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CLIMATE CHANGE RESEARCH REPORT
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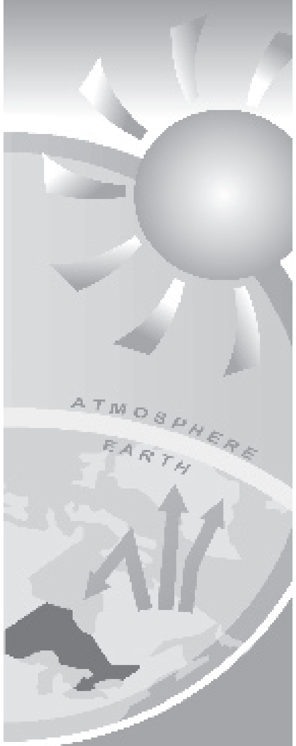

Responding to Climate Change Through Partnership

Ontario

Climate change and nature-based tourism, outdoor recreation, and forestry in Ontario:

Potential effects and adaptation strategies

Climate Change and MNR: A Program-Level Strategy and Action Plan

The following describes how the Ministry of Natural Resources works to contribute to the Ontario Government's commitment to reduce the rate of global warming and the impacts associated with climate change. The framework contains strategies and sub-strategies organized according to the need to understand climate change, mitigate the impacts of rapid climate change, and help Ontarians adapt to climate change:

Theme 1: Understand Climate Change

Strategy #1: Gather and use knowledge in support of informed decision-making about climate change. Data and information gathering and management programs (e.g., research, inventory, monitoring, and assessment) that advances our knowledge of ecospheric function and related factors and forces such as climate change are critical to informed decision-making. Accordingly, MNR will work to:

- Strategy 1.A: Develop a provincial capability to describe, predict, and assess the important short- (0-5 years), medium- (5-20 years), and long-term (20+ years) impacts of climate change on the province's ecosystems and natural resources.
- Strategy 1.B: Model the carbon cycle.

Strategy #2: Use meaningful spatial and temporal frameworks to manage for climate change. A meaningful spatial and temporal context in which to manage human activity in the ecosphere and address climate change issues requires that MNR continue to define and describe Ontario's ecosystems in-space and time. In addition, MNR will use the administrative and thematic spatial units required to manage climate change issues.

Theme 2: Mitigate the Impacts of Climate Change

Strategy #3: Gather information about natural and cultural heritage values and ensure that this knowledge is used as part of the decision-making process established to manage for climate change impacts. MNR will continue to subscribe to a rational philosophy and corresponding suite of societal values that equip natural resource managers to take effective action in combating global warming and to help Ontarians adapt to the impacts of climate change.

Strategy #4: Use partnership to marshal a coordinated response to climate change. A comprehensive climate change program involves all sectors of society as partners and participants in decision-making processes. The Ministry of Natural Resources will work to ensure that its clients and partners are engaged.

Strategy #5: Ensure corporate culture and function work in support of efforts to combat rapid climate change. Institutional culture and function provide a "place" for natural resource managers to develop and/or sponsor proactive and integrated programs. The Ministry of Natural Resources will continue to provide a "home place" for the people engaged in the management of climate change issues.

Strategy #6: Establish on-site management programs designed to plan ecologically, manage carbon sinks, reduce greenhouse gas emissions, and develop tools and techniques that help mitigate the impacts of rapid climate change. On-site land use planning and management techniques must be designed to protect the ecological and social pieces, patterns, and processes. Accordingly, MNR will work to:

- Strategy 6.A: Plan ecologically.
- Strategy 6.B: Manage carbon sinks.
- Strategy 6.C: Reduce emissions.
- Strategy 6.D: Develop tools and techniques to mitigate the impacts of rapid climate change.

Theme 3: Help Ontarians Adapt

Strategy #7: Think and plan strategically to prepare for natural disasters and develop and implement adaptation strategies. MNR will sponsor strategic thinking and planning to identify, establish, and modify short- and long-term direction on a regular basis. Accordingly, MNR will work to:

- Strategy 7.A: Sponsor strategic management of climate change issues.
- Strategy 7.B: Maintain and enhance an emergency response capability.
- Strategy 7.C: Develop and implement adaptation strategies for water management and wetlands.
- Strategy 7.D: Develop and implement adaptation strategies for human health.
- Strategy 7.E: Develop and implement adaptation strategies for ecosystem health, including biodiversity.
- Strategy 7.F: Develop and implement adaptation strategies for parks and protected areas for natural resource-related recreational opportunities and activities that are pursued outside of parks and protected areas.
- Strategy 7.G: Develop and implement adaptation strategies for forested ecosystems.

Strategy #8: Ensure policy and legislation respond to climate change challenges. Policy, legislation, and regulation guide development and use of the programs needed to combat climate change. MNR will work to ensure that its policies are proactive, balanced and realistic, and responsive to changing societal values and environmental conditions.

Strategy #9: Communicate. Ontarians must understand global warming, climate change, and the known and potential impacts in order to effectively and consistently participate in management programs and decision-making processes. Knowledge dissemination through life-long learning opportunities that are accessible and current is critical to this requirement. MNR will raise public understanding and awareness of climate change through education, extension, and training programs.

Climate change and nature-based tourism, outdoor recreation, and forestry in Ontario:

Potential effects and adaptation strategies

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Summary

In this report, we discuss the possible effects of climate change on nature-based tourism, outdoor recreation, and forestry activities in Ontario. First, we present a conceptual model to facilitate the discussion of climate change effects. We consider two periods: the short term in which climate change primarily affects supply and suppliers, and the long term in which climate change affects all components of demand, supply, governance, technology, and social values. Information on the effects of climate change on each of the nature-based tourism, outdoor recreation, and forestry activities come from a literature review and from the expert opinion of the authors. Finally, a qualitative summary of likely effects on Ontario's markets is presented. We consider changes to demand and supply and the corresponding effects on quantity consumed, price, economic impact, economic welfare, and social welfare.

- In the short term (between now and 2049, but centred on the 2020s), climate change will primarily affect the scarcity of natural resource-based products through changes to supply. Supply-side effects include changes to the quantity and quality of natural resources and changes to other factors (i.e., labour, capital, and other natural resources) used in processing.
- In the long term, climate change will likely affect the scarcity of natural resource-based products through changes both to supply and demand. Climate change effects to natural resources, factors of production, governance, and technology will all affect supply. Climate change effects on society, governance, and substitute and complementary goods all affect demand.
- Uncertainty exists in the assessment of any resource management activity. For climate change, uncertainty also arises from the cumulative uncertainty at each stage of the assessment: climate change models and future scenarios, ecological responses, and social and economic responses.
- Future social and economic conditions for natural resource-based products depend on many factors other than climate change, climate change mitigation strategies, and the ability of individuals and groups to adapt. These factors contribute to uncertainty.

Nature-Based Tourism and Outdoor Recreation

- Climate change is expected to have a net positive effect on nature-based tourism and outdoor recreation activities in Ontario. This positive effect primarily arises from increasing season length for warm weather-based activities, which have much higher participation levels than do snow and ice-based activities.
- Participation in snow and ice-based activities will likely decrease due to shortened seasons.
- Participation in land-based non-consumptive activities will likely increase because of extended season lengths and warmer temperatures.
- Recreational fishing effort (days fished) in northern Ontario will likely increase because of increased walleye (*Sander vitreus*) productivity. It is uncertain whether this increase in fishing effort will also occur in southern Ontario because of greater uncertainty about climate change effects on walleye productivity.
- Changes in participation for water-based non-consumptive activities are difficult to assess. While warmer temperatures will extend seasons, some settings for these activities will be negatively affected by lower water levels.
- It is difficult to assess how participation in hunting will change because of climate change effects. While moose (*Alces alces*) hunting opportunities will likely shift northward, the northward expansion of other large game mammals may offset the loss of moose hunting opportunities.
- Long-term effects of climate change are much more difficult to project as changes to governance, technology, society, and preferences for activities may occur.
- Climate change is only one factor among many that will shape participation for different activities. Aspects such as population growth, culture and traditions, demographics, and wealth will also affect participation.

Forest Industry

- Ontario's traditional forest products producers are expected to experience negative effects from climate change. Supplies of wood fibre in Ontario are expected to decline, while the costs of tending, extracting, and milling are expected to increase. This will be combined with an expected increase in global wood fibre and associated decrease in global forest products prices.
- Changes in supplies of wood fibre result from changes to the quantity (i.e., the number of cubic metres of wood) and quality of wood fibre (e.g., the straightness or number of knots) in the short term. Species type, quantity, and quality of wood fibre will all change in the long term.
- Quantity of wood fibre is expected to decrease. Northwestern Ontario is especially vulnerable to this reduction in fibre quantity through lower precipitation, which may reduce tree growth, and through increases in extreme events (e.g., forest fires and windstorms).
- Climate change will negatively affect most forest-dependent communities. These effects will include changes to physical environs (e.g., more forest fires) and socio-economic effects such as employment opportunities for residents.
- Changes in long-term demand for Ontario's forests may include bio-products and carbon capture and storage opportunities. The development and production of these new forest products may create jobs in forest-dependent regions. These new products could mitigate some negative effects of climate change on the traditional forest products industry.

Adaptation and Management Implications

- Adaptation to climate change may occur at the individual, producer, community, and institutional levels.
- With the right motivation, individuals have the most flexibility to adapt. However, some people may resist adaptation because they do not see relationships between actions and climate change problems, may not believe that their actions will alter climate change effects, or may not view climate change as a risk.
- To aide adaptation, institutions could invest in science and research, and could consider the possibility of climate change effects in long-term planning, policy development, and investment decisions.
- Governments may wish to consider public acceptance and differences in value systems when adopting adaptation policies since the public is more likely to accept and comply with policies they believe are fair and just.
- Tourism and recreation suppliers should be proactive and consider adaptive actions to help mitigate potential negative effects to snow and ice-based activities and to water-based non-consumptive activities. Investments in warm weather tourism should be considered.
- Forest managers may wish to plan for changed species composition and changed fire regimes in future forests. Forestry suppliers should consider new opportunities in carbon capture and storage or bio-products.

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Résumé

Dans le présent rapport, nous examinons les effets possibles du changement climatique sur les activités de tourisme axé sur la nature, de plein air et de foresterie en Ontario. Nous présentons d'abord un modèle conceptuel visant à faciliter la discussion concernant les effets du changement climatique. Nous considérons deux périodes : l'une à court terme, où le changement climatique touche principalement l'offre et les fournisseurs, et l'autre à long terme, où le changement climatique influe sur tous les éléments de la demande, de l'offre, de la gouvernance, de la technologie et des valeurs sociales. L'information concernant les effets du changement climatique sur chacune des activités de tourisme axé sur la nature, de plein air et de foresterie est tirée d'une analyse documentaire et de l'opinion d'expert des auteurs. Nous offrons ensuite un résumé qualitatif des incidences probables sur les marchés ontariens. Nous prenons en considération la fluctuation de l'offre et de la demande, ainsi que les effets correspondants sur la quantité consommée, le prix, les retombées économiques, la prospérité économique et le bien-être social.

- À court terme (dès maintenant jusqu'en 2049, en mettant l'accent sur les années 2020), le changement climatique influera principalement sur la rareté des produits provenant des ressources naturelles, par l'entremise des variations de l'approvisionnement. Les facteurs agissant sur l'offre comprennent les écarts survenant dans la quantité et la qualité des ressources naturelles et les changements touchant d'autres facteurs de transformation (p. ex., la main-d'œuvre, le capital et d'autres ressources naturelles).
- À long terme, le changement climatique influera probablement sur la rareté des produits provenant des ressources naturelles, par l'entremise des fluctuations de l'offre et de la demande. Les effets du changement climatique sur les ressources naturelles, les facteurs de production, la gouvernance et la technologie se répercuteront tous sur l'offre. Pour leur part, les effets du changement climatique sur la société, la gouvernance, ainsi que les biens de substitution et les biens complémentaires auront tous des répercussions sur la demande.
- L'évaluation de toute activité de gestion des ressources est marquée par l'incertitude. Dans le cas du changement climatique, cette incertitude se manifeste aussi de façon cumulative à chaque stade de l'évaluation : les modèles et scénarios futurs du changement climatique, les réactions écologiques, sociales et économiques.
- La future conjoncture socio-économique liée aux produits provenant des ressources naturelles sera déterminée par de nombreux facteurs autres que le changement climatique, les stratégies d'atténuation du changement climatique et l'aptitude des individus et des groupes à s'adapter. Ces facteurs contribuent à l'incertitude.

Le tourisme axé sur la nature et les activités récréatives de plein air

- On s'attend à ce que le changement climatique exerce un effet net positif sur les activités de tourisme axé sur la nature et les activités récréatives de plein air en Ontario. Cet effet positif résultera principalement du prolongement de la saison propice aux activités pratiquées par temps chaud, lesquelles ont un taux de participation beaucoup plus élevé que les activités pratiquées sur neige ou sur glace.
- La participation aux activités pratiquées sur neige ou sur glace diminuera probablement, en raison du raccourcissement de la saison.
- La participation aux activités liées aux ressources naturelles sans consommation augmentera probablement, en raison du prolongement de la saison et de l'accroissement des températures.
- L'effort de pêche sportive (jours de pêche) dans le Nord de l'Ontario augmentera probablement, en raison de la productivité accrue du doré (*Sander vitreus*). Il n'est pas sûr que cette augmentation de l'effort de pêche se produira aussi dans le Sud de l'Ontario, à cause de l'incertitude accrue qui entoure les effets du changement climatique sur la productivité du doré.
- Les changements liés à la participation aux activités aquatiques sans consommation sont difficiles à évaluer. Bien que les hausses de température prolongent les saisons, la baisse des niveaux d'eau nuira à certains des sites prévus pour ces activités.
- Il est difficile d'évaluer de quelle façon le changement climatique modifiera la participation à la chasse. Les

perspectives de chasse à l'orignal (*Alces alces*) se déplaceront probablement vers le nord, mais l'expansion vers le nord d'autres grands gibiers mammifères pourrait contrebalancer la perte des possibilités de chasse à l'orignal.

