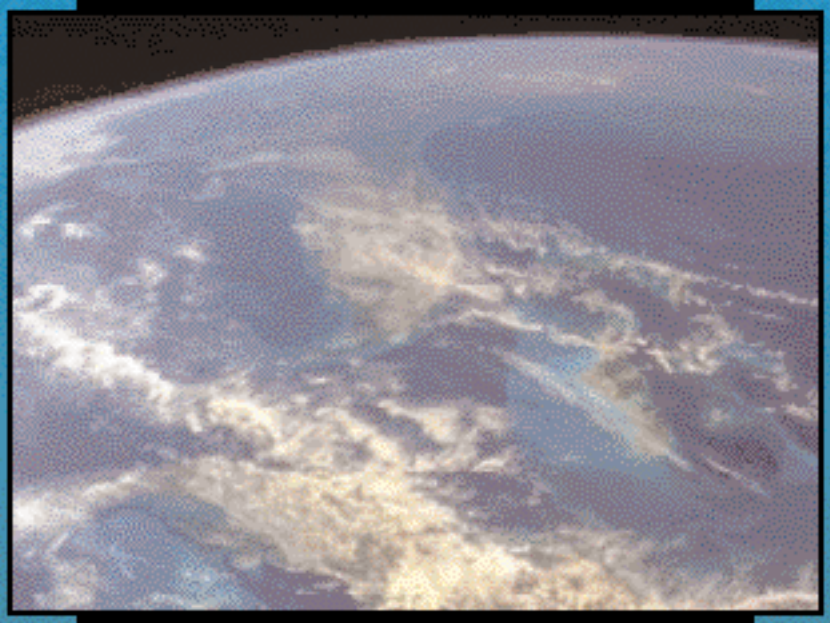

THE CANADA COUNTRY STUDY:

Climate Impacts and Adaptation

NATIONAL SUMMARY FOR POLICY MAKERS

Environment Canada

Canada

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THE CANADA COUNTRY STUDY:

Climate Impacts and Adaptation

NATIONAL SUMMARY FOR POLICY MAKERS

Editors: Barrie Maxwell, Nicola Mayer, Roger Street

Environment Canada

Canada

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The editors would like to thank a number of individuals for their comments at various stages in the preparation of this National Summary for Policy Makers. Included are members of the Canadian Climate Program Board, the Canadian Global Change Program Board, the National Air Issues Coordinating Committee, in addition to members of the Canada Country Study Steering Committee. All comments were considered and have contributed substantially to improving the content and style of the final version of this summary.

Special thanks are offered to all Canada Country Study lead authors and their associates, both for their work in preparing the individual papers upon which this National Summary is based, as well as subsequent comments on drafts of this summary.

Photographs provided through the offices of Ross Herrington, Prairie and Northern Region (EC) and Eric Taylor, Pacific and Yukon Region (EC).

Message from the Minister of the Environment

Climate change is one of Canada's biggest challenges as we head toward the millennium. If we meet that challenge, it will ensure the continued health of our planet. Otherwise future generations may suffer.

We know that the science on climate change is sound. Scientists from around the world agree that our climate is warming at an increasingly rapid rate because of higher volumes of greenhouse gases entering the atmosphere.

The Canada Country Study provides another important piece of knowledge on how climate change could impact our communities across the country. Not only does it alert Canadians to what scientists expect will happen, it suggests ways in which Canadians can adapt to changes in climate. The Study also provides a critical perspective for charting Canada's future.

The Canada Country Study helps us understand how to capitalize on economic opportunities and enhance our social well-being as we face this challenge. In some cases, we have the answers. In others, further study and consultation is required to forge the best strategies. Much work remains to be done.

Overcoming the problem of climate change will require a concerted effort. It is imperative that Canadians are well-informed when preparing to respond to the potential impacts of this phenomenon. Once Canadians understand the implications, I am confident that they will take action to safeguard our environment, health and economy for the benefit of our children and grandchildren.

I would like to thank the many individuals who have contributed to the Canada Country Study. Through your efforts, Canadians are better informed about how they can take greater responsibility in ensuring our continued prosperity.

Christine S. Stewart

THE CANADA COUNTRY STUDY
National Summary for Policy Makers

Basis

The Canada Country Study results identify what we currently know of possible impacts as a consequence of projected changes in climate and what we currently know of adaptive responses. These results are based on a review of existing scientific and technical literature, the nature of which is two-fold. Firstly, this literature includes studies of the sensitivity to and observed impacts of past and current climate, and secondly, it includes impact analyses based on scenarios of future climate change, mainly those projected by general circulation models of the atmosphere on the basis of a doubling of atmospheric carbon dioxide and assumptions reflecting our current understanding of the global climate system. As such, the identified impacts should not be seen as predictions but, rather, as indications of sensitivities and vulnerabilities associated with the projected change in climate. The diversity of these impacts and viable adaptation options, in addition to reflecting projected change in climate, reflect the geographic breadth and the environmental, economic and social diversity of Canada.

Highlights

- Responding to the impacts of projected climate change in Canada will be significantly complicated by the consequences for Canada arising from those impacts projected for the international community, particularly our trading partners and competitors.

- The environmental, economic, and social costs associated with the impacts of and adaptation to current climate in Canada (including, for example, over a billion dollars annually in the water sector alone) are large, and projected changes in climate are expected to increase those costs.

- As Canada's prosperity and well-being is strongly linked to that of its natural ecosystems and water resources, the responses of these to projected climate change will be critical in deter-mining the environmental, economic and social costs and benefits of climate change for Canada.

- The location, structure and functioning of terrestrial and aquatic ecosystems would be altered as a result of expected changes in relative season length, species distribution, population, habitat, and competition between species, and their capacity to adapt would be tested by the fast, possibly irregular rate of warming.

- In addition to natural environmental influences, all socio-economic sectors would be impacted through additional stresses on physical and social infrastructure, ranging from altered building and construction practices to adjustments in health care to changes in subsistence lifestyles with their reliance on local knowledge.

When interpreting these results, the reader should be aware that confidence is higher in the hemispheric-to-continental projections of climate change than in the regional projections, where confidence remains low. It is also worth noting that the majority of the identified changes in climate and, therefore, the identified impacts, are projected to occur over the next century, and that the average rate of warming would probably be greater than any seen in the last 10,000 years. Furthermore, although future, unexpected, large and rapid climate system changes (as have occurred in the past) are difficult to predict, future changes may also involve "surprises".

THE CANADA COUNTRY STUDY
National Summary for Policy Makers

Highlights

- Harvest levels in the agriculture, forestry and fisheries sectors are sensitive to climate. Sustaining viable production levels will depend on the capacity of these sectors to cope with the projected rate of warming and changes in climate variability, and the prospects of imperfect responses, as well as their ability to counter projected decreases in water availability and increased threats of competition, disease and other disturbances (e.g., fire).

- Adaptive capacity to climate conditions has historically been strong in such sectors as energy, transportation, and recreation and tourism, but the rate of projected warming and the prospects of future climate surprises would present serious challenges to that capacity.

- Considering Canada's vulnerability to extreme events, projected changes in their occurrence and severity would have serious ramifications for the security and integrity of our natural resources, social systems, and infrastructure with subsequent implications for the insurance industry and supporting public sectors.

- In some cases projected climate change would have positive impacts (e.g., longer growing season and lower heating demand), which could provide adaptive opportunities or could alleviate the pressures caused by other stresses (e.g., population change, other air issues, land-use alterations).

- Increased emphasis in climate impacts and adaptation research on integrated assessment, on linking with sustainable development research, and on involving stakeholders directly in research is essential for addressing gaps in our current level of understanding.

Basis

The Canada Country Study results identify what we currently know of possible impacts as a consequence of projected changes in climate and what we currently know of adaptive responses. These results are based on a review of existing scientific and technical literature, the nature of which is two-fold. Firstly, this literature includes studies of the sensitivity to and observed impacts of past and current climate, and secondly, it includes impact analyses based on scenarios of future climate change, mainly those projected by general circulation models of the atmosphere on the basis of a doubling of atmospheric carbon dioxide and assumptions reflecting our current understanding of the global climate system. As such, the identified impacts should not be seen as predictions but, rather, as indications of sensitivities and vulnerabilities associated with the projected change in climate. The diversity of these impacts and viable adaptation options, in addition to reflecting projected change in climate, reflect the geographic breadth and the environmental, economic and social diversity of Canada.

