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CENTRE DE RECHERCHE ET D'EXPERTISE EN ÉVALUATION

Research report
(final version)

Elements of a frame of reference for evaluating adaptation to climate change: The RAC-Québec case

(TRANSLATION)

Presented to the
Ouranos Consortium

by

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FOREWORD

Through the Québec component of the Regional Adaptation Collaborative (RAC-Québec), the Ouranos Consortium awarded a grant to the Centre de recherche et d'expertise en évaluation (CREXE) of the École nationale d'administration publique (ENAP) for a research project originally titled "Development of indicators for the evaluation of planning related to adaptation to climate change (ACC)."

After discussions at a meeting of the project steering committee in Québec City on September 12, 2011, the project scope was clarified in terms of a proposed frame of reference on ACC evaluation that would simplify the organization of knowledge on the subject. This frame of reference would present all elements to consider when evaluating adaptation planning. It would involve, on the one hand, modeling the ACC problem and, on the other, identifying the many indicators in the literature pertaining to adaptation and situating them in relation to this problem.

This report is based first on a good understanding of the variables having an influence on the planning processes leading to the definition and implementation of ACC. Next, from a literature review in both the ACC and evaluation field, we suggest a number of general indicators of ACC performance that let us evaluate the processes that lead to the identification, planning and implementation of adaptation measures.

The project then examines two focus areas of RAC-Québec (forestry and the built environment and infrastructure in Southern Québec) to illustrate how these indicators could be used in the context of activities specific to RAC-Québec.

The continuation of work started here, particularly through empirical validation of the proposed indicators, can lead to the development of operational indicators that actors involved in ACC can use to carry out their duties.

EXECUTIVE SUMMARY

Since it will sometimes take several decades to determine if the choices made regarding ACC are going in the right direction, the Ouranos Consortium asked CREXE to consider how to develop indicators allowing to evaluate the development of an ACC capacity. This report therefore proposes i) a frame of reference for the evaluation of ACC in the RAC-Québec context and, ii) two examples of applications of this frame of reference in sectors specific to RAC-Québec: forestry and the built environment and infrastructure in Southern Québec.

In order to develop indicators situated farther upstream to monitor and evaluate short-term effects of ACC, it seemed essential to identify the complex causal chain of phenomena produced between the adaptation measures currently implemented and their ultimate effects in ACC. Two models were devised to conceptualize these ultimate effects and identify direct and intermediate adaptation targets to consider for an early evaluation of the performance of ACC actions in the RAC-Québec framework: the problem model and the logic model. The problem model is a diagram setting out symptoms of the social problem that we are trying to resolve and their causes (in this case, the problem of ACC)**.** The logic model, for its part, establishes the connections between intermediate and ultimate ACC targets, on the one hand, and, on the other, the rationale of interventions in ACC, their targets and objectives, the program theories (nature of strategies deployed), the amount of resources allocated, the outputs produced, and the expected or obtained effects on the direct targets of the action. By juxtaposing the problem and logic models, we can sketch a complete theory of the intervention and identify the entire zone of effects around which the frame of reference is organized.

The ACC problem model was developed following a review and consultation of literature from documentary databases and the virtual libraries of national and international institutions involved in tackling CC. The logic models were developed by consulting documentation on ACC actions undertaken in the RAC-Québec framework along with scientific literature on CC in the context of forestry and the built environment in Southern Québec. The component on indicators began with a survey of the principal existing frameworks for ACC evaluation as well as scientific literature on this subject. Finally, the indicators surveyed were systematically analyzed and classified.

In setting out the issues associated with developing a public intervention on ACC, the problem model represents the decision making process leading to the adoption of an ACC measure. It identifies the essential elements around which the indicators of effects of ACC planning were developed:

- Assessment of the socio-ecological system’s vulnerability
- Assessment of adaptation options and solutions, particularly in terms of costs and efficiency
- Decision to adopt an ACC measure based on selected criteria and determinants (political considerations, efficiency and equity considerations)
- Effects of the ACC measure on the system’s vulnerability

- Effects on collective well-being

The problem model also identifies the principal determinants of decision making by a stakeholder faced with adopting an adaptation measure: organizational resources and expertise, institutional incentives and constraints, political and social pressures, and advances in scientific knowledge.

Our model does not deny the contribution of existing impact models in sectors faced with climate change (CC). These models rigorously attempt to assemble indicators to simulate the behavior of a resource beset with climate disturbances (for example, in the area of water runoff, coastal erosion, land ecosystems, etc.). Our model is situated at another level and concerns the decision making process experienced by ACC stakeholders. It should not be seen as a substitute for specific models of sectoral impacts of CC.

For its part, the analysis leading to the RAC-Québec logic model identified the points of contact between the problem and the strategies (in the RAC-Québec context) for resolving the adaptation problem. RAC-Québec seeks to act on this problem by creating capacities among adaptation stakeholders in terms of knowledge and tools to make the right adaptation decisions. However, to benefit from the research findings placed at their disposal, these stakeholders must receive the findings and use them, hence the importance of considering the dimension of knowledge transfer and use in the ACC evaluation frame of reference. A final dimension is thus added to the five others mentioned above, namely:

- Knowledge transfer and use

The problem and logic models that were developed produced a generic decision making model. From this model, we were able to derive five indicators around the components of effects that must be considered in an evaluation of ACC planning in the RAC-Québec context (the dimension of “effects on collective well-being” was left out given its distance from the ACC planning process). These indicators represent:

- Level of knowledge among adaptation stakeholders on risks and vulnerabilities and their potential impacts on the system
- Level of knowledge among adaptation stakeholders regarding 1) costs inflicted on the economic, social and environmental system if no ACC measure is implemented, and their distribution over time and probability of occurrence; 2) costs and benefits of the planned adaptation measure or its net benefits (costs of planning, preparation, implementation and monitoring of measures); 3) residual costs of CC and sharing of costs
- The decision made on the ACC measure to adopt
- The extent of use of knowledge and tools produced in the RAC-Québec framework
- Change observed in the state of vulnerability of the system due to the adaptation measure adopted and compared to the overall change of vulnerability owing to other factors

Although our models (problem model and logic model) and their associated indicators possess an undeniable generic quality, they are quite suitable to represent the major issues

of specific problems (forestry, built environment, water, etc.). However, this specific aspect is not found in the models, but rather at the level of sectoral indicators that give greater detail on certain variables of the model. In the last chapter, we show how these five generic indicators could be applied in the two specific sectors mentioned above: forestry and the built environment in Southern Québec.

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LIST OF ACRONYMS

ACC: Adaptation to Climate Change

CC: Climate Change

CCAP: 2006-2012 Climate Change Action Plan

CERIU: Centre d'expertise et de recherche en infrastructures urbaines

CFS: Canadian Forestry Service

CREXE: Centre de recherche et d'expertise en évaluation

ENAP: École nationale d'administration publique

FCM: Federation of Canadian Municipalities

FERIC: Forest Engineering Research Institute of Canada

GHS: Greenhouse Gas

GSDRC: Governance and Social Development Resource Centre

ICLEI: International Council for Local Environmental Initiatives

IDS: Institute of Development Studies

INRS: Institut national de la recherche scientifique

IPCC: Intergovernmental Panel on Climate Change

M&E: Monitoring and Evaluation

MAMROT: Ministère des Affaires municipales, des Régions et de l'Occupation du territoire

MDDEP: Ministère du Développement durable, de l'Environnement et des Parcs

MRNFQ: Ministère des Ressources naturelles et de la Faune

MTQ: Ministère des Transports du Québec

NRCan: Natural Resources Canada

NRTEE: National Round Table on the Environment and the Economy

OIQ: Ordre des ingénieurs du Québec

PIEVC: Public Infrastructure Engineering Vulnerability Committee

RAC-Québec: Regional Adaptation Collaborative - Québec

SES: Socio-ecological system

UKCIP: United Kingdom Climate Impacts Program

UNDP: United Nations Development Program

UNFCCC: United Nations Framework Convention on Climate Change

UQAM: Université du Québec à Montréal

UQAT: Université du Québec à Trois-Rivières

INTRODUCTION

Recognizing the importance of risks associated with climate change (CC), the Québec government has been highly active on this front for many years—*Implementation of the United Nations framework convention on climate change*: *Québec action plan; Québec Action Plan on Climate Change 2000-2002; 2006-2012 Climate Change Action Plan* (CCAP); *Cadre de prévention des principaux risques naturels*; Civil Protection Act; Québec Water Policy; Sustainable Development Act; and support for research and development activities. Although the CCAP is largely devoted to measures aimed at mitigating greenhouse gas (GHG) emissions, a significant place has been given in recent years to the study of regional impacts and adaptation to climate change (ACC), notably in 2001 with the creation of Ouranos, and next with the 2006-2012 CCAP. Along this line, and following research conducted within Ouranos in particular, a first ACC strategy is being developed for inclusion in the next CCAP.

The Ouranos Consortium was created in 2001 to develop the knowledge and information needed to enable its members and their constituents to adapt to climate change. With specific funding from Natural Resources Canada (NRCan), Ouranos developed and managed RAC-Québec. The creation of RAC-Québec followed observations that a multitude of regional problems tied to climate change had emerged. Implemented between 2009 and 2012, the general objective of RAC-Québec is to contribute to reducing vulnerability to CC of the built environment in Northern and Southern Québec, water management and three important socio-economic activities (forestry, agriculture and tourism) by generating relevant information developed in a framework that 1) involves the adaptation stakeholders at every step, 2) harmonizes with the adaptation actions of the Québec government, and 3) is consistent with the respective missions of people, mechanisms and organizations already in place to advance adaptation. Specific objectives are also associated with each of the activity sectors mentioned above (Ouranos, 2009, p.2)

Acting through RAC-Québec, Ouranos directs its effort to creating capabilities among adaptation stakeholders to foster the emergence of leadership cores and thereby advance decision-making in adaptation matters. This creation of capabilities depends on the award of conditional grants to fund scientific research projects aimed at producing knowledge about CC or developing adaption tools.

In many cases, it will take several decades to determine if the right adaptation choices are being made now. Moreover, since RAC-Québec activity focuses on the creation of capacities among stakeholders rather than on direct intervention, indicators must be developed that report on the creation of an ACC capacity and not on the adaptation action itself. These indicators must show if the ACC component is going in the right direction, and if the knowledge and tools produced and transferred really allow decision makers to integrate the new climate reality in their decisions to a growing degree (Bourque, March 1, 2011).

Approach to conducting the research project

There are three main difficulties in identifying indicators to report on ACC results, whether to monitor a process for planning adaptation measures or to evaluate progress made towards reaching ultimate targets1 related to ACC. First, it is important to determine what constitutes an ultimate result in ACC, i.e., the strategically (and ultimately) desired effects. Next, because these ultimate effects will not be visible for several years in many cases, any indicator pointing solely towards these effects would be insensitive and unsuitable for reporting on the early effects of actions undertaken now. Finally, because adaptation usually aims to avoid the harmful effects of CC, the results will be measurable only against probable future scenarios that by definition will not materialize. Furthermore, they must be distinguished from the effects of other determinants that often have as great if not a greater influence on CC.

An adequate appreciation and interpretation of the effectiveness and efficiency of ACC measures thus calls for developing a better knowledge of the complex causal chain of phenomena that arise between actions taken now and their ultimate effects on ACC. This makes it possible to develop indicators situated more upstream for monitoring short-term effects. This knowledge can be developed only by a mapping of phenomena and events that report on ACC and that are produced in principle between the variables[2] selected as direct targets and those associated with climate change.

These considerations are at the heart of the approach taken in this research project. Accordingly, two models—the problem model and the logic model—were developed to conceptualize the ultimate effects in ACC and identify targets for direct and intermediate intervention to consider for an early evaluation of the performance of ACC measures in the RAC-Québec framework. Only after developing these two models could a structure of indicators and indicators be identified.

- The problem model

The problem model is a diagram of symptoms of the social problem that we are trying to resolve and their causes (in this case, the ACC problem). The model is a graphical representation of the principal variables having an influence on the planning processes leading to the definition of adaptation measures. It reports not only on the issues associated with developing public intervention in adaptation (both from a general viewpoint or else in specific sectors such as forestry and the built environment), but also on the determinants of decision making of stakeholders faced with the adoption of an adaptation measure.

[1] As stated below in Chapter 2, the targets refer to unsatisfactory situations or problems that a program seeks to change. For the evaluation, the targets are the dependent variables that are influenced by interventions made under the program. Three categories of targets are generally distinguished: direct targets (short-term), intermediate targets (medium-term) and ultimate targets (longer-term) (Marceau, Otis and Simard, 1992).

[2] According to Fortin, Côté and Filion (2006), a variable is defined as a quality or characteristic of individuals, objects or situations studied in a research project and to which a value is attributed. Depending on the different qualities or characteristics measured, the attributed values can change.

- The logic model

Once all elements of the problem have been mapped, it is important to locate ACC actions within them. It was in this optic that a logic model of RAC-Québec was developed. The logic model establishes the connections between intermediate and ultimate ACC targets on one hand, and, on the other, the rationale for ACC interventions, their targets and objectives, the nature of strategies deployed, the amount of resources allocated, the outputs produced, and the expected or obtained effects on the direct targets. This RAC-Québec analysis identifies, for the needs of the project, the points of contact between the problematic situation and strategies to resolve the adaptation problem.

Taken together, the problem and logic models identify the components around which adaptation indicators can be developed. The juxtaposition of the two models makes it possible to establish a "proto-theory" (i.e., a theory in the process of formation or a primitive theory) whose scope includes both the problem and the intervention and leads to the identification of the zone of effects in relation to progress in adaptation. The indicators must be chosen within this zone of effects: from the process of planning adaptation measures to the ultimate targets of ACC.

Since the research project called for illustrating how this process could be applied in specific contexts, two sectoral logic models were developed (forestry and the built environment in Southern Québec) in addition to the more general logic model concerning RAC-Québec. The creation of these two sectoral models clarified the nature of anticipated effects of RAC-Québec action on forestry and in the domain of the built environment in order to frame a proposal for custom made indicators.

- Methodology

The ACC problem model was developed following a survey and consultation of certain literature, in particular documentary databases (Sage, JSTOR, Wiley Interscience) and virtual libraries accessible on the websites of national and international institutions involved in the fight against climate change (Ouranos, Ministère du Développement durable, de l'Environnement et des Parcs [MDDEP], NRCan, National Round Table on the Environment and the Economy (NRTEE), Governance and Social Development Resource Centre (GSDRC), Eldis climate change adaptation dossier, UK Climate Impacts Programme (UKCIP), weAdapt, Intergovernmental Panel on Climate Change (IPCC), Tyndall Centre for Climate Change Research, Institute of Development Studies (IDS))

This consultation of the literature (scientific and grey) on ACC in general, but also on the economics of CC, the logic of collective action and the influence of scientific knowledge, not only identified the components deemed essential around which the ACC planning process must revolve. It also made it possible to identify the effects of this process on the vulnerability of a social and ecological system as well as the principal determinants of decision making in adaptation.

The logic models, more focused on RAC-Québec, were developed by consulting the documentation sent by Ouranos on ACC actions undertaken in the RAC-Québec framework. Their development was rounded out by consulting certain scientific literature on CC in the contexts of forestry and the built environment in Southern Québec.

The “indicators” component started first with a survey of the main existing ACC evaluation frameworks and scientific literature devoted to this question. Next, the indexed indicators were systematically analyzed and classified in such a way as to associate them with one or more components of the problem model. This classification gave a meaning to the whole. It also revealed that certain components of the problem and logic models were not covered by the indexed indicators. The team therefore drew on the scientific literature to cover the orphan components.

The work of identifying indicators was first done from a general point of view, paving the way to indicators of a generic nature, i.e., transferable from one RAC-Québec theme to another. The same exercise was then applied in a sectoral perspective (forestry and the built environment in Southern Québec), but taking into account the issues and specific features of these two activity sectors.

- Structure of the report

This report is organized in four chapters. In Chapter 1, the ACC problem model is proposed. Chapter 2 reviews RAC-Québec through an analysis of its intentions, identification of the intervention theory that underlies it, and a description of its implementation plan and desired effects. Chapter 3 presents a discussion on the measurement and evaluation of ACC and includes generic measurement indicators. Finally, Chapter 4 suggests ACC indicators in the sectors of forestry and built environment in Southern Québec; this attempt is based on the creation of two logic models for these two sectors.

CHAPTER 1
PROBLEM THEORY
OF ADAPTATION TO CLIMATE CHANGE

Climate studies indicate an upward trend in average temperatures of the Earth in recent decades. Whatever the causes of this phenomenon, climate warming is likely to spark climate disturbances that seem to constitute a threat to the viability of ecological systems and human activities organized around these systems.

Policies to combat CC are based on two lines of action, namely, mitigation and adaptation. In recent decades, priority has generally been given to measures for mitigation of CC (Füssel, 2007). However, public authorities are becoming increasingly aware of the need to introduce adaptation measures. This awareness is reinforced by the difficulties experienced in reaching and implementing restrictive international agreements that include targets to reduce greenhouse gas emissions (Ebert and Welsh, 2011).

This chapter presents an analysis model for decision making on ACC. Its purpose is to clarify the factors that influence decision making and the effects of these decisions. In explaining the incentives and constraints of decision makers, and the effects of their choices, the model suggests the mechanisms by which scientific research in general and Ouranos activities in particular are likely to influence ACC planning.

This chapter is composed of three sections. The first is devoted to defining ACC, while the second analyzes factors that influence ACC practices. The third section describes the effects of adaptation measures.

1.1 Adaptation to climate change

ACC can be defined as a set of actions or processes aimed at reducing the vulnerability of a social and ecological system to CC, or benefiting from it (Robledo and Forner, 2005; Ackerman and Stanton, 2011). It implies changes in natural and social processes, practices and functions and the perceptions of risks, all with the goal of reducing the socio-economic and environmental costs of CC and drawing benefits where possible (Ackerman and Stanton, 2011; Robledo and Forner, 2005; World Resource Institute, 2009).

There currently exist a variety of ACC responses. Among the types of ACC, spontaneous adaptation can be distinguished from planned adaptation (Robledo and Forner, 2005; Ackerman and Stanton, 2011). Spontaneous adaptation is the automatic reaction of a social and ecological system to a natural phenomenon. Planned adaptation denotes the set of deliberate strategies and actions intended to minimize the adverse impacts of CC and maximize the positive impacts (Robledo and Forner, 2005, Ackerman and Stanton, 2011). Unlike spontaneous adaptation actions, which are generally taken by individuals as private stakeholders following a climate event, planned adaptation usually stems from public policy aimed at reducing the vulnerability of the social and ecological system to current or forecast climate changes (Ackerman and Stanton, 2011; Füssel, 2007). However, we can imagine planned adaptation actions designed in a private context, for example by farmers

or hydroelectricity producers (Hydro-Québec). Similarly, the existence of dynamic private companies is another key factor in rapid and effective adaptation to CC.

Adaptation activities can be further divided into actions to develop adaptive capacity and adaptation actions themselves (Robledo and Forner, 2005; World Resource Institute, 2009; Agrawala, Bosello and Carraro, 2010). The development of adaptive capacities refers to actions to enhance the capacity of a social and ecological system, particularly its institutions, to cope with CC. Adaption activities themselves are concrete actions to protect against CC or mitigate its impact. Water-saving programs to better manage low-flow problems are an example of this second type of activity.

ACC planning is thus a process that can take various forms and affect several aspects of the economic, social and environmental activity of a community. The next section presents a model illustrating the different factors that exert an influence on ACC decision making.