- Les effets à long terme du changement climatique sont d'autant plus difficiles à prévoir qu'il peut se produire des changements dans la gouvernance, la technologie, la société et les préférences pour certaines activités.
- Le changement climatique n'est qu'un des nombreux facteurs qui détermineront la participation à différentes activités. Divers aspects tels que l'accroissement de la population, la culture et les traditions, la démographie et la richesse influeront aussi sur la participation.

Industrie forestière

- On s'attend à ce que les producteurs de produits forestiers traditionnels de l'Ontario ressentent les effets néfastes du changement climatique. L'approvisionnement de fibre ligneuse devrait diminuer en Ontario, tandis que les coûts liés aux soins sylvicoles, à l'exploitation forestière et à l'usinage devraient augmenter. Cette conjoncture sera conjuguée à l'augmentation prévue de la fibre ligneuse à l'échelle mondiale et à la baisse correspondante des prix mondiaux des produits forestiers.
- Les changements qui surviennent dans l'approvisionnement de fibre ligneuse découlent des variations à court terme de la quantité (c.-à-d. le nombre de mètres cubes de bois) et de la qualité de la fibre ligneuse (p. ex., la rectitude ou le nombre de nœuds). Les essences, la quantité et la qualité de la fibre ligneuse sont toutes appelées à changer à long terme.
- La quantité de fibre ligneuse devrait diminuer. Le Nord-Ouest de l'Ontario est particulièrement vulnérable à cette diminution, en raison de la faiblesse des précipitations qui peut réduire la croissance des arbres et de la fréquence accrue d'événements extrêmes (p. ex., feux de forêt et tempêtes de vent).
- Le changement climatique exercera des effets néfastes sur la plupart des collectivités tributaires de la forêt. Ces effets comprendront la modification du milieu physique (p. ex., plus de feux de forêt) et des incidences socio-économiques telles que les possibilités d'emploi pour les résidents.
- Les changements qui caractériseront la demande à long terme des forêts de l'Ontario pourront toucher les bioproduits, ainsi que les possibilités de capture et de stockage de CO_2. Le développement et la production de ces nouveaux produits forestiers pourront créer des emplois dans les régions tributaires de la forêt. Ces nouveaux produits pourraient atténuer certains des effets néfastes du changement climatique sur l'industrie des produits forestiers traditionnels.

Implications liées à l'adaptation et à la gestion

- L'adaptation au changement climatique pourra s'effectuer sur le plan de l'individu, du producteur, de la collectivité et de l'institution.
- Lorsqu'il y est suffisamment motivé, c'est l'individu qui possède le plus de souplesse pour s'adapter. Cependant, certaines gens peuvent s'opposer à toute adaptation parce qu'ils ne voient pas de lien entre les actions et les problèmes du changement climatique, ne croient pas que leurs actions auront une incidence sur les effets du changement climatique ou ne considèrent pas le changement climatique comme un risque.
- Pour faciliter l'adaptation, les institutions pourraient investir dans la science et la recherche, en plus de tenir compte des effets possibles du changement climatique dans la planification à long terme, l'élaboration des politiques et les décisions d'investissement.
- Il serait bon que les gouvernements prennent en considération l'acceptation du public et les différences entre les échelles de valeur au moment d'adopter des politiques sur l'adaptation, étant donné que le public a plus de chances d'accepter et d'observer des politiques qu'il croit équitables et justes.
- Dans les domaines du tourisme et des loisirs, les fournisseurs devraient être proactifs et envisager des mesures adaptatives pour aider à atténuer d'éventuels effets néfastes sur les activités pratiquées sur neige et sur glace, de même que sur les activités nautiques sans consommation. Des investissements dans le tourisme axé sur le temps chaud devraient être envisagés.
- Les aménagistes forestiers devraient prévoir la façon dont changeront la composition des espèces et le régime des feux dans les futures forêts. Les fournisseurs forestiers devraient étudier de nouveaux débouchés pour la capture et le stockage de CO_2 ou pour les bioproduits.

Contents

1. Introduction to Climate Change[1]

Over many decades of social, cultural, and economic development, people have assumed that Earth's climate will behave in the future as it has in the past. For example, during much of the 20th Century, the summer and winter seasons in Ontario came and went at about the same time every year. The winters were long and cold and the summers were short and warm. But near the end of the century, Ontario's temperature and precipitation patterns were different. In fact, since 1900 the Earth's surface has warmed by 0.74±0.18°C, and most of this warming is attributable to human activities after World War II (IPCC 2007). Given that Earth's climate is expected to warm throughout the 21st Century (Flannery 2005, IPCC 2007), Ontarians will need to respond to this change and the uncertainty that goes with it.

Climate change will have significant effects on species (including humans) and ecosystems, and will influence most aspects of our society, including human health, transportation infrastructure, buildings, employment, water, energy production and distribution, agriculture, and forestry (IPCC 2001a,b). Accordingly, climate change will affect how agencies such as the Ministry of Natural Resources (MNR) care for the province's natural assets. In response, MNR plans to work with clients and partners to understand climate change, help reduce greenhouse gas emissions, minimize the negative effects of climate change on natural systems where possible, and help Ontarians adapt. This report is intended to assist MNR staff in evaluating and where necessary modifying program-level strategic planning, and in designing and implementing research and management programs in response to climate change.

1.1. Causes of climate change

Climate is primarily fuelled by energy (heat) from the Sun and is created by interactions between the atmosphere, oceans and lakes, ice, land, and organisms. Climate is "average weather" described statistically as the mean and variability of temperature, precipitation, and wind (IPCC 2001a).

Climate is affected by natural events and human activity. For example, solar radiation varies with shifts in Earth's orbit and tilt relative to the Sun, both of which change over tens of thousands of years (Ruddiman 2001). The Sun itself releases varying amounts of energy, affecting global climate (Alverson et al. 2001). Volcanoes cool the atmosphere by sending fine particles into the upper atmosphere, which reflect incoming solar radiation back out into space. In extreme cases, volcanic activity can affect global climate for several years (Robock 2000).

As the Sun's rays (short-wave radiation) enter the atmosphere, about 30% of the energy is reflected back into outer space by clouds, dust particles, snow, and ice; 20% is absorbed by clouds; and 50% is absorbed by everything else on Earth's surface, including rocks, soil, water, plants, buildings and pavement. Some of the heat that warms the surface returns to the atmosphere where it is absorbed by atmospheric gases. These are greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4), which stay aloft anywhere from a few years (e.g., CH_4 remains in the atmosphere for 21 years) to thousands of years (e.g., sulphur hexafluoride [SF_6] can stay in the atmosphere for 3,200 years). The more heat-collecting gas molecules that are in the atmosphere, the warmer it gets.

A small but critical part of the atmosphere comprises greenhouse gases. Water vapour, CO_2, and other naturally occurring gases help to regulate Earth's climate by capturing heat energy and acting as an insulating blanket. This blanket keeps Earth's surface temperature 33°C warmer than it would otherwise be and provides enough heat for life on Earth (IPCC 2001a).

Although greenhouse gas emissions increased with the invention of agriculture, the industrial revolution that began around 1750 marked the beginning of the period during which truly significant amounts of CO_2 and CH_4 have been added to the atmosphere. More recently, a variety of artificial compounds such as SF_6 and

[1]This section was written by Paul Gray.

perfluoropentane (C_5F_{12}) have also been introduced to the atmosphere. Although emitted in relatively small quantities, these chemicals are powerful greenhouse gases.

Atmospheric CO_2 has increased 31% since pre-industrial times, the result of burning fossil fuels (coal, oil, and gas), converting forests to non-forested conditions (this is deforestation, which contrasts with the sustainable harvest and regeneration of forests), and draining wetlands (IPCC 2001a). The increased concentrations of greenhouse gases keep more heat energy in the lower atmosphere, which increases temperature and alters precipitation (IPCC 2001b). Since the energy reaching the Earth from the Sun has remained constant since 1978, most scientists conclude the temperature change is due to greenhouse gas emissions from human activity (National Academies of Science 2006).

1.2. Ontario's climate change in the last hundred years

Although the average annual global temperature warmed about 0.74°C during the past century (IPCC 2007), warming in Canada was double the world average. However, this warming was not uniform across the country. For example, average annual temperature increased about 2.0°C in northwestern British Columbia and the Kluane region of the Yukon Territory, increased 1.2°C in southcentral Canada, but did not change in Atlantic Canada over this same period (Environment Canada 2006).

People living in southern Ontario have consistently experienced warmer than normal temperatures for many years. For example, the annual average temperature near Belleville on the shores of Lake Ontario has increased 1.14°C since 1921 (Lemieux et al. 2007). In northwestern Ontario east of Sioux Lookout the average annual temperature has increased 1.19°C since 1930, and average annual precipitation increased slightly by 0.04% (32.4 mm). Similarly, the average annual temperature along the Canada-US border has increased 1.06°C and average annual precipitation has increased significantly by 29.02% (231.1 mm) since 1895 (Lemieux et al. 2007). Warming in northeastern Ontario was significant as well. Since 1938, the average annual temperature north of Sudbury has increased 1.14°C and total annual precipitation has increased slightly by 0.04% (24.7 mm). Along the James Bay coastline, the average annual temperature has increased 1.24°C since 1895 (Lemieux et al. 2007).

Other important changes have occurred during the 20th Century as well. For example, winter snow cover in the Northern Hemisphere has decreased about 60% since the late 1960s (IPCC 2001b). The annual duration of lake and river ice cover in the mid- and high latitudes of the Northern Hemisphere has been reduced by about two weeks. For example, on Lake Simcoe, north of Toronto, freeze-up occurs about 13 days later and break-up about 4 days earlier than 140 years ago (CCME 2003). In addition to an increase in annual precipitation of 0.5 to 1.0% in the mid- to high latitudes of the Northern Hemisphere, the frequency of heavy precipitation events increased 2 to 4% over the same period.

1.3. Ontario's climate in the next hundred years

The Earth's surface is projected to warm by 1.1 to 6.4°C over the next 100 years, with land areas warming more than the oceans, and with high latitudes (including Ontario) warming more than lower latitudes (tropics) (IPCC 2007). The additional heat energy in the atmosphere will likely increase variability in temperature, precipitation (rain, snow, and ice), and wind. For example, as more heat is trapped in the lower atmosphere by additional greenhouse gases, the frequency and size of extreme events such as ice storms, heavy rains, droughts, and wind storms may increase.

Effective planning and management responses to global warming require an understanding of how Ontario's climate might change during the 21st Century. While it is widely recognized that stabilization of greenhouse gas emissions is a critical part of any effort to reduce the impacts of global warming, and that initiatives such as the Kyoto Protocol can lead to reductions, future levels of greenhouse gases are uncertain. Ultimately, 21st Century greenhouse gas emissions will depend on people's behaviour around the world. For example, if people elect to increase fossil fuel-based industrial output, emissions will increase faster than if they elect to conserve energy, use renewable energy whenever possible, and find ways to capture and store CO_2.

Global climate models project the potential effects of increased greenhouse gases on air temperature, which in turn affects precipitation, wind, air pressure, and humidity. Each global climate model (GCM) is based on different assumptions and produces somewhat different projections of future climate. Given the uncertainty about the volume of emissions and their effects, natural resource management agencies world-wide are using a number of climate models in combination with a variety of scenarios of human behaviour to depict a range of potential climatic conditions and associated effects that may occur in the next 100 years. The Intergovernmental Panel on Climate Change (IPCC) has sponsored development of 40 scenarios for use in modelling future climate. Each scenario has a different set of assumptions about future social and economic conditions (Nakicenovic et al. 2000). The resulting climate maps represent the work of thousands of scientists and modellers who have:

1. **Developed sophisticated global climate models**. Many global climate models have been developed and tested in the last 20 years, and they continue to be refined as knowledge and computing capacity improves.
2. **Developed greenhouse gas emission projections** based on a range of human behaviour scenarios. The scenarios range from a conservation-oriented to a heavily industrialized approach with high emissions. Since the amount of greenhouse gas in the future depends on highly variable factors such as global population, human behaviour, technological development, and the carbon sink/source behaviour of land and water ecosystems, projections are possible outcomes, not predictions.
3. **Combined the climate models and the emission projections** by correlating the greenhouse gas emissions to temperature and integrating them into the global climate models (see Figure 1).

Climatologists have projected the range of potential change in Canada's climate using different climate models and scenarios. For example, 32 general circulation model/scenario experiments compiled by the Pacific Climate Impacts Consortium (PCIC) project annual mean temperature increases of 3.1 to 10.6°C by the 2080s over Canada's terrestrial ecosystems. This is about double the projected global average temperature change (PCIC 2006). The 32 experiments project mean annual precipitation changes ranging from -0.2 to +8.7% for the 2020s, +0.3 to 16.7% for the 2050s, and +2.5 to 19.2% for the 2080s. However, these changes are not expected

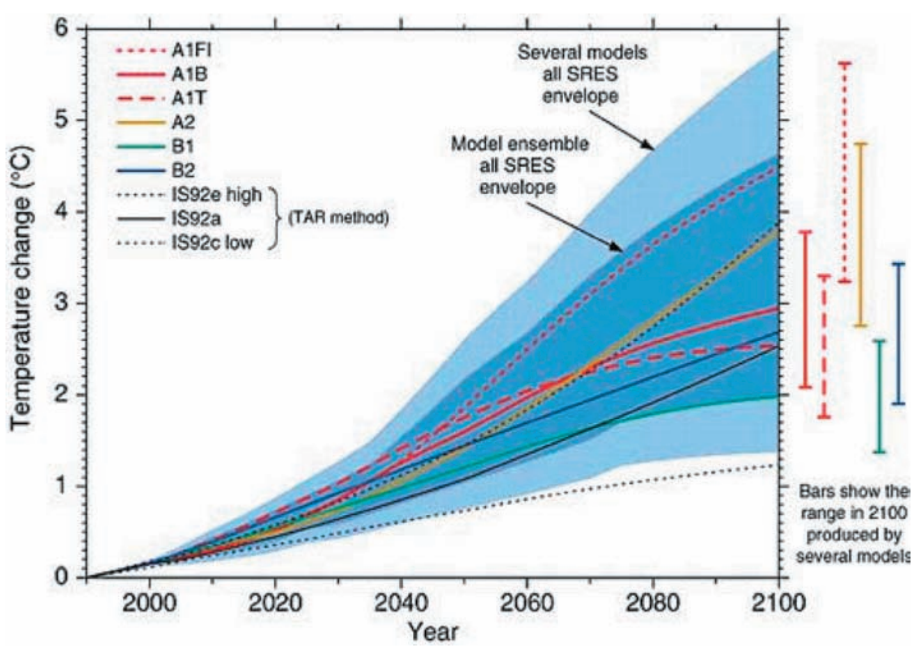


Figure 1. Global mean temperature change (°C) associated with examples of scenarios+ in the Special Report on Emission Scenarios (SRES) describing the impacts of human behaviour through the 21st Century.

