issues of a survey also apply to a Delphi study. After the researchers design the questionnaire, they select an appropriate group of experts who are qualified to answer the questions. The researchers then administer the survey and analyze the responses. Next, they design another survey based on the responses to the first one and readminister it, asking respondents to revise their original responses and/or answer other questions based on group feedback from the first survey. The researchers reiterate this process until the respondents reach a satisfactory degree of consensus. The respondents are kept anonymous to each other (though not to the researcher) throughout the process.

Representativeness of sample	Using statistical sampling techniques, the researchers randomly select a sample that is representative of the population of interest.	The questions that a Delphi study investigates are those of high uncertainty and speculation. Thus, a general population, or even a narrow subset of a general population, might not be sufficiently knowledgeable to answer the questions accurately. A Delphi study is a virtual panel of experts gathered to arrive at an answer to a difficult question. Thus, a Delphi study could be considered a type of virtual meeting or as a group decision technique, though it appears to be a complicated survey.
Sample size for statistical power and significant findings	Because the goal is to generalize results to a larger population, the researchers need to select a sample size that is large enough to detect statistically significant effects in the population. Power analysis is required to determine an appropriate sample size.	The Delphi group size does not depend on statistical power, but rather on group dynamics for arriving at consensus among experts. Thus, the literature recommends 10-18 experts on a Delphi panel.
Individual vs. group response	The researchers average out individuals' responses to determine the average response for the sample, which they generalize to the relevant population.	Studies have consistently shown that for questions requiring expert judgment, the average of individual responses is inferior to the averages produced by group decision processes; research has explicitly shown that the Delphi method bears this out.
Reliability and response revision	An important criterion for evaluating surveys is the reliability of the measures. Researchers typically assure this by pretesting and by retesting to assure test-retest reliability.	Pretesting is also an important reliability assurance for the Delphi method. However, test-retest reliability is not relevant, since researchers expect respondents to revise their responses.
Construct validity	Construct validity is assured by careful survey design and by pretesting.	In addition to what is required of a survey, the Delphi method can employ further construct validation by asking experts to validate the researcher's interpretation and categorization of the variables. The fact that Delphi is not anonymous (to the researcher) permits this validation step, unlike many surveys.
Anonymity	Respondents are almost always anonymous to each other, and often anonymous to the researcher.	Respondents are always anonymous to each other, but never anonymous to the researcher. This gives the researchers more opportunity to follow up for clarifications and further qualitative data.
Non-response issues	Researchers need to investigate the possibility of non-response bias to ensure that the sample remains representative of the population.	Non-response is typically very low in Delphi surveys, since most researchers have personally obtained assurances of participation.
Attrition effects	For single surveys, attrition (participant drop-out) is a non-issue. For multi-step repeated survey studies, researchers should investigate attrition to assure that it is random and non-systematic.	Similar to non-response, attrition tends to be low in Delphi studies, and the researchers usually can easily ascertain the cause by talking with the dropouts.
Richness of data	The richness of data depends on the form and depth of the questions, and on the	In addition to the richness issues of traditional surveys, Delphi studies

	possibility of follow-up, such as interviews. Follow-up is often limited when the researchers are unable to track respondents.	inherently provide richer data because of their multiple iterations and their response revision due to feedback. Moreover, Delphi participants tend to be open to follow-up interviews.

Note. The data adapted from "The delphi method as a research tool: An example, design considerations and applications" (2004). Retrieved from http://www.sciencedirect.com/science/article/pii/S0378720603001794

This knowledge gap makes adaptive capacity assessment more challenging for Western Newfoundland. Cuhls (n.d.) defines Delphi method is "an expert survey in two or more 'rounds' in which in the second and later rounds of the survey the results of the previous round are given as feedback. The experts answer questionnaires in two or more rounds" (p. 96). After each round of survey, a facilitator provides an anonymous summary of the experts' opinions from the previous round. This method builds towards consensus and urges experts to reconsider their submissions from the previous round.

Participants are required to answer questions of the first round in order to decide what are the most important determinants of adaptive capacity under different kinds of climate change scenarios; a list of determinants summarized from the literature are provided, and participants are asked to assign a value for the importance of determinants (e.g. on a 0 – 5 scale, where 0 means not at all important, 5 means very important). After analyzing their responses, results of the first round are displayed for a discussion of potential indicators across all the climate change scenarios. Simple examples of indicator are cited directly from the literature. Due to the necessary of a discussion, indicators for a specific determinant can be various, and a priority ranking method is applied instead of a Likert-type scale in the second round. The last step of the study is to discuss existing data resources or proxy methods for assessing the top three selected indicators. This process contributes to acknowledge what data resources are required and their availability for assessment in Western Newfoundland. However, there are some indicators that not directly measurable (e.g. experience, education). Using proxy method could capture such indicators. For example, human capital might be considered one of the most important determinants of adaptive capacity, and some indicators may include the general level of experience, education, training, and skill of forest managers, decision makers, and forestry stakeholders. To measure the indicator of experience of forest managers, decision makers, and forestry stakeholders, proxies are needed because they are immeasurable thus cannot be measure directly. For each of the indicator, one or more proxy methods might be used for assessment. Using the general level of experience as an example, questions that could be considered include: (1) the percentage of forest managers, decision makers, and forestry stakeholders that have ever deal with any issues regarding climate change; (2) the percentage of forest managers, decision makers, and forestry stakeholders that have ever attended any events related to climate change adaption. We assume that these quantitative data reveal the level of experts' experience. Figure 3 shows how this assessment process operates:

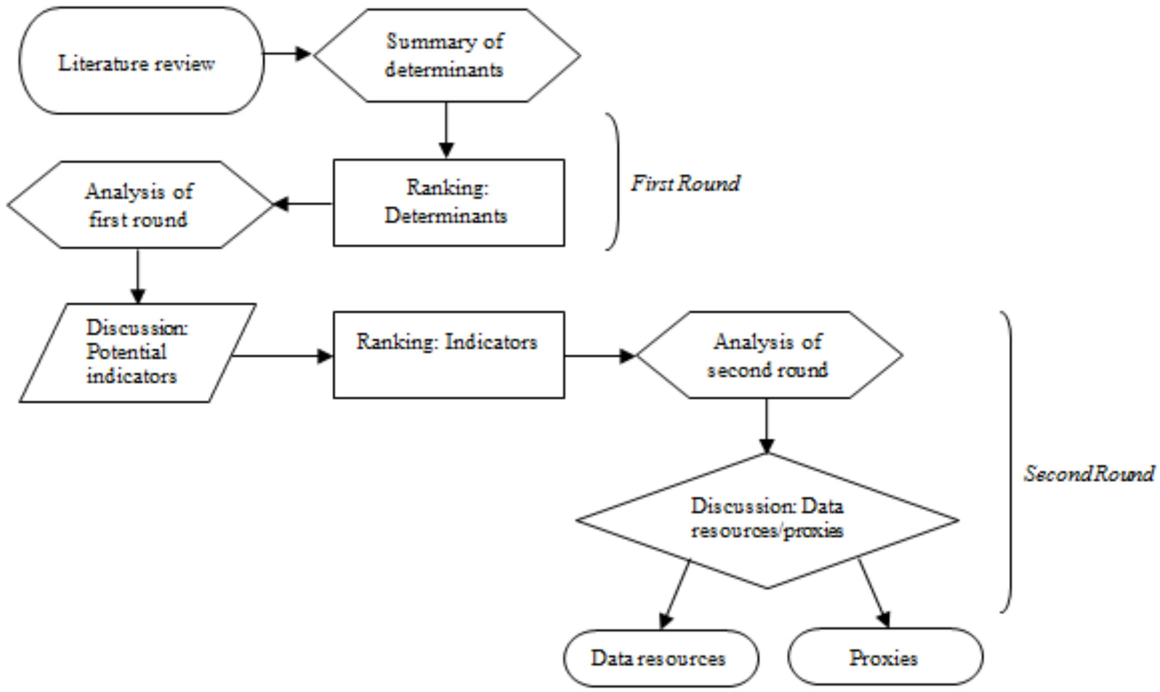

Figure 3: Flowchart of research design

Eleven determinants were retrieved from a series of review papers, they are economic resources, technology, knowledge capital, infrastructure, institution, social capital, human capital, cultural capital, natural capital, political capital, and risk management. The final decision of these eleven determinants was decided with the help of the thesis committee. When compared to Table2 (Common determinants used in assessing adaptive capacity), there is a change of the determinants presented in the report of the CCFM for three reasons. First, the participants are more familiar with the terms as they appear in the reports of the CCFM. For example, the determinant of “information and skills” is replaced by “knowledge capital” because in Williamson’s report (2013), the definition of “Knowledge” is similar to “information and skills”. Adopting “knowledge”, to some extent could avoid bias among participants. Second, some determinants in the CCFM report are deemed as independent determinant/relevant determinants, which should be separated or combined together. For instance, “equity” could be insured because of the involvement of stakeholders in a policy making process, thus the determinant of "equity" is not necessary when "political capital" is in the determinant list. Moreover, "social capital" and "human capital" are two different large topics that cannot be discussed and assessed at the same time. Third, the extra determinant, "risk management" is required for the forest sector in Western Newfoundland because the integration of risk management and adaptation helps to overcome some major difficulty such as dealing with risk-averse stakeholders (Wintle & Lindenmayer, 2008). The definitions of these eleven determinants were provided for participants during the workshop (Table 4).

Table 4: Definition of determinants

Determinant	Definition
Economic resources	include the economic assets and financial means that any actor can draw upon, for instance, access to loans, a mother company, or individual resources owned by a private entrepreneur. They may include municipal budgets, individual and household savings, business cash flow and operating funds. For the purpose of viewing adaptation within different territorial contexts, economic resources may also include regional, provincial, national, or federal aid programmes, company funds, or support for employment and innovation in a given region. Actors may also adapt by drawing upon technological resources, which may include technological upgrades to become more efficient and competitive in international markets, thereby raising the economic resources for adaptation.
Technology	in the climate change literature, technology tends to be given a very broad definition, such as "a piece of equipment, technique, practical knowledge or skills for performing a particular task", hence encompassing virtually every conceivable adaptation option. A distinction is generally made between hard and soft technologies, the former referring to physical products and the latter to practices and planning. Successful adaptation strategies will generally include both hard and soft technologies. Further distinctions can be made between traditional, modern, high and future technologies. In this assessment, the term 'technology' is generally limited to hard technologies.
Knowledge capital	climate change knowledge (scientific, local, Aboriginal, traditional, and operational) and knowledge mobilization (e.g., education, awareness raising, knowledge exchange). Such knowledge resources may include forest inventories, regional economic, labor force or other structural data. However, access to knowledge may be limited for instance by competition among companies, levels of government and communities in relation to market opportunities.
Infrastructure	encompasses both physical infrastructure such as access to roads or transport and, for example, access to decision-makers through which support (or physical infrastructure development to support businesses) may be gained.
Institution	include access to developed adaptation options and plans available to support adaptation, or those developed amidst change. The institutional dimension also refers to institutional and policy networks available to assist adaptation.

Social capital	measures the size, density and characteristics of an individual's or organization's network. High levels of social capital may facilitate improved access to information, collective actions and responses and access to resources that an individual or organization would not otherwise have access to. Trust is an important feature of functioning networks.
Human capital	is the accumulated education, training, and experience of individuals involved in SFM, including their skills, capabilities, aptitudes, and health. Human capital enables the identification and successful implementation of adaptation options. Skills refer to professional and leadership capacity.
Cultural capital	includes values, beliefs, and world views that acknowledge climate change and support adaptation.
Natural capital	natural resources and environmental services such as clean air, forests, water, soil, minerals, etc.
Political capital	access to and influence on policy, legislation, and political decisions.
Risk management	is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Risk management's objective is to assure uncertainty does not deflect the endeavor from the business goals. In a forestry context this could mean diversifying the mix of tree species grown or the provenances planted.

Note. The data was adapted from "Climate change and forest management in Canada: Impacts, adaptive capacity and adaptation options" (2010); "Preparing for and responding to disturbance: Examples from the forest sector in Sweden and Canada" (2011); "From impacts to adaptation: Canada in a changing climate 2007" (2008); "Adapting sustainable forest management to climate change: An overview of approaches for assessing human adaptive capacity" (2013); "Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment" (2012).

3.4 Participant Selection

Considering that this study is an assessment of climate change vulnerability in Western Newfoundland, potential experts from different fields of study that relate to this topic were required. The thesis committee collaborated to create a list of participants of local experts according to a previous study. The process of participant selection was conducted in two steps. Firstly, to assemble a list of potential forest experts from representative groups such as NGOs, industry, provincial/federal government, and academia. Secondly, to select participants according to the inclusion criteria as follow: (1) minimum 2 years working experience in forest-related field; (2) able to understand and communicate in English; (3) the availability of attending this project. The sufficient number, suggested by some practitioners, is about three to seven for the elicitation process. The number could increase if relevant knowledge must be gathered from both scientific and local/traditional knowledge experts (Gregory et al. 2012). As a result, an ideal number of participants would be 7-12 for this study as defined by the thesis committee. Therefore, 12-15 potential participants were identified and invited attend the research.

3.5 Data Collection

Given the complexity of the research design, a one-day workshop by using clicker technology is considered to be the most appropriate method to collect data for this study. Clicker technology, according to Connor (2009), is "a tool that can improve the quality of teaching and learning by providing meaningful and immediate feedback. It's also known as audience response or personal response system technology" (p.19). One of the main characteristics of clicker technology, which is getting immediate feedback, is particularly important for this research. As mentioned in the previous session, Delphi method contains a few rounds of survey, and the survey of subsequent rounds is created based on the result of previous rounds. Therefore, an efficient tool for analyzing the result is required, and clicker technology is ideal for achieving this goal. Beyond that, clicker technology has the advantages of fostering interaction and discussion, engaging participants, and creating a lively and interesting study environment (Connor, 2009).

There were two sessions of this workshop. In the first session, important determinants for adaptation were identified among experts with a Likert-scale ranking since the importance of every determinant can be manifested by using this ranking method. Session two was designed for indicators. It included a discussion of potential indicators of each selected determinant from the first session, a priority ranking, and a follow up discussion concerning the availability of data resources or proxy methods that help to measure indicators. Examples of indicators were provided from the review literature in order to give participants a rough idea of what indicators are. Participants' suggestions of potential indicators were typed in the rolling slide so that they could rank immediately by using clicker technology, and then discussed the data resources/proxy methods for the top three indicators. For the sake of avoiding confusion of the priority orders, a worksheet (Appendix A) is provided during the workshop. Every idea of data/proxy was marked on a sticky note for further study.