1.2 Adopting measures for adaptation to climate change

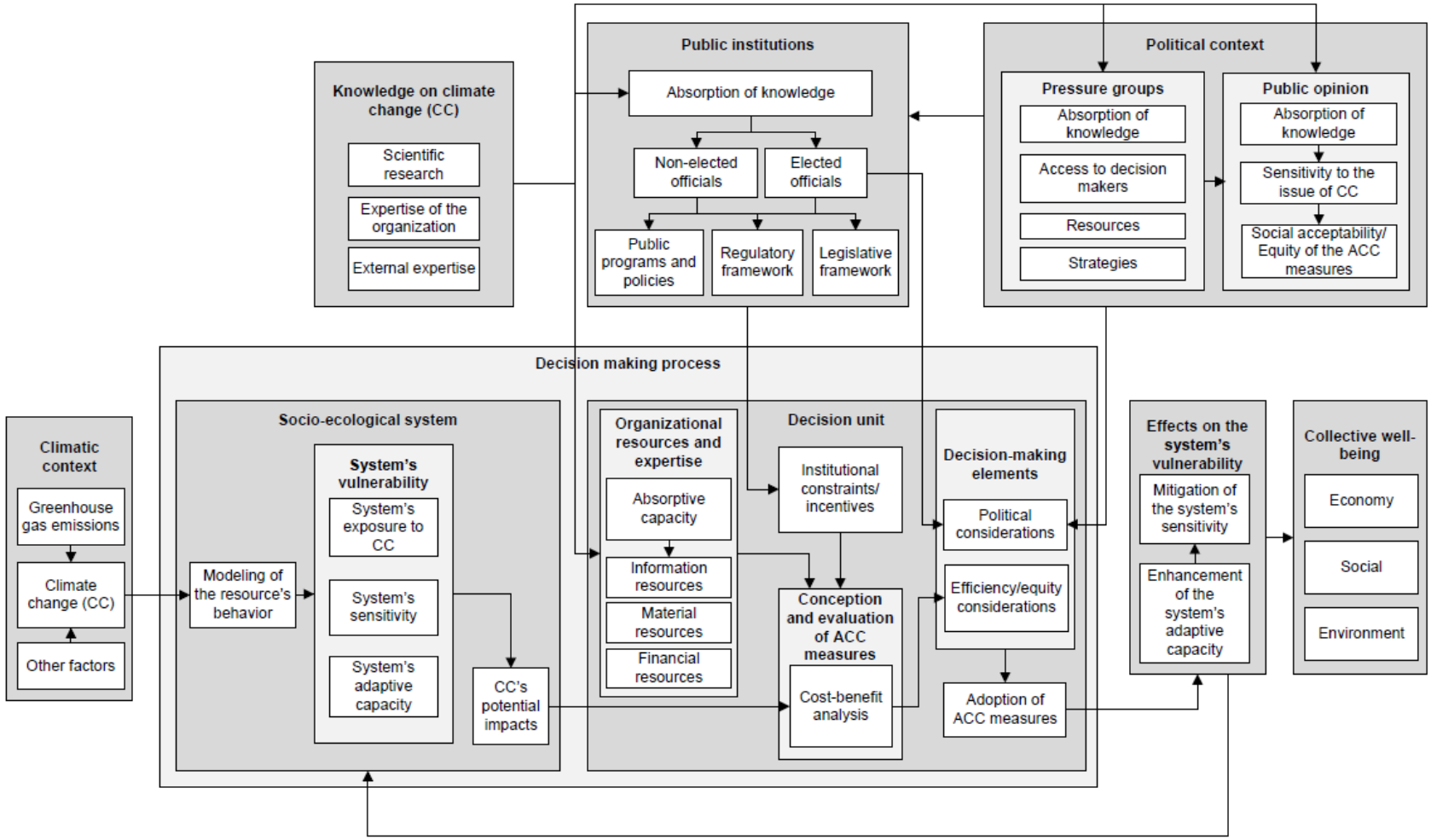
From here on, the reader is invited to consult the diagram of the problem model (Figure 1). Items in bold in the text represent parts of this model. We look at the case of a public or private decision-making unit acting within the limits of its knowledge and skills to implement ACC measures. Its decision-making process consists of assessing the needs and, as far as possible, designing and implementing effective actions to reduce the damages and maximize the benefits of CC. The decision maker's choices, which ultimately depend on costs and benefits in play, uncertainty, time horizon and attitude towards risk, are also influenced by the resources and expertise of the organization, the incentives and constraints of the institutional framework, political and social pressures and, finally, advances in scientific knowledge.

1.2.1 Analysis of the effects of climate change

- **Social and ecological system**

Social and ecological systems feel the effects of CC. A **social and ecological system** is defined as a system composed of a natural subsystem and a social subsystem (Gallopin, 2006). The significance of this concept stems from the recognition that the effects of CC depend on how these two mutually interacting sub-systems react to CC (Gallopin, 2006).

FIGURE 1: PROBLEM MODEL OF ADAPTATION TO CLIMATE CHANGE



◆ Modeling of the resource's behavior

A rigorous analysis of the effects of climate change should be based on a modeling of climate change and the reaction of the social and ecological system to CC (**the resource's behavior**). Next, the analysis of CC effects on the social and ecological system must consider the **system's vulnerability** to CC.

◆ Vulnerability to climate change

Vulnerability is the degree to which a system is sensitive to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). Vulnerability is a measure of the propensity of a social and ecological system to feel the positive and negative effects of CC (Robledo and Forner, 2005). In Africa, for instance, recurrent droughts often result in famine, epidemics and major population displacements. However, the scale of consequences differs depending on the setting and the adaptive capacity of the social and ecological system. For example, a drought in the southern United States, a region with modern infrastructures and ample technical and financial means, will clearly not have the same consequences in a region like the Sahel.

The purpose of analyzing vulnerability is to assess the possible impacts of CC on the environment, public health, economic and social activities, and so on. This analysis is an important step in the decision-making process because it makes it possible to assess CC adaptation needs and envision appropriate solutions (Malone and Engle, 2011).

Vulnerability is a function of the **system's exposure, sensitivity** and **adaptive capacity** to CC (IPCC, 2007; Malone and Engle, 2011; Gallopin, 2006).

- Exposure of the system to climate change

The concept of exposure is used to analyze the degree to which a social and ecological system is affected by CC (Gallopin, 2006). The following factors are generally considered in analyzing the exposure (Gallopin, 2006; Robledo and Forner, 2005):

1. The nature of the exposure, such as droughts, hurricanes, etc. A social and ecological system can therefore be more vulnerable to some natural phenomena than to others

2. Intensity of the exposure, i.e., the force to which a social and ecological system is exposed

3. Duration of exposure to climate disturbances

4. Frequency of exposure of the social and ecological system to CC.

- Sensitivity of the system

Sensitivity is "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise." (IPCC, 2007).

Sensitivity refers to the magnitude of the adverse or beneficial effects of CC on a social and ecological system (Gallopin, 2006). Sensitivity varies depending on the type of economic and social activities. The effects of CC will therefore be greater for climate-dependant activities, such as agriculture (Nath and Behera, 2011). Characteristics of the ecological subsystem must also be taken into account, since some natural environments are more fragile towards CC than others.

In a society, sensitivity (and hence vulnerability) also depends on the economic structure and the population. An economy dominated by primary activities or highly dependent on a single resource will be more vulnerable than a diversified economy. Similarly, a society of older people, in poor health or displaying nutritional problems, may be more vulnerable than a young, affluent, educated and healthy society.

- Adaptive capacity to climate change

Adaptive capacity to CC refers to the set of resources, structures and processes of a social and ecological system that can be mobilized to design and implement ACC measures (Westerhoff, Keskitalo and Juhola, 2011; Gallopin, 2006). These are attributes of a social and ecological system that are present prior to exposure to CC (Gallopin, 2006) and enable it to anticipate and adapt to these changes (World Resource Institute, 2009).

Agrawala, Bosello and Carraro (2010) distinguish specific adaptive capacities from generic adaptive capacities. Specific adaptive capacities primarily address CC threats through, for instance, R&D activities on CC or by establishing warning systems. Generic adaptive capacities are related to the socio-economic development of a country or region and include such factors as the existence of a public health system to cope with epidemics, transportation systems to bring help to the people affected, the protection of infrastructure, or the degree of wealth and economic diversification.

ACC capacity is determined by several factors:

1. Financial resources

ACC measures may involve costly activities such as massive investment in infrastructure. The availability of financial resources promotes the introduction of ACC policies and programs (Nath and Behera, 2011; Robledo and Forner, 2005; World Resource Institute, 2009; Westerhoff, Keskitalo and Juhola, 2011).

2. Expertise and competencies

A social and ecological system needs information generated by reliable sources, i.e., individuals and organizations that have developed credible expertise on exposure to CC and its effects. It must also be able to develop and use the adaptive technologies and

measures needed for this purpose (Nath and Behera, 2011; Robledo and Forner, 2005; Westerhoff, Keskitalo and Juhola, 2011).

3. Infrastructure (Robledo and Forner, 2005)

The presence of an effective transportation system that can evacuate disaster-stricken populations or bring assistance and a public health system able to contain epidemics induced by CC are examples of the role played by infrastructure in reducing a social and ecological system's vulnerability to CC.

4. Institutions (Robledo and Forner, 2005; World Resource Institute, 2009; Westerhoff, Keskitalo and Juhola, 2011)

Institutions are vehicles of cooperation that can mobilize a community's resources to take action in the public interest. A society's capacity to respond effectively to natural phenomena is strengthened by the existence of public or private organizations with specialized personnel and budgets earmarked for combatting CC.

◆ **Potential impacts of CC**

The analysis of **potential effects and impacts of CC** is a crucial step in the decision-making process. It lets us know if the social and ecological system is confronted with natural phenomena that threaten its balance and if ACC measures are required. The problem model considers that when CC threatens the viability or well-being of a community, it becomes an important issue that merits the attention of decision makers.

1.2.2 Effectiveness of ACC tools

Faced with real CC problems, the decision maker—whether an individual, group, company or public organization—has several possible courses of action. To reference the typology of adaptation measures proposed by Agrawala, Bosello and Carraro (2010), the decision maker may choose to:

- Bear the costs of CC, i.e., do nothing
- Collectively share costs through disaster assistance measures, insurance, etc.
- Control CC threats by building dams, protecting wetlands, etc.
- Prevent CC impacts. In agriculture, this may mean favoring drought-resistant varieties of grains or building irrigation systems
- Diversify economic activities when CC makes some of them less viable
- Move economic activities to locations that are safer or less exposed to CC
- Change societal behavior through education, regulation and information.

If the social, environmental and financial costs of CC are substantial, it becomes relevant to mobilize the resources necessary to combat these changes and mitigate their effects on the vitality and prosperity of the community. ACC decisions must be based on the principle of economic rationality (Agrawala and Franhauser, 2008). In other words, the benefits of actions resulting from these decisions must exceed the costs.

Four steps emerge in the **analysis of adaptation costs and benefits** (Agrawala, Bosello and Carraro, 2010).

- The first step is to estimate *ex ante* the gross costs of CC over a given time period. These are the costs inflicted on the social and ecological system if no CC adaptation measure is implemented. As noted above, these costs depend on the exposure to and vulnerability of the social and ecological system. It can sometimes be difficult to calculate since it implies monetizing all the external effects caused by CC.
- The second step in the decision-making process involves estimating ACC costs. Adaptation costs include the expenditure for planning, preparation, implementation and monitoring of ACC measures (Narrain, Margulis and Essam, 2011). In this connection, note that some studies estimate that more than $70 billion will be needed annually to blunt the damages caused by CC (Ackerman and Stanton, 2011; Agrawala, Bosello and Carraro, 2008; Narrain, Margulis and Essam, 2011). This money must be invested mainly in infrastructure (Narrain, Margulis and Essam, 2011).
- The third step in the analysis consists of calculating the costs avoided as a result of ACC measures.
- The last step in the analysis involves comparing the costs of implementing ACC measures to the costs avoided as a result of these measures. The measure becomes cost-effective when the amount of costs avoided is greater than the amount invested in ACC. The result of this analysis, when applied to various intervention options, also serves to classify the tools according to their effectiveness in mitigating the effects of CC.

The decision-making process is guided by the efficiency principle. According to Füssel (2007), however, the decision maker's choice is not based solely on considerations of efficiency, i.e., on the cost-benefit analysis of the intervention method. It is also important to consider the **availability of resources** and the **expertise required**, the **incentives and constraints of the institutional framework** and **political and social pressures**.

1.2.3 The organization's resources and expertise

The organization must have the **human, material** and **financial resources** to design and implement CC adaptation measures. The analysis of the exposure and vulnerability of the social and ecological system and the effectiveness of intervention methods requires the availability of experts, knowledge and advanced technologies in ACC. The adaptation measures also demand investments in infrastructure or in the relocation or reconversion of the economy. To successfully carry out these activities, the necessary financial resources must be available.

1.2.4 Knowledge

According to Tompkins and Adger (2005), making decisions about CC is difficult due to the uncertainty of **knowledge** on the phenomenon and the difficulty of measuring the effects and effectiveness of measures. In this regard, advances in science and technology may play a decisive role in combatting CC. Scientific breakthroughs would deepen our

knowledge on the causes of CC and its effects and help develop new adaptation methods and strategies (Füssel, 2007).

However, if knowledge is to play this influential role, it must be transferred to its potential recipients, be they ACC decision makers, public officials or the general public (farmers, entrepreneurs, ordinary citizens). At the conclusion of this transfer process, the influence exerted by the knowledge will vary by individual depending on their respective **absorptive capacities**. This absorptive capacity in turn varies based on individual factors (e.g., field of education) and institutional factors (e.g., the existence of an infrastructure providing access to knowledge) (Ouimet et al., 2009; Cohen and Levinthal, 1990; Zahra and George, 2002; Todorova and Durisin, 2007).

1.2.5 Institutional framework

Most countries have established government departments and agencies responsible for environmental issues in general and CC in particular. Laws and regulations have also been adopted to govern the behavior of the various stakeholders in this area. These mechanisms are intended to strengthen the capacity of these countries to effectively manage the CC issue.

Stakeholders thus find themselves invested in the ACC mission, within a **legislative** and **regulatory framework** that defines their fields of competency and intervention measures available to them (**public policies and programs,** for example, financial support for adaptation or research development).

1.2.6 Political and social context

In a democracy, **public opinion** exerts considerable influence on public choices. Decision makers, including elected officials, need the support of the public to remain in power. In this context, awareness of CC problems among a large share of the population would exert pressure on governments to put this issue on their agenda. Decision makers would also take **social acceptability** into account when choosing what means of action to take (Füssel, 2007; Tompkins and Adger, 2005).

Moreover, the effects of CC vary by social group. Climate warming may affect farming more than industry. Similarly, adaptive measures may benefit certain social groups to the detriment of others, as when the government uses public funds to support measures in high flood-risk zones. The possibility of benefiting from ACC policies while escaping the costs is an incentive to form **pressure groups** to influence public choices. People living in flood zones can join forces to exert pressure on government to obtain compensation (risk sharing) rather than move or purchase private insurance.

1.3 Effects of adaptation measures to climate change

The main objective of adaptation measures is to reduce the **vulnerability of social and ecological systems to CC** (Ackerman and Stanton, 2011; Robledo and Forner, 2005; World Resources Institute, 2009). However, these effects vary depending on the nature of the intervention method. Certain interventions may **reduce the sensitivity of the social and ecological system to CC** by, for instance, diversifying the economy's activities to make it less climate-dependent. Other measures instead seek to **enhance the capacity for**

ACC. This is especially the case when the government decides to create responsible agencies with a mission to design and implement CC policies and to fund research and development to provide the expertise and technologies required to achieve their mission. Reducing the vulnerability of the social and ecological system to climate change helps enhance **collective well-being** through economic prosperity, improved quality of the environment and public health.

1.4 Conclusion

In representing the problem associated with developing an adaptation measure, the model identified the essential components around which the indicators of effects of the ACC planning need to be developed. These five components raise certain questions that an ACC decision maker could ask himself during the adaptation planning process:

1) Assessment of the socio-ecological system's (SES) vulnerability

- To what extent is the SES exposed to climate changes (nature, intensity, duration, frequency)?
- What would be the magnitude of beneficial or adverse effects of CC on the SES?
- Which SES resources, structures, processes could be mobilized to design and implement ACC measures?
- In light of this diagnosis, are ACC measures required?

2) Assessment of adaptation options and solutions

- What social, environmental and financial costs are inflicted on the SES if no CC adaptation measure is implemented (gross costs of CC) ?
- What are the ACC intervention options? What are the costs? What costs are avoided due to each intervention? Which intervention appears most effective (in economic terms) for reducing CC impacts?
- In choosing an ACC intervention option, what are the incentives and constraints regarding: availability of resources; expertise and knowledge required; the institutional framework; the political and social context?

3) Decision to adopt an ACC measure

- What decision was made on ACC? What criteria were used (cost-effectiveness, time horizon, uncertainty, urgency, feasibility, etc.)? How was the measure implemented? What is the status of its implementation?

4) Effects of the ACC measure on the system's vulnerability

- How has the ACC intervention proved effective in reducing the vulnerability of the SES? How can we make our ACC intervention more effective?

5) Effects on collective well-being.

- Do the beneficial effects of the ACC measure compensate for all the social, environmental and financial losses incurred?

The model also identifies the principal determinants of decision making by a stakeholder in an uncertain position and faced with adopting an adaptation measure. They are: organizational resources and expertise, institutional incentives and constraints, political and social pressures, and advances in scientific knowledge. While these factors do not represent the effects of the ACC planning process, they will still be considered in an evaluation to determine the effect of an action on a stakeholder's decision making.

In the interest of seeking conciseness, our objective was to produce a simple model. However, such a representation of reality leaves certain dimensions of ACC planning unmentioned. We realize nevertheless that decision making in the ACC field is more complex than the linear process we have described. Some constraints on decision making in this field are: the time horizon for the decision, the rate of time preference, risk aversion, uncertainty, the sharing of costs and benefits of the action, and their impacts on revenue distribution.

Our study of the issue has produced a generic decision-making model. Our modeling of the problem does not deny the contribution of other existing models in sectors facing CC, which attempt to rigorously assemble indicators to simulate a resource's behavior in response to climate disturbances (e.g., water runoff, shoreline erosion, land ecosystems, etc.). Our model is situated at another level and concerns the decision-making process as experienced by ACC stakeholders. It must not be seen as a substitute for specific models of sectoral impacts of CC.

In the next section, we will complete the inventory of the components of effects by considering the RAC-Québec's intervention.

CHAPTER 2
LOGIC MODEL OF RAC-QUÉBEC

Along with the problem model, the logic model is an essential tool for prioritizing the components around which the effect of an intervention must be measured. Unlike the problem model, which considers all variables of effects in an ACC planning process, the logic model concentrates on the zone of effects directly attributable to RAC-Québec. Through a review of the rationale of the intervention, its targets and objectives, its theory, inputs, production activities, outputs and anticipated effects, the analysis that produces the logic model makes it possible to identify other components to include in a system of indicators related to ACC planning. This chapter presents this model and analysis (see Figure 2).

2.1 Rationale of RAC-Québec

> The first parameter to define in building the logic model of a program is the **rationale** or justification of this program. The reasons underpinning the program must be understood. Evaluating the relevance of interventions is tied to the rationale (Marceau, Otis and Simard, 1992).

Over the past two decades, the fight against CC has been waged mainly through the identification and implementation of policies and measures geared to climate change mitigation through actions targeting a reduction in GHG emissions. However, as emphasized by Fatih Birol (Chief Economist of the International Energy Agency) and Lord Nicholas Stern (Chair of the Grantham Research Institute on Climate Change), current commitments by countries to reduce GHG by 2020, even if they are implemented fully, will not be enough to avoid a warming of the planet by 2°C above temperatures in the 19th century (International Energy Agency, 2011)

As noted in Chapter 1, adaptation is now receiving increasing attention as a complementary strategy to mitigation measures. At the international level, the Bali Action Plan (United Nations, 2008), adopted in 2007 at the 13th session of the Conference of the Parties, recognizes adaptation as a key element in responding to the challenges posed by CC. The importance of ACC was reaffirmed at the United Nations Climate Change Conference held in Durban (South Africa) from November 28 to December 9, 2011.

Québec's actions on climate change are following this trend. Although much of the 2006-2012 Climate Change Action Plan is devoted to measures aimed at reducing GHG emissions, a certain standing is given to ACC measures (Ministère du Développement durable, de l'Environnement et des Parcs, 2008). Moreover, the ACC strategy now being prepared, which will be integrated in the 2013-2020 Climate Change Action Plan, demonstrates the growing importance granted to ACC.