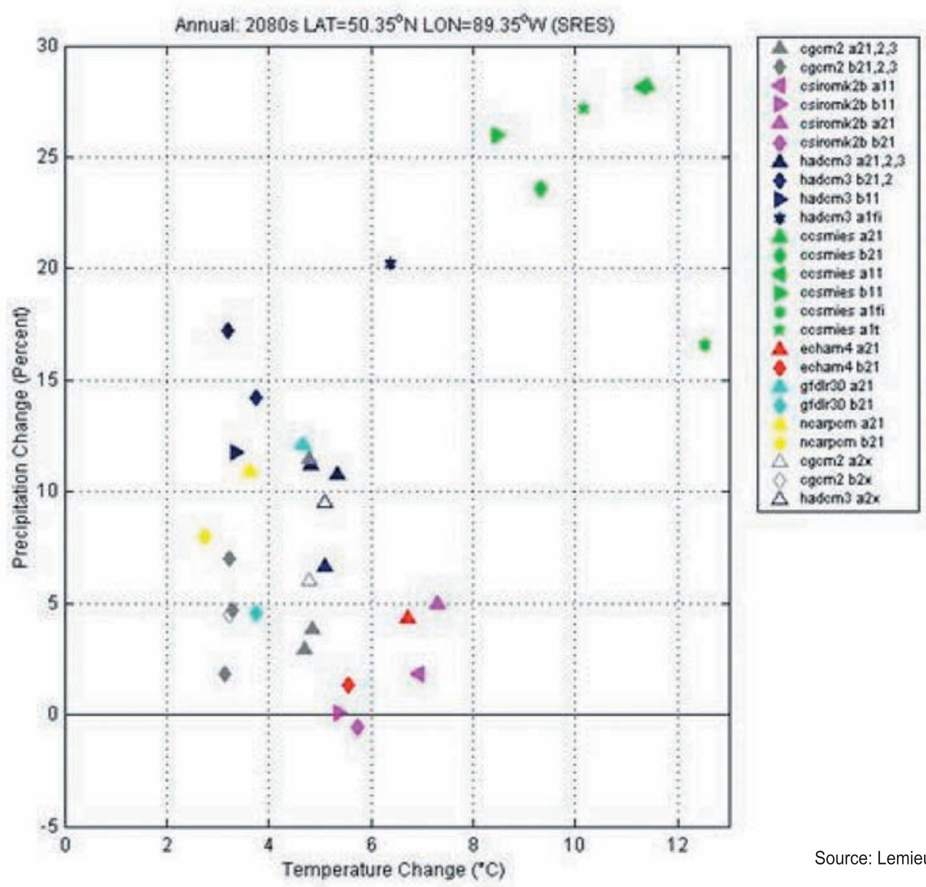
(Source: IPCC 2001a)

+ A1F1, A1B, A1T, A2, B1, and B2 each denote emission levels based on human behaviour. IS92e, IS92a, and IS92c low each denote emission levels described in the Third Assessment Report (TAR).

to be uniform across the country. The range of potential temperature and precipitation projections derived from 25 general circulation model/scenario experiments is illustrated for the Wabakimi Provincial Park area in northwestern Ontario in Figure 2.

In support of adaptive management, future climate projections can be created for areas and dates of interest. For example, Colombo et al. (2007) use the Canadian climate model and two scenarios (A2 and B2) (see Figure 3) to illustrate potential climate conditions in Ontario throughout the 21st Century. The A2 scenario, a mid-range scenario, anticipates greenhouse gas levels by 2100 reaching 1,320 parts per million by volume (ppmv) in CO_2 equivalents[2] (CO_2e) (Nakicenovic et al. 2000).

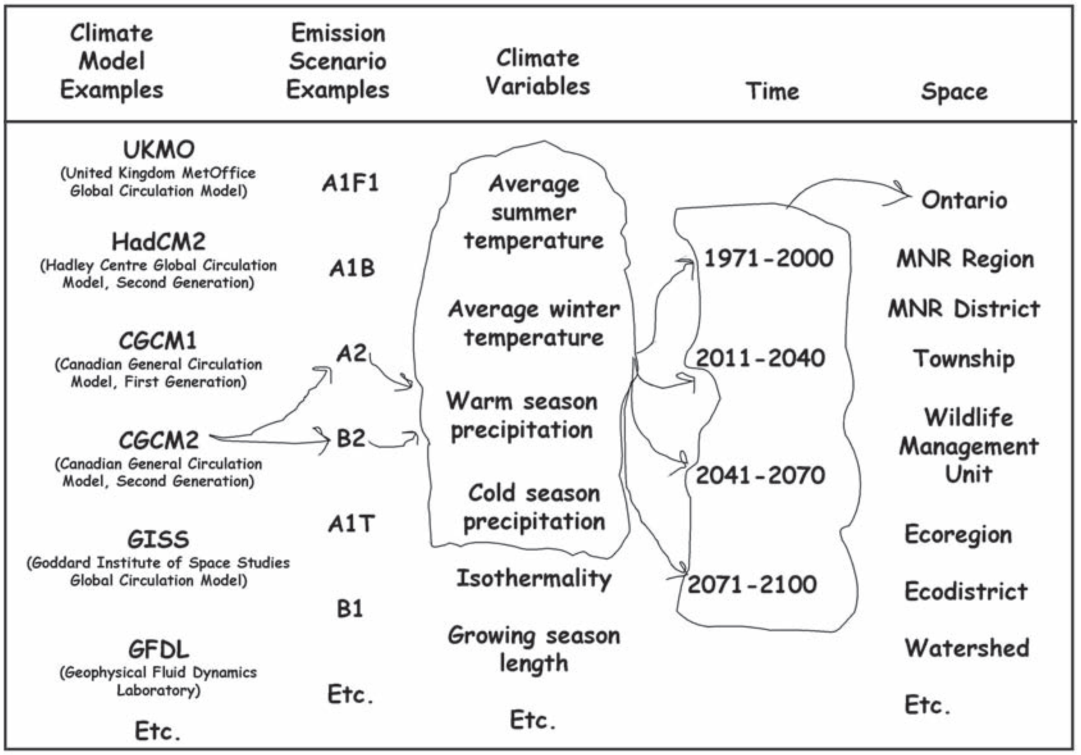
In an A2 world, Earth's human population reaches 15 billion by 2100 and reliance on fossil fuels is higher than for the more conserver-oriented scenarios. In this scenario, Ontarians will be subjected to significant warming, with the greatest increases (6 to 7°C) projected for people living in the north near Hudson Bay (see Figure 4). The average annual temperature of southwestern Ontario, including Toronto and the Niagara Peninsula, will increase 5 to 6°C. Across the province, warming will be greater in winter than summer, and greater in the north than the south (Colombo et al. 2007).



Source: Lemieux et al. (2007)

Figure 2. Results of 25 general circulation model/emission scenarios that project average annual precipitation change (%) and average annual temperature change (°C) for Wabakimi Provincial Park east of Sioux Lookout in northwestern Ontario during the 2080s.

[2] A CO_2 equivalent expresses the energy-trapping properties of any greenhouse gas [e.g., CH_4] and the length of time it remains in the atmosphere in terms of the amount of CO_2 producing the same warming effect. Here we use CO_2 equivalence to mean the heat-trapping power of all greenhouse gases (e.g., CO_2, CH_4, N_2O, SF_6, and others) combined.



+The arrows identify models, scenarios, and climate variables used by Colombo et al. (2007).

Figure 3. An example of climate models, emission scenarios, climate variables, time periods, and spatial frameworks that managers use to consider the effects of potential future climates.+

Precipitation is also projected to change compared to the 1971-2000 baseline period. In an A2 world, less precipitation will fall during the warm season period (April to September) in northwestern and southern Ontario and remain the same or increase slightly in much of northeastern and central Ontario by 2070. During the cold season (October-March), areas around Lake Superior, Lake Nipigon, Lake of the Woods, and James Bay are projected to receive more precipitation, while the far north towards the Manitoba border and all of southern Ontario are projected to receive less cold season precipitation (Colombo et al. 2007).

1.4. Responding to climate change

Climate-driven changes to Ontario's ecosystems in the 21st Century could be significant and require agencies such as the MNR to respond with new approaches. These approaches will require education and extension programs both for those whose job it is to manage resources and for the public on whose behalf they work. Biodiversity will change in response to the combined influence of climate, human activity, the movement of indigenous and non-indigenous species, and natural disturbances such as fire (which is also modified by climate). Some species will acclimate (phenotypic variation) and/or adapt (genotypic variation) to changing conditions; others will not. Species with high reproductive rates that are able to move long distances, rapidly colonize new habitats, tolerate humans, and survive within a broad range of bio-physical conditions will be most successful (Gray 2005).

Noticeable changes in ecosystem composition, structure, and function are expected with climate change. In some areas, novel species assemblages will develop, altering the existing forest, wetland, and grassland ecosystems in Ontario. From a socio-economic perspective, a shorter winter with reduced duration of lake ice cover will affect snow-and ice-dependent recreational activities, while longer periods of warmer weather may extend opportunities to pursue outdoor activities such as camping, canoeing, and swimming (Lemieux et al. 2007).

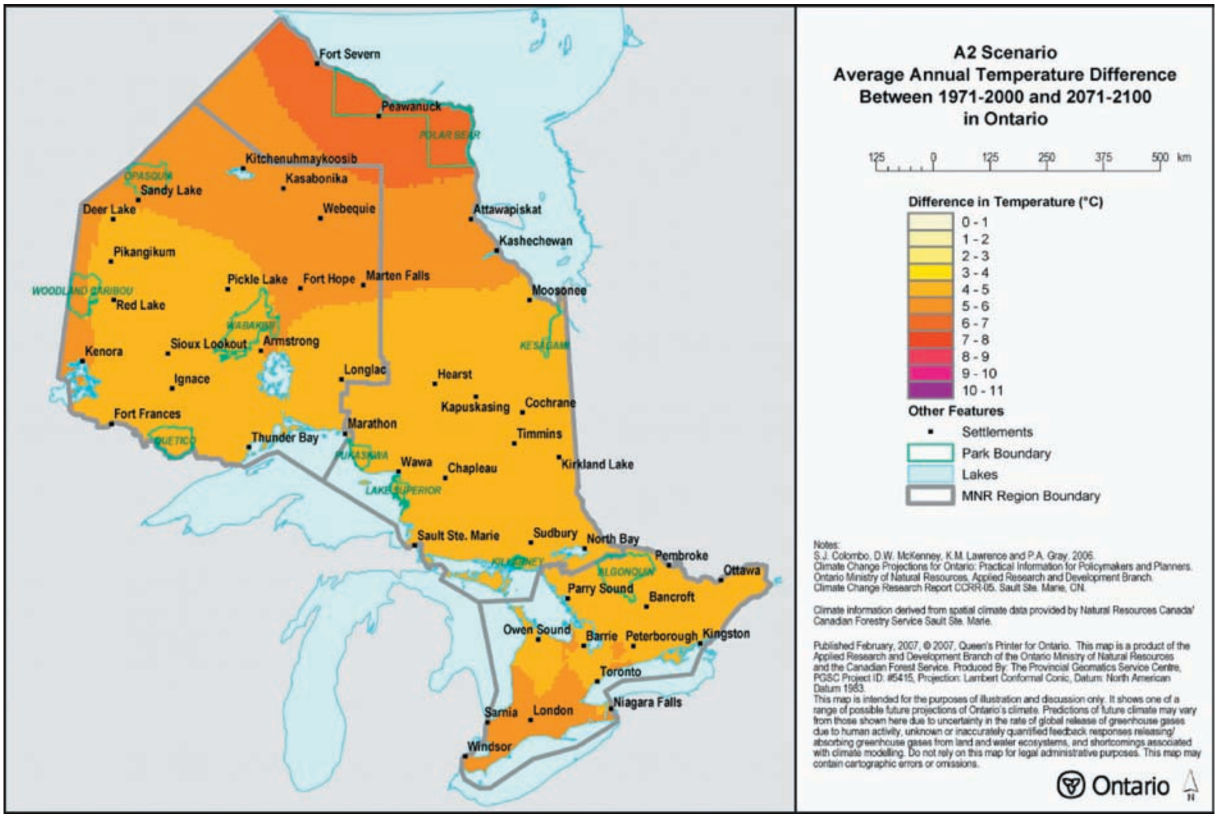


Figure 4. Projected change in average annual temperature between 1971-2000 and 2071-2100 using the A2 scenario in the Canadian global climate model.

Climate change will affect many of the societal and environmental values that Ontarians take for granted. As a result, the timing and extent of climate change and its potential harmful and/or beneficial effects need to be better understood, especially in sectors where long-term planning is needed. Knowing when to act, what actions to take, and whether it is wiser to be proactive in managing for potential change or to react to changes as they occur, depends on understanding the potential benefits as well as the risks to Ontario's infrastructure, human activities, and ecosystems. The significant uncertainty about the amount of greenhouse gas that will be emitted into the atmosphere and the associated warming must be factored into decision-making and management programs. Therefore, an adaptive approach to management will be a prerequisite for successful strategic planning in the 21st Century. Key management objectives might include:

1. Understanding the impacts of climate change through science, including research, inventory, monitoring, and assessment.
2. Reducing greenhouse gas emissions and increasing biological and geological sequestration of carbon.
3. Reducing the negative effects of climate change by using adaptive management, strategic planning, and site-specific management tools and techniques (e.g., wetland protection or remediation).
4. Helping people adapt to changes in climate through economic diversification and education, extension, and training.