3.6 Data Analysis

Participants are asked to assign a value for the importance of determinants (e.g. on a 0 – 5 scale, where 0 means not at all important, 5 means very important). The results were displayed for the participants as a histogram at the end of the first session. If the mean score (i.e. importance level) of a certain determinant is increased as the degree of the climate change becomes more severe, its indicators and data/proxies were expected to be examined and discussed at the following session. Moreover, if the mean score of a specific determinant fluctuated significantly under different climate change scenarios, it was identified for study in the second session. In the second session, potential indicators were proposed and selected by participants. Priority ranking was used for identifying significant indicators. The maximum number of ranking item was set at ten. In addition, the ranking of indicators was weighted from the most important one to the least important one (e.g. 10 – 1, the first item chosen by participants weights 10 points, the second item weights 9 points, the third item weights 8 points, and the last item weights 1 point). Further discussion of data resources/proxy methods is only for those indicators in the top three list of every selected determinant.

CHAPTER 4 Results

4.1 Participants

Among ten respondents, nine of them were government representative (90%) with five from the Federal Government (50%) and four from the Provincial Government (40%). Only one respondent represented industry (10%), and no participated from non-governmental organization or academia (Table 5).

Table 5: Percentage of participants by employment sector

Employment Sector	Count	Percentage
Federal Government	5	50%
Provincial Government	4	40%
NGOs	0	0%
Industry	1	10%
Academia	0	0%
Total	10	100%

4.2 Determinants

4.2.1 Current Climate

The most important determinants for assessing adaptation of the forest sector in Western Newfoundland under the current climate condition were defined as economic resources, human capital, and natural capital. These were evaluated with the mean scores from the rolling results (Table 6). The frequency of responses revealed the most of the answers ranged from “fairly important” to “slightly important” in this climate change scenario. The distribution of the responses was relatively even for determinants of economic resources, knowledge capital and natural capital indicating disagreement among experts. In contrast, determinants of human capital and risk management had close consensus with 6 experts selecting the same importance level (Figure 4).

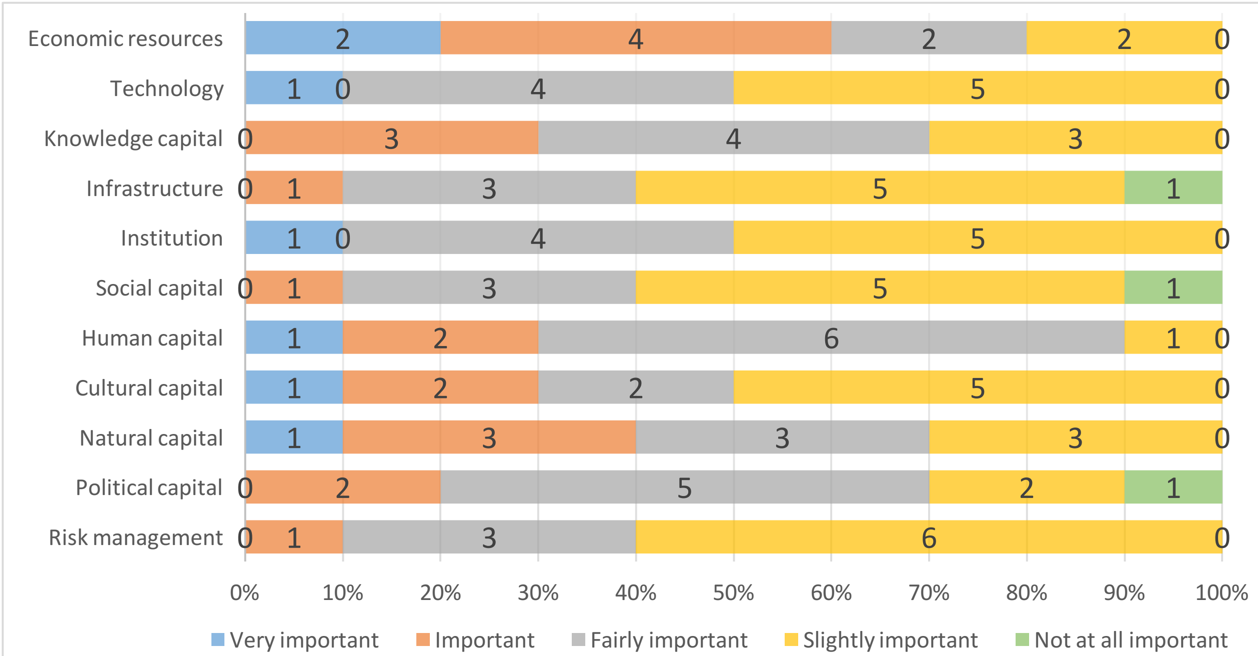

Figure 4: Importance of determinants under current climate expressed as number of people voted for each term and percentage distribution

4.2.2 Moderate Change

The most important determinants for assessing adaptation of the forest sector in Western Newfoundland under a moderate climate change scenario were economic resources, natural capital, and institution. These were evaluated with the mean scores from the rolling results (Table 6). In terms of the frequency, most of the answers ranged from "important" to "fairly important". The distribution of the responses was relatively even for determinants of infrastructure, institution, human capital, cultural capital, and political capital indicating disagreement among experts. Determinants of economic resources and risk management had the most consensus with 6 experts selected the same importance level (Figure 5).

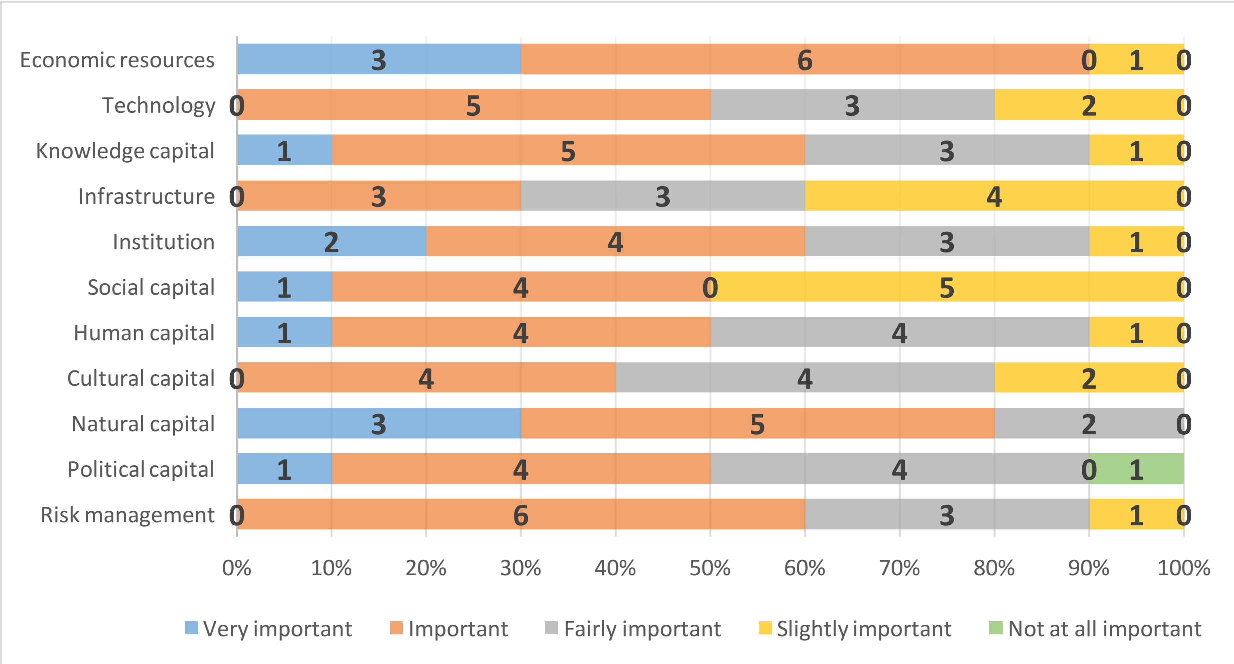

Figure 5: Importance of determinants under moderate change climate expressed as number of people voted for each term and percentage distribution