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CANADA COUNTRY STUDY

National Summary for Policy Makers

INTRODUCTION

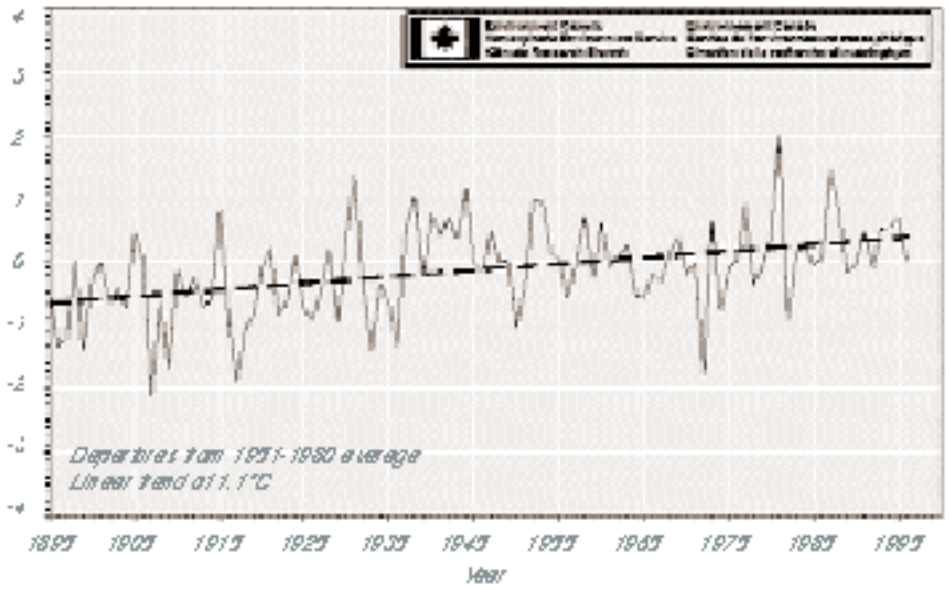
The Canada Country Study (CCS): Climate Impacts and Adaptation is a national assessment of the potential impacts of climate change and variability, including consideration of existing and potential adaptive responses. Initial efforts within the CCS have focused on reviewing existing scientific and technical literature through 26 commissioned studies that identify our current understanding of impacts and adaptation options from regional and national perspectives. The result of this initial work is state-of-the-art information on the vulnerability of Canada's economic sectors, social well-being, and ecological systems to projected changes in climate.

The results of this initial assessment are published in eight CCS volumes - six regional volumes (Arctic, Atlantic, Ontario, Pacific and Yukon, Prairies, and Québec), a national sectoral volume consisting of twelve papers (agriculture, built environment, energy, fisheries, forestry, human health, insurance, recreation and tourism, transportation, unmanaged ecosystems, water resources, and wetlands) and a cross-cutting issues volume consisting of eight papers (changing landscapes, costs, domestic trade and commerce, extra-territorial issues, extreme events, integrated air issues, sustainability, and two economies). The results are also summarized in seven plain language documents, one for each region and one at the national level. The document you are reading - the National Summary for Policy Makers - provides a digest of the results in a form directed at policy and decision makers in both the public and private sectors.

Science Background

Climate may be thought of as a description of the averages and extremes in weather for a particular location. Climate is naturally variable; from our own experience, we know that one summer is often warmer or wetter than another, or one winter is colder or snowier than another. Such variability is normal, and is related to changes in ocean currents or sea-surface temperatures, volcanic eruptions, alterations in the sun's output of energy, or other features of the climate system some of which are not yet fully understood. Our climate also includes extremes (e.g., floods, droughts, hail, tornadoes, and hurricanes) some of which can have devastating impacts on our natural and socio-economic structures and systems.

Annual national temperature departures and long-term trend, 1895- 1996

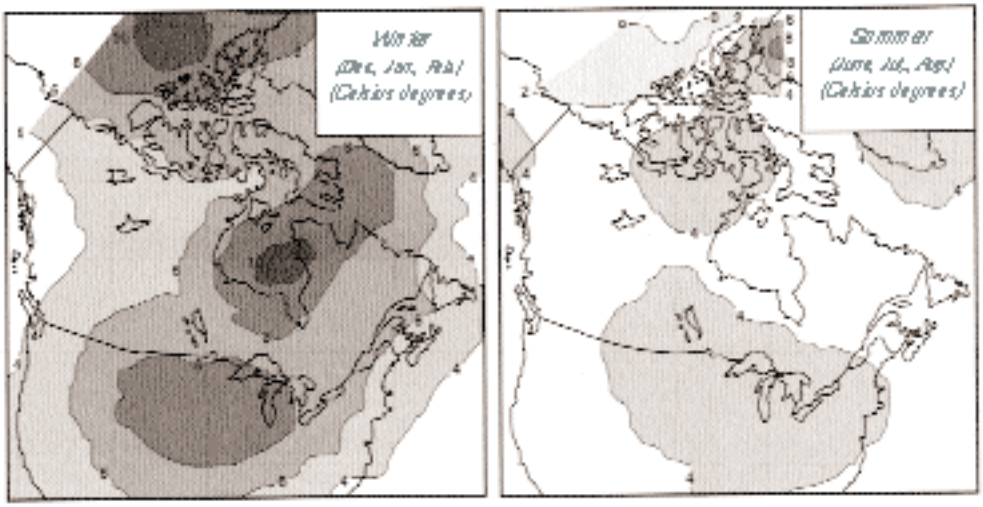


During the past century, the average annual global climate has warmed by about 0.5°C. The associated warming in Canada has amounted to approximately 1°C with regional variations ranging from warming of about 1.5°C in the western Northwest Territories (NWT), to warming of less than 1°C over southern Canada, and to a cooling of 0.8°C in extreme eastern NWT. Temperatures are analyzed with respect to eleven broad climatic-geographic regions. It should be noted that not all regions have data for the same period of time with 1948 marking the earliest year of the period over which reliable inter-regional comparisons are feasible. Over the past half century, Canada as a whole has also experienced increased annual precipitation, consistent with the global precipitation trend.

Human activities, primarily the burning of fossil fuels and changes in land use and land cover, are increasing the atmospheric concentrations of greenhouse gases, which alter radiative balances and tend to warm the atmosphere, and, in some regions, aerosols, which have an opposite effect on radiative balances and tend to cool the atmosphere. These changes in greenhouse gases and aerosols, taken together, are projected to lead to regional and global changes in temperature, precipitation, and other climatic variables, which could result in global changes in soil moisture, an increase in global mean sea level, and the prospects for more severe extreme high temperature events, floods, and droughts in some places.

CCC GCM2 2xCO$_2$ temperature projections for Canada for winter and summer seasons

Climate changes will not be distributed uniformly. For a doubling of carbon dioxide concentrations, GCM2 projects an increase of 3.5°C in the earth's average annual temperature but shows more substantial warming over much of Canada, particularly in winter.



Model	Winter	Summer
GFDL 91 - Geophysical Fluid Dynamics Laboratory GCM	2-6°C	2-3°C
GISS 87 - Goddard Institute for Space Studies GCM	2-14°C	1-2°C

Scenarios of the potential changes in climate have been developed using several approaches including general circulation models (GCMs) of

the Earth's climate incorporating increased concentrations of atmospheric carbon dioxide. The climate projections produced by the GCMs are being used with increasing confidence. Important uncertainties remain, however, with confidence being higher in the hemispheric-to-continental scale projections than in the regional projections (e.g., uncertainties associated with the spatial and temporal distribution of aerosols greatly influence regional projections). Models in which the Intergovernmental Panel on Climate Change (IPCC) has the greatest confidence project:

- greater warming of the land than of the sea in winter;
- maximum surface warming in higher northern latitudes in winter;
- little surface warming over the Arctic in summer;
- an enhanced global mean hydrological cycle; and
- increased precipitation and soil moisture in high latitudes in the winter.

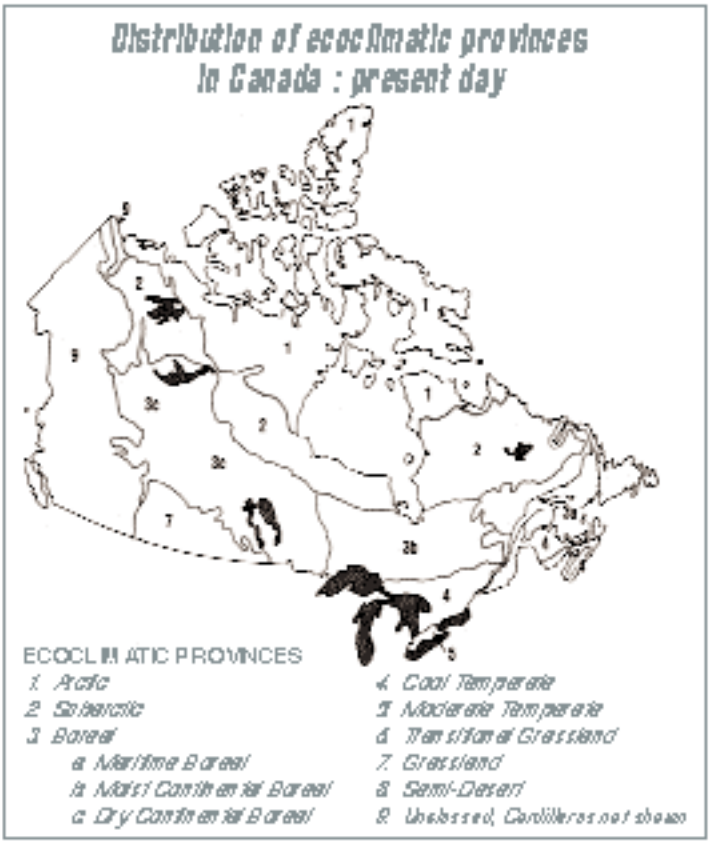
Based on the range of sensitivities of climate to changes in the atmospheric concentrations of greenhouse gases and plausible changes in emissions, climate models project that the mean annual global surface temperature will increase by between 1 and 3.5° C by the year 2100, and that global mean sea level will rise by between 15 and 95 cm. The average rate of warming is projected to be greater than any seen in the last 10,000 years, although the actual annual to decadal rate will include considerable natural variability.