2. Assessing the Effects of Climate Change on Nature-based Tourism, Outdoor Recreation, and Forestry in Ontario

Individuals, communities, organizations, and industries all benefit from natural resources. These benefits arise through the consumption of natural resources and products derived from them, the provision of ecological services and functions, and the attainment of passive use values (e.g., knowing that resources are appropriately protected) among others. Climate change has the potential to affect the benefits derived from natural resources.

To begin preparing for climate change, we reviewed literature describing the possible effects of climate change on the nature-based tourism, outdoor recreation, and forest industries in Ontario. We present a conceptual model that illustrates how climate change effects may translate into social and economic effects. Using this conceptual model, we highlight important social and economic considerations that forecasters should incorporate when modelling climate change effects. We discuss various ways that people can adapt to the effects of climate change. Based on the literature review and our expert opinion, we provide a qualitative assessment of the expected outcomes resulting from climate change for the tourism, recreation, and forestry industries. This assessment will provide researchers and managers with information to support long-range planning and policy development.

2.1. Methods

The information presented here comes from literature review and our expert opinion. Literature reviewed includes peer-reviewed journals, books, government and non-governmental organization publications as well as websites. The literature review focused on studies about climate change and tourism, recreation, or forestry. We focused on studies conducted in Ontario and studies from other jurisdictions that provided information useful for Ontario's context. The majority of the literature examined dates from the last ten years (since 1997). Expert opinion is used to comment about potential impacts in cases where little published research is available.

Considerable uncertainty surrounds all climate change research and thus, some of the information provided throughout this report. Many of the cited studies depend on assumptions that make the results hypothetical and context specific. Therefore, we present the findings in a qualitative manner, as trends or likely outcomes from scenarios. Readers are encouraged to consult the original sources to understand the limitations of surrounding predictions derived from past research. When expert opinion is used, the forecasts focus solely on qualitative changes resulting from individual climate effects.

3. Climate Change and Social and Economic Systems

Forecasting the effects of climate change on the benefits people derive from natural resources requires an understanding of the complex relationships between climate change and natural, economic, and social systems. Forecasting is complicated by uncertainties about the linkages within and among these systems.

This section introduces the socio-economic framework for assessing the effects of climate change on the natural resource-dependent sectors of forestry, nature-based tourism, and outdoor recreation. After presenting the conceptual model, we review several common methods used to measure effects on economic and social systems.

3.1. The conceptual model

Understanding the potential effects of climate change on resource use requires knowledge of factors that influence the exchange of resources. Scarcity, which is caused by human wants and needs and limited resources, drives the exchange of resources. This exchange may allow for an efficient distribution of goods and services that may maximize the benefit to society (i.e., individuals and firms)[3]. The conceptual model in Figure 5 shows key components that determine the scarcity of natural resource products. Using this model, we explain the social and economic effects of climate change on market goods such as forestry and tourism, and non-market goods such as most outdoor recreation activities. While no direct exchange for outdoor recreation exists, individuals incur costs (e.g., travel to a site, purchase of hunting licence) associated with selecting a particular experience.

3.1.1. Demand, supply and exchange

The two components of scarcity, demand and supply, drive the patterns of use of natural resources and products made from natural resources. Demand can be expressed by the type, amount, timing, and location of resource use. For example, a recreationist decides what type of activity to pursue (e.g., hiking, canoeing), for how long to pursue it (e.g., a day, a week), when to pursue the activity (e.g., day of the week, season), and where to pursue it (e.g., locally, regionally, internationally). Demand for natural resources and their products depends on preferences and needs of individuals or industries, the awareness of alternatives (e.g., the basket of available goods), and constraints (e.g., income). Demand is also influenced by the price and availability of complementary goods (e.g., snowmobiles in the case of snowmobile recreation) and substitute goods (e.g., all terrain vehicles) (See Figure 5). The attributes of demand force individuals to make trade-offs among resources of varying quantity, quality, and cost.

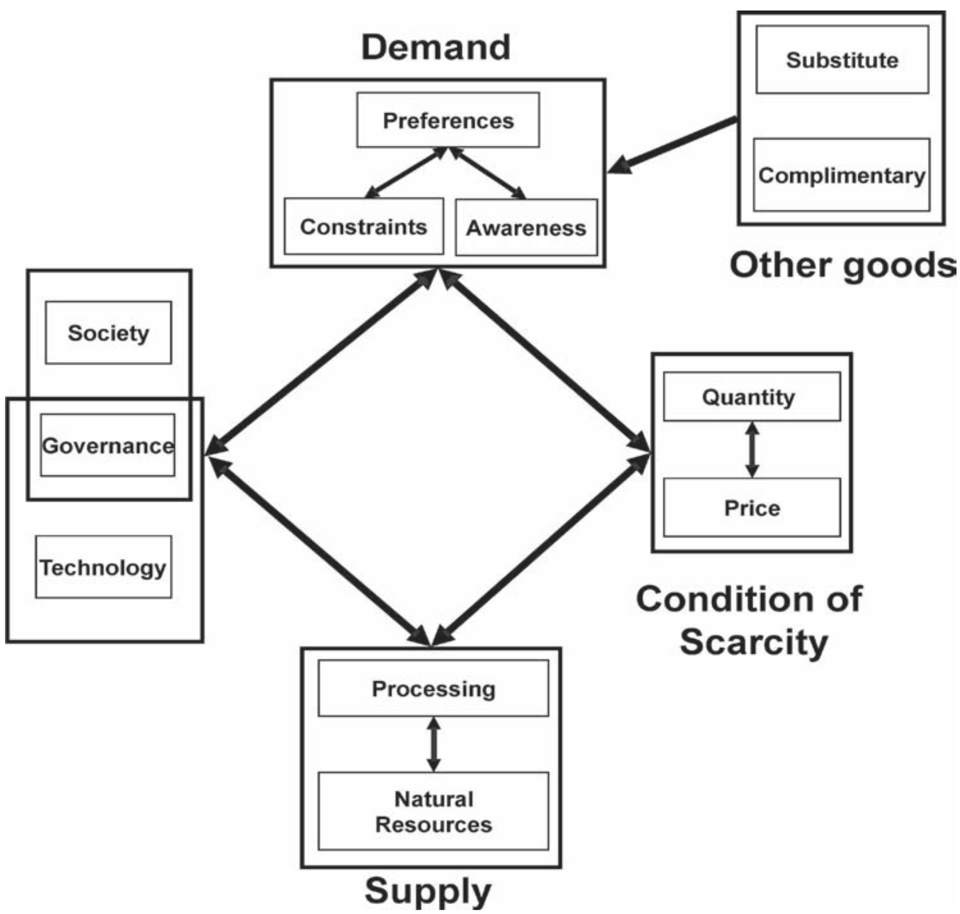


Figure 5. Key components determining the scarcity of natural resource products.

[3]See Varian (1993) for an overview of economic theory.

Supply considerations differ between market and non-market goods. For market goods, suppliers package or process natural resources, using additional factors of production (i.e., labour, capital, and other natural resources), into products of varying quality and cost. Different endowments of natural resources affect the possibilities of producing different products. For non-market goods such as outdoor recreation, supply relates to the qualities of different settings (e.g., depth of lakes, abundance of fauna). Little processing, packaging, or adjustment to these resources is made and individuals choose among available settings.

The interaction of demand and supply results in an 'exchange of goods'. For market goods, a direct exchange occurs that results in money being traded for the use of natural resources or the products produced from them. Exchange for non-market goods results in individuals incurring indirect monetary costs (e.g., travel to reach a recreation site) and non-monetary costs (e.g., congestion) for recreational opportunities.

Demand, supply, and exchange of a product must be considered at both a regional (e.g., within Ontario) and global scale (see Figure 6). The natural resource-based product markets in which Ontario participates (e.g., the forest products market, the nature-based tourism market and the outdoor recreation market) are global. Therefore, changes in global supply and demand will affect Ontario's market.

3.1.2. Factors influencing scarcity: Society, governance, and technology

The factors influencing the scarcity of natural resource-based products can be grouped into three categories: society, governance, and technology. Society refers to the values, culture, and traditions that shape the behaviours of individuals. These societal factors influence individuals' preferences for natural resource products and influence the constraints and awareness components of demand. Expressions of demand in turn help shape societal values, culture, and traditions.

Governance refers to the use of institutions, methods of collaboration, and structures of authority to allocate resources and coordinate or control activity in society or the economy (Wikipedia 2007). In some societies, governments may intervene in the economic system to attempt to provide a more socially optimal distribution

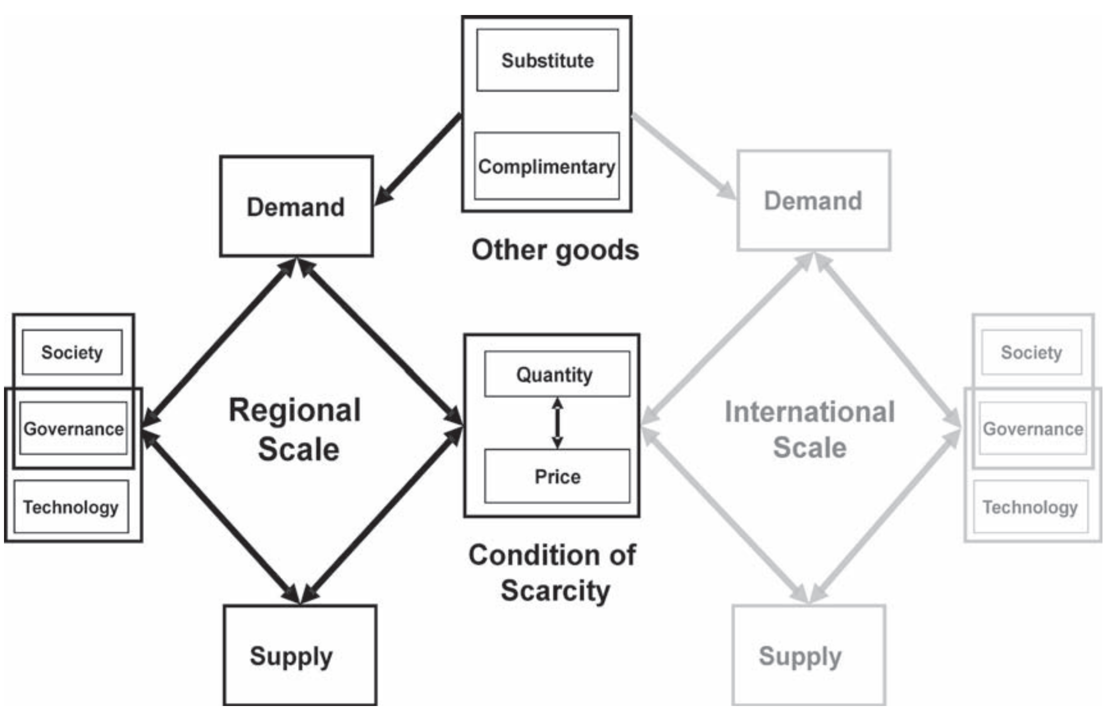


Figure 6. Components determining the scarcity of natural resource products at a regional and international scale.

of goods and services. Processes, laws, economic incentives, moral suasion, and direct production are all techniques used by governments and institutions that may affect the supply of natural resources and products derived from them. Governance may also affect the demand for resources by restricting behaviours or technologies (e.g., motorized vehicles). Societal values also shape the ways that governments allocate resources and control activities.

Technology influences how people process and use resources. Advances in technology affect the suppliers of natural resource-based products by making processing more efficient. Technological changes affecting substitute or complementary products will indirectly affect demand. Advancements in technology may be in response to climate change, resource scarcity, and/or government policies.

Reciprocal relationships exist among most of the items in the generic model. While exchange results from scarcity, exchange may also affect scarcity. This can result from changes to supply (e.g., degradation of natural capital) and from changes to demand (e.g., development of habits that affect preferences). Endowments of resources (supply) may also affect governance systems and the need to develop various technologies. Tastes and preferences of individuals (demand) may also influence the development and adoption of different technologies.

3.2. Measuring the effects: indicators

We use social welfare to measure the effects of climate change on social and economic systems. Since social welfare relates to human benefits, we do not consider values attributable to non-human species. While social welfare is our ideal, measuring this concept is complex. Equity (inter- and intra-generational) complicates the assessment of whether a change increases or decreases social welfare. For example, assume that climate change leads to greater wealth within a country, but that the wealthiest people gain while the poorest individuals lose wealth. We are left with the difficult task of evaluating whether this society is better off (more overall wealth) or worse off (greater inequity in income) from climate change. This evaluation is further complicated by the need to identify a suitable discount rate for any future costs and benefits.

We discuss four indicators that social scientists often use to measure dimensions of social welfare. These indicators focus on exchange, economic welfare, economic impact, and social measures. While some discussion of the various methods is provided, interested readers are encouraged to consult sources that specifically focus on each indicator.

3.2.1. Exchange indicators

The first set of indicators focus on exchange. For market goods, changes in scarcity cause changes to both the quantity exchanged and the prices of the goods. In a perfectly competitive market, the quantity and price of goods exchanged is determined by the intersection of the demand and supply curves. We assume perfect markets[4] when assessing potential climate-induced changes to exchange indicators. For non-market goods such as many outdoor recreation activities, researchers focus on changes in quantity consumed and changes to costs for pursuing an opportunity.

Exchange indicators are important for two reasons. First, the indicators measure the direct effect of climate change on the economic system. For example, simply knowing that prices for forest products will likely decline is important to many individuals who depend on forestry for employment and investment. Second, exchange indicators can be used to assess other specific effects of climate change. For example, knowing that climate change will result in 10% fewer snow-related recreational trips will allow researchers and managers to use this information in long-range planning and policy development. Researchers may also translate this information into measures of economic impact or economic welfare.

[4] A perfect market is a neoclassical economics concept whereby the market efficiently allocates resources. Conditions of a perfect market include rational, self-interested behaviour of individuals, perfect awareness and information about transactions, perfect competition (e.g., many buyers and sellers), mobility of resources (e.g., the ability to enter and exit the market), and ownership rights (Hussen 2000).

3.2.2. Economic welfare

At a macroeconomic scale, economic welfare is maximized when a nation allocates the use of its scarce resources to produce a combination of goods and services that maximizes the benefit received. The types of benefits and therefore the exact combination of goods and services produced depend on the needs and preferences of society.