4.2.3 High Change

The most important determinants for assessing adaptation of the forest sector in Western Newfoundland under high climate change scenarios were economic resources, natural capital, institution, and human capital. These were evaluated with the mean scores from the rolling results (Table 6). In terms of the frequency, most of the answers ranged from "very important" to "important". The distribution of the responses was relatively even for determinants of infrastructure, social capital, cultural capital, and risk management indicating disagreement among experts. Determinants of economic resources and natural capital have most consensus with more than 8 experts selected the same importance level (Figure 6).

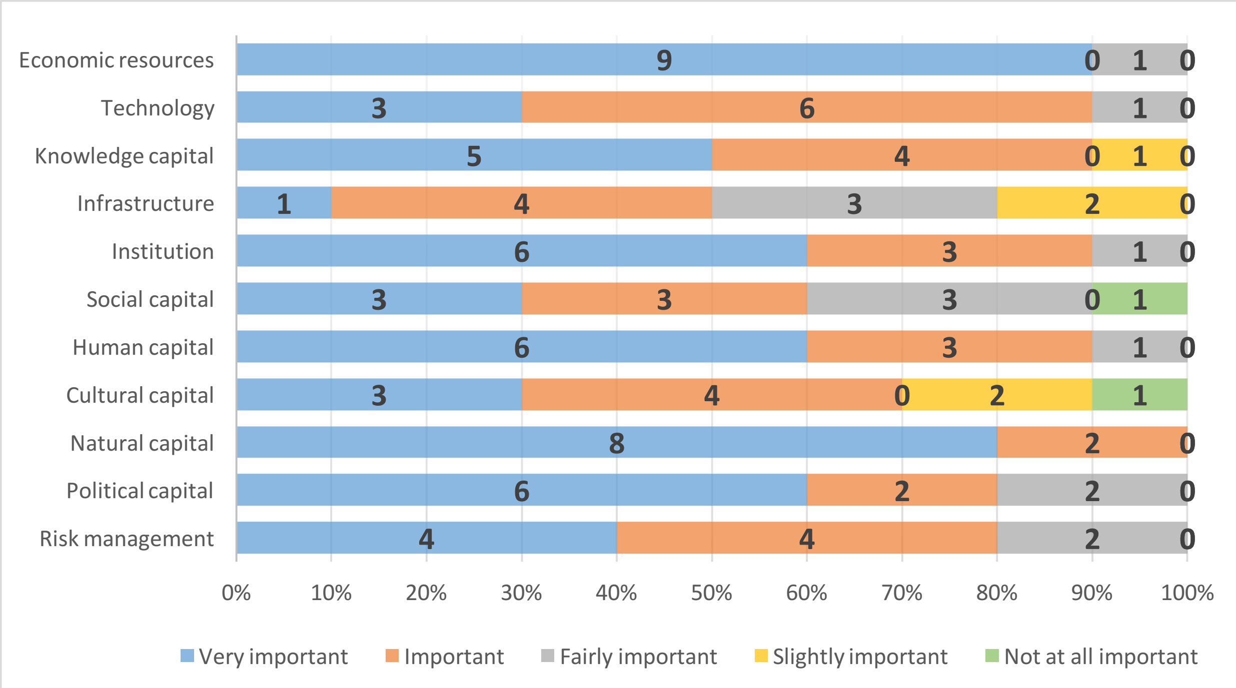

Figure 6: Importance of determinants under high change climate expressed as number of people voted for each term and percentage distribution

4.2.4 Comparative: Importance of Determinants across Climate Change Scenarios

As shown in Figure 4 through Figure 6, the color of light blue, which represents “very important”, takes a great proportion of responses when compares to Figure 4. The proportion of “important” increases as the proportion of “fairly important” decreases, which illustrates a trend that if the degree of climate change becomes more severe, the determinants are more important for the forest sector in Western Newfoundland. Table 6 also shows the majority participants voted for a high level of importance as climate change scenarios became severe.

From the mean score of the ranking results across three climate change scenarios (Table 6), determinants of economic resources and natural capital always score the highest with 3.6 (economic resources) and 3.2 (natural capital) for the scenario of current climate conditions. These two determinants have the same score of 4.2 for moderate change scenario, and same score of 4.8 for high change scenario respectively. Besides, determinants of human capital and institution are significant for this region even though there are some fluctuations of their importance in different climate change scenarios. For instance, in the climate change scenario of current climate, human capital is the second important determinant while in the moderate change scenario, institution is the third important determinant. In both of these two scenarios, the determinant of economic resources always occupies the first position and natural capital is the second. However, in both of the moderate change and high change scenarios, economic resources and natural capital are the most important determinants as they have the same level of importance for the forest sector in Western Newfoundland. In high change scenario, institution and human capital also have the same level of importance. As the severity of climate change increases, experts' opinions become more unanimous on the importance of determinants in the region of Western Newfoundland. The uniformity of importance level has reached the maximum with only one or two participants holding a different view on economic resources and natural capital under the high change scenario. Determinants of infrastructure, social capital, and cultural capital are the least important items for this area, but cultural capital has been considered as one of the top five important determinants under the current climate conditions.

Table 6: Mean score of determinants across three scenarios

Determinants	**Current Climate**	**Moderate Change**	**High Change**
Economic Resources	3.6	4.1	4.8
Technology	2.7	3.3	4.2
Knowledge Capital	3	3.6	4.3
Infrastructure	2.4	2.9	3.4
Institution	2.7	3.7	4.5
Social Capital	2.4	3.1	3.7
Human Capital	3.3	3.5	4.5
Cultural Capital	2.9	3.2	3.6
Natural Capital	3.2	4.1	4.8
Political Capital	2.8	3.4	4.4
Risk Management	2.5	3.5	4.2

4.3 Indicators

4.3.1 Economic Resources

The result shows that "government budgets" and "regional, provincial, national, or federal aid programmes" are the top two important indicators for assessing economic resources in the context of adaptive capacity in Western Newfoundland with 16.24% of the weights and 13.14% respectively. "Government budgets" is extremely important for assessing economic resources. It got the weight of 89, which is 17 higher than the second most important indicator. Both "D/S ratio" and "Bond rating" have almost the same weight of 11% and should be deemed as the third most significant indicators. However, they are not as important as the second most important indicator for their weights are much less than the second most important indicator (Table 7).