Considerable uncertainty remains regarding the implications of these changes for climate variability and extremes. Models, however, suggest an increase in the occurrence of extremely hot days and a decrease in the occurrence of extremely cold days. There is considerable confidence that warmer temperatures will lead to a more vigorous hydrological cycle suggesting possible changes in precipitation patterns in space and time which translate into the potential for more severe droughts and/or floods in some locations and less severe droughts and/or floods in others. Several studies support the expectation of more intense summer convective storms and mid-latitude winter storms.

Although changes experienced could differ substantially from the global mean value, the climate of Canada is projected to change with significant regional variations. A number of factors, however, are contributing to the uncertainties surrounding projections of Canada's climate, including the inadequacies of regional-scale climate projections when considered relative to the spatial scales of variability of natural and social systems of this country.

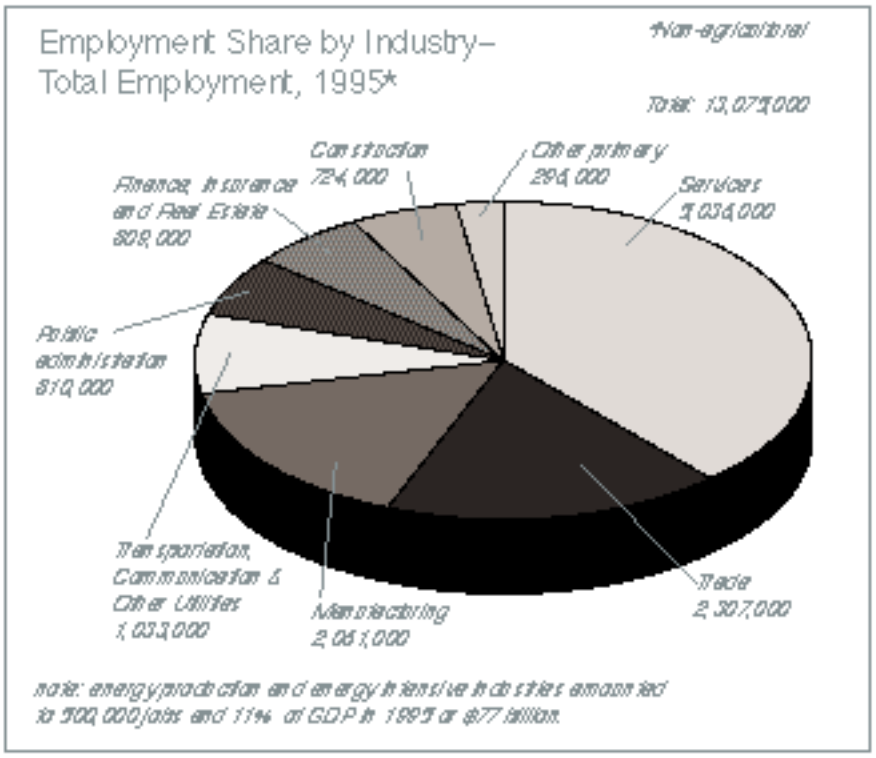
Natural Environmental and Socio-Economic Settings

Canada is ecologically, climatically and socio-economically diverse. Recognition of this diversity is essential to understanding the potential effects of climate change on regions and sectors within Canada, and in formulating and implementing viable response options.



Temperature and precipitation, along with socio-economic activity, play dominant roles in the ecological patterns across the country. The current mixture of managed and unmanaged ecosystems reflects this influence and results in differentiated physical characteristics and capacities to support vegetation, wildlife and socio-economic activity. The strong link between Canada's prosperity and well-being and that of its natural ecosystems is well known and it is expected that the ecosystem responses to climate change will be significant in determining the environmental, social and economic costs and benefits of climate change for Canada.

Canada is the second largest country in the world but is sparsely populated, with most of its population concentrated along its southern border. More than most industrialized nations, Canada depends primarily on the land for its economic and social well-being, with one in three workers employed directly or indirectly in agriculture, forestry, mining, energy production and other energy intensive and land-based activities. A profile of the Canadian economy as shown by contribution to total GDP by various socio-economic sectors provides one indicator of the relative importance of each sector to the country as a whole.



SOURCE: Statistics Canada

Canada's prosperity and well-being are affected by a number of changes and development trends (e.g., population dynamics, land-use changes, changes in the global and regional economy, air and water pollution, consumption and technological changes). Climate change is an additional factor that will affect the evolution and adaptation of Canada's natural and human systems. In the decades ahead, it will act in combination with these other changes and trends, resulting in either a negative or positive impact for a particular region or sector or, in some cases, providing an opportunity that could benefit a particular region or sector.

Scope of the Assessment

In structuring this summary document, results are presented in a cascade from international through to regional levels. Nationally, four broad policy areas are used to organize the results:

- protecting infrastructure (built environment, insurance);
- maintaining vibrant industry (energy, transportation);
- ensuring social well-being (human health, tourism and recreation, traditional life-style); and
- sustaining food and fibre production (agriculture, fisheries, forestry).

The purpose of grouping these in such a fashion is to promote integration of impacts as well as to identify which sectors are likely to influence different areas of the community. Water and natural resources, reflecting their importance as foundation blocks in the socio-economic structure of the country, are singled out for special note.

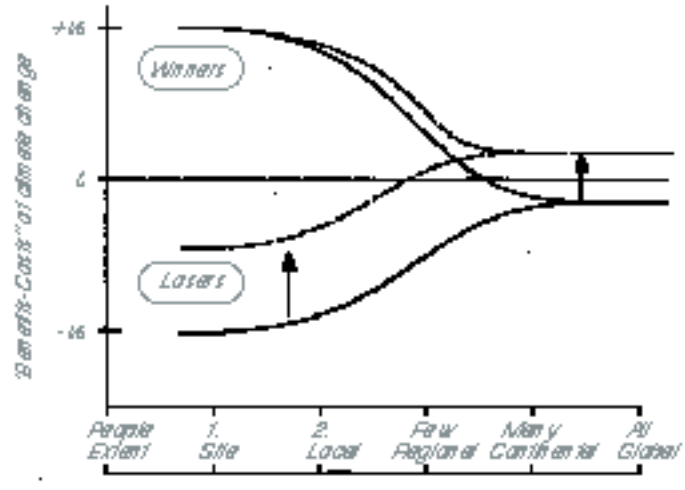
Our current understanding of the potential impacts of climate change on Canada is somewhat limited by uncertainties related to both regional-scale climate projections

and relationships between climate and ecological, economic, and social systems. Accepting such limitations, the large volume of scientific and technical literature and the degree of agreement found in it provide a reasonable level of confidence in the sensitivity and vulnerability of physical, biological and socio-economic systems to climate change and variability that are projected by the Canada Country Study.

The literature reviewed to produce this assessment has used a range of $2\times CO_2$ scenarios and sensitivity studies, as well as economic and ecological models, therefore providing a broad understanding of the sensitivities to changes in climate and not just sensitivity to a $2\times CO_2$ climate. Although most of the literature reviewed has focused on a $2\times CO_2$ world, it is not unreasonable to expect that some of the kinds of impacts that are identified would begin to be manifest before the atmospheric concentrations of CO_2 doubles. It is also important to recognize that $2\times CO_2$ is not a magic concentration and it is likely that, unless action is taken, $2\times CO_2$ will be passed on our way to even higher concentrations.

It should also be noted that results of many of the impact studies have tended to emphasize the negative impacts of climate change. It is recognized, but poorly understood due to limited research, that climate change may have some benefits (e.g., reduced stress and/or provide opportunities) for some regions/sectors within Canada or may have a neutral effect on climate-insensitive sectors. In this assessment, specific attention has been placed on providing as balanced a picture as possible for Canada. The above figure illustrates how important scale may be. At the local or regional scale, costs or benefits may be large, but as they are aggregated over large scales, the magnitudes of both tend to diminish.