At a microeconomic scale, economic welfare measures the efficiencies (consumer and producer surpluses) that result when individuals or firms act in rational ways to maximize their welfare through the exchange of goods and services. Consumers' surplus results when consumers were willing to pay more for a product than was required. Producers' surplus occurs when producers are able to supply a product for less than they received for it. For non-market goods such as outdoor recreation, estimates of economic welfare focus on consumer surplus since no producers exist.

One way to estimate economic welfare at the microeconomic scale is to sum individual welfare values. A cost-benefit analysis uses net present value (NPV) to determine if a given scenario will result in a net benefit or a net loss to society. Cost-benefit analysis requires accurate measurement of all benefits and costs associated with a scenario, summed over the time under consideration and discounted to the present.

An important goal for cost-benefit analyses is to establish changes to economic value (e.g., of a recreation activity, tourism experience, or forest product) arising from a scenario. For market-based products, it is possible to estimate these values through market prices. For non-market goods (e.g., recreation), other information must be used. Methods of estimating the value of non-market goods include revealed preference and stated preference methods. Revealed preference models use artificial costs such as travel when valuing choices (e.g., recreational trips). Differences in the quality of recreation opportunities are established by differences in travel costs incurred by individuals (see Hunt and Moore [2006] for an example related to climate change). Sometimes one can estimate the value of an attribute of interest (e.g., the value of angling for a specific fish species) by statistically separating sales prices for items such fly-in fishing packages into prices for the attributes that it comprises (e.g., location, facilities). See Hunt et al. (2005) for an example of this hedonic pricing application.

Stated preference methods ask individuals about their willingness to pay for resources beyond the market price (consumer surplus). Methods such as contingent valuation and stated preference choice models recover the value of resources by crafting experiments that involve hypothetical trade-offs between resource quality and cost.

Economic welfare measures assume that we can assign a monetary value to social welfare. Economic welfare measures do not often consider equity issues. They assume that a dollar in the pocket of one person is worth the same to society as a dollar in the pocket of any other person.

3.2.3. Economic impacts

While economic welfare examines the efficient allocation of resources, economic impacts measure the expected outcomes (expenditures, employment, and taxation) from economic activity. Expenditures are at the heart of economic impact analysis. Expenditures may arise from the construction of infrastructure or from the sales of goods and services. With appropriate information on how different sectors interact, it is possible to trace these expenditures throughout an economy.

Economic impacts are presented in terms of direct, indirect, and induced impacts. Consider the construction of a new saw mill. Direct expenditures refer to the expenditures the company incurs to build the mill. Indirect expenditures occur when construction contractors pay for construction materials (e.g., plastics, steel, etc.) and pay for subcontractors to complete parts of the work. Induced effects occur when employees involved in constructing the sawmill spend their wages on other goods and services (e.g., food, entertainment). The full effect of these direct, indirect, and induced expenditures results in a cycling of the initial expenditure through an economy. This cycling is usually expressed as a multiplier effect. Given information on expenditures, it is possible to translate expenditures into employment and tax measures.

An often overlooked aspect of economic impact analysis is the implicit assumption of new expenditures. If a particular expenditure would have occurred in an economy regardless of the change under consideration, the economic impacts of the expenditure may be irrelevant. For example, consider a skier who spends $1000/year on skiing related equipment in a community. If climate change removed the opportunity for this individual to ski, we might conclude that climate change would result in a loss of $1000/year (direct effect) on the community's economy. However, if this person spent the $1000/year on golf accessories in that same community, the real change to the local economy is zero. Positive economic impacts also do not necessarily translate into economically efficient allocations of resources or cause an increase in social welfare [5].

Equity is a reason that economic impacts are relevant measures for social welfare. Unlike most economic welfare studies, economic impact models provide measures of changes to the distribution of economic activity at differing scales. For example, it is possible to show changes in the distribution of economic activity at the community, regional, provincial, and national scale resulting from the opening of a sawmill. However, economic impact analyses do not address distributional changes in economic activity at individual levels.

Economic impacts of future scenarios can be assessed by using modelling techniques and by examining analogue events. For example, the potential impacts of warmer and drier conditions expected in western areas of the United States by 2025 have been estimated from the effects of a past, prolonged drought on tourism and recreation in Lake Mead, Arizona (Jones et al. 2006).

3.2.4. Social measures

Many researchers focus on social measures of climate change. These measures focus on effects that are external to the economic system. Social indicators focus on changes to the quality of life or changes to the structure of society. Some social indicators that may be useful to quantify the effects of climate change on the natural resource sector in Ontario include quality of life indicators (e.g., genuine progress index, gross national happiness), social and community cohesion indicators (e.g., anti-social acts recorded by law enforcement agencies), socioeconomic status (e.g., unemployment, people living in poverty), and visitor satisfaction.

3.3. Effects and consequences of climate change

For most natural resource products (both market and non-market), the effects of climate change will vary over time. Two periods are discussed in this report, the short term and the long term[6]. Short-term effects are those occurring between the present and 2049 but are centred on the 2020s. This period corresponds with the definition of 'short term' used in previous climate change research and reflects approximately one generation. The long term is considered anything occurring beyond 2050. This use of short- and long-term horizons is only for illustration purposes as changes continuously occur to production possibilities and components of Figures 5 and 6.

This next subsection provides a generic description of the potential effects of climate change on social and economic systems in the short and long term. In addition to presenting the effects, we illustrate how the effect of climate change on economic systems may be derived using basic economic theory.

3.3.1. Short-term effects on scarcity

In the short term, climate change will affect the scarcity of natural resource-based products through changes to supply. Changes to supply may affect the quantity and price of goods exchanged. Supply-side effects

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[5]For example, consider a fictitious case where a new regulatory control on forest harvesting results in higher delivered wood costs. These higher costs reduce economic welfare. However, positive economic impacts would occur if the additional costs of harvesting trees results in greater employment and expenditures in a local community.

[6]Readers should not confuse these terms with economic concepts of short run and long run.

include changes to the abundance and variability of natural resources. Climate change may also affect factors of production (labour, capital, or other natural resources) used in processing. For goods traded in international markets, we must consider changes at both regional and international scales.

The potential to substitute some factors of production (labour, capital, and natural resources) during the processing of resources may allow suppliers to adapt to climate change. However, few substitutes for natural capital (e.g., water) exist and there are limits to this short-term adaptation strategy[7]. We expect few other climate-induced changes in the short term. While technology and governance structures will begin to adapt, the effects of such changes will likely be undetectable.

We assume that initially changes to demand for natural resource-based products resulting from climate change will be minimal. However, with increasing incidences of extreme weather, some temporary, short-term changes in demand are possible. Forecasters also need to be aware of short-term fluctuations in demand caused by factors other than climate change.

3.3.2. Long-term effects on scarcity

Over the long term, individuals can expect climate change to affect scarcity through changes in supply (as in the short term) and through changes in demand. Climate change mitigation strategies pursued in the short term will affect the magnitude of expected long-term climate change effects.

Climate-induced changes to natural resources, factors of production, governance, and technology all affect supply in the long term. The impact of, and potential adaptation to, climate change effects in the short term will also contribute to changes in supply (see Figure 6). Advances in technology could enhance supplies of natural resources (e.g., genetic improvements in tree species) or could improve efficiency of processing. Governments may intervene in the economic system to correct any market failures that arise or to ensure a socially optimal level of undersupplied goods and services. Possible changes in government structures and government mandates, usually based on societal preferences, will affect supply.

Long-term changes in demand will result from climate-induced changes in society and governance, and changes in the types and availability of substitute and complimentary goods. Attributes of society include population growth, population distribution, demographics, religion, culture, politics, traditions, social conventions, and economics. Shifts in social norms (i.e., shared beliefs or socially enforced patterns of behaviour) will shape demand functions for natural resources and products processed from natural resources. Governance factors include international relations, governance structures, political regimes, laws, and regulations. Innovations resulting in new substitute or complimentary goods may draw users away from traditional products produced from natural resources. Finally, the short-term effects of climate change will also influence long-term demand.

3.3.3. Consequences

With changes expected in few components of our conceptual model, short-term predictions of climate change effects on social and economic systems may be quite simple. For example, with stable demand a decrease in natural resources will result in higher prices and lower quantity consumed for any good produced from these resources.

With the influence of social, governance, and technological factors in the long term, changes to demand and supply functions will make it difficult to predict changes to exchange indicators, economic welfare, and economic impacts. For example, consider potential changes to alpine skiing in Ontario. Suppose a warmed climate means a reduced supply of naturally available opportunities. However, changes in snowmaking technology allow ski resorts to continue to supply alpine skiing opportunities. Suppose the reliance on snowmaking reduces the quality

[7]The law of diminishing marginal substitutability states that it becomes increasingly difficult to substitute one input for another while maintaining the same level of output (Pearse 1990).

of the opportunity. Simultaneously, demand for Ontario's alpine ski resorts increases due to lost opportunities in the United States. These changes in supply and demand may allow more opportunities to be consumed at higher prices. In this case, there will be positive economic impact to Ontario due to increased spending, although welfare may decrease due to reduced snow quality and crowding from tourists.

As with any model, our conceptual approach to understand the effects of climate change on social welfare is a simplification of reality. Particularly, the approach is subject to uncertainty that affects many of the key concepts (e.g., ecological system response to climate change, societal response) that will affect any forecast.

4. Response and Adaptation

Adaptation is a key component of coping with climate change. Spittlehouse and Stewart (2003, p. 2) define adaptation as "adjustments in ecological, social and economic systems in response to… changes in climate". This is in contrast to changes in behaviour to reduce greenhouse gas emissions or to try to prevent further changes in climate. The term adaptation covers many activities that can be classified in several ways (e.g., by timing, leads, type, and social scale categories) (Becken 2005, Grothmann and Patt 2005). We discuss adaptation to climate change by type and by the social scale at which it is pursued (e.g., individual, community, industry, or government). While the social scale has implications for implementation success, any adaptation strategy should maximize potential benefits while minimizing negative effects.

Adaptation to the effects of climate change on natural resources and products made from natural resources occurs in several places within the conceptual model presented in section 3.1. In the short term, adaptation will likely occur primarily on the supply side as suppliers substitute factors of production. In the long term, adaptation to climate change occurs in society, government, and technology with consequent effects on the exchange of natural resource-based goods.

4.1. Consumer adaptation

Individual consumers likely have the most flexibility to adapt to climate change. Autonomous adaptation by rational individuals occurs if the net benefits (i.e., expected benefits minus costs of adaptation) the individual expects to receive by adapting are greater than the benefits from pursuing the original behaviour. Adaptation by individuals to changes in natural resources and products made from natural resources are most likely to involve behavioural or soft adaptation strategies (e.g., product substitution). While individual adaptation may occur in response to changes in the forest industry, individual adaptation in response to changes to nature-based tourism and outdoor recreation is complex and is explored in detail below.

Individual adaptation will be a key component in coping with the effects of climate change on tourism and recreation opportunities. By adapting, participants may suffer little loss of personal utility (i.e., the sum of benefits an individual receives from pursuing an activity). Behavioural changes may involve changes in the timing of participation, resource (e.g., location) and activity substitution (Shelby and Vaske 1991), and changes in equipment or techniques. For example, golfers in a warmed southern Ontario climate may choose to participate early in the morning to avoid the heat of midday. For resource substitution, participants may choose a different site if degradation occurs at a currently used site. For example, if water quality at one lake becomes poor for swimming, recreationists may move to a different lake. This form of adaptation is important; the loss of recreational welfare resulting from damage to Alaska's Prince William Sound by the Exon Valdez oil spill was less than originally expected when resource substitution was considered (Hausman et al. 1995). In the case of widespread effects of climate change, resource substitution may not be possible, or may involve travelling long distances (e.g., those wishing to participate in snow and ice-based sports may have to travel long distances to reach snow-reliable areas).

Behavioural changes often involve the substitution of one tourism or recreation activity for another. About 50% of recreational anglers surveyed in the southern United States stated that there were other recreational activities (e.g., camping, hunting, golf, and swimming) that would provide them with the same level of satisfaction as fishing (Ditton and Sutton 2004). The ability of tourists and recreationists to substitute areas and activities arises because the activity is seldom the reason for taking a trip. Instead, recreation and tourism pursuits are goal-oriented behaviours that focus on the achievement of psychological outcomes (Driver and Tocher 1970). These psychological outcomes include relaxation, solitude, escape, challenge, and affiliation among others. Therefore, individuals may achieve these outcomes from a wide array of settings and activities.

Finally, participants may be able to adapt to climate change by using new techniques or types of equipment. An experiment by snowmobilers and ATV enthusiasts found that ATVs equipped with snow tires provide a suitable recreation alternative to snowmobiles (Scott et al. 2002).

4.2. Producer adaptation

The ability of industry (i.e., suppliers) to adapt to climate change is more constrained than the ability of an individual. Most suppliers of products made from natural resources have capital investments that are not readily sold or moved. As economic entities, suppliers will only undertake autonomous adaptation if they expect the discounted benefits of adaptation will exceed the discounted costs of adaptation (Scheraga and Grambsch 1998). The amount and likelihood of adaptation will also depend on the planning horizon (i.e., longer planning horizons will usually result in greater adaptation) of the company and the cost burden they are willing to accept. Adaptation methods used by suppliers can involve techniques to enhance the natural resource, affect processing or affect behaviour (i.e., business planning). The first technique is designed to increase the supply of natural resources (e.g., fish breeding and stocking programs increase the number of fish in a lake). Processing and business planning adaptations involve changing how products are processed and distributed to the customer. Table 1 provides examples of the adaptation strategies undertaken by forestry and tourism industries.

Table 1. Adaptation strategies available to producers in tourism, recreation, and forestry activities, in response to climate change.