Table 7: The weighted count and percentage of potential indicators in economic resources

Potential Indicators	**Weighted count**	**Percentage (%)**
Average income	52	9.49
Regional, provincial, national, or federal aid programs	72	13.14
Government budgets	89	16.24
D/S ratio	58	10.58
Bond rating (provincial's ability to borrow money)	59	10.77
Per capita debt	47	8.58
Investment per hectare	48	8.76
Percentage of GDP	37	6.75
Economic Value of the forest sector to the province	48	8.76
Unemployment rate	38	6.93
Totals	548	100

4.3.2 Technology

The top three indicators are "the capacity to develop technological options for adaptation", "access to technology/transferability of technologies", and "use of renewable energy in forest sector" with percentage of 24.41%, 21% and 19.69% respectively (Table 8). "The capacity to develop technological options for adaptation" is extremely high when compares to the other two indicators in the top three list.

Table 8: The weighted count and percentage of potential indicators in technology

Potential Indicators	Weighted count	Percentage (%)
The capacity to develop technological options for adaptation (Investment in R&D)	93	24.41
Access to technology: Transferability of technologies	80	21
Invest in new technology	67	17.59
Use of renewable energy in forest sector	75	19.69
Advancement of engineered wood products	66	17.32
Totals	381	100

4.3.3 Knowledge Capital

The top three significant indicators for the determinant of knowledge capital are "climate change knowledge (scientific, operational)", "availability of data resources and ability to identify data gaps", and "knowledge mobilization" with percentage of 20.64%, 19.16%, and 17.94% respectively (Table 9).

Table 9: The weighted count and percentage of potential indicators in knowledge capital

Potential Indicators	Weighted count	Percentage (%)
Climate change knowledge (scientific, operational)	84	20.64
Climate change knowledge (local, Aboriginal, traditional)	60	14.74
Knowledge mobilization (e.g., education, knowledge exchange)	73	17.94
Public awareness raising, public communication	48	11.79
Access to information	64	15.72
Availability of data resources and ability to identify data gaps (climate change)	78	19.16
Totals	407	100

4.3.4 Infrastructure

The participants propose only four potential indicators of infrastructure. According to the ranking results, two indicators have the same weight, which means all these potential indicators should be considered when assessing the determinant of infrastructure.

Table 10: The weighted count and percentage of potential indicators in infrastructure

Potential Indicators	**Weighted count**	**Percentage (%)**
Forest access (roadways, stream crossings)	91	27.33
Equipment	79	23.72
Climate monitoring stations	84	25.23
Research infrastructure (e.g. labs, field monitoring labs)	79	23.72
Totals		100

4.3.5 Institution

The top three indicators are “legislation and policy to support climate change”, “emergency response plans for climate change”, and “gross-governmental/institutional collaborations” with percentage of 24%, 20.8%, and 19.73% respectively (Table 11). Specifically, “legislation and policy to support climate change” weights much more than the other two indicators.

Table 11: The weighted count and percentage of potential indicators in institution

Potential Indicators	**Weighted count**	**Percentage (%)**
Legislation and policy to support climate change, SOP	90	24
Efficient processes	68	18.13
Third party certification systems	65	17.33
Emergency response plans for climate change	78	20.8
Cross-governmental/institutional collaborations	74	19.73
Totals	375	100

4.3.6 Social Capital

The experts propose only three indicators and two of them ("networks among individuals, groups organizations" and "participation and representation in support networks") have the same weight of 93. "Collaborative environments" is the least important indicator with a weight of 84 in the priority ranking (Table 12).

Table 12: The weighted count and percentage of potential indicators in social capital

Potential Indicators	Weighted count	Percentage (%)
Networks among individuals, groups, organizations	93	34.44
Participation and representation in support networks	93	34.44
Collaborative environments (e.g. workshops, conferences)	84	31.11
Totals	270	100

4.3.7 Human Capital

The top three indicators are "General level of experience of forest managers, decision makers, and forestry stakeholders within the SFM system of interest" with a weight percentage of 24.18%, "General level of education of forest managers, decision makers, and forestry stakeholders with the SFM system of interest" with a weight percentage of 23.1%, and "the number of positions engaged to climate change in forestry" with a weight percentage of 19.29% for assessing the determinant of human capital in Western Newfoundland (Table 13).

Table 13: The weighted count and percentage of potential indicators in human capital

Potential Indicators	Weighted count	Percentage (%)
General level of experience of forest managers, decision makers, and forestry stakeholders within the SFM system of interest	89	24.18
General level of education of forest managers, decision makers, and forestry stakeholders within the SFM system of interest	85	23.1
Leaders' influence on adaptation decisions	66	17.93
Number of positions engaged to climate change in forestry	71	19.29

The existence of professional organizations in forestry	57	15.49
Totals	368	100

4.3.8 Cultural Capital

The participants propose only four potential indicators of infrastructure. According to the ranking results (Table 14), the top three are “public understanding of climate change” (27.93%), “public values willingness to pay/act” (26.43%), and “level of public engagement” (25.83%).

Table 14: The weighted count and percentage of potential indicators in cultural capital

Potential Indicators	**Weighted count**	**Percentage (%)**
Public understanding of climate change	93	27.93
Public values willingness to pay/act	88	26.43
Level of public engagement	86	25.83
Media activity	66	19.82
Totals	333	100

4.3.9 Natural Capital

The top three indicators are “forests”, “water”, and “wildlife/wildlife habitat” with the percentage of 22.81%, 21.75% and 15.65% respectively (Table 15). Actually, the weight of “wildlife/wildlife habitat” a bit lower when compares to the other two indicators in the top three list, and is much closer to the rest of other indicators.

Table 15: The weighted count and percentage of potential indicators in natural capital

Potential Indicators	**Weighted count**	**Percentage (%)**
Forests	86	22.81
Water	82	21.75
Soil	56	14.85
Minerals	42	11.14
Wildlife/wildlife habitat	59	15.65
Air quality	52	13.79
Totals	377	100

4.3.10 Political Capital

Top three indicators are "incorporating stakeholders input into decision alternatives" (22.77%), "the number of public consultation" (21.9%), and "presence of climate change in political platforms" (21.04%). The weight of these three indicators are about the same in comparison with the other indicators (Table 16).

Table 16: The weighted count and percentage of potential indicators in political capital

Potential Indicators	**Weighted count**	**Percentage (%)**
The number of public consultation	76	21.9
Incorporating stakeholders input into decision alternatives	79	22.77
Transparency in the dissemination of results	66	19.02
Communicating feedback	53	15.27
Presence of climate change in political platforms	73	21.04
Totals	347	100

4.3.11 Risk Management

The experts propose only three indicators. The most significant one is "whether risk/uncertainty considered in decision making" with percentage of 36.11% among all the indicators. The second and third most significant indicators are "monitoring and adaptive management" and "degree of forest sector diversification" with 32.87% and 31.02% respectively (Table 17).