FIGURE 2: LOGIC MODEL OF RAC-QUÉBEC

Logic model: Regional Adaptation Collaborative-Québec (RAC-Québec)

Rationale		- Emergence of multiple regional problems connected with climate change - Involvement of the Quebec government and other stakeholders in research and development (R&D) to reduce greenhouse gas (GHG) emissions and adapt to climate change (ACC) - Need for a central structure to support adaptation stakeholders, centralize information of value, and foster interaction between the research community and users of scientific knowledge. - Market failure in the production of information (scientific knowledge a non-rival good)
Targets	**Direct**	- Funds available to undertake scientific research - Knowledge/tools on CC and ACC measures
	Interme-diate	- Transfer of knowledge/tools on CC and ACC measures - Adoption of ACC measures
	Ultimate	- Vulnerability of social and ecological systems (adaptive capacity and sensitivity to ACC measures) - Collective well-being In the following sectors: Built environment (Northern Quebec, Southern Quebec), Water (water management); Socio-economic activities (Forestry, Agriculture, Tourism and Recreation)
Objectives	**General objective** Contribute to reducing vulnerability to CC for the built environment, water management and three important socio-economic activities by generating relevant information in a framework of development that 1) involves the adaptation stakeholders at every step, 2) harmonizes with actions by the Quebec government in adaptation, and 3) is consistent with the respective missions of individuals, mechanisms and organizations already in place to advance adaptation. Ouranos must provide dynamic coordination, optimal integration, relevant valuing and effective management.	**Six specific objectives** ***- Built environment (Northern Quebec):*** Contribute to reducing vulnerability to CC by integrating ACC in the maintenance and development policies of the Nunavik environment ***- Built environment (Southern Quebec):*** Contribute to reducing vulnerability to CC by facilitating adaptation of the built environment by developing tools enabling municipalities to better implement an adaptation plan ***- Water management***: Contribute to reducing vulnerability to CC by launching adaptation on target problems by providing information and specialized tools to government water managers and drainage basin organizations. ***- Forestry***: Promote taking CC into account in implementing adaptation strategies advocated by the forest manager, the MRNF, to ensure that the resulting socio-economic benefits are maintained in future while following the principle of sustainable development. ***- Agriculture***: Contribute to reducing vulnerability to CC by relying on existing mechanisms and organizations to advance adaptation by the Quebec agricultural sector through the development and transfer of information tools on climate conditions and their trends, which will foster better management of agro-climatic risks in supporting crop management, plant health and the design of hydro-agricultural structures. ***-Tourism***: Reduce vulnerability to CC by promoting adaptation to CC of the different channels of tourism and recreation while maximizing opportunities to develop products by identifying achievable strategies for sustainable operations of their activities.
Nature of intervention		- Conditional grants to research teams to fund the production of knowledge on ACC. - Partnership and collaborative mode of governance to integrate potential knowledge users upstream
Implementation	**Inputs**	- Budget envelope available for RAC-Québec provided by Natural Resources Canada (NRCan) - Human, informational and material resources dedicated specifically to RAC-Québec by Ouranos and its partners
	Process	- Subsidize research - Work with users to target needs - Identify specialists on the subject and promote synergy between them - Validate the relevance of developing and supporting the project with a program committee - Support the development of detailed project proposals - Have the scientific quality of proposals assessed - Set up a project steering committee - Promote projects and results in different frameworks and forums (conference, workshop, seminar, meeting of the program committee, symposium, etc.)
	Outputs	- Tangible deliverables (funds distributed, teams funded knowledge transfer documents produced and distributed) - Intangible deliverables (barriers eliminated to the transfer and use of knowledge produced, involvement of ACC stakeholders in RAC-Québec activities, awareness of stakeholders about ACC, etc.
Outcomes		- **Researchers** are active on the ACC problem, developing expertise in this field - Relevant **knowledge/tools** on CC and ACC measures are **generated** - **Knowledge/tools** on CC and ACC measures are **transferred** to key decision-makers and **used** by them in making their ACC decisions - **ACC measures** are adopted by key decision makers - **Adaptive capacity** of key systems for the built environment, water management, forestry, agriculture, tourism and recreation is improved - **Vulnerability to CC** for the built environment, water management, forestry, agriculture, tourism and recreation is reduced - The **collective well-being** is preserved or improved

In parallel, the Ouranos Consortium, created in 2001, contributes to developing knowledge and information required to enable its members and their constituents to adapt to climate change.

Even if it is bound to grow in importance, the ACC field is potentially in competition with other challenges in a context of limited resources. The creation of a centralized structure such as the Regional Adaptation Collaborative and its different regional components thus responded to a need to back up adaptation stakeholders and centralize the information to highlight (Ouranos, 2009, p. 4). The goal was above all to stimulate two-way communication between the information producers and the decision makers who consume this information. This aspect constitutes the rationale of RAC-Québec (Bourque, March 1, 2011).

From an economic point of view, RAC-Québec intervention is also understandable in terms of market failure. Information (in this case, knowledge about CC) is a non-rival good (i.e., a good whose use by one person does not prevent its use by others). The free market can produce non-rival goods, but only if it can exclude those who do not pay for their use. Although mechanisms can be imagined to exclude certain persons from using information (for example, charge a subscription fee to consult certain journals that disseminate research findings), it could not be considered as a completely exclusive good. The free market will therefore lack sufficient incentive to produce the information at optimal levels.

Furthermore, because information on CC is collective in nature, it seems desirable to distribute it as widely as possible. Since information is a non-rival good, it should be distributed at a minimal price to society as a whole. This means that to be able to make a profit from this information, its cost should be equivalent to zero (marginal cost). However, the market is unable to produce a good at a zero cost, since research activity entails costs that must be paid one way or another. Since no one would be prepared to pay these costs (except perhaps hydroelectricity producers such as Hydro-Québec and BC Hydro, which can allocate resources to fund exclusive research on CC impacts on hydroelectricity production capacity), public funding is necessary, hence the justification for government intervention.

2.2 Targets, objectives and nature of the intervention

The **targets** are unsatisfactory situations or problems that a program seeks to change. For the evaluation, the targets are dependent variables that are influenced by actions taken under the program. Three categories of target are generally distinguished: direct targets (short term), intermediate targets (medium term) and ultimate targets (longer term) (Marceau, Otis and Simard, 1992).
The **objectives** express the expected result, or the desired state of the targets after the program intervention. In the evaluation, the question of whether objectives were achieved assumes that the actual effects of the program (and sometimes the outputs) can be compared to a clear and precise reference point: the quantified objectives, i.e., the value of the target variables after the intervention (Marceau, Otis and Simard, 1992).
The **nature of the intervention** refers to the tools chosen by the program designers to act upon the program targets (Marceau, Otis and Simard, 1992).

The goal of RAC-Québec is to contribute to reducing CC vulnerability in the sectors of the built environment in Northern and Southern Québec, water management and three important socio-economic activities (forestry, agriculture and tourism) by generating

relevant information in a development framework that 1) involves the adaptation stakeholders at every step, 2) harmonizes with the adaptation actions of the Québec government, and 3) is consistent with the respective missions of people, mechanisms and organizations already in place to advance adaptation. Specific objectives are also associated with each of these six activity sectors (these objectives for forestry and the built environment in Southern Québec are described in Chapter 4). In the pursuit of these goals, Ouranos must provide dynamic coordination, optimal integration, relevant use and effective management (Ouranos, 2009, p. 2).

In light of these objectives, certain targets or levers that require action (direct or indirect) can be inferred. RAC-Québec actions are geared toward creating capacities in adaptation stakeholders in a way that fosters the emergence of leadership cores in ACC, leading to the implementation of adaptation measures. This creation of capabilities depends on the award of conditional grants to fund scientific research projects (nature of the intervention) aimed at producing knowledge about CC or developing tools to reduce a system's vulnerability by improving its adaptive capacity to CC (direct targets).

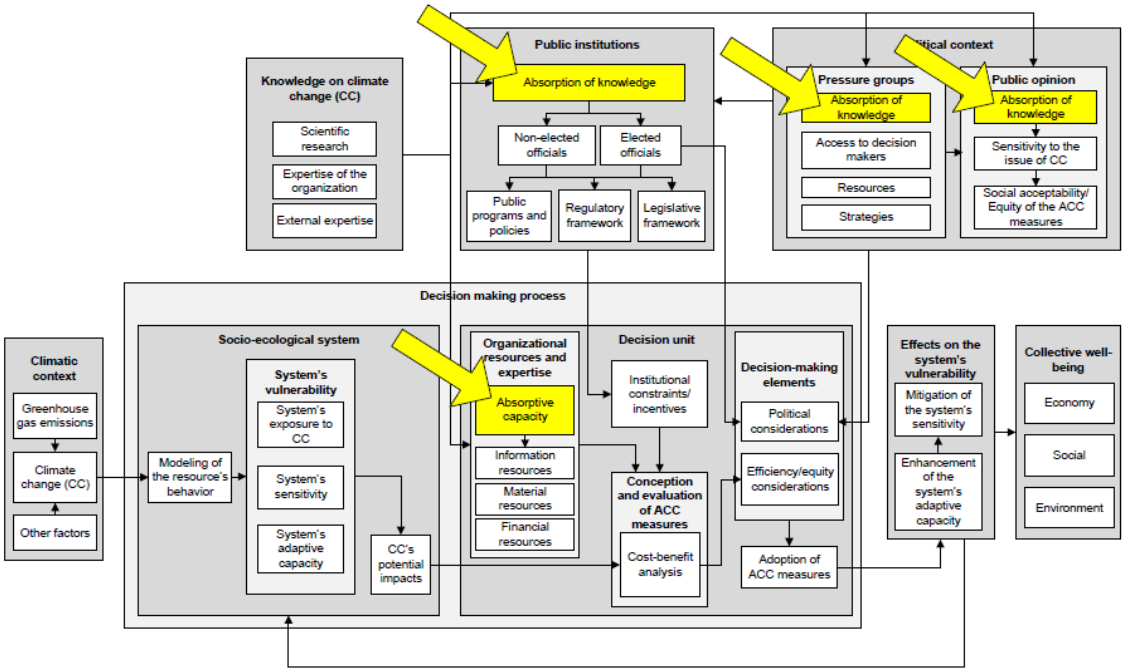
Capacity building also requires a partnership and collaborative governance mode by RAC-Québec in a way that includes potential knowledge users farther upstream to clearly define their information needs and maximize the probability that the results of funded research will be used. We will return to this idea in Section 2.3.

The knowledge and tools should then be transferred to their potential users and used by them (intermediate target #1) to implement adaptation measures (intermediate target #2) that will act upon the adaptive capacity and vulnerability to CC of the targeted systems (ultimate targets).

Ultimately, it is the collective well-being that will be influenced as CC consequences are reduced by better adaptation of the system and a reduction in its vulnerability.

Figure 3 presents an overlapping of the ACC problem and the intervention in the RAC-Québec framework. It lets us visualize which variables and factors the intervention seeks to influence. It shows that the knowledge and tools produced under RAC-Québec mainly furnish "informational resources" to stakeholders involved in the decision-making process. This information made available concerns climate variability, biophysical and socio-economic processes, and evaluation methods. However, decision makers are not the only recipients of research products. They can also be absorbed by institutional stakeholders (elected and non-elected officials), members of pressure groups and the general public.

FIGURE 3: PROBLEM MODEL OF ADAPTATION TO CLIMATE CHANGE WITH THE INTERVENTION OF RAC-QUÉBEC



2.3 Inputs, production activities and outputs

The **inputs** are the principal resources (human, financial, etc.) invested to carry out the program actions (Marceau, Otis and Simard, 1992).
The **production activities** are the principal processes, projects and activities accomplished through the use and transformation of different resources invested in the program (Marceau, Otis and Simard, 1992).
The **outputs** are the goods and services produced by the program's production activities and delivered to customers (Marceau, Otis and Simard, 1992).

With the budget envelope made available by Natural Resources Canada and the resources mobilized by Ouranos and its partners (inputs), RAC-Québec was launched. The launch consisted of forming specific expert committees for each adaptation issue in order to set directions and priorities for selecting activities to undertake and partners to fund (production activities and outputs). Meetings and workshops were also held with researchers and specialists to propose ideas for projects to develop. The next step in implementation consisted of managing the intervention, coordination and scientific and technical monitoring of partner activities (production activities).

At the level of outputs, the actions of RAC- Québec contributed to the production of tangible and intangible deliverables. With regard to tangible deliverables, the activities for which Ouranos partners received funding produced knowledge and tools that were next used to produce knowledge transfer documents and activities.

The dimension of knowledge transfer lies at the heart of Ouranos activity within the RAC-Québec framework, taking the form of intangible outputs. This second class of outputs

represents the results of the collaborative functioning of activities, awareness and mobilization of key decision makers in ACC, and the involvement of potential users of the generated knowledge at all steps of the RAC- Québec scientific effort (two-way knowledge transfer). Inspired by the Decision-making Continuum of Natural Resources Canada (Ouranos, 2009, p.12), this operations mode leads to deliverables that are halfway between the outputs and the effects. These intangible deliverables are perceived as being able to facilitate knowledge transfer in order to advance adaptation. They mainly consist of efforts to i) build awareness to change the perception of climate risks and uncertainties, ii) improve understanding of the CC problem in relation to other objectives of decision makers in order to facilitate integration of the adaptation and iii) encourage stakeholders to insert adaptation within their manoeuvring room.

2.4 Effects sought by RAC-Québec

The **effects** represent the state of the target situation following the program actions. The evaluation of program effects (expected or unexpected) of the program aims to confirm if its actions changed or corrected the targets (unsatisfactory situations or problems) compared to the situation prevailing before the program was implemented (Marceau, Otis and Simard, 1992).

The production of outputs (tangible and intangible) from RAC-Québec should lead to effects that will be associated with the previously identified targets. First, the funds distributed will stimulate research on the ACC problem, thus developing expertise in this field. Next, this research will produce knowledge and tools on CC and ACC measures. If the knowledge and tools is transferred to key decision makers in ACC, the latter will be better equipped to make informed decisions on the importance of taking ACC action and on the best measures to develop and implement. The adoption of ACC measures should improve the adaptive capacity and reduce the vulnerability of key systems for the built environment, water management, forestry, agriculture, tourism and recreation. Ultimately, the collective well-being will be preserved or improved. However, the order of these effects is not necessarily sequential. For example, one could observe an improvement in a system's adaptive capacity without necessarily having to implement an adaptation measure.

2.5 Conclusion

Overlaying the problem model and the logic model makes it possible to sketch a complete theory of the intervention and leads to the identification of the entire zone of effects around which to build the indicators. In the previous chapter, we saw that the indicators of effects in ACC planning should revolve around the vulnerability assessment of the social and ecological system, the assessment of adaptation options and solutions, the decision to adopt an ACC measure, the effects of the ACC measure on the system's vulnerability and, finally, the effects in terms of collective well-being.

For its part, RAC-Québec seeks to act upon this problem through participation, awareness building, the development of strategic partnerships and the creation of capacities among adaptation stakeholders, capacities in terms of knowledge and tools to make the right adaptation decisions and move ACC forward. To profit from the research findings made available to them, the stakeholders must receive them and use them. The dimension of knowledge transfer and use is thus added to the five components presented in Chapter 1.

6) Knowledge transfer and use

- Who are the potential users of knowledge? What knowledge do they need? To what extent are these needs considered in planning research projects?

- To what extent is the produced scientific knowledge transferred to potential recipients?

- To what extent is this knowledge used by its recipients?

- What factors facilitate and constrain the transfer and use of knowledge?

This sixth dimension of the reference tool is fully compatible with the Decision-making Continuum of National Resources Canada. The idea behind this diagram is to illustrate, within a continuum, the progress of adaptation stakeholders towards the implementation of adaptation strategies. The stakeholders of a system can move through different stages (lack of awareness, general awareness, targeted mobilization, targeted awareness-building, deep analysis, decision point) before taking ACC measures. All along the continuum, knowledge of the system and CC play a paramount role in these awareness and mobilization efforts.

The stages of the Decision-making Continuum in adaptation describe the state of mobilization and awareness within a system. Our frame of reference rounds out this continuum by considering, in the evaluation, the question of the influence of scientific research on the decision makers. This influence is possible only after a transfer process in which the knowledge produced has reached the right people, led to changes in their knowledge and frames of references, and influenced the decision making.

CHAPTER 3
ELEMENTS OF AN EVALUATION FRAME OF REFERENCE FOR RAC-QUÉBEC

As with any emerging area, ACC is far from reaching maturity (Magnan, 2009). Researchers have identified a number of shortcomings in adaptation, such as inadequate planning for known climate risks (Repetto, 2008). The prevalence of such "adaptation deficits" (Burton, 2004, 2005; Burton and May, 2004) makes it all the more imperative to evaluate adaptation processes and their results in order to ensure effectiveness, efficiency and equity in adaptation planning and in the implementation of identified actions (Preston, Westaway and Yuen, 2011).

Although progress has been slow, the emergence of adaptation evaluation cannot be denied. One factor adding complexity is that existing evaluation frameworks often place the emphasis on different and varied aspects of planning, making it difficult to identify an appropriate planning process. This lack of consensus illustrates that a systematic approach to monitoring and evaluation of ACC has not yet emerged. It is also symptomatic of a limited capacity to carry out evaluations and incorporate them into adaptation policies. Consequently, while adaptation is examined critically on occasion, the evaluation of ACC is far from being an institutionalized practice (Preston, Westaway and Yuen, 2011).

We believe, however, that the concepts brought out and components of effects identified in the problem and logic models may prove useful in giving a certain meaning to the many ACC indicators found in the literature. Following a discussion on evaluating ACC, this chapter presents a structure for classifying adaptation indicators based on the components of effects identified earlier. We will then present certain indicators taken from existing evaluation frameworks that will help us adequately grasp the dimension that demands a measure. For certain components, our review of the relevant literature did not yield satisfactory indicators. We will then propose, on a trial basis and temporarily, a series of indicators to remedy this situation.

3.1 Evaluation of adaptation

The evaluation of adaptation policies is an emerging field that is making some progress. A number of countries (such as Finland, Great Britain, Germany), organizations and international funds (like UNDP, the Global environment facility, the Adaptation Fund) have defined frameworks and indicators for evaluating ACC. However, until now, very few of these frameworks and indicators have been used systematically[3].

3.1.1 Process indicators and results indicators

The procedural aspect of adaptation is very well presented in the ACC monitoring and evaluation (M&E) frameworks. Swart et al. (2009) believe that the development of these frameworks must concentrate on determining the process indicators. These indicators define, and if possible, quantify the factual and behavioral changes necessary to reach the

[3] Finland and the United Kingdom are examples of countries that evaluated their ACC policy.

ultimate adaptation targets. They also make it possible to monitor the progress made in implementing adaptation measures.

These indicators also make reference to the institutional conditions required for successful adaptation, such as the existence of a horizontal coordination entity, the adoption of a national implementation program, a funding program for adaptation, etc. (Harley et al., 2008). M&E frameworks thus consider the capacity of institutions, governments and civil society to understand CC and integrate adaptation into decision making. The purpose of their indicators is to verify the adequacy of political and institutional mechanisms in promoting CC knowledge and actions (Anderson, 2011). An example is this indicator from the EPA Network of Environmental Protection Agencies: "Existing national adaptation plans and/or strategies, or those in preparation." This indicator aims to verify the presence of a national adaptation strategy, or at least whether such a strategy is being prepared. Process indicators contrast with outcome-based indicators which measure the effectiveness of adaptation policies and activities in general.

3.1.2 Vulnerability indicators

According to Harley et al. (2008), a successful adaptation calls for implementing measures for adapting to CC and avoiding negative impacts, insofar as avoidance costs are less than the resulting benefits. The adaptation measures must ultimately shift human, economic and ecological systems from a state of climate vulnerability to one of climate resilience. The indicators must therefore capture changes in sensitivity to potential dangers and changes in adaptation capacity to reduce the vulnerability and enhance resilience (Harley et al., 2008).

In linking a process of climate risk management to the vulnerability of certain marginalized groups and to results in terms of development that they know, an M&E framework for ACC would assess to what extent the adaptation needs of these populations are considered, the degree to which climate risk was integrated in the development and if sufficient precautions were taken to avoid a poor adaptation (Anderson, 2011; Brooks et al., 2011).

The vulnerability indicators must therefore give decision makers useful information to identify priority needs and thus justify certain actions.

Given the wide range of potential evaluation needs, it is unlikely that a single set of vulnerability indicators could apply in all contexts. An agreement among stakeholders on desired adaptation objectives is often proposed before embarking on devising indicators (Harley et al., 2008), which greatly compromises any attempt at developing a somewhat more generic M&E framework.

3.2 Proposal for adaptation indicators

There are numerous frameworks for evaluating ACC. A non-exhaustive review of documents produced by national and international organizations (UNDP, UNFCCC, UKCIP, etc.) and the scientific literature identified no less than 22 M&E frameworks and 336 indicators. Table 1 presents an overview of areas covered by the indicators found in these frameworks. These indicators may also be consulted in Appendix 1.

Given this large number of indicators, it is no small task to obtain a consensus on a limited number of indicators. To propose a reasonable number, we worked to identify indicators that

were more generic than specific. In this effort, the concepts that emerged and components of effects identified in the problem and logic models proved useful. Indeed, the generic decision-making model developed in our modeling of the problem made it possible to organize this mass of indicators and then identify a certain number that we felt adequately captured the phenomenon described. Where necessary, other complementary indicators were proposed. For each component of the models, the indicator proposal will be preceded by some descriptive details on the listed indicators.

3.2.1 Vulnerability assessment of the social and ecological system

The first component emerging from the problem model represents the action of assessing the vulnerability of the social and ecological system. As already noted, vulnerability measures a system's susceptibility to feel the negative effects of CC, and is a function of its sensitivity to CC and its adaptive capacity.

Obviously, the factors that make a system vulnerable or adaptable are sector-dependent. Indicators of the vulnerability or adaptive capacity of a system must therefore be identified in terms of specific factors for each area of intervention (forestry, built environment, agriculture, tourism, water resources, etc.). Once again, our intention is not to deny the contribution of other existing models in sectors confronting CC that feature certain indicators associated with the behavior of a resource faced with climate disturbances. On the contrary, the products of these specific models are of great interest since they reveal the vulnerabilities of a particular sector and hence the specific effects to achieve. One would then only have to use the products of these models in order to make specific indicators for our model. However, our intention was not to review these models but rather to focus the analysis on the decision-making process in order to identify the generic components of the problem.