Effects of geographic / economic scale on net gain (benefits minus costs) arising from effects of climate change on society and the role adaptation might play in mitigating the more negative outcomes.



Information on adaptation options is, in general, less often available than results of climate change impacts. Where such information does exist, it is often subjective in nature. Interpreting a region's or sector's adaptive capacity should include rigorous research on social and cultural acceptability, as well as research on the necessary institutional and financial mechanisms to manage climate change.

IMPACTS AND ADAPTATION

International

Canada, as a member of the global community, is sensitive to potential impacts and responses in other countries. These sensitivities could have implications for Canada's balance of trade and foreign policy, international relations and security, environmental refugees, and international finance.

Forestry, fisheries, agriculture and energy are four areas in which Canada has significant net export positions. All are natural resources for which domestic and international productive capacities and demand could be altered by projected climate change, thus affecting supply and demand patterns and international prices. While both agriculture and forestry have been suggested as sectors in which Canada's overall competitive position could improve due to climate change, this has not been convincingly demonstrated as yet. The eventual outcome with respect to energy and fisheries is also somewhat uncertain. Much of the uncertainty here lies in

how these resources within other countries will be affected and how those nations respond.

An improvement in Canada's export capability could have implications for Canada's foreign policy position with regard to international trade conventions; for example, an increased export capability could affect our position on import barriers. International finance could also be affected by climate change as a result of altered trade and commerce relationships among nations.

Concerns have been raised that differentiated impacts on food growing capacities and water resources as a result of projected changes in climate could exacerbate existing regional conflicts and/or possibly introduce new conflicts. Also of concern, is the possibility of increased diplomatic turmoil as tensions increase over transboundary water management, control of such waters as the Northwest Passage, air pollution and international common property such as marine fisheries stocks - all of which are sensitive to changes in climate. From a Canadian perspective increased regional conflicts and diplomatic turmoil could also lead to increased demands for Canadian peacekeeping as well as a heightened role concerning Canadian security. Domestically, these international implications raise concerns related to the possibility of environmental refugees migrating to Canada with subsequent implications for health and social systems, as well as potential impacts on the labour market.

Domestic

Introduction

There are significant implications for Canada as a consequence of projected changes in climate. Almost certainly there will be impacts on domestic trade and commerce although their exact nature is unclear at this time. For example, climate change is projected to moderate the temperature of the more northerly areas of the country, providing incentive for increased commercial activity there, though a significant migration of population northward seems unlikely.

Costs

Our current climate is variable and Canadians and the economy react to it in different ways. There are many examples of successful adaptation to climate, ranging from adopting design codes, to developing and planting appropriate types of vegetation, to situating buildings or roads in certain locations, to promoting specific types of recreation activities, and so on. Canadians spend billions of dollars annually adapting to our current climate.

While some partial estimates of potential costs have been made, these are limited in scope and remain uncertain or even speculative. Values cited by the IPCC of some percentage of GDP (i.e. 1-2% of GDP for developed countries assuming a doubling of atmospheric carbon dioxide by 2050 and a mean global warming of 2.5°C) reflect predominately estimates for the U.S. and extrapolations thereof. These values should not be taken as an estimate of the aggregate potential cost of climate change to Canada, however, as there is considerable disagreement about the underlying studies and the applicability of their results to other regions. To date, estimates downplay the incalculable risk of costly catastrophe scenarios and the possibility of unanticipated impacts, disregard the costs of adapting to a changing climate and all but ignore the social value of most non-market goods and services. As a result, a reasonable argument could be made to raise existing estimates substantially.

The costs of climate change adaptations are expected to arise from either technological, environmental or social considerations:

- Technical adaptation includes many engineered solutions such as building dykes and sea walls, and preparing buildings and pipelines in permafrost areas to withstand destabilization of the ground supporting them.
- Environmental adaptation comprises the redistribution and changing structure of natural ecological systems. The costs

associated with this sort of adaptation are largely unknown.

- Social adaptation costs are associated with loss or change in employment or lifestyle, including dislocation, due to impacts upon natural resources (e.g., fisheries, forestry, and agriculture) and our human systems. These social impacts not only have financial costs associated with them, but have psychological impacts as a sense of worth, esteem and history are often attached to job or place.

Domestic Operations for Security Forces

Canada's security forces are often called upon to provide assistance during times of regional and national disasters. Although there is considerable uncertainty as to the nature of changes in extreme weather events as a result of climate changes, projected changes in the frequency or severity of these events could lead to an increased demand for military assistance, such as in the case of the 1997 Red River flooding in southern Manitoba. This would result in increased costs for domestic operations. In the Arctic, increased surveillance, search and rescue, and other security forces' activities related to maintaining Canadian sovereignty are likely as a result of expected increases in accessibility amongst the Arctic Islands and through the Northwest Passage associated with projections of less severe ice conditions and somewhat less severe weather and climate conditions on average.

Spring 1997 flooding in southern Manitoba

Protecting Infrastructure

Canada's infrastructure, both the various buildings and structures themselves as well as the protection afforded them by insurance, are affected by the frequency, magnitude, and duration of severe and extreme events as well as the cumulative effects from daily climate conditions.

Building and Construction

The built environment includes homes, buildings, supporting infrastructure, roads, railways and engineering structures such as dykes and pipelines. Impacts from climate change on the built environment could include changes in construction requirements to deal with an altered climate, changes in the frequency and intensity of floods and other extreme events, and with projected changes in land stability (e.g., landslides and permafrost melting).

Earthflow in permafrost terrain, Dekaie Creek, Mackenzie Mountains, N.W.T.

- Construction season: The length of the summer construction season is projected to increase while the length of the winter season could decrease. While an advantage for southern Canada, a shortened winter season in the North could create difficulty for access (due to projected decreases in the viability of winter roads) and for heavy construction (due to concerns regarding disturbing sensitive tundra areas with heavy equipment).

- Permafrost: Increases in frost heave, thaw settlement and slope instability associated with projected permafrost melting could negatively affect the structural integrity and design of northern structures and construction requirements, including utility lines and pipelines. Foundation conditions are vulnerable in the North as permafrost thaws, with differential settlement possibly leading to changes in the integrity of structures, or even collapse of buildings. Utility lines and pipelines may rupture. Mining operations might become easier, but waste dumps, tailings dams, and water diversion channels could be vulnerable, possibly leading to their collapse and increased and expensive maintenance.
- Building security/integrity: Cost savings from projected decreases in snow loadings on buildings and structures are possible in some areas; however, projected increases in wind and rain loadings and in freeze/thaw cycles could have negative impacts. The stability of foundations is of concern in those areas where increased winter rainfall, increased freeze/thaw cycles and drier summers are projected.


Windstorm damage

- Flooding and other extreme events: Although there remains considerable uncertainty regarding projections of changes in flooding and other extreme events, the potential implications of these changes for buildings and construction, warrant their consideration. The flooding of low-lying homes, docks and port facilities, as well as stresses on water distribution and sewage systems associated with projected increases in sea level, extreme rain/snow fall, and spring ice jams on rivers are a major concern. Particularly vulnerable to changes in extreme events are electricity transmission and utility lines (due to changes in wind and ice loading), bridge piers, and dams (due to changes in flood levels and ice jams). Premature structural failure due to deterioration over months and years could be accelerated where increased occurrences of such things as temperature extremes and frequency of combined wind and rain are anticipated.

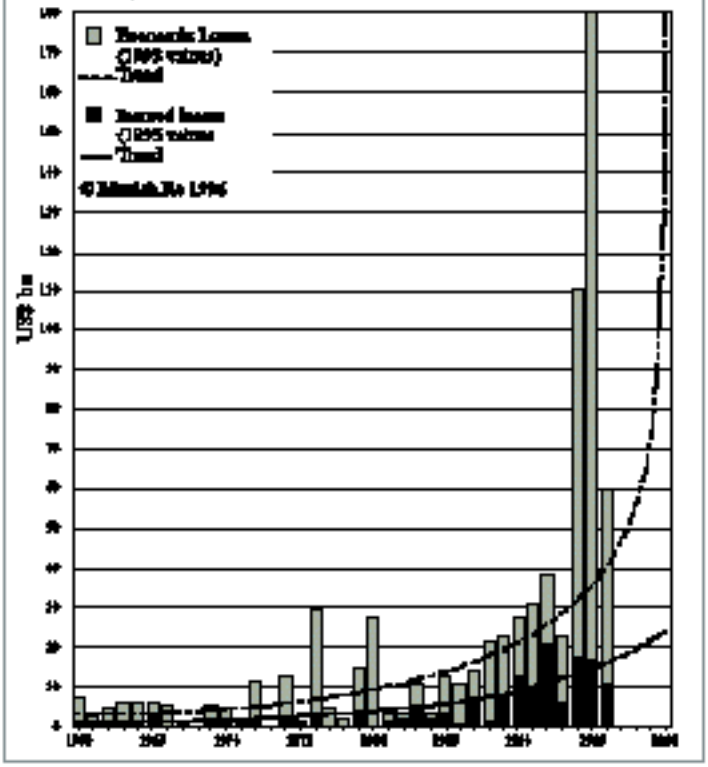
In many cases, the current margin of safety built into the National Building Code is expected to be sufficient to maintain safe and economical structures, given good workmanship and materials and no significant changes in variability. Adaptation options to address concerns related to structural safety, as well as energy conservation and the minimization of life-cycle costs of building and structures, include:

- upgrading and/or moving of facilities and structures (such as riverine flood control systems);
- strengthening of land use planning regulations, particularly in damage-prone areas;
- revised design criteria and siting where new construction is involved to reflect changing climate conditions; and
- coastal zone management that weighs the relative merits of engineered and natural solutions.