Table 17: The weighted count and percentage of potential indicators in risk management

Potential Indicators	**Weighted count**	**Percentage (%)**
Is risk/uncertainty considered in decision making	78	36.11
Degree of forest sector diversification	67	31.02
Monitoring and adaptive management	71	32.87
Totals	261	100

4.4 Data Resources and Proxy Methods

Existing data/proxy methods for every indicator were identified during the discussion. As mentioned in Chapter 3, proxy methods are listed as the alternatives for assessment if no available data in Western Newfoundland (Figure 3). During discussion, two of the potential indicators ("climate monitoring stations" and "research infrastructure") of infrastructure were deemed to be the same category by the experts, thus need to be discussed simultaneously. Similarly, for the determinant of cultural capital, experts also suggested that indicators of "public values willingness to pay/act" should be combined with "level of public engagement" and discussed the data/proxies together. The facilitator made notes of discussion during the workshop (Table 18).

Table 18: Notes of data resources/proxy methods

"•" refers to existing data resources; "o" refers to proxy methods; "#" refers to number.

Economic Resources	
Indicator 1: Government budgets	• Budget report (federal website, provincial website) • University (economists, published, document)
Indicator 2: Regional, provincial, national, or federal aid programs	• Listed in budgets (government portals) • Office of climate change (provincial) • Disaster response (military)
Indicator 3: D/S ratio (bond rating)	• Public available data (website) • Forecasted: academia federal government (economic analysis) o global oil prices trends
Technology	
Indicator 1: The capacity to develop technological options for adaptation (Investment in R&D)	• # of research and development in operation (actual institutions) • Economic analysis • FP Innovation • # of patterns in R&D (Newfoundland & Labrador) • Ratio of R&D investment with value of investment (value ratio) • Published journals/ RD work (Research being done)

Indicator 2: Access to technology: transferability of technologies	• Organization charts/managers to assist with the transfer of technology (government departments) • Needs survey on available & access technologies • Networks which link technology • # of technology transfer to individuals (companies with technology transfer role)
Indicator 3: Use of renewable energy in forest sector	• Survey or census on home heating (statistic Canada) • Industrial reports on use of renewable fuel/oil • Department records (industry services data on wood burning) • # of LEED building • # of hybrids
Knowledge Capital	
Indicator 1: Climate change knowledge (scientific, operational)	• # of publications of scientific Journals (climate change, global change, Biology) • Increase in impact factor (journals) • # of long term experiment in climate change • Proceeding of conferences and meetings • Climate change operational (Standard operating procedures, Best management practices, strategic documents) o Traditional ecological knowledge (integration with science, interpretation)
Indicator 2: Availability of data resources and ability to identify data gaps (climate change)	• Government Datasets • Library • Data housing institution • Archived datasets • Trend of open data portals (e.g. 21 Federal Department on Geographical data, the availability of all provinces web publication) • Huge companies
Indicator 3: Knowledge mobilization (e.g., education, knowledge exchange)	• Curriculum (University Environment resource program addressing climate change, course Available • Workshops conferences (Knowledge exchange opportunity) • Access to information
Infrastructure	
Indicator 1: Forest access (roadways, stream crossings)	• Forest Environmental Information System database • Accessible (Satellite imaginary) • Government history (state of forest)
Indicator 2: Climate monitoring stations/Research infrastructure (e.g. labs, field monitoring labs)	• Department of environment (list of monitoring stations) • Environment Canada • CFS (Climate monitoring stations) • Infrastructure to optimize multiple stressors o Citizen-base science o NGO monitoring programs

Indicator 3: Equipment	• Government inventories and asset investment (distribution) • Life-cycle of equipment (government fleet management) • Research equipment • Other inventories from non-government suppliers (e.g. universal and Canadian helicopters) • Canadian Interagency Forest Fire Center (forest fire center, physical researches)
Institution	
Indicator 1: Legislation and policy to support climate change, SOP	• Federal and provincial act and regulations • Emergency Management Systems (government/industry) o Third party certification systems o Canadian Boreal Forest Agreement (CBFA)
Indicator 2: Emergency response plans for climate change	• Government websites (emergency services/ collaborative) • Municipal government plans • Incorporation of multi-agents in emergency response o Canadian disaster response (participations)
Indicator 3: Cross-governmental/institutional collaborations	• Reports on academic collaboration (policy) • Memorandum of Understanding (MOU), Memorandum of Agreement (MOA), Collaborative Research Agreement (CRA) • Research funding • International-government agreement • Climate Change Forest Management • CBFA
Social Capital	
Indicator 1: Networks among individuals, groups, organizations	• # of formalize committees/groups • NGO established with climate change focus • National research networks • IPCC • Public advisory committee • Participants in 5-year operation plan o # of organization & individuals represented o Influence of media (government response)
Indicator 2: Participation and representation in support networks	• # of participants in process • demographic of representation (e.g. youth aboriginals) • Level of media involvement • Openness of meeting process (public accessible) • # of feedback mechanisms o Engagement outcomes/ changes to policy/evaluations
Indicator 3: Collaborative environment (e.g. workshops, conferences)	• # of governmental representative on provincial networks • Virtual workshops (# of individual signed-in, # of question) • Use of social media (activity, # of likes on posts, # of shares)
Human Capital	

Indicator 1: General level of experience of forest managers, decision makers, and forestry stakeholders within the SFM system of interest	• Demographics in organizations (statistics) • Census data on individuals • Volume of work publications (research gate) ○ Volume of work ○ Years of services ○ Awards (acknowledgement)
Indicator 2: General level of education of forest managers, decision makers, and forestry stakeholders within the SFM system of interest	• Level of education (survey of organization) • CNA/MUN graduates (forestry, environmental science) • University Output/gradate • Retention (graduates that stay in NL)
Indicator 3: Number of positions engaged to climate change in forestry	• Organization chart (work plans) • Start-ups related to climate change contractual services • Post-doc (grad students/ researchers/professors) ○ Publication ○ Research grants ($ towards climate change research) ○ # of application
Cultural Capital	
Indicator 1: Public understanding of climate change	• Opinion polls (voting in support) • political platforms • public response (media: social/press)
Indicator 2: Public values willingness to pay/act	• purchasing practices (investment in green energy/products) • donation • taxes (carbon tax) • Opinion polls • Tree planning activities
Indicator 3: level of public engagement	• # of public at engagement sessions (protest) • NGO's focuses on climate change • online activity
Natural Capital	
Indicator 1: Forests	• Forest Resource Investment (FRI) • Growth and Yield tables • National forest investment (Remote Sensing products) • Research (scientific publications, dendrology)
Indicator 2: water	• Water resources directions • Watershed protect (research, watershed intactness) • Municipal water monitoring/treatment • # of communities with boil orders or other impact?
Indicator 3: wildlife/habitat	• Wildlife Division (survey on population, monitoring, COSEWIC) • conservative area (Species Status Advisory Committee) • FRI (disease report, biodiversity, Conservation Data Center)
Political Capital	
Indicator 1: Incorporating stakeholders input into decision alternatives	• Results of public consultation (proceedings accountability to participants) • Incorporative in management plans • Environment assessment process (stakeholder concerns must be

	addressed) • Funding of political parties by stakeholders
Indicator 2: The number of public consultation	• # of public consultations • Inclusion of consultation (public) in legislation • Human resource ($ dedicated to public consultation)
Indicator 3: Presence of climate change in political platforms	• # times climate change is said in platform • Inclusion in platforms • cross-section use of climate change in platforms • Political forums on climate change • Members in green party
Risk Management	
Indicator 1: Is risk/uncertainty considered in decision making	• Risk assessment tool • Disclosure (acknowledge & quantification of uncertainty) • Management plans
Indicator 2: Monitoring and adaptive management	• Monitoring plans existence • committed to formal Adaptive Management process • Revisions to management plan (audit reports)
Indicator 3: Degree of forest sector diversification	• Volume/value of products produced • New products (research and development on new products) • Management activities (alternate/non-traditional) • Entrepreneurship in sector (Business)

CHAPTER 5 Discussion

5.1 Overview

In the context of vulnerability assessment of the forest sector under climate change conditions, adaptive capacity has the potential of reducing the negative impacts on the environment, which leads to the reduction of vulnerability of the forest sector (Williamson, Hesseln, & Johnston, 2010). The latest report of CCFM states that assessment of adaptive capacity is a relatively new area of consideration in forestry-related assessments and still one of the more challenging aspects of vulnerability analysis (Edwards et al., 2015) which is true for the forest sector in Western Newfoundland. However, due to the complexity of management environment and the rise of uncertainty, the relevance of “adaptive capacity” in the day-to-day operations of Canadian SFM systems is increasing (Edwards et al., 2015).