From the perspective of the adaptation planning process, this vulnerability assessment activity has a very general objective: improve knowledge on CC impacts on the system in question so that needs for CC adaptation can be estimated and appropriate solutions identified. Generic indicators could also be envisaged.

Table 1 shows that several frameworks took into account the vulnerability assessment component. Certain indicators stood out in this regard (Table 2).

TABLE 1: OVERVIEW OF EVALUATION COMPONENTS CONTAINED IN THE EVALUATION FRAMEWORKS ANALYZED

Model components	Variables	Frameworks/authors	Indicators (n)
Vulnerability assessment of the socio-ecological system	Potential effects of CC	Brooks et al. (2011)	1
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	1
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	1
		EEA Workshop (cited in Swart et al. (2009))	2
		Harley et al. (2008)	2
		National Indicator 188 (UKCIP, 2008)	1
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	1
		UN/ISDR (2008)	2
		Lamhauge, Lanzi and Agrawala (2011)	3
		Sanahuja (2011)	3
		UNFCCC Secretariat (2010)	7
		Twiggs (2007) cited in Villanueva (2011)	2
Assessment of adaptation options and solutions	Design and assessment of ACC measures	EEA Workshop (cited in Swart et al. (2009))	3
		Harley et al. (2008)	3
		National Indicator 188 (UKCIP, 2008)	1
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	10
		UN/ISDR (2008)	1
		Lamhauge, Lanzi and Agrawala (2011)	8
		Sanahuja (2011)	1
		UNDP (2007)	3
		UNFCCC Secretariat (2010)	12
		Spearman and McGray (2011)	5
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	3
		UNDP and GEF (2007) cited in Villanueva (2011)	2
		Twiggs (2007) cited in Villanueva (2011)	1
	Cost-benefits assessment	Brooks et al. (2011)	1
		Lamhauge, Lanzi and Agrawala (2011)	1
Decision to adopt an ACC measure	Adoption of ACC	Brooks et al. (2011)	2
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	3
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	6
		National Indicator 188 (UKCIP, 2008)	1
		UN/ISDR (2008)	2
		Lamhauge, Lanzi and Agrawala (2011)	2
		Sanahuja (2011)	3
		UNDP (2007)	1
		UNFCCC Secretariat (2010)	7
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	7
		UNDP and GEF (2007) cited in Villanueva (2011)	3

Model components	Variables	Frameworks/authors	Indicators (n)
Determinants in the adaptation process	Public programs and policies	Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	1
		Harley et al. (2008)	1
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	1
		UN/ISDR (2008)	3
		Iwanciw and Zalles (2010) cited in Spearman and McGray (2011)	1
	Regulatory framework, legal framework	Brooks et al. (2011)	1
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	1
		UN/ISDR (2008)	1
		Spearman and McGray (2011)	1
	Political context of the action	The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	1
		Lamhauge, Lanzi and Agrawala (2011)	1
		Sanahuja (2011)	1
		UNFCCC Secretariat (2010)	2
		UNDP and GEF (2007) cited in Villanueva (2011)	1
	Sensitivity to the CC question	Harley et al. (2008)	1
	The organizational resources and expertise	Lamhauge, Lanzi and Agrawala (2011)	2
		Twiggs (2007) cited in Villanueva (2011)	1
	Knowledge about CC	EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	1
		Harley et al. (2008)	1
		UN/ISDR (2008)	2
		Lamhauge, Lanzi and Agrawala (2011)	10
		Sanahuja (2011)	1
		Spearman and McGray (2011)	1
		Twiggs (2007) cited in Villanueva (2011)	2
	Capacity for absorbing knowledge	Brooks et al. (2011)	2
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	4
		Harley et al. (2008)	2
		Lamhauge, Lanzi and Agrawala (2011)	5
		UNDP (2007)	3
		UNFCCC Secretariat (2010)	1
Effects of the ACC measure on the system's vulnerability	Improved capacity of the system to adapt	Brooks et al. (2011)	1
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	3
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	2
		Finnish National Adaptation Strategy cited in Swart et al. (2009)	1
		Government Strategy Report 2008 cited in Swart et al. (2009)	3
		EEA Workshop (cited in Swart et al. (2009))	1
		Harley et al. (2008)	6

Model components	Variables	Frameworks/authors	Indicators (n)
		UN/ISDR (2008)	10
		Lamhauge, Lanzi and Agrawala (2011)	13
		Sanahuja (2011)	7
		UNDP (2007)	9
		UNFCCC Secretariat (2010)	3
		Spearman and McGray (2011)	3
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	2
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	1
		UNDP and GEF (2007) cited in Villanueva (2011)	4
	Mitigation of the system's sensitivity to CC	Brooks et al. (2011)	3
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	2
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	5
		Finnish National Adaptation Strategy cited in Swart et al. (2009)	5
		Government Strategy Report 2008 cited in Swart et al. (2009)	1
		Lamhauge, Lanzi and Agrawala (2011)	5
		Sanahuja (2011)	4
		UNDP (2007)	3
		UK Adaptation Sub-Committee (2011)	19
		Spearman and McGray (2011)	2
		Moser (2007) cited in Spearman and McGray (2011)	5
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	5
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	6
		UNDP and GEF (2007) cited in Villanueva (2011)	7
		Natural England (2010)	15
Effects in terms of collective well-being	Collective well-being	Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	1
		Lamhauge, Lanzi and Agrawala (2011)	1
		Sanahuja (2011)	1
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	4

TABLE 2: EXAMPLES OF INDICATORS TO ASSESS SYSTEM VULNERABILITY

Sources	Indicators
Brooks et al. (2011)	Mechanisms for targeting the climate vulnerable (e.g. for carrying out climate risk assessment and vulnerability assessment and using the results of such assessments to inform development policy and practice).
Pilot Program for Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Coverage of climate risk analysis and vulnerability assessments based on current scientific evidence
The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	No. and type of projects that conduct and update risk and vulnerability assessments
EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	Key climatic vulnerabilities. This might be based, for example, on risk assessments by region and sector.
UNFCCC Secretariat (2010)	Research ongoing and adequate on the impacts of, or adaptation to, climate change
	Impacts well known, within the limits of uncertainty

The first four indicators provide information on activities under way without looking at the effects in terms of improved knowledge on the risks, sensitivity, and capacity for adaptation. It is this knowledge that is critical for correctly estimating the potential impacts of CC and hence the adaptation needs.

The second UNFCC indicator and that of the EPA Network of Environmental Protection Agencies are more interesting, since they involve obtaining a certain knowledge on the vulnerabilities of systems and the impacts of CC. Very generally, an indicator of ACC planning for this first component would be expressed as follows:

Proposed indicator No. 1 – Level of knowledge among adaptation stakeholders on risks and vulnerabilities and their potential impacts on the system

3.2.2 Assessment of adaptation options and solutions

We saw in Chapter 1 that economic rationality should underpin ACC decisions, i.e., their benefits should exceed their costs. While the consulted frameworks contain several indicators related to the design of adaptation measures (e.g., involving the stakeholders in planning measures, possible partnerships, objectives of the measure, its implementation plan, etc.), we identified only one indicator that referred to the idea of pitting a measure's benefits against its costs in choosing and designing an ACC measure (see Table 3).

TABLE 3: INDICATOR TO ASSESS ADAPTATION OPTIONS AND SOLUTIONS

Sources	Indicators
Brooks et al. (2011)	Benefit/ cost ratios of adaptation options identified/ implemented (based on ratio of value of assets and productivity made less vulnerable to adaptation expenditure).

In addition, note that the desired effect at this stage of the planning process is the possession of information required to make the best decision from a standpoint of economic efficiency. An indicator for this second component might take this form:

Proposed indicator No. 2 – Level of knowledge among adaptation stakeholders regarding 1) costs inflicted on the economic, social and environmental system if no ACC measure is implemented, and their distribution over time and probability of occurrence; 2) costs and benefits of the planned adaptation measure or net benefits (costs of planning, preparation, implementation and monitoring of measures); 3) residual costs of CC and cost-sharing.

3.2.3 Decision to adopt an ACC measure

Table 4 presents a sample of indicators from consulted M&E frameworks concerning the adoption of ACC measures. In Chapter 1, we saw that adaptation measures can take various forms. As with the first component (assessment of the system's vulnerability), the nature of the adaptation measure whose implementation must be verified will have an aspect unique to its context. For this reason, some indicators refer to the adoption of a specific ACC measure, as is the case for the first three indicators below. However, the next two are more general in scope.

TABLE 4: EXAMPLES OF INDICATORS FOR THE DECISION TO ADOPT AN ACC MEASURE

Sources	Indicators
The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	Development of early warning systems
UN/ISDR (2008)	Social development policies and plans are being implemented to reduce the vulnerability of populations most at risk.
Lamhauge, Lanzi and Agrawala (2011)	Number and type of disaster risk reduction instruments e.g., insurance instruments promoted
UNDP (2007)	Number of risk-reducing practices/measures implemented to support adaptation of livelihoods and/or resource management
UNFCCC Secretariat (2010)	Adaptation measures identified and their implementation launched

Since our problem model is a generic decision-making model, the simplest indicator that can be imagined for this component must make it possible to tell us whether or not the planned adaptation measure was, or will be, implemented like the UNFCCC indicator. The suggested indicator would therefore take the following form:

Proposed indicator No. 3 – The decision made on the ACC measure to adopt.

It is understood that the decision we are looking at may or may not be strategic in nature and the decision to do nothing is also a possibility. Furthermore, this indicator does not concern the adequacy of the measure (this question will be resolved through an evaluation of its effects on the system's vulnerability) but whether or not a decision was made. It is assumed that, at this point, the measures examined are good ones and appear desirable.

◆ Determinants of the adaptation process

At the beginning of this chapter, we saw that many indicators of adaptation planning aim to measure the key components of the ACC process (process indicators). These components are related to factual and behavioral changes as well as institutional conditions required for a successful adaptation. Some M&E frameworks contain indicators involving these components (Table 5).

TABLE 5: EXAMPLES OF PROCESS INDICATORS

Sources	Indicators
Lamhauge, Lanzi and Agrawala (2011)	Adaptation in government staff training curricula
Harley et al. (2008)	Is a national framework in place and what spatial scale does it cover?
	The public's perceived attribution of the source and the significance of exposure to its local manifestations
UN/ISDR (2008)	National institutional and legal frameworks for disaster risk reduction exist with decentralized responsibilities and capacities at all levels
The Adaptation Fund Results Framework for Action (2010) cited in Brooks et al. (2011)	Number of news outlets in the local press and media that have covered the topic

Such indicators are certainly relevant, but we believe they must be interpreted differently. In Chapter 1, we saw that a decision maker's choice whether or not to go forward with an ACC measure may be influenced by certain determinants (the resources and expertise of the decision maker's organization, the existence of public programs and policies providing incentives to adopt measures, favorable regulatory and legislative frameworks, social and political pressures, available knowledge on CC). In light of our model of the problem, indicators such as those presented in Table 5 should not be interpreted solely as indicators of adaptive capacity, but as determinants of whether or not to adopt an ACC measure. In other words, besides favoring adaptation (even if they don't guarantee the implementation

of measures), such factors may also contribute to attaining the operational objective sought at this stage of the adaptation process (the decision to go forward with a measure). For example, the first indicator (Lamhauge, Lanzi and Agrawala, 2011) could indeed reveal the existence of adaptation expertise within a government organization. But by pairing this information with the final decision of the adaptation process, such an indicator offers an element for interpreting the success or failure of the adaptation process.

We will therefore not propose indicators for the determinants of the adaptation process. However, these determinants should nonetheless be subject to control in any evaluation of an ACC planning process. It will then be up to the evaluator to ensure this control through the methodological procedures that he uses for the evaluation.

◆ Knowledge about CC

Among determinants of the adaptation planning process, knowledge about CC merits further development. The development and use of this knowledge has a great influence on the problem by informing decision makers on the potential impacts of CC, adaptation options available, their benefits and costs, the effectiveness of the ACC measures implemented, etc. They also contribute to informing stakeholders with public institutions and the general public on CC matters.

In Chapter 2, we showed that RAC-Québec was acting on the adaptation problem by promoting, through interactions and loops between the research community and knowledge-users, scientific production on CC and the development of tools for reducing a system's vulnerability or improving its adaptive capacity. However, before influencing the problem in a pronounced manner, knowledge produced must reach its intended recipients and be used by them in the ACC planning process. While the availability of CC knowledge is a determinant in the decision making, the question of knowledge transfer and use remains no less an element to consider, given that RAC-Québec is attempting to act on this determinant.

The aspect of knowledge transfer and use is presented in some M&E frameworks analyzed (Table 6). The first eight indicators presented below deal with dimensions of the transfer process – for example, the number of stakeholders participating in knowledge sharing/training (Lamhauge, Lanzi and Agrawala, 2011) – or effects in terms of use – for example, the identification and incorporation of the most effective adaptive responses in strategies (UNFCCC Secretariat, 2010). The last three indicators represent determinants likely to promote use (e.g., ability to manage information and identify credible knowledge, setting up systems to monitor and disseminate information, and engagement in knowledge networks).

TABLE 6: EXAMPLES OF INDICATORS OF KNOWLEDGE ABSORPTION AND USE

Sources	Indicators
UN/ISDR (2008)	National and local risk assessments based on hazard data and vulnerability information are available and include risk assessments for key sectors.
Lamhauge, Lanzi	Number of stakeholders participating in knowledge sharing/training

Sources	Indicators
and Agrawala (2011)	Extent of use and outreach of education material/training facilities
	No. of stakeholders requesting and accessing knowledge products
	Extent of research dissemination
UNDP (2007)	Communicate climate change risks, disseminate information, or make decisions based on high quality information), as relevant
	Number of relevant networks or communities with which lessons learned are disseminated
UNFCCC Secretariat (2010)	Most effective adaptive responses identified and incorporated in council strategies, plans
Harley et al. (2008)	The ability of decision makers to manage information, the processes by which they determine which information is credible and the credibility of the decision makers themselves
UN/ISDR (2008)	Systems are in place to monitor, archive and disseminate data on key hazards and vulnerabilities.
Lamhauge, Lanzi and Agrawala (2011)	Number of organizations engaging with knowledge network

RAC-Québec must therefore demonstrate that the knowledge and tools it has helped to produce were used by their potential recipients and influenced their actions. In general, the indicator to choose here could be expressed as follows:

Proposed indicator No. 4 – The extent of use of knowledge and tools produced in the RAC-Québec framework

Knowledge use can be conceived as a succession of plateaus to reach, each representing a level of effect in terms of use (Landry, Lamari and Amara, 2003; Landry, Amara and Lamari, 2011; Knott and Wildavsky, 1980). These different standards can be used to propose a scale to describe the level of use. In a project like that of RAC-Québec, the use may materialize gradually over a long period and maybe even several years.

- **Reception**: The potential recipient receives the knowledge or tools transferred (transfer products). At this stage, the recipient is not considered to have been sensitized, but rather has physically received the transfer product.
- **Reflection**: The recipient has read and understood the transfer products. He is not yet deemed to be sensitized, but now has an altered level of knowledge.
- **Change in the frame of reference:** Consultation of the transfer products has led the recipient to see a problem or object differently. His awareness on this issue has been increased.
- **Efforts to use:** The recipient makes efforts to justify decisions or positions taken by using the transfer products.
- **Adoption**: The transfer products used have directly influenced the decision made (adoption of an adaptation measure).

The next level, the **implementation** (the decision influenced by the transfer products is implemented, merging with the decision to adopt the ACC measure (seen in Section 2.3). The final level, the **influence** (the decision influenced by the transfer products has tangible effects on the intended beneficiaries) will be covered in the next section by looking at the effects of the measure on the system's vulnerability.

3.2.4 Effects of the ACC measure on the system's vulnerability

The adaptation measures aim to reduce the vulnerability of social and ecological systems to CC. As with the assessment of the system's vulnerability, the context of the intervention plays a paramount role. The desired effects will differ depending on the nature of the ACC measure, the vulnerabilities to be reduced and the elements of adaptive capacity that we wish to strengthen.

Table 7 presents a sample of indicators for measuring effects. The first four indicators clearly illustrate the idea described in the above paragraph. These indicators refer to effects that the designers of these frameworks would doubtless consider important to attain based on vulnerabilities of greatest concern depending on their context. An example is the exposure of infrastructure to flooding due to extreme weather conditions (UK Adaptation Sub-Committee, 2011).

TABLE 7: EXAMPLES OF INDICATORS TO MEASURE SYSTEM VULNERABILITY

Sources	Indicators
Finnish National Adaptation Strategy cited in Swart et al. (2009)	Availability of real-time hydrological information
Harley et al. (2008)	The stock of human capital, including education and personal security
UK Adaptation Sub-Committee (2011)	Insurance claims for weather related causes (flooding, storms, subsidence)
	Number of properties flooded
Spearman and McGray (2011)	Change in degree of exposure to climate risks and threats
	Evidence of changed quality of climate-sensitive natural resource base

Since systems are not all vulnerable in the same way and do not have the same adaptation needs, it is difficult to identify a set of indicators with universal application. At the very least, the evaluation exercise must, as with the last two indicators presented above (Spearman and McGray, 2011), determine whether a change in the degree of exposure to climate risk is observable after adopting an ACC measure. Insofar as is possible, the evaluation must also say if this change can be attributed to this measure. It is therefore necessary, when launching the ACC planning process, to reflect on what the state of the system would be after it has adapted to the vulnerabilities it faces. This exercise will lead to the identification of specific indicators that will point to a general indicator:

Proposed indicator No. 5 – Change observed in the state of vulnerability of the system due to the adaptation measure adopted and compared to the overall change in vulnerability owing to other factors

3.2.5 Effects on collective well-being

According to Brooks et al. (2011), an M&E framework for adaptation must include components of collective well-being by verifying whether the development paths are maintained despite the climate situation. However, Frankel-Reed (2008) believes that the usual indicators of development and environment are not adapted to the ACC field. They do not reflect the nature of the concept, which has more to do with building capacities, adopting behaviors and measures to reduce climate risks with a view to achieving development results. However, here are several indicators that refer to aspects of collective well-being (Table 8).

TABLE 8: EXAMPLES OF INDICATORS IN TERMS OF COLLECTIVE WELL-BEING

Sources	Indicators
Pilot Programme for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	HDI score (country), MDG indicators, % of people classified as poor and food insecure in most affected regions, mortality and economic losses from climate extremes
Lamhauge, Lanzi and Agrawala (2011)	Impact of flood (no. of people affected, inundation depth, duration, value of flood damage)
Sanahuja (2011)	Human security: Displaced populations; Climate change refugees; Changes in migrants and migrant working; Increased Rural – Urban Migration; Increased social unrest over resources
Asian Development Bank (2006) cited in Spearman and McGray (2011)	Number of newly established industrial and commercial enterprises in the project areas increases compared with base year 2006.
	Land values for commercial and industrial purposes in project areas increases by at least 20% over 2005 levels by 2012.
	Urban poverty incidence in the project areas is reduced compared with 2003 incidence of 6.7%
	Direct economic losses from floods and waterlogging are reduced compared with current average losses.

Since our research project is limited to evaluating the process of adaptation planning, we will not propose any indicators here. However, it seems necessary to clarify certain points. In our problem model, we chose to illustrate that vulnerability reduction and improved adaptive capacity do not constitute the final elements in the causal chain. Adaptation actions must be set in a collective context: i) first, to show the influence that ACC can have on different development perspectives (economic, societal, environmental), and next ii) because it is important, in the choice of adaptive measures, to select and implement measures producing more beneficial than adverse effects. Such an examination must be

done by considering all gains and losses for society associated with the adaptation measures.

3.3 Conclusion

The problem and logic models that we developed brought out a generic model for decision making. From this model we were able to propose five indicators around the components of effects that must be considered in evaluating ACC planning in the RAC-Québec context. These indicators represent:

1- The level of knowledge among adaptation stakeholders on risks and vulnerabilities and their potential impacts on the system

2- The level of knowledge of adaptation stakeholders regarding 1) costs inflicted on the economic, social and environmental system if no ACC measure is implemented, and their distribution over time and probability of occurrence; 2) costs and benefits of the planned adaptation measure or its net benefits (costs of planning, preparation, implementation and monitoring of measures); 3) residual costs of CC and sharing of costs

3- The decision made on the ACC measure to adopt

4- The extent of use of knowledge and tools produced in the RAC-Québec framework

5- The change observed in the state of vulnerability of the system due to the adaptation measure adopted, and compared to the overall change in vulnerability owing to other factors.