Insurance

The insurance industry shows the greatest interest in catastrophic events such as hurricanes, tornadoes, wind, and hailstorms. It is anticipated that any change in the frequency or severity of such extreme events will alter demands on insurance for claim payments. This in turn affects insurance coverage and premiums under the traditional industry actuarial approach of "the past is the key to the future". Of serious concern is the possibility that abrupt climate change, resulting in more frequent claims disasters, could produce higher and more frequent claim payments before adequate reserves are built up.

Economic and insured losses due to great natural disasters, 1960-1996, with trends extrapolated to 2000



Thus the traditional industry approach would not have enough time to take such changes into account. The following figure illustrates the change in economic and insured losses over the past 35 years.

Property and casualty insurance is probably the most vulnerable as increases in the frequency and/or severity of catastrophes could produce restrictions in insurance coverages, premium increases, or any combination thereof. Stronger building codes and their better enforcement are being advocated as means of reducing sensitivities.

Among the consequences of these implications to insurance coverage may be greater public or personal responsibility to deal with natural disasters such as flood, drought, and wind storms. In the Prairies, it is anticipated that premiums in the agricultural sector may need to increase, with changed availability and eligibility criteria possible. Such restructuring may cause additional financial strain on agriculture and other sectors.

Existing and new enterprises would be adversely affected by reduced availability and coverage, as well as increased cost, across all lines of property and casualty insurance in many parts of Canada. Thus there would be a potential negative socio-economic impact. Finally, the insurance sector itself could also be impacted in a detrimental fashion by climate change due to the depletion of reserves, reductions in viable market, and the restructuring that would naturally follow.

Climate and Canadian Buildings and Construction

Climate plays a key role in the design and long-term viability of Canada's built environment. Climate information, for example, is the basis of design wind and snow loads contained in the National Building Code and these load values are updated from time to time based on the most recent climate data. To the degree that the new data presents a more accurate assessment of current climate variability, the risk of loss in a future extreme event is better managed. In Howe Sound, British Columbia, for example, heavy rainstorms have caused floods containing glacial debris to occur on the steep slopes, destroying rail and highway bridges, damaging buildings, even sweeping them into the Sound, with major loss of life. One such incident in 1982 caused direct damages over $1 million, while the accumulated incidents have caused the B.C. Ministry of Highways to spend over $20 million building defenses. In addition to extreme events, however, climate on a day-to-day basis also hastens premature failure of walls and roofs, and gradual loss of function of roads, towers, bridges and dams as a consequence of interaction with wind and wind-borne rain, solar radiation, and pollutants. If these climate-related conditions were properly accounted for in building design, $7 billion annually could be saved on wall and roof renovation.

Maintaining Vibrant Industry

The manufacturing, industrial and non-renewable resource extraction industries are closely intertwined with the availability of appropriate energy and transportation. Projected impacts of climate change on Canada's industrial sector are primarily related to possible changes in heating and cooling demands, possible implications from greenhouse gases reduction requirements, as well as altered transportation availability. For the foreseeable future, fossil fuel use is expected to remain dominant within the Canadian industrial sector. The viability of alternative sources of energy, such as wind and solar, will remain sensitive to cloud and wind regimes.

Energy

Demand: The industrial sector is the largest energy user in Canada, accounting for 43% of the total end-use energy demand. Energy demand for the industrial sector is expected to increase to 47% by 2020, thus remaining the most important energy user. The energy demands of the residential sector are anticipated to decrease in relative terms (from 19% of total end-use demand in 1995 to 15% in 2020) due to implementation of energy efficient technologies and appliances. Energy demand profiles for heating are expected to decrease and for cooling are expected to increase as a result of projected increases in temperature. It has been suggested that the Prairie agricultural sector could experience increases in energy requirements to meet projected increases in demands associated with irrigation, grain drying and harvesting.

Supply - Electricity: Hydro-electric generation potential is sensitive to changes in water availability and river flow regimes. Projections of water availability and flows suggest possible increases in generation potential in Labrador and northern Québec, and possible decreases in Ontario, the Prairies, and southeastern British Columbia. Transmission lines are sensitive to storm-related outages and, as such, concerns have been raised regarding the security of these lines should projected changes in extreme events occur. Particularly vulnerable are those industries dependent on a sustainable and uninterrupted supply of electricity (e.g., aluminum production).

Supply - Fossil fuels: Offshore oil and gas operations in the North could benefit from a retreat in the southern ice boundary, but are sensitive to more intense and frequent extreme storms projected as a result of a potentially longer open-water season. Pipeline costs in the Arctic are likely to be more expensive due to the need to address increased permafrost instability. Costs for ice-breaking tankers should be reduced. Uncertainties are still high enough, however, that the positive impacts cannot be incorporated into current design while negative impacts have to be included due to the conservative approach adopted by industry for frontier activities. As a consequence, there may be an increased cost for frontier oil and gas operations in the short term. For coal mining operations, increased erosion and landslides may be a concern in mountainous areas, such as British Columbia.

Historically, the energy industry has been able to adapt fairly successfully to changes in supply and demand, and to tackle new challenges such as the search for oil and gas under ice-covered waters through innovation. As a result, the adaptation capacity of the energy sector is considered to be high. This capacity may be challenged, however, by the expected rate of climate change and by possible surprises. Suggested adaptive responses include altered design criteria, energy efficiency and conservation, and the use of alternatives (such as solar and wind).

Transportation

Land-based: It is expected that overall land-based transportation costs could be reduced due to shorter and/or less harsh winters (more efficient engine operation, less warm-up time, shorter snow removal seasons although with greater amounts during the winter season in some areas of the country). This is particularly applicable for southern areas of the country. In the North, however, such as in the Mackenzie Basin, winter transportation costs may be raised due to a reduced length of season for ice roads. Projected increases in permafrost instability will likely lead to increased maintenance costs for existing all-weather roads and rail-beds.

Marine: The shipping season could lengthen for areas currently characterized by sea ice for all

or part of the year, such as Hudson Bay and the western and central Arctic, and marine design needs related to sea ice may be relaxed. Projected sea-level rise will generally contribute to deeper drafts in marine harbours and channels, but could lead to significant damage to coastal support infrastructure in Atlantic and Arctic Canada. The potential of increased storm activity has raised concerns regarding the necessity of increased navigational aid support.

Freshwater: Although longer open-water seasons are possible, projected reduction of water levels could translate into significant, negative impacts for commercial navigation on major rivers and lakes, such as the Great Lakes - St. Lawrence River system. On the Mackenzie River, the barge season could lengthen (by as much as 40%), but navigation may be more difficult with the projected lower water levels.

Air: The impacts on air travel have not been rigorously investigated; however, it is suggested that aviation would be more sensitive to climate change than any other mode of transportation. Inclement weather causes delays for Canadian airlines that cost more than $81 million in 1981 due to disrupted flights. For smaller aircraft, longer seasons for the operation of float planes are likely, with conversely shorter seasons for snow and ice landing strips.

Ensuring Social Well-Being

Social well-being may be measured by such con-siderations as the level of human health, access to recreation and tourism, and the sense of self engen-dered by vocation. The entire range of climate elements influences all aspects of our enjoyment of life.

Human Health

Climate change is likely to have wide-ranging and mostly adverse impacts on human health. These impacts would arise by both direct pathways (e.g., exposure to changes in thermal stress and to changes in extreme events) and indirect pathways (e.g., increases in some air pollutants, pollens and mold spores, malnutrition, increases in the potential transmission of vector-borne and water borne diseases, and stresses on the general public health infrastructure).