Strategy	Tourism and Recreation	Forestry
Enhance resource	Adopt biologically-based adaptation strategies • Genetic engineering • Stocking (e.g., fish) Improve technical strategies • Snowmaking or cloud seeding	Adopt biologically-based strategies • Genetic engineering • Targeted regeneration (e.g., helping trees migrate) or silviculture Improve protection strategies • Fire protection, pesticides
Change processing	Construct infrastructure • Artificial and/or indoor attractions (e.g., artificial, non-snow ski surfaces (Scott 2006)) • Structures to cope with effects (e.g., shade structures, extended boat launch ramps)	Adopt new technology • Processing techniques (e.g. to compensate for changes in wood quality and quantity (Spittlehouse 2005)
Change behaviours	Be flexible • Operating seasons • Regulations Diversify • Activities not dependent on weather or climate • Activities expected to benefit from climate change • Cultural activities Increase insurance • Weather insurance or weather derivatives Embrace climate change • Climate change tourism Market and educate	Be flexible • Harvest schedules • Alternate species Diversify • New products • New industries

The amount and cost of adaptation required to respond to climate change will depend on the location, the extent of climate change and initial resource endowment. For example, the need to increase snowmaking in southern Ontario will be greater (e.g., 47% to 66%) than in northern Ontario (e.g., 28% to 52%) (Scott and Jones 2006a). In the long term, many downhill ski area operators in eastern North America could see a doubling of their snowmaking expenses by 2050 under a high-impact climate change scenario. This increase in snowmaking costs could result in a 5% increase in overall operating expenses, which could jeopardize the financial viability of some operations (Scott et al. 2006). For activities where adaptation is essential, the costs of adaptation will increase the price of the final good. If the demand and willingness-to-pay are sufficient, increased costs could be passed on to consumers but some businesses may close. Small companies, those with low profitability or those with limited access to financing may face financial pressures with negative effects of climate change. Such businesses may be less likely to take adaptive action than companies with higher profit margins or easier access to financing. With business closures, negative impacts to communities are likely to follow.

Consideration of climate change impacts and opportunities should become a formal part of long-term planning processes for any resource-dependent industry (Ohlson et al. 2005). Operators should assess whether new products and services are needed to cope with climate change effects (Mather et al. 2005, Gyimothy 2006). While companies that make business decisions around climate change may profit, adaptation has diminishing marginal returns. Producers may eventually be forced to close if natural resources upon which they depend are severely degraded.

4.3. Community adaptation

Community adaptation will be important for forest dependent and nature-based-tourism dependent communities. Residents of forest-based communities are at greater risk from the socio-economic effects of climate change on forests and the forest industry and they are also the least likely to be equipped to adapt. Residents of forest-based communities may not have easy access to information about climate change. This may result from the isolation of forest-based communities and a lack of broader social networks (Davidson et al. 2003). Available information likely supports the views of local industry representatives without concern for other viewpoints (Davidson et al. 2003). In addition, residents of single industry communities are unlikely to question the authority of industry representatives (Davidson et al. 2003). Women, who often express greater concern about climate change risk and are more likely to support climate change policies (Zahran et al. 2006), may be under-represented in the leadership of male oriented forest-based communities (Davidson et al. 2003). Females are also less likely than males to exhibit activism towards the forestry sector (McFarlane and Hunt 2006). Therefore, forest-based communities may have less appreciation for the potential effects of climate change and be less willing to take proactive measures. Residents of these communities also usually possess specialized skills and these communities have a shortage of human capital (Davidson et al. 2003).

Resiliency is a key factor that will allow forest-based communities an opportunity to adapt successfully to climate change. General methods of enhancing community resiliency include policies supporting economic diversification (entrepreneurship ethic, effective community organizations, strong leadership, and commitment to the community), programs supporting the development of human capital (e.g., adult education programs, skills training, and health care) and infrastructure development (e.g., utilities) (Teitelbaum et al. 2003).

4.4. Factors motivating adaptation

People’s perceptions of risk are important in predicting behavioural intentions to take action on climate change (O’Connor et al. 1999). For example, individuals are more likely to support costly climate change initiatives if they experience climate change effects or perceive climate change as likely and threatening to their well-being (Cameron 2005, Zahran et al. 2006). The greater the expected risk of damages, the greater the likelihood of an individual pursuing adaptation. For example, Fijian tourism providers typically focus on planning for concrete and foreseeable high-risk impacts such as cyclones (Becken 2005).

Finally, general environmental beliefs are important in predicting behavioural intentions to take action on climate change (O'Connor et al. 1999). Demographic variables such as gender, age, and education as well as knowledge of the causes of climate change are also important predictors of intentions to take action (O'Connor et al. 1999). Those individuals with 'new ecological values' (e.g., concern for intergenerational equity, carrying capacity, resource scarcity, or biocentric values) are more willing to assume costs of climate change prevention, as are those individuals who believe that bureaucratic agencies are competent (Zahran et al. 2006). Also, those individuals with higher perceived efficacy (ability to contribute meaningfully) are more likely to support climate change-related policy action (Zahran et al. 2006).

The media, public agencies, friends, and colleagues influence individual perceptions of climate change risk (Grothmann and Patt 2005). This finding suggests that risk communication and education about climate change may help to spur action (Zahran et al. 2006). However, the lack of a direct link between climate-damaging activities and climate change means that many people do not see these activities as dangerous (Lorenzoni and Pidgeon 2006) or the need for potentially costly adaptation. People who reside in areas with currently cool climates may be less likely to perceive climate change (in the form of increased temperatures) as negative (Lorenzoni and Pidgeon 2006).

Grothmann and Patt (2005) propose a model for an individual or group's decision to adapt to climate change. First, they appraise the risk, which comprises probability (the individual's expectation about being exposed to a threat) and severity (the amount of damage should they be exposed). If a threshold of severity or probability is reached, the individual will consider adaptation. The individual or group will next assess their perception of a specific adaptation's efficacy (i.e., will a specific action be effective in protecting against the threat) and will assess their self-efficacy (their ability to execute the adaptive measures). Finally, they will assess the perceived costs of adaptation.

An important consideration in assessing the potential for adaptation is what people would be willing to give up to mitigate or adapt to the effects of climate change. For climate change adaptation, people are being asked to exchange private benefits (e.g., current lifestyle) for social benefits (e.g., reduced climate change). When a sample of Harvard graduate students was asked how much they would be willing to pay in gas taxes to completely solve the problem of climate change by 2100, the median response was $0.50 per gallon (Viscusi and Zeckhauser 2006). When asked what percentage of their income they would be willing to sacrifice the median amount was 3% (Viscusi and Zeckhauser 2006). Results of a 1997-1998 survey of university students in Oregon indicated that the greater amount of climate change a mitigation method is expected to prevent (e.g., a 2°C increase in temperature as opposed to a 1°C increase in temperature) the more respondents were willing to pay (Cameron 2005). For some people the benefits of their current (e.g., consumptive) lifestyle outweigh the potential risks associated with climate change (Lorenzoni and Pidgeon 2006). People may wish to take action against climate change but at the same time maintain a high standard of living for their family (Norgaard 2006).

4.5. Barriers to adaptation

Barriers to adaptation are physical or psychological conditions that may prevent an individual, producer, community or institution from undertaking adaptation activities. For example, discussion of climate change may cause emotions that are unpleasant and that violate the norms of social interaction. These feelings include fear or loss of the sense of continuity of life, helplessness, guilt, and threats to the sense of identity (Norgaard 2006). To avoid these unpleasant emotions people may manage their emotions instead of taking action to adapt to climate change. People may also rationalize away their contribution to the problem or feel powerless to affect change (Norgaard 2006). If people do not admit that a problem exists, that they are contributing to the problem, or that they could potentially be part of the solution, it will be difficult to motivate them to act. For some people, climate change may not be perceived as personally threatening (as compared to medical risks such as cancer or heart disease), or may be perceived to be beneficial (e.g., warming in cool climates) and therefore not worthy of their attention (Lorenzoni and Pidgeon 2006).

Financial barriers prevent effective adaptation to climate change (Grothmann and Patt 2005). For consumers, producers or communities with limited access to financing, adaptation may not be feasible. For adaptation strategies that will occur over a long period, the discount rate (the rate that the real value of money decreases over time) used could affect whether they are deemed economically viable. The use of a high discount rate could have negative social and environmental implications by preventing adaptation.

Poorly designed laws, regulations, or policies and lack of information on causes and appropriate adaptation methods may hinder adaptation. For example, many Fijian accommodation providers who were surveyed stated that lack of financial resources, knowledge, and government incentives prevented them from implementing climate change mitigation or adaptation measures (Becken 2005). Failure to consider the complex effects of natural systems can also lead to unintended and adverse effects. For example, the construction of sea walls in some areas to prevent flooding associated with sea level rise increased flooding in other areas (Scheraga and Grambsch 1998).

4.6. Institutional adaptation

Some types of adaptation are best implemented at the government or institutional level. Forms of adaptation that are considered public goods (e.g., the re-creation of barrier islands to prevent coastal flooding) or common pool resources (e.g., stocking of public waters with fish) are two types of adaptation that the economic system does not efficiently allocate. Therefore, governments may act to ensure a socially optimal level of these types of adaptation to climate change.

Institutions should start the process of adaptation with the establishment of research capacity. Investment in science and research, by management agencies, academia, industry, and others will help individuals and industries understand the effects of climate change on natural resources (McKinnon and Webber 2005). The sooner reliable knowledge is available, the sooner these entities can act. Governments and institutions should be proactive and include the possibility of climate change effects in long-term decision-making, planning processes, policy development, and investment decisions (Ohlson et al. 2005). The possibility of climate change effects should be incorporated in these processes even if the type and magnitude of effects remain uncertain. Such strategies can improve resilience by preparing governments and institutions to cope with any changes (Ohlson et al. 2005). Strategies and techniques for integrating climate change concerns into policy and planning include:

- Identifying problems and vulnerabilities that may result from climate change (Ohlson et al. 2005).
- Building and restructuring institutional capacity.
- Creating flexible and proactive policy and management guidelines.
- Removing policy and operational barriers that may prevent individual or industry adaptation (Spittlehouse 2005).
- Working closely with climate change researchers and considering adaptive management techniques.
- Considering uncertainty when analyzing the benefits of various adaptation strategies.
- Providing incentives for adaptation.
- Providing adaptation measures directly.
- Building social and human capital (e.g., education, skills, job experiences) and providing programs for economic diversification (Teitelbaum et al. 2003).

Adaptation policies adopted by governments should be publicly acceptable and account for differences in value systems. Measures of public opinion can help governments assess strategies that may be publicly acceptable. Governments must also consider ethical issues, intergenerational equity, and distributional equity associated with adaptation strategies. The public is more likely to accept and comply with policies that they believe are fair and just (Lawrence et al. 1997). The amount of adaptation that institutions or resource managers undertake may depend on their risk tolerance. Many argue for the use of the precautionary principle: society should act to minimize the likelihood of potentially irreversible environmental consequences from occurring (Hussen 2000).

Affecting change related to climate may be problematic for policy makers for many reasons. First, people may not realize that climate change is occurring. Second, when presented with such evidence, individuals may choose not to acknowledge it, or may rationalize away their contributions or their potential to support a solution. Finally, once people recognize that climate change is a real and important problem, they may not see the benefits from an adaptation or mitigation strategy.

4.7. Public opinion

To provide effective management of Ontario's natural resources under the changing climate regimes predicted over the next century, the Ontario government may wish to know the opinions of Ontarians on both climate change and the government's role in helping adapt to climate change.

People worldwide feel that the risks associated with climate change outweigh any potential benefits (e.g., through global warming) (Lorenzoni and Pidgeon 2006). Several polls show that in the fall and winter of 2006 the environment and climate change are important issues on the minds of Canadians. Ontarians are no different. An increase in media coverage of climate change at that time also indicates an increasing interest in the topic (see McPherson in prep).

Although Ontarians agree that climate change is an important issue, opinions differ on the effects, who is responsible, and who should lead adaptation efforts. Many people believe that climate change will affect others, and that it will not be personally threatening. For example some people believe that climate change will affect mostly third world countries (because they are more vulnerable and less able to adapt) (Lorenzoni and Pidgeon 2006).

A third of Ontarians feel that the indifference of companies that pollute is responsible for global warming while another third of Ontarians feel that the lack of effective measures taken by governments is responsible for global warming (Leger Marketing 2006). Over two thirds of Canadian respondents reported that the current federal government approach to climate change is "not tough enough" (Environics 2006).

5. Social and Economic Effects of Climate Change on Nature-based Tourism and Recreation in Ontario

The United Nations World Tourism Organization defines tourism as "the activities of persons travelling to and staying in a place outside their usual environment for not more than one consecutive year for leisure, business and other purposes" (Statistics Canada 2006). Tourism is differentiated from recreation in that tourists usually travel significant distances from home and spend at least one night at their destination. Nature-based tourism and recreation opportunities in Ontario include, but are not limited to camping, fishing, hunting, skiing (downhill and cross-country), snowboarding, snowmobiling, dog sledding, canoeing, kayaking, boating, water sports, hiking, all terrain vehicle (ATV) touring, mountain biking, wildlife viewing, golfing, sight seeing and touring, snowshoeing, rock climbing, and ice climbing. The relationship between climate and tourism and recreation is well documented; for more information, see sidebar.

This section discusses the effects of climate change on nature-based tourism and outdoor recreation in Ontario. The conceptual model presented in section 3.1 provides the foundation for this discussion.

5.1. Short-term tourism and recreation demand

We assume that climate change will have minimal short-term effects on the demand for nature-based tourism and recreation in Ontario. If significant effects of climate change arise earlier than anticipated, this assumption may not hold true. Although we do not expect short-term demand to change significantly, temporary changes are possible due to fluctuations in weather. For example, increased precipitation in Britain caused an increase in international departures from that country during the current and subsequent year, and the British are more likely to take short-duration (day or weekend) trips during hot summers (Agnew and Palutikof 2001).

Since we expect climate change to have minimal effects on short-term demand, we based estimates of short-term demand on current demand. Significant demand for Ontario's nature-based tourism and recreation products exists as evidenced by participation rates for different activities. In 2004,18.2 million overnight tourists with an outdoor interest spent $4.1 billion in Ontario (OMTR 2006). Most of this demand was domestic (77%), with the United States being the largest international source area (15%), while only 3% of visitors came from other international destinations (OMTR 2006). In 2001, 5.9 million visitors to Ontario were classified as resource-based tourists (OMTR 2003). A study of outdoor recreation participation in Ontario indicated that residents spend approximately $2.9 billion annually on outdoor recreation activities in natural areas (e.g., swimming, fishing, hunting, berry-picking, and wildlife viewing) (Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians 2000).