The proposed indicators concern evaluation of the process of adaptation planning. While we did not propose indicators related to effects on collective well-being, the collective aspect of adaptive actions should not be forgotten, if only to recall that any intervention leads to gains and losses for society as a whole.

While our models (problem and logic) and the indicators associated with them have an undeniable generic component, a specific character can nonetheless be attributed to them. However, this specific aspect is not found in the models (since regardless of the sector, ACC planning can be explained using a decision-making model) but rather in sectoral indicators that give greater detail on certain variables of the model. In the final chapter we will see how our five generic indicators can be applied in two particular sectors, namely forestry and the built environment in Southern Québec.

CHAPTER 4
FRAMES OF REFERENCE FOR SPECIFIC EVALUATIONS

To transpose our generic models and indicators to the sectors of forestry and the built environment in Southern Québec, we started with RAC-Québec's generic logic model and adapted it to the distinctive characteristics of these two sectors. The logic models specific to the forestry and built environment sectors (see Figures 4 and 5) give more detail on the nature of certain sectoral effects expected in ACC. From there, the indicators developed in Chapter 3 were recalled and adapted to reflect the distinctive character of these effects. Our approach in the forestry element will be illustrated first, followed by the built environment in Southern Québec.

4.1 The forestry component of RAC-Québec

Like the general logic model of RAC-Québec described in Chapter 2, the specific model for the forestry sector is based on an analysis of its rationale, intervention targets, objectives pursued, nature of the intervention, implementation plan (input, production activities, outputs) and anticipated effects (see Figure 4).

4.1.1 Logic model

- **Rationale**

The impacts of climate change on forests are far from negligible. According to Bernier and Schoene (2009) and Williamson et al. (2009), they include a diminished snow cover in boreal and temperate forests and earlier snowmelts, longer and more severe forest fire seasons, violent storms, outbreaks of disease and infestations of harmful insects and pests in certain large homogeneous forest ecosystems (due to higher temperatures together with poor forest management).

Climate change also comes with social issues. For example, it can bring about additional risks to the health and security of local populations due to the higher frequency of forest fires (Bernier and Schoene, 2009).

The challenges linked to CC are also of an economic nature. In Canada, CC is liable to impact the economic benefits from the forest products industry (Williamson et al., 2009) and have repercussions on the cost, quality, quantity and accessibility of timber (Lemprière et al., 2008). Furthermore, CC could have negative consequences on revenue from tourism and recreation (for example, large areas of degraded forests reduce the landscape appeal of certain regions). It also may reduce the availability of forest products (such as food, firewood, medicinal herbs) on which aboriginal communities depend.

FIGURE 4: LOGIC MODEL OF THE RAC-QUÉBEC FORESTRY SECTOR

Logic model: Regional Adaptation Collaborative-Québec (RAC- Québec) Forestry

CREXE
CENTRE DE RECHERCHE ET D'EXPERTISE EN ÉVALUATION

Rationale		- Vital economic role of the forest resource for many communities and sizable share of Quebec exports - Understanding of climate/natural disturbances/forest growth interrelationships essential in a context in which climate change (CC) may have a major impact on the forest - Need to better integrate the impacts of CC in forest management to help forests adapt to climate change (ACC), maximize potential positive impacts and reduce vulnerability - Knowledge has advanced on links between the forest and CC, but much remains to be done to apply and generalize the conclusions - Market failure in the production of information (scientific knowledge a non-rival good)
Targets	**Direct**	- Knowledge/tools on CC and ACC measures in the forestry sector
	Interme-diate	- Transfer of knowledge/tools on CC and ACC measures to key decision makers in forestry - Adoption of ACC measures by key decision makers in forestry
	Ultimate	- Vulnerability: Sensitivity of key systems for forestry/Adaptive capacity of key systems for forestry - Collective well-being
Objectives		Promote taking CC into account when implementing adaptation strategies recommended by the forest manager, the MRNFQ, to ensure that the resulting socio-economic benefits are maintained in future while observing the principle of sustainable development.
Nature of intervention		- Conditional grants to research teams to fund the production of information and tools on ACC. - Awareness of CC impacts among all stakeholders in forestry
Implementation	**Inputs**	- Budget envelope available through RAC-Quebec for the forestry component ($1,001,000) - Human, informational and material resources from the partners involved (Ouranos, Chief Forester, Ministère des Ressources naturelles et de la Faune (MRNFQ), Canadian Forestry Service (CFS), Natural Resources Canada (NRCan), UQAM, UQAT, Université Laval, Forest Engineering Research Institute of Canada (FERIC)
	Process	- Promote adaptation to CC by integrating vulnerability assessment and the development of adaptation solutions within the three major pilot projects for developing eco-system based forest management plans now underway involving industry and government (P1) - Establish seed transfer models for black spruce, jack pine, and white spruce to enable stakeholders to re-forest today with tomorrow's climate in mind (P2) - Assess the vulnerability of the industry and forest managers in terms of their sensitivity, exposure and adaptive capacity to enable the sector to better understand where the socio-economic risks lie (P3) - Continue to develop hydro-climatic indicators to allow MRNFQ to better evaluate growth and future composition of the forest and eventually allow the Chief Forester to integrate more information in calculating forest potential (P4) - Share experiences and knowledge to strengthen the capacities of public managers, sensitize stakeholders in the sector, identify success stories and emphasize research and development that is increasingly pertinent for decision making (P5)
	Outputs	- Research teams funded - Funds distributed - Meetings of partners - Knowledge transfer documents produced and distributed - Pilot project conducted
Outcomes		- Relevant **knowledge/tools** on CC and ACC measures are **generated**: Vulnerability assessment and development of adaptation solutions (P1); Transfer models for black spruce, jack pine and white spruce established (P2); Vulnerability of the industry and forest managers assessed based on their sensitivity, exposure and adaptive capacity (P3); development of hydro-climatic indicators (P4); success stories identified (P5). - **Knowledge/tools** on CC and ACC measures are **transferred** to key decision-makers and **used** by them in making their ACC decisions: Assessment of vulnerabilities and development of adaptation solutions integrated in three major pilot projects for developing ecosystem-based forest management plans (P1); Forest sector stakeholders understand better where the socio-economic risks lie (P3); Experiences and knowledge shared (P5); Sector stakeholders made aware (P5); R&D more relevant for decision-making valued (P5) - **ACC measures** are adopted by key decision makers: Reforestation with plants adapted to tomorrow's climate (P2) - **Sensitivity** to CC is reduced in the forest sector: Plants are adapted to tomorrow's climate (P2) - **Adaptive capacity** is improved for key forestry systems: The MRNFQ can better assess growth and future composition of the forest, and the Chief Forester manages to integrate more information for calculating forest potential (P4); capacity of public manages strengthened (P5) - The **collective well-being** is preserved or improved. Communities that depend on harvesting forest resources can continue to do so in a manner that conforms to sustainable development principles.

At the international level, a recent analysis of national reports and national adaptation action plans by the International Union of Forest Research Organizations (IUFRO) reveals that forests are already considered an important component of the ACC response. Most developed and developing countries advocate sustainable forest management as an adaptation measure and the concept is often included in national laws (United Nations Food and Agriculture Organization, 2011).

In Canada, the Canadian Council of Forest Ministers established ACC as a new strategic issue for the sector at a meeting in 2007 (Lemprière et al., 2008). There have also been initiatives to adapt forests to CC. For example, the Forest Communities Program (with a $25 million budget for the period 2009-2012) was launched by Natural Resources Canada to help local communities adapt to CC.

In addition, according to Lemprière et al. (2008), the provincial and territorial governments have developed strategies to deal with CC and supported research on the subject. Regional workshops have been held to explore adaptation options in particular forest contexts and some companies have started to incorporate the CC issue in their forest management plans.

In Québec, the forest resource plays a vital economic role in many communities. It also represents a sizable share of provincial exports (Bourque and Simonet, 2008; Natural Resources Canada, 2007). Given the significance of anticipated CC impacts on the forest and questions in calculating future forest capacity, there is a real need to better understand climate/natural disturbances/forest growth interrelationships in order to better integrate CC impacts in forest management and thus help forests adapt to CC. Although the state of knowledge on links between the forest and CC has advanced in recent years, much remains to be done to apply and generalize the conclusions. This explains the rationale for RAC-Québec (Ouranos, 2009, p.13).

Public intervention can also be justified in terms of market failure on the same grounds as described in the analysis of the rationale of the generic RAC-Québec model (see Chapter 2, Section 2.1), all the more since the Québec government owns the resource and is responsible for calculating forest potential.

Targets, objectives and nature of the intervention

The goal of the RAC-Québec forestry component is to promote taking CC into account when implementing adaptation strategies recommended by the Ministère des Ressources naturelles et de la Faune, which manages the forests, to ensure that its socio-economic benefits are maintained in the future while following the principle of sustainable development (Ouranos, 2009, p.13)

In light of this goal, and considering the generic targets and objectives of RAC-Québec, a program theory for the forestry component can be established in the following manner. By funding research (nature of the intervention) that creates knowledge on CC and ACC measures in forestry (direct target), followed by a knowledge transfer process (intermediate target #1), the RAC-Québec actions are intended to foster the adoption of adaptation measures by key decision makers in the forestry area (intermediate target #2). The adoption of these measures should improve the adaptive capacity (ultimate target #1) and reduce the

vulnerability of forests (ultimate target #2), which will influence collective well-being (ultimate target #3).

- **The implementation plan (inputs, production activities, outputs)**

In terms of inputs, a budgetary envelope of just over $1 million is dedicated to the forest component of RAC-Québec (financial resources). Human, informational and material resources are also invested by each partner in the component: Ouranos, Chief Forester, Ministère des Ressources naturelles et de la Faune (MRNFQ), Canadian Forestry Service (CFS), Natural Resources Canada (NRCan), UQAM, UQAT, Université Laval, Forest Engineering Research Institute of Canada (FERIC).

The production activities of the forestry component are organized around five projects:

1- Promoting adaptation to CC by integrating vulnerability assessment and the development of adaptation solutions in three major pilot projects to develop ecosystem-based forest management plans (Project 1).

2- Establishing seed transfer models for black spruce, jack pine and white spruce to enable stakeholders to re-forest today with tomorrow`s climate in mind (Project 2).

3- Vulnerability assessment of the industry and forest managers based on their sensitivity, exposure and adaptive capacity to help the sector better understand where the socio-economic risks lie (Project 3).

4- Developing hydro-climatic indicators to enable the MRNFQ to better estimate growth and future composition of the forest and eventually to help the Chief Forester integrate more information for calculating forest potential (Project 4).

5- Sharing of experience and knowledge to strengthen the capacities of public managers, sensitize stakeholders in the sector, identify success stories and value research and development that is increasingly relevant to decision making (Project 5).

- **The effects**

Through its five projects, the RAC forestry component aims to have effects on five targets.

The first target involves **knowledge/tools** on CC and ACC measures in the forestry industry. The desired effect is to generate relevant knowledge/tools on CC and ACC measures.

The second target concerns the **transfer and use of knowledge/tools on CC and ACC measures** by key decision makers in forestry. The desired effect here is to see that knowledge/tools are transferred to key decision makers and used by them in their ACC decision making.

The third target concerns the **adoption of ACC measures** by key decision makers in forestry.

The **vulnerability of forest systems** (capacity to adapt and sensitivity) represents the fourth target. The aim is to improve adaptive capacity and reduce the sensitivity of key forestry systems.

Finally, the intervention seeks to influence the **collective well-being** by preserving or improving it.

Based on the first four targets, we analyzed the objectives and desired effects of the five projects associated with the forestry component. We then linked these specific effects to the generic targets (see the logic model under the "Effects" heading). We did not consider the collective well-being target, since our mandate concerned the ACC planning process.

4.1.2 Indicators for the forestry component

To come up with specific indicators for the RAC-Québec forestry component, we created a matrix using the elements necessary for this purpose (see Table 9). Starting on the left, the general targets that we wish to influence are first recalled. Next, the desired effect (generic and specific) on this target is stated. Note that the nature of the specific effects was drawn from the intentions of the five forestry projects (given above in the sub-section on the implementation plan). Next, starting with the generic indicators proposed in Chapter 3, we adapted them to reflect the specific effects expected. In addition, some of the proposed indicators come from existing M&E frameworks surveyed in the literature.

TABLE 9: FRAME OF REFERENCE TO ASSESS THE FORESTRY COMPONENT OF RAC-QUÉBEC

Targets	Effects		Generic indicators	Specific indicators
Knowledge/tools on CC and ACC measures in the forestry sector	Relevant knowledge/tools are generated on CC and ACC measures	Vulnerability assessment and development of adaptation solutions **(Project 1)**	The level of knowledge of stakeholders…	…on vulnerability assessment and the development of adaptation solutions
		Seed transfer models established for black spruce, jack pine and white spruce **(Project 2)**		… on the method for transferring seeds for black spruce, jack pine and white spruce
		Vulnerability of the industry and forest managers assessed in terms of their sensitivity, exposure and adaptive capacity **(Project 3)**		… on the vulnerability of the industry and forest managers
		Hydro-climatic indicators developed		… on how to do hydroclimatic monitoring

Targets	Effects		Generic indicators	Specific indicators
		(Project 4)		
		Success stories identified **(Project 5)**		… on best ACC practices in the forestry sector
Transfer of knowledge/tools on CC and ACC measures to key forestry decision makers	Knowledge/tools on CC and ACC measures are transferred to key decision makers and used by them in their ACC decision making	Vulnerability assessment and adaption solutions integrated in three major pilot projects to develop ecosystem-based forest development plans **(Project 1)**	The extent of use of knowledge and tools produced through RAC- Québec	Use of R&D findings in developing ecosystem-based forest management plans
		Forest sector stakeholders better understand where the socio-economic risks lie **(Project 3)**		Changes occur in the reference framework of forest stakeholders
		Experience and knowledge shared **(Project 5)**		Experience and knowledge received by potential recipients
		Sector stakeholders are made aware **(Project 5)**		Changes occur in the reference framework of forest stakeholders
		R&D more relevant for decision making is highlighted **(Project 5)**		Use of R&D findings in decision-making
Adoption of ACC measures by key decision makers in forestry	ACC measures are adopted by key decision makers	Reforestation with plants adapted to tomorrow's climate **(Project 2)**	The decision made on the planned ACC measure	Decision made on reforestation
Vulnerability of key systems for forestry: sensitivity and adaptive capacity	Adaptive capacity of key forestry systems is improved	The MRNFQ can better assess growth and future composition of the forest, and the Chief Forester can integrate more information in the calculation of forest potential **(Project 4)**	Change observed in the state of system vulnerability due to the adaptation measure	Level of competence of the MRNFQ in its capacity to assess growth and future composition of the forest
				Level of competence of the Chief Forester in his capacity to

Targets	Effects		Generic indicators	Specific indicators
				integrate more information in the calculation of forest potential
		Capacities of public managers strengthened **(Project 5)**		Level of competence of public managers
	Forestry sector sensitivity to CC is reduced	Plants are adapted to tomorrow's climate **(Project 2)**		Plants are adapted
				No. and type of natural resource assets created, maintained or improved to withstand conditions resulting from climate variability and change (by type of assets) (The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011))
				Increment of growing stock and total drainage in forests (Finnish National Adaptation Strategy cited in Swart et al. (2009))
				Tree species composition (Finnish National Adaptation Strategy cited in Swart et al. (2009))
				Area of afforestation (m^2/ha) (Lamhauge, Lanzi and Agrawala (2011))

4.2 The built environment in Southern Québec component

This second case study will take the same approach as for the forestry component. A logic model of this second specific RAC-Québec component will be developed first (see Figure 5). From this model, specific indicators will then be proposed.

4.2.1 Logic model

- **Rationale**

The built environment, which is concentrated in municipalities and more specifically in cities, contributes to CC and feels its effects. While CO_2 and other GHGs are mainly emitted by urban infrastructure and activities (motor vehicles, energy consumption for heating, ventilation and lighting of residential and office buildings), CC in turn has effects on infrastructure and the public.

A number of authors—including the Pew Center on Global Climate Change (2011) and UN-Habitat (2010)—agree that cities will experience significant effects as a result of climate warming. One cause in particular is the urban heat island effect in which the urban infrastructure retains heat and generates a rise in temperature.

According to the Pew Center on Global Climate Change (2011), drought, rising temperatures and also rising sea levels, more frequent and intense coastal storm surges, more abundant precipitation and flooding caused by CC are likely to have impacts on:

- Urban infrastructure (for example, damage to roads and buildings following floods)
- Public health (for example, increased mortality rates due to heat waves, exacerbation of respiratory disease following the rise in temperatures resulting in higher ozone and smog levels)
- Contamination of freshwater and drinking water (for example, contamination of the drinking water supply network by salt water due to rising sea levels and reduced river flows) and others

These impacts risk translating into a variety of issues such as 1) an increase in the economic costs associated with rebuilding roads and buildings, hospital stays and missed work and school days, 2) an increase in social costs (following a higher incidence of respiratory disease, premature death) and, 3) considerable environmental damage (e.g., degradation of plant and wildlife habitat, proliferation of invasive species).

FIGURE 5: LOGIC MODEL OF THE REGIONAL ADAPTATION COLLABORATIVE-QUÉBEC (RAC-QUÉBEC) BUILT ENVIRONMENT IN SOUTHERN QUÉBEC

Logic model: Regional Adaptation Collaborative-Québec (RAC- Québec)
Built environment (Southern Québec)

CREXE
CENTRE DE RECHERCHE ET D'EXPERTISE EN ÉVALUATION

Rationale		- Shortcomings noted in the adaptive capacity of municipalities in dealing with infrastructure issues raised by climate change (CC), thus increasing the vulnerability of communities - Municipalities and other infrastructure owners in Québec are generally poorly equipped to analyze their climate risks; poor understanding of processes for implementing adaptation strategies - Need to improve knowledge to better assess vulnerabilities, review design, maintenance and rebuilding practices and improve public policies to incorporate CC-related considerations - Market failure in the production of information (scientific knowledge a non-rival good)
Targets	**Direct**	- Knowledge/tools on CC and adaptation to climate change (ACC) measures in the built environment sector
	Interme-diate	- Transfer of knowledge/tools on CC and ACC measures to key decision makers in the built environment - Adoption of ACC measures by key decision makers in the built environment
	Ultimate	- Adaptive capacity of key systems in the built environment - Vulnerability/sensitivity of key systems in the built environment - Collective well-being
Objectives		Contribute to reducing the vulnerability of municipalities faced with CC by facilitating the adaption of the built environment by developing tools enabling municipalities to better implement an adaptation plan
Nature of intervention		- Conditional grants to research teams to fund the production of information and tools on ACC - Awareness of CC impacts among all stakeholders in the municipal world
Implementation	**Inputs**	- Budget envelope available through RAC-Québec for the built environment of Southern Quebec ($1.18 million) - Human, informational and material resources from the partners involved (Ouranos, MAMROT, MTQ, OIQ, SNC-Lavalin, Carleton University, Infra, PIEVC, City of Montreal, Quebec City, INRS, Université Laval, UQAM, Centre for expertise and research in urban infrastructure (CERIU), Urban Ecology Centre)
	Process	- Quantify the magnitude of changes expected for precipitation and integrate the information in known tools such as intensity-duration-frequency (IDF) curves to better grasp the anticipated impacts and develop an approach enabling engineers and other professors to consider CC in the design of structures to manage rainwater (P1) - Establish and promote, along with principal stakeholders and experts in the field, best practices (presently known and applicable in the Québec context) in adaptation for infrastructure (P2) - Document best practices for inserting vegetated systems for retention / filtration / infiltration and in situ water treatment in an urban environment from the perspective both of developing design criteria for vegetated infrastructure and opportunities for landscape presentation of this equipment, while integrating the potential contribution of these practices into improving the urban living environment and ways to ensure social acceptability to help stakeholders and cities choose and implement the most important adaptation strategies (P3) - Assess and develop urban resilience to strengthen adaptive capacity and suggest actions aimed at integrating CC in existing urban transformation processes (physical, socio-economic, political) using the case of Quebec City to help develop an adaptation plan at a neighborhood level (P4) - Develop an approach to identify and assess CC-related risks in an urban setting and make recommendations to reduce these risks, taking the City of Montreal as a case study (P5) - Develop a better understanding of the connection between municipal policies developed by central services of the City of Montreal and the realities of the urban territory (on a neighborhood scale) around the theme of adaptation to CC to make recommendations for policies that favor adaptation (P6)
	Outputs	- Research teams funded - Funds distributed - Meetings of partners - Knowledge transfer documents produced and distributed - Pilot project conducted
Outcomes		- Relevant knowledge/tools on CC and ACC measures are generated: Magnitude of expected changes in precipitation is quantified and the information is integrated in known tools (e.g. IDF curves) (P1); Best practices in adaptation for infrastructure are established (P2); Best practices for inserting vegetated systems for retention/filtration/infiltration and in situ water treatment in an urban setting are documented (P3); Approach to identify and assess CC-related risks in an urban setting developed and recommendations made to reduce these risks (P5); A better understanding of the connection between municipal policies developed by central services of the City of Montreal and the realities of the urban territory (on the neighborhood scale) around the theme of adaptation to CC. - Knowledge/tools on CC and ACC measures are transferred to key decision-makers and used by them in making their ACC decisions: Best practices in adaptation for infrastructure promoted (P2); Contribution of practices (inserting vegetated systems for retention / filtration/ infiltration and water treatment) integrated in the improvement of the urban living environment as well as ways to ensure their social acceptability (P3); Stakeholders and cities helped in choosing and implementing the most appropriate adaptation strategies (P3); Recommendations made for policies promoting adaptation (P6) - ACC measures are adopted by key decision makers: Actions are proposed to integrate CC in existing urban transformation processes (physical, socio-economic, political) (P4) - Adaptive capacity is improved for infrastructure and communities: Urban resilience assessed and developed; adaptive capacity strengthened (P4) - The collective well-being is preserved or improved: The survival and integrity of municipal infrastructure in Quebec and sustainable development of the territory is assured; High costs for rehabilitation are avoided

At the international level, CC and its impacts on the built environment are taken into account in a variety of initiatives. For example, the 22nd Governing Council of UN-Habitat held from March 30 to April 3, 2009, resulted in the adoption of a resolution on cities and climate change[4]. Among other things, this resolution calls on governments to lead concerted and coordinated action to include the question of cities and CC (mitigation and adaptation) in their national strategy on climate change.