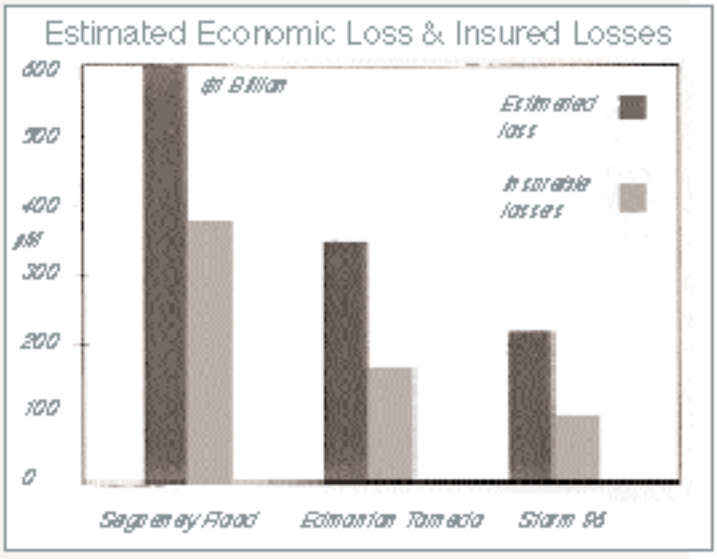
The Storm of '96

Vancouver Island, the Lower B.C. Mainland and the Fraser Valley were paralyzed between December 22, 1996 and January 3, 1997 with a series of brutal winter storms that left up to 85 cm of snow. The accumulation was unprecedented for this region and the 24 hr fall of 64.5 cm at Victoria International Airport was the 3rd highest snowfall, in a major city, in Canadian history. Downdown Victoria received 85cm during the same time period.

The environmental impact that resulted included massive releases of untreated sewage into the rivers and oceans. Sectors that were heavily impacted during Storm '96 were: Horticulture, Other Agriculture Operations, Marinas, Vicking Air, The Public Sector, Structural Damage to the Built Environment and Transportation.

Economically, the losses are currently estimated at $200M. The diagram below illustrates these losses in comparison with the losses experienced during the Saguenay Flood in 1996 and the Edmonton tornado 1987.

If mechanisms could be developed to avert even 10% of the negative impact experienced during this event the savings would be in the range of $20M.



Potential direct health impacts of climate change:

- Thermal extremes - The young, the elderly, the frail, and the ill, especially those in large urban areas, are particularly susceptible to projected increases in the frequency and severity of heat waves. If temperatures warm as projected, sensitive populations in urbanized areas in southeastern Ontario and southern Québec could experience increased incidence of heat-related illnesses and death.
- Extreme events - Although impacts on extreme events are somewhat uncertain, an increase in the frequency and severity of extreme events may lead to: (a) increases in deaths, injuries, infectious diseases, and stress-related disorders; and (b) increases in other adverse health effects associated with social disruption and environmentally-forced migration. A recent extreme precipitation event was partly responsible for a 1995 outbreak of toxoplasmosis in the capital regional district of British Columbia.

Potential indirect health impacts of climate change:

- Infectious diseases - It has been suggested that western equine encephalitis, eastern equine encephalitis, and the snowshoe hare virus could expand their ranges in Canada. Malaria could potentially return to southern Canada and the area in which populations are susceptible to dengue and yellow fever may extend northward into Canada. Other diseases which may increase their geographic distribution/incidence include heartworm, Lyme disease, Rocky Mountain Spotted Fever, and hantavirus.
- Respiratory disorders - Projected increases in temperature could affect the seasonality of certain respiratory disorders and could exacerbate air pollution in both urban and rural areas, and thus accentuate respiratory disorders.
- Environmental contamination - Illnesses, related to environmental contamination (e.g. by Bacillus anthracis), water contamination (e.g. by Giardia, Cryptosporium, Leptospira, and sea-food toxins), and reduced water quality (e.g. by parasites), are projected to experience an increased incidence.

Additional health impacts might result from changes in water quantity, nutritional health (e.g., dietary changes resulting from shifts in migratory patterns and abundance of indigenous food sources), weather-related accidents, and increased numbers of environmental refugees.

Recreation and Tourism

Summer: The summer outdoor recreational season is likely to be extended, resulting in an increased demand for summer recreational facilities. Sea-level rise could reduce beach area in some places and result in increased maintenance costs. Projected lower water levels in freshwater lakes and rivers could result in existing recreational facilities being located farther from the shore. In some areas the lower freshwater levels combined with the warmer temperatures may cause increased algal growth, thus impairing the recreational experience and water quality. Projections of increases in temperature may lengthen the summer sports seasons across Canada (e.g., the golfing season in Québec may be extended by up to 3 to 4 weeks). Recreational fishing, hunting for game and waterfowl and bird-watching are also likely to be impacted as fish and wildlife may be displaced due to habitat loss or increased competition.

Winter: Outdoor recreation activities may have a shorter season (e.g., ice fishing, where lesser ice thickness will become a concern), especially in more southerly latitudes. Ski resorts may have to rely increasingly on artificial snow-making to maintain a viable industry presence in the south.

People may be expected to adapt to changing climate conditions by using alternative recreational locations, reducing or stopping participation, and substituting activities. The recreation and tourism industry may be able to adapt by: creating a capacity for flexibility in locating facilities; taking advantage of advances in equipment technology; and diversifying,

including providing a number of recreational alternatives having a range of climatic requirements and sensitivities.

Skiing and climate

Skiing is influenced by climate, with temperature and precipitation amount being important controls on the season length for and the quality of skiing. In southern Ontario, unusually mild weather during the critical Christmas season can be enough to influence the success of the entire skiing season. When such conditions occurred in the winter of 1979-1980, losses in direct recreational expenditures in the south Georgian Bay region were about $10 million.

Industry adaptation has included investment in snow making equipment which can improve marginal conditions and extend the season, although it has its own temperature limitations. Some operators diversify their facilities so that poor skiing seasons can be compensated for by income from activities such as golfing during other seasons of the year.

Winter recreation

Traditional Lifestyles

The subsistence economic sector (hunting, trapping, fishing) is worth about $15,000 per household annually in the Arctic and about half that in the subarctic and often provides up to half of the total local economy. For indigenous people, the role of subsistence lifestyles in maintaining a sense of self and of connection to heritage is equally important. Subsistence living depends upon both the availability and distribution of wildlife and related resources, and the use of traditional knowledge and local adaptations to environmental conditions. Natural ecosystems are vulnerable to projected climate change with consequent changes possible in their location, habitat characteristics, and species composition. As a result, subsistence patterns (locations, timing, type of game) and the sustainability of subsistence lifestyles are also vulnerable. At present, reliance on traditional knowledge and local adaptations generally enables year-to-year variations in environmental conditions to be managed. The pace of anticipated climate change compounded by other changes may, however, confound the aforementioned measures needed for dealing successfully with the projected impacts.

Sustaining Food and Fibre Production

Agriculture, fisheries, and forestry play a significant role in Canada's economic well-being and have vital, sometimes defining, regional roles in the country's economic and social structure. The social and cultural values of these resources to Canadian lifestyles and the value of the associated ecosystems are difficult to quantify but are central to the overall well-being of this country. Climate in terms of air temperature and the availability of adequate water, as well as through its impacts on pest, diseases and competitors, is crucial to defining viability of these resources and is expected to remain so under projected changes in climate.

Agriculture

An important dimension to the relationship between climate and agriculture is the wide range of conditions for agricultural production existing in different regions. These differences are reflected in the projected impacts:

- Crop development: The rate of development of grain crops is projected to increase, with the time between seeding and harvesting being reduced (e.g., reduced by up to 3 weeks in most regions for spring-seeded cereals and coarse

grains). In northern regions, the increased development rate could reduce the risk of frost-induced crop injury.

- Yields: In the Prairies, spring-seeded cereal yields are projected to decrease in the west and increase in the east. Ontario and Québec are projected to experience similarly variable results except that northern areas may experience increased production especially for corn. In both the Atlantic region and British Columbia, increased grain yield potential is foreseen, but realization of this potential is likely dependent on increased irrigation. In the Peace River area, positive impacts on cereal yields are expected to be confounded by increases in crop moisture stress and accelerated crop maturation. Oilseed yields may be generally reduced in Canada, although the effects may possibly be offset by northern expansion of the area capable of oilseed production.
- Land capability: The Peace River region and northern agricultural areas in Ontario and Québec could see some expansion of the land area suitable for commercial crop production. Agricultural opportunities may develop in the southern Yukon and the lower Mackenzie River area, but they are not expected to be substantial. The area suitable for growing fruit and vegetables could expand beyond current southern locations in Québec, Ontario and British Columbia.
- Livestock: For the western Prairies, increased summer stress on livestock is plausible due to dry pastures and poor feed production, while reduced cold stress in winter is likely.
- Economics: Limited studies of the economic impacts of climate change suggest that there will be substantial variations at the sub-provincial or sub-regional levels with the potential for increased variability in annual farm profits.

There is a strong consensus that projected changes in climate could result in longer and warmer frost-free periods across Canada and, thereby, generally enhance thermal regimes for commercial agriculture. These changes in agro-climatic conditions are not expected to impact regions on an equal basis, with the longest extensions of the frost-free season expected in Atlantic Canada. The extent to which these longer and warmer frost-free seasons might benefit Canada, however, will in all likelihood be diminished by less soil moisture in all regions and under all climate change projections. Hence, it is crucial that all assessments of the implications of climatic change for Canadian agriculture take account of the possibility of both negative and positive impacts on agro-climatic properties.