5.1.1. Factors affecting short-term demand

Demand for a tourism and recreation opportunity depends on consumers' preferences, constraints, and awareness of alternatives. Social and governance factors also influence demand. Climate in the source region and in the destination region influences individuals' demand for tourism and recreation (Hamilton et al. 2005a, b). People maximize their tourism and recreation participation when climatic conditions in destination regions are dry, moderate (temperatures around 21^{o}C), calm, and clear (Lohmann and Kaim 1999, Agnew and Palutikof 2001, Lise and Tol 2002, de Freitas 2005). Domestic tourism expenditures in Canada are greater during warmer than during cooler summers (Wilton and Wirjanto 1998). However, optimal climate settings for tourism differ among people and activities pursued (e.g., winter tourism) (Maddison 2001, Lise and Tol 2002). Some of the influence of climate on tourism and recreation demand is indirect. For example, temperature and precipitation ranges are responsible for creating Ontario's ecosystems and hydrological regimes. These in turn provide unique hiking, camping, and sightseeing opportunities as well as fishing, hunting, boating, canoeing, and kayaking opportunities.

The role of climate in tourism and recreation participation

Climate is of primary importance to potential tourists when selecting a destination for a recreational or leisure-based vacation experience (Hu and Ritchie 1993, Lohmann and Kaim 1999, Mather et al. 2005). Generally, tourists and recreationists prefer climatic conditions that are dry, with warm temperatures, blue skies, few scattered clouds, and light winds (Lohmann and Kaim 1999, de Freitas 2005). The optimum average daily temperature for tourism has been modeled at 21^{o}C (Lise and Tol 2002, Agnew and Palutikof 2001), however, different populations and different tourism activities, such as winter tourism, have been shown to command different optimal climate settings (Lise and Tol 2002, Maddison 2001). For example, optimal temperatures for a round of golf in Toronto range between 18^{o}C and 28^{o}C. Outside of this range, the number of rounds played declines (Scott and Jones 2006c). Participation in golf also decreases with increased precipitation and decreases when wind speeds exceed 20 km/h (Scott and Jones 2006c).

Ideal climatic resources not only increase visitation but also command an economic premium. Skiers in the Lake Tahoe area were willing to pay approximately $0.60 per week per foot of snow (Englin and Moeltner 2004).

We do not expect climate change to affect the short-term demand for nature-based tourism and recreation in Ontario. However, social factors such as population growth, economic growth, demographics, culture, population distribution, social conventions, personal safety, and governance factors such as politics, international relations, and travel regulations will affect demand. For example, demographic change is expected to increase visitation to Canada's National Parks by 14% in 2025, whereas climate change is expected to increase visitation by between 5% and 8% in the 2020s (Scott and Jones 2006b). Each of these variables will have a different effect depending on the activity. In the United States, an increase in per capita income was associated with increased participation in skiing but decreased participation in hunting (Mendelsohn and Markowski 1999). Since the largest portion of international visitors to Ontario comes from the United States, the value of the Canadian dollar, customs regulations, and the strength of the United States economy will also affect demand.

5.2. Short-term changes to the supply of tourism and recreation opportunities

Climate change will likely affect the short-term supply of tourism and recreation opportunities by changing the amount, cost, and quality of opportunities (Aall and Hoyer 2005). These effects will be both direct and indirect. Where climate and weather is considered a tourism or recreation resource (e.g., sunshine in the case of a 'sun' vacation), changes in expected and realized weather (e.g., temperature, precipitation, storms) will have direct effects. Increased temperatures are likely to be the most prominent short-term direct effect of climate change on tourism and recreation in Ontario (see Table 2). Warmer temperatures are expected to increase opportunities for warm-weather tourism and recreation by extending the season lengths for activities such as camping (Wall et al. 1986), golf, and swimming (Scott and Jones 2006a). Increases in season length are also expected for other warm weather activities including ATV riding, bird watching, boating, canoeing, climbing, fishing, hiking, horseback riding, hunting, kayaking, mountain biking, sailing, and windsurfing.

During winter, increased temperature and decreased snow accumulation in areas of Ontario (Colombo et al. 2007) may directly affect the availability of snow and ice-based sports. A reduction in season length is expected at all alpine ski areas in Ontario due to lack of snow and higher temperatures (Scott and Jones 2006a). Even in the short term, northern Ontario can expect the average length of the ski season to be reduced by between three and 28 days (Scott and Jones 2006a). Negative effects on ice-fishing, skating, and snowmobiling will occur due to reductions in ice cover season and the unpredictability of ice strength (Lofgren et al. 2002, Scott et al. 2005, Scott and Jones 2006a). Dog sledding and ice climbing opportunities will also be reduced.

Indirect climate change effects occur when climate induces a change in another tourism or recreation resource (e.g., fish populations for fishing trips). Indirect effects include changes to ecosystems, hydrological, and cryological systems (Aall and Hoyer 2005, Gossling and Hall 2006). Increased susceptibility of Ontario's boreal forest ecosystem to fire and insect disturbances (Parker et al. 2000, Wotton et al. 2005) may negatively affect the quality of recreational experiences by decreasing the aesthetic value[8]. High forest fire indices could also result in travel bans that reduce the opportunities for activities such as ATV riding, camping, hiking, and canoeing.

Climate induced changes to the hydrological system could have strong and negative effects on water-based tourism and recreation activities. Reduced water levels may reduce boating opportunities and fishing opportunities by lowering lake levels that will restrict areas navigable by boat and increase hazards to navigation. Low water levels will also reduce access to launch ramps, marinas, and favourite recreation spots (Wall 1998). Evidence of this (e.g., marina operators incur dredging costs due to low water levels) is already available in the Great Lakes (Bergmann- Baker et al. 1995, Scott and Jones 2006a). Canoeing and kayaking opportunities may also be negatively affected. Low water levels on canoe routes could increase the lengths of portages. However, increases

[8] Research studies suggest that disturbed settings are not aesthetically pleasing (e.g., Hunt and Haider 2004) and that activities such as canoeing may be negatively affected by natural disturbances (Englin et al. 1996).

Economics of current tourism opportunities

Nature-based tourism is an important part of Ontario's economy. Nature-based tourism opportunities in Ontario include, but are not limited to, camping, fishing, hunting, skiing (downhill and cross-country), snowboarding, snowmobiling, dog sledding, canoeing, kayaking, boating, water sports, hiking, all terrain vehicle (ATV) touring, mountain biking, wildlife viewing, golfing, sight seeing/touring, snowshoeing, rock climbing, and ice climbing.

In 2004, Ontario had 18.2 million overnight tourists with an outdoor interest (OMTR 2006). These visitors with an outdoors interest are international or domestic visitors who participated in any outdoor activity, visited a national or provincial park or historic site, or stayed at a campground or cottage. These overnight outdoor tourists spent an estimated $4.1 billion in Ontario and represented 39% of all overnight visitors in 2004 (OMTR 2006). While most overnight outdoor tourists are Ontarians, United States tourists spent $1.1 billion while other international tourists spent $0.5 billion in Ontario (OMTR 2006). Most tourists with an outdoors interest visited Ontario during the summer (55%); only 9% visited during the winter months.

Resource-based tourism refers to visitors who engaged in at least one resource-based activity (an activity that has a direct relationship to the outdoors and likely occurs on Crown land) during their trip (OMTR 2003). In 2001, there were 5.9 million resource-based visitors to Ontario (OMTR 2003). These tourists spent $1.3 billion in Ontario in 2001 and generated over 20,000 direct and over 15,000 indirect jobs province-wide. This generated $550 million in taxes for all levels of government (OMTR 2003).

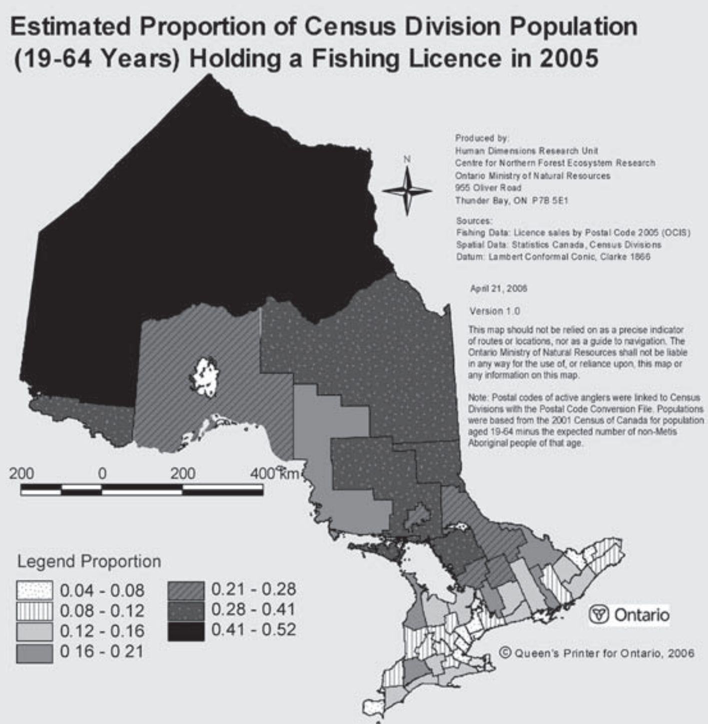
Outdoor recreation also contributes substantially to Ontario's economy. In 1996, residents of Ontario spent $2.9 billion on outdoor activities in natural areas (e.g., swimming, fishing, hunting, berry picking, and wildlife viewing) (Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians 2000). Nature-related expenditures contributed $4.5 billion to Ontario's gross domestic product and contributed $1.4 billion in tax revenues to various levels of government (Federal-Provincial-Territorial Task Force on the Importance of Nature to Canadians 2000).

Consumptive activities of angling and hunting contribute significantly to Ontario's economy. In 1995, there were over 2.0 million anglers in Ontario, with 0.5 million of these being non-resident anglers from the United States. In 1995, the total direct expenditures attributable to recreational fishing were $1.7 billion. Big game hunting also contributes significantly to the economy. In 1997, deer hunters spent approximately $58.5 million on expenses directly related to deer hunting, while moose and bear hunters spent approximately $63.4 million and $18.5 million, respectively (OMNR 2002).

Hunt and McFarlane (2002) surveyed southern and northern Ontario residents in 2000 about their participation in different activities. The ten most popular outdoor recreation activities (by participation rate) for the respondents are presented in the table (above right).

Respondents from northern Ontario placed much greater importance on consumptive, motorized, and winter activities than did southern Ontario respondents. The map below illustrating the number of Ontario residents 19-65 years of age holding fishing licences clearly demonstrates this difference between northern and southern Ontarians.

Rank	Northern Ontario	Southern Ontario
1	Day hiking	Day hiking
2	Fishing (open water)	Wildlife viewing
3	Wildlife viewing	Bird watching
4	Motor boat or jet skiing	Fishing (open water)
5	Hunting	Canoeing
6	Bird watching	Motor boat or jet skiing
7	Snowmobiling	Cross country skiing
8	Ice fishing	Mountain biking
9	Canoeing	Snowmobiling
10	ATV or dirt bike riding	Hunting



in heavy precipitation events could increase the frequency and levels of high flows (Dove et al., in prep). This could negatively affect river-running activities by making conditions dangerous. A summary of climate changes and potential effects on supply of tourism and recreation opportunities is provided in Table 2.

Recreation and tourism activities vary in quality. Better quality opportunities command higher prices, higher visitation rates, and provide a larger set of benefits. While the quality of a recreation or tourism site does not directly affect the execution of an activity, if the quality is sufficiently reduced, individuals may not participate. We may expect climate change to affect the quality of some tourism and recreation opportunities. For example, mountain bikers take significantly less trips to forested areas that have burned; a result that is at least partially due to trail obstructions created by fallen and dead trees (Loomis et al. 2001).

Table 2. General short- and long-term expected effects of climate change on tourism and recreation in Ontario.

Parameter affected	Short term climate effect	Tourism and recreation effect	Long term climate effect	Tourism and recreation effect
Temperature Precipitation	• Longer warm weather, snow-free, and open water seasons	• Longer seasons for warm weather activities	• Longer warm weather, snow-free, and open water seasons	• Same as short term
	• Warmer summer temperatures	• Increased enjoyment by participants	• Warmer summer temperatures	• Temperature thresholds reached • Reduced water quality
	• Decreased cold weather, snow and ice season	• Shorter seasons for snow and ice -based activities • Unpredictable seasons • Reduced quality due to low snow	• Decreased cold weather, snow and ice season	• Same as in short term • Some seasons eliminated
Hydrological	• Reduced water levels	• Increased navigation hazards • Reduced access	• Reduced water levels	• Same as in short term
Ecosystem	• Increased forest fires	• More travel restrictions • Aesthetic effects	• Increased forest fires	• Same as in short term
			• Change in ecosystem composition	• Change in angling and hunting opportunities • Aesthetic effects

[9] The percentage of Ontarians born outside of Canada has risen steadily since 1991 from 23.7% to 26.8% (Statistics Canada 2007).

5.3. Long-term tourism and recreation demand

Long-term assessments of demand for tourism and recreation must consider the evolution of preferences for these activities. Individuals form preferences from many factors including the customs and traditions of society. Over the course of different generations, value systems and social norms may change causing the demand for activities to wane or increase. For example, participation rates for recreational fishing in Canada are declining (Fisheries and Oceans Canada 2005). Cultural shifts can also be expected as the ethnic origin of Ontarians[9] and visitors continues to change.

Actions taken by governments to mitigate the effects of climate change could also influence tourism and recreation demand. Demand may be reduced through increased costs or through command and control actions. For example, stricter fishing regulations may reduce anglers' desire to participate in the sport. Any future

[9] The percentage of Ontarians born outside of Canada has risen steadily since 1991 from 23.7% to 26.8% (Statistics Canada 2007).

government action or policy in response to any factor affecting demand (e.g., population growth, population distribution, demographics, political factors, technological changes, social norms, or marketing strategies) will affect demand. Preferences may also be influenced by government policies and media stories on the risks and impacts of climate change (Grothmann and Patt 2005). Changes in environmental conditions, recreational use, environmental ethic, demographics, technologies, and governance all have the potential to affect future demand for recreation and tourism as do short-term effects of climate change on domestic and international tourism supply and any adaptation that may have occurred.