In Canada, the ICLEI (International Council for Local Environmental Initiatives) and the Federation of Canadian Municipalities (FCM) are participating in the Partners for Climate Protection[5] program, a network of municipal administrations engaged in combatting CC. More than 180 Canadian municipal administrations currently belong to this program.

Moreover, more than 20 Canadian communities, including several towns and cities (such as Montreal, Québec City, Toronto, Edmonton, Halifax), have started assessing their vulnerability to CC and/or planning their adaptation.[6] This is also happening in Trois-Rivières and Sherbrooke through the Québec government's *Climat municipalités* program (Ministère du Développement durable, de l'Environnement et des Parcs, 2008). For the most part, the adaptation strategies of municipal administrations are still at a preliminary stage (ICLEI and Federation of Canadian Municipalities, 2009).

Despite growing awareness among Québec municipalities of the seriousness of infrastructure issues raised by CC and of the existence of technical and financial support[7], gaps are observed in their adaptive capacity, thereby increasing their vulnerability. Indeed, municipalities and other infrastructure owners in Québec are generally poorly equipped to analyze their climate risks and do not have a good understanding of processes for implementing adaptation strategies (Ouranos, 2009; Mailhot et al., 2008; Natural Resources Canada, 2007). This problem calls for improving knowledge to better assess vulnerabilities, reviewing design, maintenance and rehabilitation practices, and improving public policy to introduce CC considerations (Ouranos, 2009, p.7).

Public intervention can also be justified in terms of a market failure on the same grounds as described in the analysis of the relevance of the RAC-Québec generic model (see Chapter 2, Section 2.1).

- **Targets, objectives and the nature of the intervention**

The goal of the built environment in Southern Québec component of RAC-Québec is to contribute to reducing the vulnerability of municipalities to CC by facilitating the

[4] This resolution is accessible at: www.unhabitat.org/downloads/docs/6695_1_592242
[5] See on this subject http://fmv.fcm.ca/fr/partners-for-climate-protection/
[6] See ICLEI and the Federation of Canadian Municipalities (2009) for a complete list of communities. See also Richardson (2010) for a more detailed description of the ACC experiences of some of these communities.
[7] In particular, the Québec government's Climat Municipalités Program (http://www.mddep.gouv.qc.ca/programmes/climat-municipalites) and the existence of various guides on ACC including the guide developed by Ouranos (in 2010) on preparing a plan for adapting to climate change intended for Québec municipalities: http://www.mddep.gouv.qc.ca/programmes/climat-municipalites/Plan-adaptation.pdf

adaptation of the built environment through the development of tools enabling municipalities to better implement an adaptation plan (Ouranos, 2009, p. 7).

The RAC-Québec program theory for the built environment in Southern Québec is not really different from that of the forestry component. By funding research (nature of the intervention) to create knowledge on CC and ACC measures in the built environment (direct target), followed by a knowledge transfer process (intermediate target #1), the RAC-Québec action is intended to foster the adoption of adaptation measures by key decision makers in the area of the built environment (intermediate target #2). The adoption of these measures should improve the adaptive capacity (ultimate target #1) and reduce the sensitivity of cities, towns and communities in Southern Québec (ultimate target #2), which will influence collective well-being (ultimate target #3).

- **The implementation plan (inputs, production activities, outputs)**

In terms of inputs, a budgetary envelope of about $1.18 million is dedicated to the Southern Québec built environment component within RAC-Québec (financial resources). Human, informational and hardware resources are also invested by each partner in the component: Ouranos, Ministère des Affaires municipales, des Régions et de l'Occupation du territoire (MAMROT), Ministère des Transports du Québec (MTQ), Ordre des ingénieurs du Québec (OIQ), SNC-Lavalin, Carleton University, Engineers Canada, Public Infrastructure Engineering Vulnerability Committee (PIEVC), City of Montreal, Québec City, Institut national de la recherche scientifique (INRS), Université Laval, UQAM, Centre for expertise and research in urban infrastructure (CERIU), Urban Ecology Centre, etc.

The production activities of the Southern Québec built environment component are organized around six projects:

1- Quantify the magnitude of expected changes in precipitation and integrate the information in known tools such as Intensity-Duration-Frequency (IDF) curves to better grasp anticipated impacts and develop an approach enabling engineers and other professionals to consider CC when designing structures to manage rain water runoff.

2- Along with the principal stakeholders and experts in the field, establish and promote best practices for adapting infrastructure (known now and applicable in the Québec context).

3- Document best practices for inserting vegetated systems for retention/filtration/infiltration and in situ water treatment in urban settings from the angle of both developing design criteria for vegetated infrastructures and landscape development opportunities of this equipment. This is based on integrating the potential contribution of these practices to improving urban living environments and on ways to ensure their social acceptability to help stakeholders and cities choose and implement the most appropriate adaptation strategies.

4- Assess and develop urban resilience in order to strengthen adaptive capacity and suggest actions to integrate CC into existing urban transformation processes

(physical, socio-economic, political) using the Québec City case to help develop an adaptation plan on a city neighborhood scale.

5- Develop an approach to identify and assess vulnerabilities related to flooding (an event that CC may exacerbate) in urban environments and make recommendations to reduce these risks, taking Montreal and the Rivière des Prairies as a case study.

6- Develop a better understanding of the connection between municipal policies developed by the central services of the City of Montreal and the realities of the urban territory (at a neighborhood level) around the theme of CC adaptation in order to recommend policies that promote adaptation.

- **The effects**

Through its six projects, the built environment in Southern Québec component aims to have an effect on five targets.

The first target involves **knowledge/tools** on CC and ACC measures in the built environment. The desired effect is to generate relevant knowledge/tools on CC and ACC measures.

The second target concerns the **transfer and use of knowledge/tools on CC and ACC measures** by key decision makers in the built environment (e.g., in towns and cities). The desired effect here is to see that knowledge/tools are transferred to these decision makers and used by them in their ACC decision making.

The third target concerns the **adoption of ACC measures** by key decision makers in the built environment.

The **vulnerability** of communities (adaptive capacity and sensitivity) represents the fourth target. Improved adaptive capacity is the desired effect.

Finally, the aim of the intervention is to influence the **collective well-being** by preserving or improving it.

As with the forestry component, taking the first four targets, we analyzed the objectives and desired effects of the six projects associated with the built environment component. We then related these specific effects to the generic targets (see the logic model, under the "Effects" heading). Once again, we did not consider the collective well-being target, since our mandate concerned the ACC planning process.

4.2.2 Indicators for the built environment in Southern Québec

Specific indicators for the built environment in Southern Québec are presented in Table 10 below. The table also recalls all the elements that led to these indicators—general target that we hope to influence, then the desired effect (generic and specific) on this target. Once again, the nature of the specific effects was identified from the intentions of the six projects of the component under study. Next, starting with the generic indicators proposed in Chapter 3, we adapted them to reflect the specific effects expected. In addition, some of the proposed indicators come from existing M&E frameworks.

TABLE 10: FRAME OF REFERENCE TO ASSESS THE BUILT ENVIRONMENT IN SOUTHERN QUÉBEC COMPONENT OF RAC-QUÉBEC

Targets	Effects		Generic indicators	Specific indicators
Knowledge/tools on CC and ACC measures for the built environment	Relevant knowledge/tools are generated on CC and ACC measures	Magnitude of expected precipitation changes is quantified **(Project 1)**	The level of knowledge of stakeholders…	…on the magnitude of changes expected in precipitation
		Best practices established in infrastructure adaptation **(Project 2)**		...on best practices in infrastructure adaptation
		Best practices documented for inserting vegetated systems for retention / filtration / infiltration and in situ water treatment in an urban setting **(Project 3)**		…on best practices for inserting vegetated systems for retention / filtration / infiltration and in situ water treatment in an urban setting
		Urban resilience assessed **(Project 4)**.		…on urban resilience
		Approach developed to identify and assess vulnerabilities to flooding in urban environments and recommendations made to reduce these vulnerabilities **(Project 5)**		…on approaches for identifying and assessing vulnerability to flooding in an urban setting
				…on approaches for reducing vulnerability to flooding in an urban setting)
		A better understanding gained of the connection between municipal policies developed by central services of the City of Montreal and the realities of the urban territory (on the neighbourhood scale) around the theme of ACC **(Project 6)**		… on the connection between municipal policies developed by central services of the City of Montreal and the realities of the urban territory (on the neighbourhood scale) around the theme of ACC
Transfer of knowledge/tools on CC and ACC measures to key decision makers in the built	Knowledge/tools on CC and ACC measures are transferred to key decision makers and used	Information on the magnitude of expected precipitation changes is integrated in known tools (e.g. IDF curves) **(Project 1)**	The degree of use of knowledge and tools produced through RAC-	Extent to which information on the magnitude of expected changes is integrated in known tools

Targets	Effects		Generic indicators	Specific indicators
environment	by them in their ACC decision-making	Best practices in infrastructure adaptation promoted **(Project 2)**	Québec	Efforts made to promote best practices in adaptation
		Contribution of practices (insertion of vegetated systems for retention / filtration / infiltration and water treatment) integrated in the improvement of quality of urban life **(Project 3)**		Extent to which the contribution of practices for inserting vegetated systems for retention / filtration / infiltration and water treatment is integrated in improving the urban living environment
		Stakeholders and cities helped in choosing and implementing the most appropriate adaptation strategies **(Project 3)**		Adaptation strategies adopted after help is received
		Recommendations issued for policies promoting adaptation **(Project 6)**		Effort made to recommend policies fostering adaptation
Adoption of ACC measures by key decision makers in the built environment	ACC measures are adopted by key decision makers	Actions proposed to integrate CC in existing urban transformations (physical, socio-economic, political) **(Project 4)**	Decision is made on the planned ACC measure	Decision made on actions to integrate CC in existing urban transformation processes (physical, socioeconomic,political)
Vulnerability of infrastructure and communities	Adaptive capacity of infrastructure and communities is improved	Urban resilience developed; Adaptive capacity strengthened **(Project 4)**.	Change observed in the state of system vulnerability due to the adaptation measure	Procedures are in place to assess disaster risk impacts of all major development projects, especially infrastructure (UN/ISDR, 2008)
				Value of assets and economic activities protected or made less vulnerable as a result of adaptation interventions (e.g., based on capital assets with reduced physical exposure compared with business-as-usual scenario, turnover of businesses incorporating adaptation measures resulting from projects, etc.) (Brooks et al., 2011).

Targets	Effects		Generic indicators	Specific indicators
				No. and type of adaptation assets (physical as well as knowledge) created in support of individual or community livelihood strategies (The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011))
				Numbers of people experiencing reductions in vulnerability (Brooks et al., 2011)
				Percentage of population covered by adequate risk reduction systems (The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011))
				No. of people affected by climate variability (The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)
				Realised flood damage in communities (Government Strategy Report (2008) cited in Swart et al. (2009)
				Impact of flood (no. of people affected, inundation depth, duration, value of flood damage) (Lamhauge, Lanzi and Agrawala (2011)
				Value of planned new development in high-risk areas compared with projected baseline value (UNDP and GEF (2007) cited in Villanueva (2011))

Targets	Effects		Generic indicators	Specific indicators
				Length of coastline covered by project interventions, coupled with population of adjacent coastal areas (UNDP and GEF (2007) cited in Villanueva (2011))

4.3 Conclusion

This completes the illustration of our approach in two sectors of RAC-Québec. Of course, a deeper analysis of each project would make it possible to refine the wording on each specific indicator. For example, for the forestry sector, the "plants are adapted" indicator could be broken down into several indicators based on the species targeted by the project. Similarly, the indicator "Changes occur in the reference framework of forest stakeholders" could also be broken down differently based on the stakeholders in question (managers, workers, local authorities, etc.). In another example, in this case from the built environment sector, the indicator "Decision made on actions to integrate CC in existing urban transformation processes" could be broken down into several indicators depending on the actions envisaged under the project.

CONCLUSION

Contributions of this study to understanding ACC

For this research project we produced a frame of reference for evaluating ACC and demonstrated its use in the sectors of forestry and the built environment in Southern Québec. To develop the proposed frame of reference, we first analyzed the issues surrounding ACC problem. This analysis resulted in a problem model that illustrates the main variables influencing the planning process leading to the definition of adaptation measures.

Without denying the importance of the contribution from other existing models of resource behavior in sectors confronted by CC, our model reports on the issues involved in developing public action for adaptation (whether at the generic level or in specific sectors such as forestry and the built environment). Our model also considers the determinants of decision making for stakeholders faced with adopting adaptive actions. For purposes of conciseness, our objective was to produce a simple model. Although our model may appear to simplify a very complex reality, we are aware that decision making in the area of ACC involves numerous constraints.

From our study of the ACC problem, we situated the ACC actions by first developing a RAC-Québec logic model, followed by specific logic models for the sectors of forestry and the built environment in Southern Québec. Taken together, the problem and logic models helped us identify the essential elements to consider in a frame of reference for ACC evaluation.

The research project also led us to survey the principal frameworks for monitoring and evaluation (M&E) of ACC and then to analyze and classify their indicators based on the components of our evaluation frame of reference. This classification not only served to clarify the large body of existing indicators, but also inspired certain indicators of our own at the generic and sectoral levels (forestry and built environment in Southern Québec). It should be noted, however, that this classification is not exhaustive, since a systematic inventory of all existing M&E frameworks for ACC was not done. However, this limitation is minimized by the number and rationale of the sources consulted.

The project produced many contributions and benefits. First of all, the problem and logic models made it possible to formulate a comprehensive theory of ACC action and to identify the entire zone of effects around which a frame of reference is organized.

Amid the many existing M&E frameworks in ACC and approaches used to develop them, this work provides a sound conceptual and theoretical base likely to contribute to the field of ACC planning evaluation. The modeling of the ACC problem is based on a survey of literature in the ACC field as well as in economics, policy analysis, and knowledge transfer and use. This plurality of disciplines and rationalities in analyzing the question of ACC planning gives a certain originality to our work.

We also believe that the indicators compiled and classified will be a useful contribution to practitioners evaluating ACC. This list includes many indicators that can be mobilized and adapted to particular evaluation contexts and needs.

◆ Follow-ups to this study

The work begun through this project and possible continuing efforts, including empirical validation of the proposed generic indicators could lead to the development of operational indicators for ACC stakeholders to use in performing their duties. This empirical validation geared to a targeted activity sector, would be done by i) producing a pre-evaluation study that would adapt the frame of reference in this report to the selected sector, followed by ii) proposing evaluation scenarios based on more refined knowledge of the sector, and iii) implementing the selected evaluation scenarios.

The pre-evaluation study would identify the specific characteristics of the selected sector in terms of the essential components around which the indicators of effects of ACC planning were developed in this report, namely:

- Assessment of the vulnerability of the social and ecological system
- Assessment of adaptation options and solutions, particularly in terms of costs and returns
- Decision to adopt an ACC measure based on selected criteria and determinants (political considerations, equity and efficiency considerations)
- Knowledge transfer and use
- Impacts of the ACC measure on system vulnerability
- Impacts on collective well-being

These specific characteristics could be related to, for example:

- Factors defining the vulnerability of the particular social and ecological system (nature of the resource, types of risks, etc.);
- The stakeholders, their interests and the nature of their relationship (decision makers, institutions, the public, interest groups);
- ACC strategies or technologies in the sector;
- The advancement of knowledge in CC according to the sector and level of knowledge absorption by stakeholders.

Based on this characterization, we can transpose the generic indicators into more specific context-adapted indicators and propose a methodology for measuring them in the field. Hence, the "operational" indicators for sectors of activity as wide-ranging as forestry, agriculture and tourism will not be the same given the distinctiveness of the sectors, in particular at the level of the nature of the resource (or SES), the stakeholders concerned, and the economic, environmental and social factors involved.

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ANNEXE

LIST OF ANNEXE TABLES

TABLE 11: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "ASSESSMENT OF THE VULNERABILITY OF THE SOCIAL AND ECOLOGICAL SYSTEM" COMPONENT OF THE CREXE MODEL

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Vulnerability assessment of the social-ecological system	Possible impacts of CC	Brooks et al. (2011)	Climate risk management indicators (the extent to which climate risk management is integrated into development processes, actions and institutions)	Mechanisms for targeting the climate vulnerable (e.g., for carrying out climate risk assessment and vulnerability assessment and using the results of such assessments to inform development policy and practice).
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Increased knowledge of climate change, variability, impacts in govt., private sector, civil society, education sector	Coverage of climate risk analysis and vulnerability assessments based on current scientific evidence
			Enhanced integration of learning/knowledge into climate resilient development	Rationale & quality of knowledge assets (publications, studies, platforms, etc) created
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	Relevant threat and hazard information generated and disseminated to stakeholders on a timely basis	No. and type of projects that conduct and update risk and vulnerability assessments
		EEA Workshop (cited in Swart et al. 2009)	Process indicators	Are climate change scenarios available?
				Is there a vulnerability assessment available?
		Harley et al. (2008)	Level of adaptive capacity	Availability of climate change scenarios
				Availability of vulnerability assessments
		National Indicator 188 (UKCIP, 2008)	The indicator measures progress on assessing and managing climate risks and opportunities, and incorporating appropriate action into local authority and partners' strategic planning.	**Level 0: Baseline**: The Authority has begun the process of assessing the potential threats and opportunities across its estate and services (for example, flood and coastal resilience plans, emergency planning, community risk registers/strategies etc.) and has identified and agreed the next steps to build on that assessment in a systematic and coordinated way. **Examples of evidence**: The Authority has identified a lead official to identify and provide advice to service/ department heads on potential impacts of future climate change on its functions; The Authority has undertaken an audit of existing relevant risk registers and action plans in place (e.g., community risk register); The Authority has established a process for actions it needs to take to meet higher levels.

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Level 1: Public commitment and prioritized risk-based assessment: The Authority has made a public commitment to identify and manage climate related risk. It has undertaken a local risk-based assessment of significant vulnerabilities and opportunities to weather and climate, both now and in the future. It can demonstrate a sound understanding of those not yet addressed in existing strategies and actions (e.g., in land use planning documents, service delivery plans, flood and coastal resilience plans, emergency planning, community risk registers/strategies etc). It has communicated these potential vulnerabilities and opportunities to department/service heads and other local partners and has set out the next steps in addressing them. **Examples of evidence**: The authority and partners have made a public commitment to manage climate risks e.g. signed up to the Nottingham Declaration or an equivalent; A Local Climate Impacts Profile or equivalent process is ongoing; Initial assessment produced using the UKCIP scenarios; Department/service heads facing significant vulnerabilities and opportunities have an understanding of the issues, with evidence of actions already in place to address these; Evidence of working in partnership and pooling of resources and expertise across sectors, areas and council tiers where applicable.
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	N/A	Key climatic vulnerabilities. This might be based, for example, on risk assessments by region and sector.
		UN/ISDR (2008)	Identify, assess and monitor disaster risks and enhance early warning	National and local risk assessments based on hazard data and vulnerability information are available and include risk assessments for key sectors.
				National and local risk assessments take account of regional/ trans-boundary risks, with a view to regional cooperation on risk reduction.
		Lamhauge, Lanzi and Agrawala (2011)	Research	Vulnerability profile developed
				Production of climate predictions under different scenarios (indicators, projections, maps, desertification indices)

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Increased capacity to assess vulnerabilities and risks of climate change
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Gender issues**: Acting on the Role of gender in DRR. Motivational Influences in gender analysis
				Demographic issues : Mapping Adaptation to Climate Change in Populations which are aging
				Traditional knowledge: Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change
		UNFCCC Secretariat (2010)	N/A	Research ongoing and adequate on the impacts of, or adaptation, to climate change
				Impacts of climate change known indicatively (qualitative information)
				Impacts well known, within the limits of uncertainty
				Potential threats and opportunities across estate and services starting to be assessed
				Local risk-based assessment of significant vulnerabilities and opportunities made
				Comprehensive risk assessment
				Comprehensive risk-based assessment undertaken and priority risks for services identified
		Twiggs (2007) cited in Villanueva (2011)	Component of resilience 1: Hazards/risk data and assessment	Community hazard/risk assessments carried out which provide comprehensive picture of all major hazards and risks facing community (and potential risks).
				Ongoing monitoring of hazards and risks and updating of assessments.