The assessment of adaptation strategies has focused mainly on the Prairies or the boundaries of Canadian agriculture as defined by the current climate (where appropriate soils may limit expansion). Adaptation options include delaying the onset and rate of climate change through the reduction of greenhouse emissions using altered crop mixes and cropping practices or coping with and adapting to climate change by spreading the risks, reducing the potential occurrence and/or magnitude of negative impacts, capitalizing on new "opportunities" arising from climate change and developing appropriate research and education programs.

Adaptive measures at the farm or local level include: switching to different cultivars or introducing higher value field crops; increased use of irrigation; and diversification of farming mix to include more livestock. At the regional or national level, adaptation approaches could include: altered subsidy structures to reflect actual climate risk; crop assistance programs

linked to soil conservation; and strengthened rural education programs to encourage sustainable land use practices.

Most studies to date, however, have not generally addressed the economic feasibility of such adaptation options nor the ability or willingness of the farm community to undertake them.

Fisheries

- Pacific marine: Decreased and more variable sustainable harvests are projected for southern salmon populations. Pacific cod abundance is also projected to be reduced. Increased, more consistent sustainable harvests are anticipated for northern salmon populations, with sockeye salmon most vulnerable.
- Atlantic marine: Overall sustainable harvests from coastal and estuarine waters could decrease due to projected decreases in freshwater discharge and consequent declines in ecosystem productivity. Widespread changes in sustainable harvests, locations of fishing grounds, and efficiencies of fishing gear for many species are plausible due to complex and likely unpredictable changes in the ocean currents that shape offshore marine habitats and migration patterns.
- Arctic marine: Increases in sustainable harvests are projected for most fish populations, due to increased ecosystem productivity as shrinking ice cover permits greater nutrient recycling.
- Southern freshwater: There may be decreases in sustainable harvests for many of these fisheries due to declining water levels in lakes, declining flow rates in streams, and reductions in nutrient loading and recycling for many lakes and streams on the Canadian Shield. The proportion of the overall sustainable harvest comprised of valuable cold water fish, including species such as trout, whitefish, and grayling, could be reduced.
- Northern freshwater: Increases in sustainable harvests are projected for most northern freshwater fish species, due to longer, warmer growing seasons and relatively small changes in water levels. Potentially, there will also be an increase in the diversity of fish species that can be harvested sustainably due to projected increases in the diversity of thermal habitats available to support species currently limited to more southerly ranges.

The daily activities that sustain the life of individual fish (e.g., feeding, predator avoidance, body maintenance and growth) and the seasonal activities that maintain the existence of populations (e.g., gonad development, reproduction, parental care) are all strongly effected by the annual pattern of water temperatures that fish experience. For fish, the temperature tolerance zones for survival, growth and reproduction are species-specific characteristics.

Concerns have been expressed that pooling and averaging of impacts can hide smaller scale inequities and that responses at the larger scale alone may not be sufficient. In addition, fisheries adaptation options identified, for the most part, have been used previously in response to other environmental or use changes and each has limitations, typically assuming orderly change. As such, considerations in the development of adaptation options include:

- recognition of the possibility of an increased rate of change and the potential of surprises;
- need for close ties with sustainable ecosystem use objectives; and
- need for responses at the local level to minimize negative impacts and maximize gains while aiming for a net gain overall (i.e., address concerns that pooling and averaging may hide inequities).

Forestry

Changes are projected in the growth and regeneration capacity of forests in many regions of Canada. In some cases, this could alter the functioning and compositions of forests with implications for associated natural ecosystems

and the long-term sustainability of the forest products market.

Forest regime: Generally, as a result of projected changes in climate, Canadian forests could experience increased drought stress, an increase in frequency and severity of fire, increase in vegetation growth rates, and potentially, more frequent and severe storms and wind damage in coastal areas. Forests are expected to shift northward (and to higher altitudes), but expansion may be limited by the ability of species to migrate. Some species may become extinct at the edges of their current range as more competitive species move in from the south and northern expansion is curbed by geographical and anthropogenic obstacles. The boreal forest (for example) is expected to undergo an extensive reduction in size. Grasslands and temperate deciduous species may invade from the south and northern expansion of the boreal forest is limited by poor soils, permafrost and insufficient sunshine amounts. Forest structure of the Pacific northwest is expected to remain similar to the present with richness in species diversity compensating for individual species migration. Wildlife habitat and natural reserves may suffer due to a lack of connectivity and the imbalance between habitat and climate created by climate change.

Forest industry: While an increased potential harvest level appears favoured (at least indirectly) by projected temperature levels for Canada, losses due to possible forest decline and modified fire and insect regimes, as well as drought stress in some areas, could challenge the adaptive capacity of the industry. This seems likely to be the case where long-run sustainable yield levels are considered. As a consequence, the overall impact on the Canadian forest industry is expected to vary by regions.

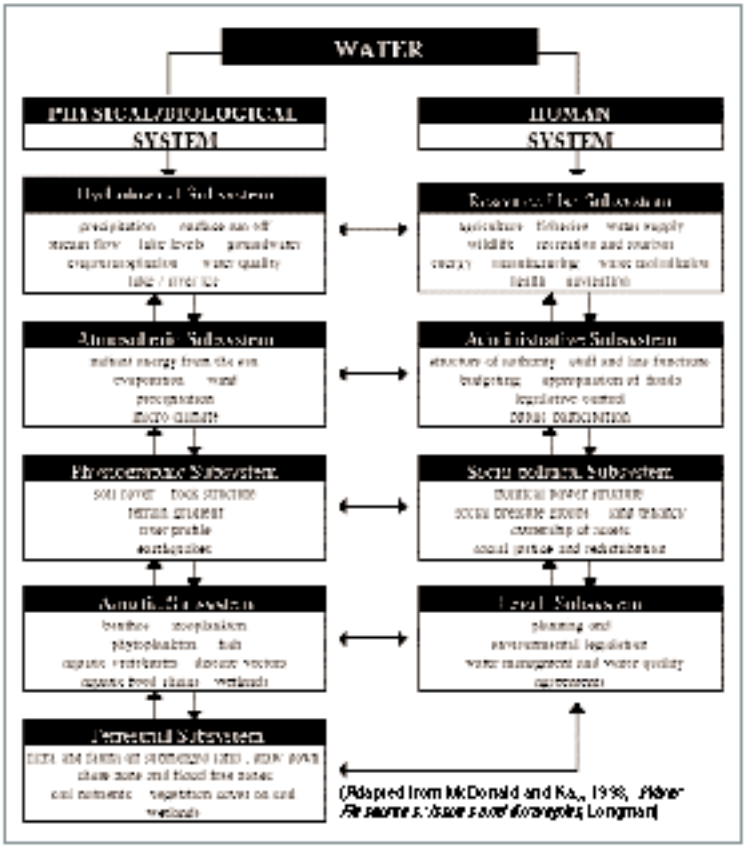
The adaptability of the forestry sector is dependent on the industry's ability and willingness to adapt to whatever species do prevail as a consequence of climate change, to salvage-cut dying stands, to plant cut areas with species better adapted to the altered climate, and to move to locations where resources are more plentiful. Confidence in the industry's ability to adapt is, in part, a reflection of the expectation that future impacts will be simply extensions of the types of conditions currently dealt with - that is, same problems, different locations and extent. Adaptation, in addition to considering the social and environmental costs, will need to address concerns regarding ecosystem sustainability (e.g., increasing forest landscapes to reduce fragmentation and maintaining migration corridors, and managing stands and landscapes to reduce crown and large area fires).

Foundation Blocks

Water

Both directly and indirectly, nature and society rely on water. Water is the foundation for species existence and is a limiting factor, along with temperature and sunlight, for species and ecosystem distribution. Almost everything

Two water systems



(Adapted from McDonald and Kay, 1988, *Water Resources: Issues and Strategies*, Longman)

humans rely on is somehow dependent upon water. Not only must we drink water and eat foods whose growth and productivity depend on sufficient water, but water also plays a central role in many economic and societal functions as suggested by the diagram above.

In many parts of Canada there are conflicting demands for water which could be exacerbated by projected changes in climate. It has been suggested that improved management of water infrastructure and demand-side management of water supply have the potential to mitigate some of the impacts of conflicting and increasing water demands. Sectoral adaptive strategies to climate change should include consideration of the many and competing demands for water (e.g., natural ecosystems, municipalities, manufacturers, recreation and tourism, agriculture, hydro-electric generation and the requirements of the United States). For example, the agriculture sector on the Prairies has identified an expected increase in the need to irrigate crops in response to projected changes in climate. Irrigation requires capital investments and a sufficient supply of water. With a projected reduction in overall available water in this region it may not be realistic to expect that increased irrigation will be a viable adaptation strategy for agriculture.