Williamson and Isaac (2013) summarized the current literature on adaptive capacity and presented fourteen different assessment approaches. According to the reviewed literature, a combination of three approaches (determinant, indicator, and proxy) is considered a relatively effective and straightforward method for assessing adaptive capacity. However, as mentioned in Chapter 2, adaptive capacity varies regionally thus the adaptive capacity assessment method should be modified based on the local condition. All participants in this study agree that all the determinants summarized from reviewed literature are important elements for developing methods of adaptive capacity assessment of the forest sector in Western Newfoundland. For each of the determinant, a minimum of three potential indicators was proposed, and the participants identified the most significant indicators. Using existing data resources exclusively can assess most of these indicators, however some required proxy measures.

5.2 Determinants

Under current climate conditions, the level of importance of all the determinants were relatively low when compared to moderate to high change climate scenarios, with only three determinants exceeding "fairly important". These three determinants (economic resources, human capital, and natural capital) are not only important for the current climate, but also score as important determinants in both of the moderate change and high change climate scenarios. Others determinants become increasingly important as the climate change scenarios depicted in the exercise became more severe. For example, the determinant of institution is one of the five least important determinants under current climate conditions while it increases in important to the top three under both the moderate and high change climate scenario for the forest sector in Western Newfoundland. This is because the characteristic of unpredictable climate changes requires a society to be ready to respond, and institutions enhance the adaptive capacity of a society (Gupta et al., 2010). Institutions have long been identified as a key determinant of adaptive capacity in relation to climate change because it governs human interaction with a changing environment (Brown, 2009). Consequently, the determinant of institution will be more important for assessment as the climate change becomes extreme.

Economic resources is undoubtedly the most important factor for adaptation across varying climate change scenarios. Most of the participants placed a high value on economic resources for adaptive capacity assessment, likewise, all the literature that have been reviewed also underscore the importance of economic resources in the climate change context. The determinant of economic resources is the basis of any adaptive actions thus economic resources is necessary to be measured when assessing the adaptive capacity of the forest sector in Western Newfoundland. Moreover, other determinants, which are categorized as the "basic determinants" in Chapter 2 (Table 2), are also the indispensable elements for any adaptive capacity assessment.

In addition to basic determinants, there are additional determinants that are particularly important for forest sector in Western Newfoundland. For example, natural capital, which has been mentioned in only two reviewed literatures (Williamson & Isaac, 2013; Williamson et al., 2010), is considered to be one of the most important determinants for adaptive capacity assessment in Western Newfoundland. Few studies have identified natural capital as one of the vital determinants for adaptive capacity assessment. Even though Newfoundland is less forest-dependent than Quebec or Ontario (Patriquin et al., 2009), natural capital is particularly important for Western Newfoundland due to the relatively importance of the forest sector to the economy of Western Newfoundland which is a natural resource-based economy (Wernerheim & Long, 2010). For the determinant of human capital, it has been reported that strong institutions and high levels of human capacity (e.g. high level of education and experience among forest practitioners) in Canada contributed to a relatively high general adaptive capacity (Johnston et al., 2010). The forest sector in Western Newfoundland, with thousands of people employed in the forest sector, human capital is inevitably an important determinant for adaptation to occur.

The results show a positive relationship between the importance level of all determinant and the degree of a changing climate, which means the importance level of all determinants are increasing from the least climate change scenario to the highest change scenario. Although the other determinants are not as significantly important as economic resources, natural capital, institution, and human capital, all participants agree that eleven determinants of the first session should be taken into account to precisely assess the adaptive capacity of the forest sector in Western Newfoundland. Take one determinant as an example, even the least important determinant (i.e. infrastructure) is below the "fairly important" level in the current climate conditions, it becomes higher than the "fairly important" level in the high change scenario. More specifically, the determinant of infrastructure under the high change climate scenario is more important than the second most important determinant under the current climate conditions. It's reasonable to conclude that all the eleven determinants chosen from the reviewed literature are important for the adaptive capacity assessment in Western Newfoundland.

5.3 Indicators

The participants accepted some of the potential indicators chosen from the reviewed literature based on the condition of the forest sector in Western Newfoundland. All potential indicators were ranked in priority sequence in the workshop. The ranking results show the three most significant indicators of every determinant (Table 18). Most of these indicators are mentioned in previous studies and they are either the most important or the second most important indicators for assessment. However, some indicators were suggested by experts and ranked in the top three that were novel and not in the current literature. For example, the D/S ratio (Bond rating) was not cited from the reviewed literature but proposed by the participants as one of the most important indicators for assessing economic resources. Similarly, the use of renewable energy was considered a significant indicator of the determinant of technology. Spittlehouse (2005) concluded in his study that forest-dependent communities would face significant challenges with a changing climate. According to the report of Anderson &Yates Forest Consultants Inc. (2010), consuming fuel wood "has been an important part of the subsistence tradition in Newfoundland since settlement. A survey conducted in 2001 estimated that 44% of households in Newfoundland and Labrador use wood for heating" (p.7). As a consequence, Newfoundland is vulnerable to climate change if there is no other energy that can replace fuelwood. The amount of renewable energy used in Newfoundland reflects the degree of local people rely on wood harvesting for fuel, through which the level of the adaptive capacity can be indirectly measured. In general, indicators proposed by the participants were ranked to be the second/third most important indicators for this study, such as emergency response plans for climate change and cross-governmental/institutional collaborations are two of the most important indicators of institution. Again, no peer-reviewed study has mentioned them as the indicators of institution for adaptive capacity assessment. However, according to its definition in the adaptive capacity assessment context (i.e. includes access to developed adaptation options and plans available to support adaptation, or those developed amidst change; the institutional dimension also refers to institutional and policy networks available to assist adaptation), these indicators are reasonable measures for adaptation planning or the establishment of potential institutional networks that assist adaptation. Moreover, the number of positions engaged to climate change in forestry was proposed as an indicator of human capital by the participants during the workshop.

Other indicators proposed by participants included wildlife/wildlife habitat for the determinant of natural capital, as well as presence of climate change in political platforms for political capital, which have not been discussed as indicators for adaptive capacity assessment in other studies, were proposed by participants under the condition of the forest sector in Western Newfoundland.