TABLE 12: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "ASSESSMENT OF ADAPTATION OPTIONS AND SOLUTIONS" COMPONENT OF THE CREXE MODEL

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Assessment of adaptation options and solutions	Designing and assessing ACC measures	EEA Workshop (cited in Swart et al. 2009)	Process indicators	Have cross cutting issues been identified
				Is there stakeholder engagement?
				Is there local guidance on adaptation?
		Harley et al. (2008)	Level of adaptive capacity	Identification of crosscutting issues (e.g., links to other sectors)
				Level of stakeholder engagement
				Availability of local adaptation guidance
		National Indicator 188 (UKCIP, 2008)	The indicator measures progress on assessing and managing climate risks and opportunities, and incorporating appropriate action into local authority and partners' strategic planning.	**Level 2**: **Comprehensive risk-based assessment and prioritized action in some areas:** The Authority has undertaken a comprehensive risk based assessment of vulnerabilities to weather and climate, both now and in the future, and has identified priority risks for its services. It has identified the most effective adaptive responses and has started incorporating these in council strategies, plans, partnerships and operations (such as planning, flood management, economic development, social care, services for children, transport etc). It has begun implementing appropriate adaptive responses in some priority areas. In its role as a community leader the council has started working with its LSP encouraging identification of major weather and climate vulnerabilities and opportunities that affect the delivery of the LSP's objectives. **Examples of evidence**: Comprehensive risk assessment produced (for example using the UKCIP method); Nottingham Declaration accreditation; Council Members and department and service heads have a detailed understanding of weather and climate risk in all vulnerable areas identified in risk assessment and actions taken in priority areas; Documents like Local Development Frameworks include climate change adaptation; Local adaptation partnership established; LSP partners are aware of actions being

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				taken by the council, feel engaged in the process and confirm they have started to identify weather and climate risk that affect the delivery of their own objectives. **Level 3**: **Comprehensive action plan and prioritised action in all priority areas:** The Authority has embedded climate impacts and risks across council decision making. It has developed a comprehensive adaptation action plan to deliver the necessary steps to achieve the existing objectives set out in council strategies, plans, investment decisions and partnership arrangements in light of projected climate change and is implementing appropriate adaptive responses in all priority areas. This includes leadership and support for LSPs in taking a risk based approach to managing major weather and climate vulnerabilities/ opportunities across the wider local authority area. **Examples of evidence**: Action plan developed and published; Nottingham Declaration accreditation at a higher level; Detailed understanding of risk and action taken to embed relevant adaptation response in council strategies, plans, partnerships and operations by all department/service heads where weather and climate risks have been identified; Initial cost analysis undertaken and potential sources of funding identified for major vulnerabilities; LSPs feel fully engaged and action plan includes commitment from authority and LSP; Pooling of skills, knowledge and resource across LSP; Consulted with authorities responsible for climate change management and others who can provide advice on good practice e.g. Environment Agency, Natural England, Defra.
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	Policies and measures that are undertaken as adaptation activities (both implemented and proposed; see e.g. IVM/EPA project on adaptation frameworks and the PEER project). The information on	Objectives of the measure. For example, is the main objective of the measure to proactively reduce the risks of, and sensitivity to, any climatic change, or to mitigate damages following an extreme climatic event, or

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
			policies and measures should include, where possible and relevant:	to capitalize or benefit from a changing climate? Or is the main objective to raise national public awareness on climate change and climate change adaptation?
				Type of (policy) instrument/method of implementation. How will a measure (e.g. a tax regulation) be implemented?
				Key stakeholders involved.
				Aims and targeted sectors of the measure. Which sector or issue domain is the policy measure addressing?
				Elements of adaptation strategies and plans that are covered by the policies and measures.
				Possible links to existing (European and national) regulations/policies.
				Duration and target dates and deadlines. Implementation date of the measure and its duration.
				Implementation scale of the instrument: Is the measure implemented nationally, regionally or locally?
				Budgetary and financial implications of the measure
				Joint activities with other Member States and developing countries, including joint implementation of measures, research activities or agreements.
		UN/ISDR (2008)	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	Community participation and decentralization is ensured through the delegation of authority and resources to local levels.
		Lamhauge, Lanzi and Agrawala (2011)	Coordination	Linkages developed between institutions
				Level of stakeholder participation in dialogue, planning and decision making
				Extent of participation in networks
				Strengthened community of practice on climate change
				A comprehensive strategy on climate change awareness, outreach, communication, and public learning accompanied by supporting mechanisms
				Establishment of peoples/ producer collectives/ working groups
				Establishment of institutions/committees addressing

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				adaptation related issues (e.g. watershed management)
				No. of actors that have initiated follow-up programmes on climate risk reduction
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Multi-sector holistic efforts:** - Focus on the social development and compensatory measures to reduce vulnerability, identifying concrete tasks for the Ministry of Education, Ministry of Housing and Territorial Zoning, National Environmental Authority and the Ministry of Health, to further DRR through education, land use planning and vulnerability reduction of critical infrastructure, such as schools and health care facilities
		UNDP (2007)	Coverage: the extent to which projects reach vulnerable stakeholders (individuals, households, businesses, government agencies, policymakers, etc.)	Number of households, businesses (or other appropriate units) engaged in vulnerability reduction or adaptive capacity development activities, as a proportion of households or other units in the community or region targeted by the project.
			Sustainability: the ability of stakeholders to continue the adaptation processes beyond project lifetimes, thereby sustaining development benefits	Number of project beneficiaries involved in capacity development for implementation of specific adaptation measures or decision-support tools
				Support for project activities among participating communities
		UNFCCC Secretariat (2010)	Process-based indicators used by Finland	Some adaptation measures identified but not yet necessarily implemented
				Need for adaptation measures recognized to some extent in the sector
				Adaptation measures identified and plans made for their implementation
				Need for adaptation measures quite well recognize in the sector
				Need for adaptation measures widely recognized and accepted in the sector
				Implementation of adaptation measures widely launched and their benefits assessed
			Process-based indicators used by the UK	Next steps to build on that assessment identified and agreed upon
				Most effective adaptive responses identified and incorporated in council strategies, plans
				Comprehensive action plan
				Comprehensive adaptation action plan

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				developed
				Implementation, monitoring and continuous review
				Robust process for regular and continual monitoring and review exists to ensure progress
		Spearman and McGray (2011)	Process indicators	Degree and quality of participant involvement in adaptation decisions
				Thoroughness of accounting for climate risks and vulnerability in decision making
				Whether and how the adaptation process is sustained
			Evaluation	Availability of methodologies, guidelines to assist local planners
			Coordination	Mandated institution has a set of indicators and indicators by which to coordinate other players
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	Project management and capacity building: operational and strengthened project management and monitoring systems.	Timely and informative reporting of local project management offices reflects accurate and on-time project implementation in line with agreed assurances.
				Domestic systems-based project management and monitoring system, including Project Performance Management System, is operationalized.
			Flood management sector planning: selected sector assessments and planning to support development of integrated flood management plans (grant financed through the advisory technical assistance).	Basin-wide flood-warning system development needs are assessed; flood insurance is appraised with support from advisory technical assistance; next actions for inclusion in a future flood management plan are agreed upon by key provincial authorities by 2008
		UNDP and GEF (2007) cited in Villanueva (2011)	Policies and plans revised on the basis of the scenario planning to accommodating increasing coastal risk associated with the sea-level rise, accelerated erosion, and more destructive storms	Number of policies and plans relating to coastal development under review, in order to ensure climate change issues are addressed.
			Construction of storm shelters and improvements in the resilience of settlements, to reduce vulnerability to tropical storms and associated storm surges.	Numbers of stakeholders involved in piloting of vulnerability reduction measures at local level.
		Twiggs (2007) cited in Villanueva (2011)	Component of resilience 1: Hazards/risk data and assessment	Hazard/risk assessment is participatory process including representatives of all sections of community and sources of expertise.

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
	Costs/benefits assessment	Brooks et al. (2011)	Climate relevant development/vulnerability indicators (assessment of reductions in the vulnerability of human populations to climate change related hazards and risks as a result of adaptation interventions)	Benefit/ cost ratios of adaptation options identified/ implemented (based on ratio of value of assets and productivity made less vulnerable to adaptation expenditure).
		Lamhauge, Lanzi and Agrawala (2011)	Research	Studies identify risk and benefits of managing environmental resource(s)

TABLE 13: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "DECISION TO ADOPT AN ACC MEASURE" COMPONENT OF THE CREXE MODEL

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Decision to adopt an ACC measure	Adoption of ACC measures	Brooks et al. (2011)	Climate risk management indicators (the extent to which climate risk management is integrated into development processes, actions and institutions)	Proportion of development initiatives that are modified compared to a "business-as usual" case in order to make them more climate-resilient
			Climate relevant development/vulnerability indicators (assessment of reductions in the vulnerability of human populations to climate change related hazards and risks as a result of adaptation interventions)	Coverage of CC interventions (proportion of portfolio that includes measures to address climate change).
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Improved institutional capacity to respond to climate variability and change	No. and quality of policies introduced/adjusted to address climate change, quality of participatory panning processes, adaptation monitoring
			Scaled-up investments in climate resilience and their replication	Climate resilient investments (no. and value)
			Replication of PPCR in non-PPCR countries	No. of countries and sectors applying climate proofing and climate resilience principles and sharing through PPCR, countries replicating PPCR approaches
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	Relevant threat and hazard information generated and disseminated to stakeholders on a timely basis	Development of early warning systems
			Percentage of targeted population aware of predicted adverse impacts of climate change, and of appropriate responses	No. and type of risk reduction actions or strategies introduced at local level
			Development sectors' services responsive to evolving needs from changing and variable climate	No. and type of health or social infrastructure developed or modified to respond to new conditions resulting from climate variability and change (by type)
				No. of physical assets strengthened or constructed to withstand conditions resulting from climate variability and change (by asset types)
			Climate change priorities are integrated into national development strategy	No., type, and sector of policies introduced or adjusted to address climate change risks
				No. of targeted development strategies with incorporated climate change priorities enforced

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
		National Indicator 188 (UKCIP, 2008)	The indicator measures progress on assessing and managing climate risks and opportunities, and incorporating appropriate action into local authority and partners' strategic planning.	**Level 4: Implementation, monitoring and continuous review**: The Authority and LSP are implementing the comprehensive adaptation action plan across the local authority area, and there is a robust process for regular and continual monitoring and review to ensure progress with each measure and updating of objectives. The Authority and LSP are taking appropriate adaptive responses. **Examples of evidence**: Clear and robust continuous monitoring and review system in place; Outputs from the review and monitoring process are ploughed back into the action plan and other relevant council and LSP strategies
		UN/ISDR (2008)	Reduce the underlying risk factors	Social development policies and plans are being implemented to reduce the vulnerability of populations most at risk.
				Economic and productive sectoral policies and plans have been implemented to reduce the vulnerability of economic activities
		Lamhauge, Lanzi and Agrawala (2011)	Risk reduction	No. and type of DRR instruments e.g. insurance instruments promoted
			Environmental Education and Training	No. of trained committees that developed and adopted risk reduction plans
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Increasing awareness**: School Campaigns as part of Annual DRR Day
				Information management: Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future
				Education: Inclusion of climate change adaptation and other issues in curriculum at secondary and tertiary educational institution
		UNDP (2007)	Coverage: the extent to which projects reach vulnerable stakeholders (individuals, households, businesses, government agencies, policymakers, etc.)	Number of risk-reducing practices/measures implemented to support adaptation of livelihoods and/or resource management.
		UNFCCC Secretariat (2010)	Process-based indicators used by Finland	Adaptation measures identified and their implementation launched
				Cross-sectoral cooperation on adaptation measures started
				Cross-sectoral cooperation on adaptation measures an established practice

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
			Process-based indicators used by the UK	Adaptive responses implemented in some priority areas
				Adaptive responses implemented in all priority areas
				Comprehensive adaptation action plan across the local authority area implemented
				Appropriate adaptive responses implemented
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	To develop and pilot a range of coping mechanisms for reducing the vulnerability of farmers and pastoralists to climate change, including variability.	At least five distinct coping mechanisms for climate change and variability adopted by small-scale farmers.
			Climate change adaptation measures of rural communities in agricultural production are piloted and tested.	Adoption of improved crop varieties and livestock breeds in the project site increased by at least 25%.
			Risk reduction strategies in pilot area contribute to improved adaptive capacity and resilience to drought.	Number of households in the project site planting improved crop varieties increased by at least 25%.
				Number of households in the project site having traditional Sanga breeds increased by at least 25%.
				At least two improved crop varieties and livestock breeds introduced in the project site.
				Number of households in the project site using improved technologies, such as rainwater harvesting, increased by at least 25%.
			Livestock rearing improved through the introduction of various adaptation measures aimed at improving integrated pasture management and strengthening animal biocapacity.	At least two adaptation measures identified and tested.
		UNDP and GEF (2007) cited in Villanueva (2011)	Policies and plans revised on the basis of the scenario planning to accommodating increasing coastal risk associated with the sea-level rise, accelerated erosion, and more destructive storms	Number of new policies introduced or existing policies and plans are updated as a result of scenario planning exercises
			Resilience of coastal geomorphological and ecological system enhanced	Number of different resilience-enhancing measures employed by project, combined with number of ecological and geomorphological system addressed
				Number of sites/locations where resilience building measures are piloted.

TABLE 14: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "ADAPTATION PROCESS DETERMINANTS" COMPONENT OF THE CREXE MODEL

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Determinants in the adaptation process	Public programs and policies	Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	New and additional resources for climate resilient development	Leverage factor of PPCR funding, financing from other sources
		Harley et al. (2008)	Process-base top-down indicator of adaptive capacity	Is a national adaptation framework in place and what spatial scale does it cover?
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	N/A	Existing national adaptation plans and/or strategies, or those in preparation. This should include providing information on when such plans were developed or are expected to be developed, as well as their objectives.
		UN/ISDR (2008)	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	Dedicated and adequate resources are available to implement disaster risk reduction plans at all administrative levels.
			Use knowledge, innovation and education to build a culture of safety and resilience at all levels	Country wide public awareness strategy exists to stimulate a culture of disaster resilience, with outreach to urban and rural communities.
			Reduce the underlying risk factors	Disaster risk reduction is an integral objective of environment-related policies and plans, including for land use, natural resource management and climate change adaptation.
		Iwanciw and Zalles (2010) cited in Spearman and McGray (2011)	Risk reduction	Percentage of "risk mitigation" funds provided by the central government to local, regional, and national investment projects
	Regulatory framework, legal framework	Brooks et al. (2011)	Climate risk management indicators (the extent to which climate risk management is integrated into development processes, actions and institutions)	Institutional framework of regulatory and legal support, plus macroeconomic management for climate resilience (e.g. requirements for certain types of development initiative to be subject to screening for climate change-related risks).
		EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	N/A	Institutional and legal framework for adaptation activities. This should include providing information on which national ministries and agencies have been given the mandate to undertake climate change adaptation activities. It should also include providing

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				information on any national laws and/or regulatory measures that facilitate climate change adaptation activities.
		UN/ISDR (2008)	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	National institutional and legal frameworks for disaster risk reduction exist with decentralized responsibilities and capacities at all levels[8] .
		Spearman and McGray (2011)	Process indicators	Number and quality of laws or policies addressing climate change
	Political context of the action	The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	Percentage of targeted population aware of predicted adverse impacts of climate change, and of appropriate responses	No. of news outlets in the local press and media that have covered the topic
		Lamhauge, Lanzi and Agrawala (2011)	Coordination	No. of proposals by civil society and communities incorporated by the government
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Social mobilization**: Adaptation to climate change civil organizations active and functioning
		UNFCCC Secretariat (2010)	Process-based indicators used by the UK	Public commitment and impacts assessment
				Public commitment made to identify, communicate and manage climate-related risk
		UNDP and GEF (2007) cited in Villanueva (2011)	Capacity to plan for and respond to changes in climate-related coastal risks improved through awareness building and enhance access to information on potential climate changes impacts, coupled with guidance on and improved access to available adaptation measures.	Understanding of climate changes related coastal risks among general and public and key stakeholder groups (QBS).
	Sensitivity to ACC question	Harley et al. (2008)	Adaptive capacity	The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations
	The organization's resources and	Lamhauge, Lanzi and Agrawala (2011)	Environmental Education and Training	Adaptation in government staff training curricula
				No. of training sessions/workshops

[8] Each indicator increases according to a scale based on advancement of the risk reduction process: Illustration of advancements for each level of disaster risk reduction processes: **Level 1**: No progress has been made and/or progress has stopped or moved backwards; **Level 2**: Minor progress achieved in disaster risk reduction actions, with no systematic commitment; **Level 3**: Institutional commitment to reduction disaster risk, but no substantial progress; **Level 4**: Systematic commitment at policy level, but insufficient resource allocation; **Level 5**: Full achievement with sustained commitment. This scale is adapted for each indicator (see HFA document).