Canadians spend over a billion dollars per year in the water resources sector adapting to current climate conditions. These adaptations include the construction of dams, sewers, drainage ditches, floodways, and other infrastructure. Adapting to climate change that includes a potentially more vigorous hydrological cycle will likely increase these expenditures substantially.

Natural Ecosystems

Terrestrial: Plant growth is expected to increase on average. Where natural ecosystems are fragmented with patches linked by corridors, further disruptions and land-cover changes could sever these links, causing even greater fragmentation and consequent disruption of migration pathways. The boundaries of the ranges of existing vegetative and wildlife species could shift to higher latitudes and higher elevations, including the invasion of southern or lower elevation species, respectively. This reflects an expected northward shift in the ecoclimatic regions, as well as a change in their relative size and composition. Wildlife and biodiversity, currently reflective of existing conditions, are vulnerable under projected changes in temperatures, habitat loss or degradation, changes in food abundance or availability, and changes in predation rates, parasites and diseases. For example, Canada's tundra area may shrink by more than 30% of its current size, so that it may be confined mainly to the islands north of the Arctic mainland, and its vegetative content would likely change in response to snow cover and soil moisture changes. High Arctic Peary caribou and muskoxen may become extinct, while mainland caribou would come under significant stress. A real concern is the capacity for terrestrial species to adapt to a rate of climate change that is anticipated to be faster than any experienced historically. An additional impact of a warmer tundra region is increased carbon dioxide and methane emissions as permafrost melts, thus amplifying projected climate change.

Wetlands: Wetlands are a critical resource providing habitat for species (including some of Canada's rare, threatened, or endangered ones), storage for atmospheric carbon, nutrient and mineral cycling, water purification, and natural flood control. The most important waterfowl

Prairie wetlands

breeding area in North America is the Prairies wetland area, while the Great Lakes provide important migration and staging habitats.

Distribution of ecoclimatic provinces in Canada: (a) present day; (b) as projected for a doubling of atmospheric carbon dioxide using the Goddard Institute for Space Studies model

ECOCLIMATIC PROVINCES

1. Arctic
2. Subarctic
3. Boreal
   a. Maritime Boreal
   b. Moist Continental Boreal
   c. Dry Continental Boreal
4. Cool Temperate
5. Moderate Temperate
6. Transitional Grassland
7. Grassland
8. Semi-Desert
9. Undefined; Cordilleras not shown

As a consequence of climate change, semi-permanent wetlands may change from open-water dominated basins to vegetated areas and wetland salinity could increase significantly. Where lowered water level is the major impact, waterfowl habitat may be significantly altered both in quantity and quality. Over a third of the wetlands in Canada's parkland region may shrink under warmer temperatures despite increased precipitation; the impact is expected to be less severe in the grassland region. There is some possibility that prairie wetlands may expand northward offsetting some of the anticipated losses in other parts of the region.

Aquatic: Many fish species in lakes and streams are likely to shift northward by about 150 km for every 1° C rise in temperature; as a result, freshwater habitat for some key aquatic wildlife including salmonids could be lost in parts of Canada. Cold water species such as brook trout might be at greater risk. Reduced sea ice thickness and extent will result in mixed impacts. Some species such as the sea otter may benefit from being able to expand into new areas while others such as seals may decline due to reduced sea-ice expanses for breeding and feeding. The polar bear is particularly of concern; it could become extinct through starvation if the Arctic Ocean becomes seasonally ice free for a long enough period. Some large breeding colonies of seabirds, including colonies of Common Murre and Northern Gannets in Newfoundland, are at risk due to projected increases in sea level.

Migratory Birds: Summer and winter habitats and migratory routes are vulnerable as a result of projected changes in climate. Included are important coastal staging grounds that could be subject to sea-level rise such as those in Atlantic

Snow geese in Hudson Bay lowlands and decline of breeding grounds

The sensitivity of migrating birds to climate and an example of the consequences may be seen in the case of snow geese that traditionally nest at Hudson Bay sites. Cold conditions in the northernmost nesting areas such as Southampton Island and southwestern Baffin Island have prompted snow geese which prefer those sites to spend more time further south, in this case the Hudson Bay coastal flats north of Churchill. The increased number of birds spending time there and the longer periods of residence time have resulted in a habitat that is overgrazed, damaged, and in some areas destroyed. Due to the short, cold growing season in the Arctic, it would take 20 to 30 years for the damaged habitat to come back.

Canada and wetlands which could be subject to drying such as those in the Prairies. In addition, the environment of migratory bird sanctuaries may no longer be suitable for the intended species and there may be implications for international agreements governing affected migratory birds.

FUTURE DIRECTIONS

The Canada Country Study has generated a wide range of recommendations for future climate impacts and adaptation research based on science gaps identified in its 26 component studies. These recommendations fall into two categories, both of equal importance.

The first encompasses climate impact research needs of a "traditional" nature - areas and methodologies that have received the bulk of research attention to date, but where continued work is needed to improve our understanding and confidence levels further. Most of the recommendations of this type have come from the CCS regional and sectoral component reports. They include:

- Baseline data: There is a need to enhance monitoring activities and to develop compatible and accessible databases across Canada in the areas of: hydrological parameters; structure and functioning of marine and freshwater aquatic and terrestrial ecosystems and their component species (commercial and non-commercial); socio-economic parameters; and climate, weather, and extreme events.
- Key model development areas: There is a need for improved capabilities in the following areas:
  - Scenarios need to be developed that focus on better projections of weather system dynamics and variability, including extremes;
  - Regional projections of climate change that consider the physiographic characteristics that play a significant role in Canada's climate and which incorporate biosphere-atmosphere feedbacks;
  - Predictive models linking marine and hydrologic, and physical and biological processes to climate change; and
  - Quantitative and qualitative models for estimating impacts and testing adaptive strategies.
- First order impact research: There is still need for first order impact research. For example, needing development is long-term, multi-disciplinary research on fundamental ecological (i.e. physical and biological) conditions, sensitivities and trends which is rare in Canada, and even worldwide. This type of work is essential to resolving many remaining questions about Canadian vulnerabilities.
- Sensitivity analysis: There is also a need for sensitivity analyses, research into the indirect effects and integrative nature of second and third order impacts on natural and human systems. This will require developing links between scientific, financial and statistical analyses and using remote sensing plus other techniques to better estimate the risk of impacts from climate change.

The second category of recommendations deals with research issues that provide integrated understanding of climate impacts and adaptation at a regional or national scale. Most of these come from the CCS cross-cutting issues component papers. In advancing work in this category, a multi-disciplinary and integrative approach is necessary. This is essential if progress is to be made in understanding how to reduce Canada's vulnerabilities to climate change and how to maximize potential benefits. This type of work requires a focus on coordination and communications on a number of levels: between scientists in the natural and social sciences, between researchers and users or stakeholders particularly those at the local level, between the science and policy communities, and between the public and private sectors. The importance of such interaction cannot be emphasized too strongly.

The main recommendations in this second category focus on the following areas:

- Integrated impact assessments: There is a strong need for work where multiple stressors (such as other air issues) are considered so that a better understanding of second and third order impacts of climate change result. (Canada's studies on the Mackenzie Basin and Great Lakes-St. Lawrence Basin have helped to show the way forward.) Currently there are some initiatives underway, for example, the Toronto-Niagara Region Program that is examining the impact of atmospheric change on Southern Ontario.
- Sustainable development: There is a need for climate change and sustainable development to be represented in an explicit manner in each other's research agendas.
- Costing research: Emphasis should be placed on developing a benchmark estimate of the costs over time of adaptation to, and residual impacts from, climate change for Canada (e.g., estimating a time profile of marginal costs of CO_2 emissions).
- Extreme events: In anticipation of extreme events in Canada in the future being a costly affair, a significant effort concentrating on case studies of past extreme events and on perception of risk related to such hazards is warranted.
- Traditional ecological knowledge: In line with the need to involve stakeholders directly in climate impacts and adaptation research, increased attention to both the future applicability of such knowledge in a rapidly changing climate and how such knowledge may be used to complement "western science" is needed.

FINAL WORDS

Through the Canada Country Study and its review of the existing scientific and technical literature, two points become clear. We have a limited understanding of the range and extent of impacts of climate change on Canada and, as such, there is considerable work required to refine that understanding and to develop workable adaptation approaches. This work is necessary in defining an acceptable and responsive climate change portfolio that includes both adaptation and mitigation. Limitations, however, in our capacity to pursue the various research directions that the Canada Country Study has recommended and, thus the lack of full scientific understanding of the details of the various impacts of climate change, should not delay implementing adaptive strategies that are believed to have low risk, are justified for other reasons (precautionary principle), or are known to be environmentally sound (no-regrets principle).