5.4 Data resources and Proxy Methods

Proxy methods are not necessary when there are enough data resources existing for assessment. Therefore, only a portion of indicators needed proxy methods to complete the adaptive capacity assessment. For the forest sector in Western Newfoundland, valuable data is available for assessing the adaptive capacity, and the availability of these data resources demonstrates that the assessment method of adaptive capacity is likely to be feasible in the region of Western Newfoundland. Proxy methods as a supplement for the assessment make the results more precise and more accurate. It’s worth mentioning that some data resources, according to the opinions of participants, are applicable simultaneously for different indicators. For example, the data resources of networks that link technology could be the data for assessing the determinant of social capital for one of its indicators is the networks among individuals, groups, organizations.

5.5 Conclusion

The goal of this study was to identify the most appropriate method for assessing the adaptive capacity of the forest sector in Western Newfoundland. This goal was accomplished by reviewing relevant literature and gathering information on three questions based on the condition of the forest sector in Western Newfoundland under different climate change scenarios. The eleven determinants retrieved from the reviewed literature were all selected to be the important determinants for adaptive capacity assessment in this region. The second question, which refers to the indicators of each determinant, was addressed by having discussion and priority ranking. The required data/proxy methods of the top three indicators were also identified during the workshop, through which the appropriate method for adaptive capacity assessment in Western Newfoundland can be simply concluded as the equations as follows:

$$Adaptive\ Capacity\ (AC) = f\ (ER, T, KC, INF, INS, SC, HC, CC, NC, PC, RM)$$

Note. ER refers to "Economic Resources"; T refers to "Technology"; KC refers to "Knowledge Capital"; INF refers to "Infrastructure"; INS refers to "Institution"; SC refers to "Social Capital"; HC refers to "Human Capital"; CC refers to "Cultural Capital"; NC refers to "Natural Capital"; PC refers to "Political Capital"; RM refers to "Risk Management".

In the context of vulnerability assessment, adaptive capacity is an important factor of reducing the negative impacts on both the ecosystem and the human society regardless of the degree of climate change. The existence of available data resources demonstrates that the method of adaptive capacity assessment used in this study is feasible for the forest sector in Western Newfoundland. This finding is not limited in this area since determinants for adaptation could be different depending on different ecosystems (Keskitalo et al., 2011). It is possible and applicable to modify this assessment method by identifying different important determinants according to the circumstance of a region. However, further study and practical implementation are needed to examine whether this method is pragmatic and applicable or not for adaptive capacity assessment.

One weakness of this research is insufficient time for discussion. Participants were enthusiastic about discussing more appropriate indicators for a certain determinant during the workshop. A decision of combining two proposed indicators were made by the participants after the priority ranking, which verifies that better indicators could be figured out if enough time was provided for the discussion. The other limitation of the research is constrained by the function of clicker technology. For example, Likert-scale ranking was considered to be the most optimal method for both of two rounds. However, if the number of suggested potential indicators is too much, participants would be overwhelmed for they are still required to rank for each of them under different determinants. Alternatively, priority ranking was chosen for session 2, but it is impossible to evaluate the importance of each of the indicators independently. This might lead to ignore some indicators that have the same level of importance as the top three indicators. Moreover, the results could not show the individual’s answer by using priority ranking in the second session.

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Appendix A: Examples of indicators

Determinants		Indicators
Economic resources	Indicator1	Average income
	Indicator2	Availability of economic resources
	Indicator3	Investment in innovation
	Indicator4	Private investment in research and development
	Indicator5	Municipal budgets
	Indicator6	Individual and household savings
	Indicator7	Business cash flow and operating funds
	Indicator8	Regional, provincial, national, or federal aid programmes
	Indicator9	Company funds, or support for employment and innovation in a given region
Technology	Indicator1	Availability of technological options
	Indicator2	The ability to develop technological options for adaptation
	Indicator3	Companies' ability to implement new technology to provide new products
	Indicator4	Access to technology
	Indicator5	Invest in new technology
Information and skills	Indicator1	Climate change knowledge (scientific, local, Aboriginal, traditional, and operational)
	Indicator2	Knowledge mobilization (e.g., education, awareness raising, knowledge exchange)
	Indicator3	Access to information/ information gap
	Indicator4	Availability and interpretation of relevant information clearly affects the adaptive capacity of forest managers, planners and policy-makers
	Indicator5	The society's value of new information or new ways of thinking
Infrastructure	Indicator1	Buildings
	Indicator2	Equipment
	Indicator3	Roadways
	Indicator4	Quality of basic infrastructure
	Indicator5	Water and energy generation facilities
	Indicator6	Stores
	Indicator7	Factories
	Indicator8	Machinery
Institution	Indicator1	The laws
	Indicator2	Norms
	Indicator3	Rules
	Indicator4	Customs that guide behavior
Social capital	Indicator1	Relationships and networks among individuals, groups, and organizations the relationships between and among community members that contribute to collective action
	Indicator2	The interrelations and networks of individuals, organizations, and community leaders

	Indicator3	Participation in support networks
Human capital	Indicator1	General level of experience of forest managers, decision makers, and forestry stakeholders within the SFM system of interest
	Indicator2	General level of education of forest managers, decision makers, and forestry stakeholders within the SFM system of interest
	Indicator3	General level of training of forest managers, decision makers, and forestry stakeholders within the SFM system of interest
	Indicator4	General level of skill of forest managers, decision makers, and forestry stakeholders within the SFM system of interest
	Indicator5	Availability of key factors that contribute to current education, training and skills (e.g., presence of education and training institutions, organizational commitment to training, professional standards).
	Indicator6	The current level of understanding and awareness of forest managers, decision makers, and forestry stakeholders regarding the potential impacts of climate change on the SFM system of interest and of adaptation options for minimizing negative impacts and maximizing opportunities.
Cultural capital	Indicator1	Values, beliefs, and world views that acknowledge climate change and support adaptation
Natural capital	Indicator1	Forests
	Indicator2	Water
	Indicator3	Soil
	Indicator4	Minerals
Political capital	Indicator1	The number of public consultation
	Indicator2	Incorporating stakeholders input into decision alternatives
Leadership	Indicator1	Leaders' views about climate change
	Indicator2	Leaders' influence on adaptation decisions)

Note. The data adapted from "Climate change and Ontario forests: prospects for building institutional adaptive capacity" (2009); "Climate change and forest management in Canada: impacts, adaptive capacity and adaptation options" (2010); "Preparing for and responding to disturbance: examples from the forest sector in Sweden and Canada" (2011); "From impacts to adaptation: Canada in a changing climate 2007" (2008); "Adaptive capacity deficits and adaptive capacity of economic systems in climate change vulnerability assessment" (2012); "Adapting sustainable forest management to climate change: an overview of approaches for assessing human adaptive capacity" (2013).

Appendix B: Indicator worksheet

Indicator worksheet

1. Determinant of ***Economic Resources***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

2. Determinant of ***Technology***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

3. Determinant of ***Knowledge Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

4. Determinant of ***Infrastructure***

Indicator	Priority Order	Note

A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

5. Determinant of ***Institution***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

6. Determinant of ***Social Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

7. Determinant of ***Human Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		

G		
H		
I		
J		

8. Determinant of ***Cultural Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

9. Determinant of ***Natural Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

10. Determinant of ***Political Capital***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

11. Determinant of ***Risk Management***

Indicator	Priority Order	Note
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		