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
	expertise			conducted/no. of people trained
		Twiggs (2007) cited in Villanueva (2011)	Component of resilience 1: Hazards/risk data and assessment	Skills and capacity to carry out community hazard and risk assessments maintained through support and training.
	Knowledge about CC	EPA Network of Environmental Protection Agencies cited in Harley et al. (2008)	S/O	National (and European) research programmes and databases.
		Harley et al. (2008)	Adaptive capacity	The range of available technological options for adaptation
		UN/ISDR (2008)	Use knowledge, innovation and education to build a culture of safety and resilience at all levels	Relevant information on disasters is available and accessible at all levels, to all stakeholders (through networks, development of information sharing system.
				Research methods and tools for multi risk assessments and cost benefit analysis are developed and strengthened.
		Lamhauge, Lanzi and Agrawala (2011)	Environmental Education and Training	No. and quality of publications, articles, TV programmes
				Development of knowledge platforms/ website
				No. of training modules/materials published and disseminated
				No. of hits on web-based platform
				No. of stakeholders participating in knowledge sharing/training
				No. of policy reviews
				Advocacy campaign developed
			Indicators of action for increasing environmental resilience	No. of knowledge communication centres/dialogue platforms
			Research	Development of models and tools produced
				Availability of relevant data
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Disaster risk reduction**: - Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and awareness raising on enhanced climatic disasters - Identifying of key actions to be taken at the national and sub-national levels
		Spearman and McGray (2011)	Process indicators	Rationale and quality of informational inputs to adaptation decisions

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
		Twiggs (2007) cited in Villanueva (2011)	Component of resilience 1: Hazards/risk data and assessment	Assessment findings shared, discussed, understood and agreed among all stakeholders, and feed into community disaster planning.
				Findings made available to all interested parties (within and outside community, locally and at higher levels) and feed into their disaster planning.
	Knowledge absorption capacity	Brooks et al. (2011)	Climate risk management indicators (the extent to which climate risk management is integrated into development processes, actions and institutions)	The use of climate information (and M&E information) in policy & programme design (e.g. policies and programmes informed by evidence of emerging climate trends and scenarios of future climate change).
				Mechanisms for targeting the climate vulnerable (e.g. for carrying out climate risk assessment and vulnerability assessment and using the results of such assessments to inform development policy and practice).
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Catalytic replication outcomes: Improved institutional capacity to respond to climate variability and change	Decision making incorporates climate information
			Catalytic replication outcomes: Scaled-up investments in climate resilience and their replication	Evidence of lessons learned
			PPCR outcomes and outputs: Improved integration of resilience into country development strategies, policies, plans, etc.	Degree to which planning integrates climate proofing and vulnerability assessment, integration and dissemination of CRM
			Enhanced integration of learning/knowledge into climate resilient development	Evidence of use of knowledge and learning
		Harley et al. (2008)	Adaptive capacity	The ability of decision makers to manage information, the processes by which they determine which information is credible and the credibility of the decision makers themselves
			Process-base bottom-up indicator of adaptive capacity	Are local level experiences informing actions within and across sectors?
		Lamhauge, Lanzi and Agrawala (2011)	Environmental Education and Training	Extent of use and outreach of education material/training facilities
			Research	No. of stakeholders requesting and accessing knowledge products
				Extent of research dissemination
				No. of organisations engaging with knowledge network

CREXE model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
			Coordination	Level of incorporation of research in climate change strategies
		UNDP (2007)	Impact: the extent to which projects reduce vulnerability and/or enhance adaptive capacity (through bringing about changes in adaptation processes: policy-making/planning, capacity building/awareness raising, information management, etc.	Communicate climate change risks, disseminate information, or make decisions based on high quality information), as relevant,
			Replicability: the extent to which projects generate and disseminate results and lessons of value in other, comparable contexts	Number of 'lessons learned' codified.
				Number of relevant networks or communities with which lessons learned are disseminated.
		UNFCCC Secretariat (2010)	Process-based indicators used by Finland	Need for adaptation recognized among a group of pioneers in the sector

TABLE 15: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "IMPACT OF THE ACC MEASURE ON THE VULNERABILITY OF THE SYSTEM" COMPONENT OF THE CREXE MODEL

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Effects of the ACC measure on the vulnerability of the system	Improvement of system's capacity to adapt	Brooks et al. (2011)	Climate risk management indicators (the extent to which climate risk management is integrated into development processes, actions and institutions)	How well the components of the national system conduct National Adaptive Capacity functions (with reference to, for example, the World Resources Institute National Adaptive Capacity framework).
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Scaled-up investments in climate resilience and their replication	Increased capacity to manage climate resilient investments
			Improved integration of resilience into country development strategies, policies, plans, etc.	Budget allocations take account of climate change
			Increased capacity to integrate climate resilience into country strategies	Evidence of cross-sectoral mechanism to address climate variability and change, evidence of ministries/agencies taking lead in updating strategies
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	No. and type of targeted institutions with increased capacity to minimize exposure to climate variability risks	No. of staff trained to respond to, and mitigate impacts of, climate-related events
				Capacity of staff to respond to, and mitigate impacts of, climate-related events from targeted institutions increased

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
		Finnish National Adaptation Strategy cited in Swart et al. (2009)	Indicators of sustainable development	Availability of real-time hydrological information
		Government Strategy Report 2008 cited in Swart et al. (2009)	Adaptation	Progress made in observation and warning systems
				Progress made in research and development
				Adaptation plans made in various sectors and progress of the first measures taken
		EEA Workshop (cited in Swart et al. 2009)	Process indicators	Is disaster planning in place?
		Harley et al. (2008)	Adaptive capacity	The availability of resources and their distribution across the population
				The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed.
				The stock of human capital, including education and personal security
				The stock of social capital, including the definition of property rights.
				The system's access to risk-spreading processes (e.g. insurance)
			Level of adaptive capacity	Availability of disaster plans
		UN/ISDR (2008)	Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation	A national multi-sectoral platform for disaster risk reduction is functioning.
			Identify, assess and monitor disaster risks and enhance early warning	Early warning systems are in place for all major hazards, with outreach to communities.
			Use knowledge, innovation and education to build a culture of safety and resilience at all levels	School curricula, education material and relevant trainings include risk reduction and recovery concepts and practices.
			Reduce the underlying risk factors	Planning and management of human settlements incorporate disaster risk reduction elements, including enforcement of building codes.
				Disaster risk reduction measures are integrated into post-disaster recovery and rehabilitation processes.
				Procedures are in place to assess disaster risk impacts of all major

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				development projects, especially infrastructure
			Strengthen disaster preparedness for effective response at all levels	Strong policy, technical and institutional capacities and mechanisms for disaster management, with a disaster risk reduction perspective are in place.
				Disaster preparedness plans and contingency plans are in place at all administrative levels, and regular training drills and rehearsals are held to test and develop disaster response programmes.
				Financial reserves and contingency mechanisms are in place to enable effective response and recovery when required.
				Procedures are in place to exchange relevant information during disasters and to undertake post-event reviews
		Lamhauge, Lanzi and Agrawala (2011)	Risk reduction	No. of households/communities participating in afforestation/improved agricultural practices/watershed management
				Early warning system in place
				No. of households that seek out, test, adapt and adopt ideas and practices that strengthen their livelihoods
			Policy and administrative management	Incorporation of adaptation in regulatory measures and advisories
				No. of (villages, communities, countries, regions) with adaptation/ resource management/ environmentally sustainable strategies/plans
				Inclusion of climate change in policy frameworks (e.g. PRSP, agricultural policies, development policy frameworks)
				Evidence of climate change mainstreaming in development plans
				No. of policy submissions per year (to e.g. Hyogo Framework for Action, COP)
				Reference to climate change as an important factor in understanding risk reduction (in x no. of policy documents)
				A percentage of DRR plans reflect potential climate change impacts

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Resources/no. of projected allocated to climate change adaptation
			Environmental Education and Training	Increased community capacity through implementation of pilot projects
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Land use**: - Promoting adaptation to coastal crop agriculture to combat increased salinity - Adaptation to agriculture systems in areas prone to enhanced flash flooding. - Focuses on governance and territorial management, stressing the rationale of local DRM and urban dimensions of risk, along with the pivotal role of local authorities. - Design and implement zoning regulations and building codes
				Changes in resource use practices: - Adaptation to fisheries in areas prone to enhanced flooding through adaptive and diversified fish culture practices - Promoting adaptation to coastal fisheries through culture of salt tolerant fish special in coastal areas
				Public health: - Mapping of the Eco-zones and the changes in Vector-Borne diseases
				Policy and planning: - Mainstreaming adaptation to climate change into policies and programmes in different sectors (focusing on disaster management, water, agriculture, health and industry). - State policies and programmes in the food production & security sector integrate climate change adaptation priorities
				Economics: - Government taking responsibility for developing financial mechanisms to reduce the vulnerability of the portfolio of public investments by introducing DRR considerations into the investment planning processes, as well as developing mechanisms for financial protection. - Compensation for flood damages - Facilitate access to credit
				Insurance: - Adequately addressing loss and damage from the impacts of climate change

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				- Exploring options for insurance and other emergency preparedness measures to cope with enhanced climatic disasters
				Financial sector: - Recognizing the reality of climate change and mainstream it into all business processes. It is a decision factor for business planning and strategies, portfolio management, and at individual transaction level. - Developing and supplying products and services for the new markets which will come with integrated adaptation e.g. at micro-level in developing countries, and for ecological services. - Working with policymakers to realize the transition to integrated adaptation. - Ensuring that contingency plans consider "worst case" disasters.
		UNDP (2007)	Coverage: the extent to which projects reach vulnerable stakeholders (individuals, households, businesses, government agencies, policymakers, etc.)	Number of policies introduced or adjusted to incorporate climate change risks.
				Number of investment decisions revised or made to incorporate climate change risks.
			Impact: the extent to which projects reduce vulnerability and/or enhance adaptive capacity (through bringing about changes in adaptation processes: policy-making/planning, capacity building/awareness raising, information management, etc.	Percent change in stakeholders' behaviors utilizing adjusted practices or resources for managing climate change risk
				Percent improvement in stakeholders' capacities to manage climate change
				Percent improvement in perceived adaptive capacity; Percent improvement in stakeholder perceptions of the range or robustness of options available to cope with recurrence of primary climate change-related threat(s); Supplementary indicators specific to the TA(s) addressed by the project should also be considered, where possible.
			Sustainability: the ability of stakeholders to continue the adaptation processes beyond project lifetimes, thereby sustaining development benefits	Number of beneficiaries of project receiving training in implementation of specific adaptation measures or decision-support tools.
				Local (or spatially appropriate) availability of skills and resources necessary to continual adaptation after conclusion of project

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Number of outside programmes, policies or projects incorporating project results into their processes
				Stakeholder perceptions of adaptation sustainability, accessed via qualitative survey
		UNFCCC Secretariat (2010)	Process-based indicators used by Finland	Adaptation incorporated into regular decision making processes
				Adaptation measures under the adaptation strategy or recognized otherwise
			Process-based indicators used by the UK	Climate impacts and risks embedded across council decision making
		Spearman and McGray (2011)	Substantive outcome	Utility and quality of early warning systems
				Change in stakeholder response to climate risk, or utilization of adaptation options
				Evidence of community, sectoral, or institutional understanding and capability to deal with or avoid climate-induced losses
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	Nonstructural flood management systems: operational flood warning and management systems for up to 35 municipalities and counties linked to the provincial flood-warning and management system.	Warning time against potential floods in the project area is increased (current warning time is a few hours to one day).
				Forecasting and warning data are more frequently accurate
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	Capacities of service organizations in pilot regions strengthened to address climate change adaptation and drought.	At least four service organizations in pilot regions capacitated to adapt to climate and prepare for drought periods
		UNDP and GEF (2007) cited in Villanueva (2011)	Policies and plans revised on the basis of the scenario planning to accommodating increasing coastal risk associated with the sea-level rise, accelerated erosion, and more destructive storms	Number of policy makers and planners trained in scenario planning (alternatively number of government departments represented among those trained).
			Investment decision made on basis of risk assessment based on climate change scenario planning	Number of private sector bodies (organisation and individual business) engaged by project and provided with training in climate risk management and scenario planning.
			Capacity to plan for and respond to changes in climate-related coastal risks improved through awareness building and enhance access to	Perceived change in likely ability to respond effectively to future change in coastal risks

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
			information on potential climate changes impacts, coupled with guidance on and improved access to available adaptation measures.	Population covered by awareness building programmes to increase understanding of risks associated with climate change among general and public and key stakeholder groups.
	Mitigation of system's sensitivity to CC	Brooks et al. (2011)	Climate relevant development/vulnerability indicators (assessment of reductions in the vulnerability of human populations to climate change related hazards and risks as a result of adaptation interventions)	Numbers of beneficiaries of climate change interventions (i.e. numbers of people benefiting from projects or project components that address climate change issues, e.g. through integration of measures to promote resilience or reduce climate change-related risks).
				Numbers of people experiencing reductions in vulnerability, represented by movement from more vulnerable to less vulnerable category/score in key indicators (based on variety of context specific indicators converted into scores that can be aggregated across contexts).
				Value of assets and economic activities protected or made less vulnerable as a result of adaptation interventions (e.g. based on capital assets with reduced physical exposure compared with business-as-usual scenario, turnover of businesses incorporating adaptation measures resulting from projects, etc).
		Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Transformative impacts: Improved quality of life of people living in areas most affected by climate change Increased climate resilience in economic, social and eco-systems	EWSs, changes in land degradation, social protection, insurance, credit access, livelihood diversification, etc.
			PPCR outcomes and outputs: Increased capacity to withstand/ recover from climate change and variability	Project-level indicators including e.g. reduced impacts & losses, continuity of climate-sensitive services (e.g. water, infrastructure)
		The Adaptation Fund Results Framework (2010) cited in Brooks et al. (2011)	Number of people with reduced risk to extreme weather events	Percentage of population covered by adequate risk reduction systems
				No. of people affected by climate variability
			Ecosystem services and natural assets maintained or improved under climate change and variability-induced stress	No. and type of natural resource assets created, maintained or improved to withstand conditions resulting from climate variability and change (by type of assets)
			Percentage of households and communities having more secure (increased) access to livelihood assets	No. and type of adaptation assets (physical as well as knowledge) created in support of individual or

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				community livelihood strategies
				Type of income sources for households generated under climate change scenario
		Finnish National Adaptation Strategy cited in Swart et al. (2009)	Indicators of sustainable development	Food self-sufficiency
				Use of pesticides
				Increment of growing stock and total drainage in forests
				Tree species composition
				Length of the ice breaking assistance season
		Government Strategy Report 2008 cited in Swart et al. (2009)	Adaptation	Realized flood damage in communities
		Lamhauge, Lanzi and Agrawala (2011)	Risk reduction	Area of afforestation (m2/ha)
				Construction of climate-proof infrastructure
				Percentage of population with improved and sustainable access to water sources
				No. of people benefitting from water, livestock and natural risk management projects
			Indicators of action for increasing environmental resilience	Reduction of climate change hazards through coastal afforestation with community participation
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Physical infrastructure and basic services:** - Construction of flood shelter, and information and assistance centre to cope with enhanced recurrent floods in major floodplains. - Enhancing resilience of urban infrastructure and industries to impacts of climate change - Providing sustainable drinking water to coastal communities to combat enhanced salinity due to sea level rise. - Protect – Safeguard existing coastal land uses by implementing measures such as sea walls, dikes, beach nourishment and wetland restoration. - Engage in actions that compensate for climate-related changes (e.g. constructing raised homes on pilings to accommodate rising sea levels).

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Food security: - Resilience of the food production & security sector to climate change enhanced
				Water resources and quality: - Targets environmental dimensions of disaster risk management, in particular adaptation to climate change and water resources management. - Reallocation of reservoir yield - Water conservation and demand management (including metering and price structure) - Expand well fields - Rainwater harvesting
				Relocation: - Relocate human settlement (homes, roads, etc.) away from areas of potential flooding, allowing the rising sea to advance inland
		UNDP (2007)	Coverage: the extent to which projects reach vulnerable stakeholders (individuals, households, businesses, government agencies, policymakers, etc.)	Number of stakeholders (individuals, households, communities, etc.) served by new or expanded climate information management systems (e.g., early warning systems, forecasting).
			Impact: the extent to which projects reduce vulnerability and/or enhance adaptive capacity (through bringing about changes in adaptation processes: policy-making/planning, capacity building/ awareness raising, information management, etc.	Percent reduction in perceived vulnerability:
				Percent improvement in stakeholder perceptions of vulnerability to a recurrence of primary climate change related threat(s) combined with: Perceived success of project interventions in delivering mechanisms to reduce vulnerability
		UK Adaptation Sub-Committee (2011)	Preparedness in land use planning: impact (land use planning)	Insurance claims for weather related causes (flooding, storms, subsidence)
				Number of properties flooded
			Components of vulnerability (land use planning)	**Development in flood risk areas**: Number of buildings constructed in areas prone to river, coastal and surface water flood risk, not accounting for flood defenses (2001 – 2011) Number of buildings at low, moderate and significant likelihood of river and coastal flooding, accounting for flood defenses (2001 – 2011) Proportion of new dwellings built in areas of high flood risk (1989 – 2009)
				Development in areas at risk from coastal erosion:

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				Change in land covered by buildings in areas at risk from coastal erosion (protected and non-protected) (2001 – 2011)
				Factors affecting risk of surface water flooding and heat stress: Change from 'natural' to 'man-made' surfaces (2001 – 2011) Change in area of urban greenspace Waste heat
			Actions (land use planning)	**Catchment/neighborhood level measures**: Resolution of Environment Agency flood risk planning objections Number of properties with 'increased protection' from flood risk Uptake of sustainable drainage and permeable paving measures
				Property-level measures: Uptake of measures to increase resilience and resistance to flood risk in new development Uptake of measures to manage surface water run-off rates in new development Uptake of measures to reduce heat gain in new development
			Impact (water resources)	Supply demand balance – Drought orders
				Supply demand balance – Security of supply by water company
				Total demand – Freshwater abstraction ('non-tidal') by sector
				Public water demand – Total water put into public water supply
				Drivers of household demand – Population
				Drivers of household demand – Average per capita consumption
				Water supply – Catchments where additional water is available for licensing
				Waterbodies at risk of environmental damage from abstraction
			Actions (water resources)	Proportion of properties metered
				Uptake of water efficiency measures (measured through water saved through demand management
				Total industry leakage
				Winter storage reservoirs for irrigation

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
		Spearman et McGray (2011)	Substantive outcome	Change in degree of exposure to climate risks and threat
				Evidence of changed quality of climate-sensitive natural resource base
		Moser (2007) cited in Spearman and McGray (2011)	Capital Assets (physical)	Area of productive rangeland
			Capital Assets (financial)	Number of people with access to credit
			Capital Assets (human)	Percentage of school-aged children in school
			Capital Assets (social)	Legitimacy of natural resource management committees
			Capital Assets (natural)	Quality of housing structure
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	Flood protection for strategic and priority flood-prone areas in the upper reaches of the four main river basins in Hunan Province is improved.	Annualized flood damage and disaster relief costs are reduced in participating cities as a result of increased standards for flood protection works and improved flood emergency preparedness.
			Structural flood protection, resettlement, and environment management: flood protection works are completed in priority locations as part of Hunan's River Basin Flood Control Plan and the 11th Hunan Provincial Five-Year Plan and in compliance with People's Republic of China regulations and ADB safeguard policies.	Flood-control level of county-level cities is improved to 1 in 20-year-return flood from below 1 in 5-year-return flood recurrence by the end of project.
				Flood-control level of municipal cities is improved to 1 in 50 or 100-year-return flood by the end of the project.
				Satisfaction level of the 20,133 relocated persons is restored to pre-resettlement levels in terms of income and livelihood.
				Percentage of environment management plan monitoring targets is achieved.
		Global Environment Facility (2008) cited in Spearman and McGray (2011)	To develop and pilot a range of coping mechanisms for reducing the vulnerability of farmers and pastoralists to climate change, including variability.	Livestock and crop yield losses reduced by at least 25% among small-scale farmers in the project site.
			Risk reduction strategies in pilot area contribute to improved adaptive capacity and resilience to drought.	Number of households in the project site with improved farm outputs increased by at least 25%.
				Farm output in yields per/hectare increase by at least 25%.
				Soil erosion rates in the project site reduced by at least 10%
			Markets developed for diversified products from community agricultural production and support mechanisms	Livelihood strategies at household level in the project site increased to more than two.

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
			for tapping those in the pilot area.	Income generated from farm product sales (in the project site) increased by at least 10%.
		UNDP and GEF (2007) cited in Villanueva (2011)	Investment decision made on basis of risk assessment based on climate change scenario planning	Value of planned new development in high-risk areas compared with projected baseline value.
				Number of private planning application of development in high-risk areas.
			Resilience of coastal geomorphological and ecological system enhanced	Length of coastline covered by project interventions, coupled with population of adjacent coastal areas.
				Area and length of coast where project leads to changes associated with enhanced resilience (e.g. rehabilitation of dune systems , (re-stablishment of mangroves, corals, resumption of sediment transport to eroding beaches etc.
			Capacity to plan for and respond to changes in climate-related coastal risks improved through awareness building and enhance access to information on potential climate changes impacts, coupled with guidance on and improved access to available adaptation measures.	Percentage of population with access to key resources for adaptation compared with project baseline, measures (EWS storms shelters, postdisaster financial assistance).
				Percentage of population benefiting from access to shelters and other improvements in physical infrastructure such as installations of storm shutters etc.
				Perceived changes in individual vulnerability by members of coastal communities (QBS).
		Natural England (2010)	Resilience	Extent of semi natural habitat
				Land cover dominance and plant diversity
				Bird population indices
				Landscape distinctiveness
				Coastal habitat creation
				Good ecological status of WFD water bodies
				Abstractions
				Air quality
				Nitrogen deposition
				Ecosystem fragmentation
				Area of land under conservation agreements
				Progress in assessing /planning for climate change
				Soil organic matter and soil organic

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
				carbon content
				Area of functioning floodplain
				Area of green infrastructure within urban areas

TABLE 16: INDICATORS IDENTIFIED IN THE LITERATURE ASSOCIATED WITH THE "IMPACT IN TERMS OF COLLECTIVE WELL-BEING" OF THE CREXE MODEL

CREXE Model		Existing frameworks		
Components of the model	**Variables**	**Authors**	**Variables**	**Indicators**
Effects in terms of collective well-being	Collective well-being	Pilot Program for Climate Resilience (PPCR) (2010) cited in Brooks et al. (2011)	Transformative impacts: Improved quality of life of people living in areas most affected by climate change	HDI score (country), MDG indicators, % of people classified as poor and food insecure in most affected regions, mortality and economic losses from climate extremes
		Lamhauge, Lanzi and Agrawala (2011)	Risk reduction	Impact of flood (no. of people affected, inundation depth, duration, value of flood damage)
		Sanahuja (2011)	Indicators of Action of Increasing Social Resilience	**Human security:** - Displaced populations - Climate change refugees - Changes in migrants and migrant working - Increased Rural – Urban Migration - Increased social unrest over resources
		Asian Development Bank (2006) cited in Spearman and McGray (2011)	Sustainable and inclusive socioeconomic growth in flood-prone areas of Hunan Province.	Number of newly established industrial and commercial enterprises in the project areas increases compared with base year 2006.
				Land values for commercial and industrial purposes in project areas increases by at least 20% over 2005 levels by 2012.
				Urban poverty incidence in the project areas is reduced compared with 2003 incidence of 6.7%
			Flood protection for strategic and priority flood-prone areas in the upper reaches of the four main river basins in Hunan Province is improved.	Direct economic losses from floods and waterlogging are reduced compared with current average losses.