Current preferences for optimal tourism climate are used to model changes in demand. For example, contingent visitation studies have attempted to assess specific patterns of future tourist behaviour through stated preference choice models (see Richardson and Loomis 2004 and Braun et al. 1999). Models based on current preferences have forecast an increase in tourism in higher latitude and higher altitude countries (Hamilton et al. 2005a, b). However, these survey results are hypothetical because respondents based their responses on their preferences at the time the survey was conducted.

5.3.1. Long-term demand trends

Long-term demand for outbound tourism from Ontario could decrease because of climate change. In the south and central regions of Ontario, the most populated area of the province, winter temperatures could increase by 4° to 6°C in the 2080s (Colombo et al. 2007). This could reduce the demand for outbound tourism from Ontario that is typically based on the desire to flee cold winters. Temperatures in the Caribbean (a traditional winter destination) may also rise to uncomfortable levels meaning that tourists may prefer to stay home, travel domestically, or travel elsewhere[10] (Mather et al. 2005).

The demand for inbound tourism to Ontario may also increase. As temperatures increase, some areas of the world may become too warm, resulting in tourists travelling to escape the heat. The increase in demand for temperate climates has been coined ‘sunbird tourism’ whereby so called ‘sunbirds’ may travel to Canada to escape the heat stress of large urban United States centres (Scott et al. 2004). Predictions for travel in and out of Canada include a 25% to 75% increase in arrivals with a uniform 1°C increase in global temperature by 2025, while departures from Canada could decrease by 25% for a 1°C increase in global average temperature (Hamilton et al. 2005a). This may result in an overall increase in demand for Ontario’s tourism resources.

5.4. Long-term changes to the supply of tourism and recreation opportunities

Climate change will continue to affect the supply of nature-based tourism and recreation opportunities directly. Unlike in the short term, indirect effects (i.e., effects caused by changes to ecosystems and hydrological systems) will also play a key role in determining the supply of tourism and recreation opportunities.

The positive effects of increased temperature seen in the short term (e.g., longer seasons of weather suitable for camping, hiking, mountain biking, golfing, and beach recreation) could be magnified. For example, under a high greenhouse gas emissions (A1) scenario, the golf season in the Greater Toronto area could be as long as 323 days in the 2080s, up from 265 days in the 2020s and 214 days currently (the 2000s) (Scott and Jones 2006a). For some activities temperatures above comfort thresholds may diminish opportunities in the long term (e.g., see Scott and Jones 2006c).

Supplies of water recreation opportunities may decline despite a longer warm weather season. The negative impacts on water recreation in the short term (e.g., reduced boating opportunities, hazards to navigation, reduced access to launch ramps, reduced depths at marinas, more portages on canoe routes, and reduced white water opportunities) will continue and perhaps be magnified in the long term. By the 2050s, stream flows may be 30%

[10] Average annual temperatures in the Caribbean are expected to increase by 2 to 3°C in an A2 scenario (IPCC 2001a).

lower than current flows (1961-1990) in the Great Lakes Basin (Mortsch et al. 2000) and water levels in Lake Ontario could decrease by one metre (Lofgren et al. 2002). Warmer temperatures mean increased risk of algae and bacteria growth that negatively affects swimming opportunities (Dove et al. in prep).

Climate change will reduce the season for winter sports in northern Ontario and potentially eliminate seasons for some winter sports in southern Ontario (Scott and Jones 2006a). By the 2090s the ice-fishing season, which depends on the number of “ice-in” days, could be reduced from over 100 days to 28 to 40 days on Lake Superior, while Lake Erie is predicted to have as few as 11 to 27 “ice-in” days (Lofgren et al. 2002). Even with the use of snowmaking technology, the alpine ski season in northern Ontario could be halved by the 2080s (Scott and Jones 2006a). In southern Ontario, the alpine ski season could be reduced to 59 days in the 2080s down from 149 in the baseline years of 1961-1990 (Scott and Jones 2006a).The cross-country ski and snowmobiling seasons in southern Ontario may be eliminated as early as the 2050s (Scott et al. 2005, McBoyle and Scott 2006). In the interim, the seasons for snowmobiling, an activity for which snowmaking is impractical and expensive given the spatial extent of trails, may experience greater inter-annual variability making participation unpredictable (McBoyle and Scott 2006).

In the longer term, indirect effects such as changes in ecosystem and species composition are more likely. Higher water temperatures may result in a northward shift in range for Ontario’s fish species. Increases in stream and lake temperatures may result in lower abundance of cold-water recreational fish species such as lake trout (*Salvelinus namaycush*) and brook trout (*Salvelinus fontinalis*). However, warmer waters may provide opportunities for cool water species such as walleye and warm water species to expand their ranges northward. Walleye yields in northern Ontario are expected to increase (Government of Canada 2004)[11]. Warmer waters could mean an influx of warm water fish species and the possibility of exotic species expanding their ranges northward and altering angling opportunities. While new fish species may become available, the expansion of warm water and exotic species may negatively affect native fish populations including walleye (Dove and Lewis in prep).

Besides range shifts, a loss of freshwater marshes from reduced water levels may negatively affect fishing opportunities. A loss of freshwater marshes in Ontario may also affect birdwatching and waterfowl hunting opportunities (Wall 1998). Sea level rises that damage saltwater marshes may negatively affect bird species that migrate through Ontario.

We expect changes in the ranges of recreationally desirable mammals such as moose and deer (*Odocoileus virginianus*). Moose populations are expected to retreat to the far northern sections of the province under a warmed climate (Thompson et al. 1998). The decline of moose populations in the southern parts of their range is expected to occur from increased summer temperatures, less preferred habitat, increased incidence of meningeal worm (*Paralaphostrongylus tenuis)*, and potentially elevated wolf (*Canis lupus*) predation (Thompson et al. 1998). The range of deer is expected to expand northward into the traditional moose territory north of Lake Superior (Thompson et al. 1998).

Changes to vegetation may also affect tourism and recreation. Several studies suggest that biophysical characteristics (e.g., wetlands), disturbance types, and tree species influence evaluations of aesthetic quality of Ontario’s forested ecosystems (Haider and Hunt 2002, Hunt and Haider 2004). Consequently, changes in forest composition and species may affect the scenic backdrop upon which many recreation and tourism activities rely. An increase in area burned by forest fires (Wotton et al. 2005) could negatively affect hiking, wildlife viewing, sightseeing, and canoe tripping (e.g., Englin et al. 1996).

5.4.1. Supply of new opportunities

It is possible that supplies of new tourism and recreation opportunities will arise in the long term. These opportunities may arise through a combination of changed demand preferences and novel combinations of

[11]Studies have shown both increases and decreases in habitat availability for walleye depend upon the rate and level of temperature increase projected and the possibility of competition with other species (Dove and Lewis, in prep).

natural resources due to climatic changes. One example of a new tourism and recreation opportunity is what Aall and Hoyer (2005) call 'climate change tourism' whereby tourists flock to destinations affected by climate change to view the effects. For example, tourists have travelled to areas affected by hurricanes to see the devastation left by the storm. In Norway, climate change has led to an increase in glacier tourism and has resulted in the construction of tourist information centres complete with climate change information (Aall and Hoyer 2005). If certain ecosystem types or opportunities become scarce from climate change, their desirability may increase.

5.5. Climate change effects on activities

Most studies about climate change effects on tourism and recreation have focused on exchange level indicators (e.g., participation and cost). Less information is available about the consequences of climate change on economic welfare, economic impact, or other social measures. In most cases, changes to participation levels are associated with similar changes to these other indicators of societal welfare (e.g., participation increases are usually associated with positive economic impacts and economic welfare). While this association between participation and societal welfare does not imply that other measures of societal welfare are unimportant, the association does suggest that understanding changes to participation is a key component for any assessment of climate change effects on tourism and recreation. In this section, we present evidence and expert opinion about the expected effects of short- and long-term climate change on recreational activities in Ontario. Activities are sorted into themes of land-based non-consumptive, water-based non-consumptive, snow and ice-based non-consumptive and consumptive, hunting, and recreational fishing activities. Hunting and recreational fishing are separated due to their direct dependence on game conditions and the importance of these activities for tourism and recreational purposes. Tables 3 and 4 provide details about the anticipated short- and long-term effects of climate change on participation for these activities.

5.5.1. Land-based, warm weather, non-consumptive activities

We expect participants in most land-based, warm weather activities to benefit from climate change effects through increased opportunities (e.g., longer seasons) in both the short and long term. Increasing temperatures may also increase the quality of these warm weather activities (e.g., greater enjoyment of beach and water recreation activities in warmer weather). Camping participation is expected to increase in the long term. For example, summer occupancy rates at Pinery Provincial Park are projected to increase to 112% of current capacity (Scott and Jones 2006a). The number of rounds of golf played in Toronto in the 2080s could increase 32% to 73% (Scott and Jones 2006c).

In some cases, small increases in temperatures experienced in the short term may increase visitation, but large increases in temperature in the long term may have negative effects such as heat stress. For example, golf participation begins to decline above 28^{o}C (Scott and Jones 2006c), and by 2050, days with temperatures above 30^{o}C are expected to quadruple (Hengeveld et al. 2005). Increases in extreme summer temperatures could prompt the timing of tourism demand for warm weather activities to shift under climate change. Currently (during the baseline years of 1961-1990), Canada and the northern United States see peak visitation during the summer months. By the 2080s, all but the most northerly part of Ontario (i.e., north of Red Lake) may see a bi-modal peak in tourism visitation (i.e., most visitation may occur in the spring and fall when the weather is more moderate) (Scott et al. 2004). However, we must consider that recreation participation appears to follow a culturally defined (e.g., fishing seasons, school holidays) rather than climate-defined season (Hunt and Moore 2006).

Long-term, indirect effects of climate change such as ecosystem changes could reduce participation in activities that are expected to benefit from the direct effects of climate change in the short term. While survey respondents indicated that they would increase their visitation to Banff and Waterton Lakes National Parks under scenarios with warmer temperatures, they stated they would decrease visitation if changes in the number of glaciers, composition of vegetation or populations of grizzly bears, moose, and big horn sheep occurred (Scott and Jones 2006b, Scott et al. 2006). The expected long-term changes appear to have surpassed the survey participants' threshold of acceptable change. However, preferences based on current norms could change. Changes to bird migration patterns may affect birdwatching participation an activity which contributes significantly to the economy of the Point Pelee National Park region (Hvenegaard et al. 1989).

5.5.2. Water-based non-consumptive activities

While warming temperatures are likely to extend water-based recreation seasons, Ontario's water-based recreation and tourism activities (e.g., canoeing, kayaking, swimming, sailing, and windsurfing) may not benefit. The possibility of lower water levels or reduced water quality may negatively affect participation or reduce the enjoyment of those who continue to participate in these activities. Variability in water levels (e.g., extreme high or extreme low flows) may also prove problematic for suppliers of river running (e.g., white water canoeing and kayaking and river rafting) opportunities. Low water levels may also negatively affect consumers and suppliers of canoe trips due to more and longer portages along routes.

Table 3. Predicted short-term (present to 2049) changes to participation in nature-based activities in Ontario from climate change.

General Activity	Region	Partici-pation	Rationale	Activities	Supporting Evidence[a]
Land-based, non-consumptive	Ontario	↑	Longer season* Warmer season**	ATV riding Bird watching Camping Golfing Hiking Horseback riding Rock climbing Sightseeing Wildlife viewing	* Scott and Jones (2006c) ** Scott and Jones (2006a)
Snow and ice-based	Ontario	↓	Shorter season* Reduced quality	Alpine skiing Cross-country skiing Dog sledding Ice climbing Ice fishing Snowmobiling	* McBoyle and Scott (2006) * Scott and Jones (2006a) * Scott et al. (2005) * Lofgren et al. (2002)
Water-based non-consumptive	Ontario	?	Longer season* Warmer season Lower water levels** Reduced water quality***	Flat-water canoeing Flat-water kayaking Motor boating Sailing Swimming White-water canoeing White-water kayaking	* Scott and Jones (2006a) ** Bergmann-Baker et al. (1995) *** Scott and Jones (2006b)
Hunting	Ontario	=	Little change in short term	Deer Migratory bird Moose Small game	
Recreational fishing	southern Ontario	?	Longer season Lower water levels Cold water species reduction* Warmwater species increase**	Recreational fishing	*Minns and Moore (1992) * Jones et al. (2006) ** Dove and Lewis (in prep)
Recreational fishing	northern Ontario	↑	Longer season Lower water levels Coldwater species reduction* Coolwater species increase** Warmwater species increase***	Recreational fishing	* Minns and Moore (1992) * Jones et al. (2006) ** Government of Canada (2004) *** Dove and Lewis (in prep)

a – not all references provide support for each specific activity

Table 4: Predicted long-term (2050 and beyond) changes to participation in nature-based activities in Ontario from climate change.

General Activity	Region	Partici-pation	Rationale	Activities	Supporting Evidence[a]
Land-based, non-consumptive	Ontario	↑	Longer season* Warmer season** Substitution from winter activities***	ATV riding Bird watching Camping Golfing Hiking Horseback riding Rock climbing Sightseeing Wildlife viewing	* Scott and Jones (2006c) ** Scott and Jones (2006a) *** Scott et al. (2005)
Snow and ice-based	Ontario	↓	Substitution from US destinations* Shorter season** Reduced quality	Alpine skiing Cross-country skiing Ice climbing Ice fishing Snowmobiling	* McBoyle and Scott (2006) * Scott et al. (2006) * Hamilton et al. (2003) ** Scott and Jones (2006a) ** Scott et al. (2005) ** Lofgren et al. (2002)
Water-based non-consumptive	Ontario	?	Longer season* Warmer season Substitution from winter activities Lower water levels** Reduced water quality*	Flat-water canoeing Flat-water kayaking Motor boating Sailing Swimming White-water canoeing White-water kayaking	* Scott and Jones (2006a) ** Bergmann-Baker et al. (1995) ** Jones et al. (2006)
Hunting	Ontario	?	Warmer season Deer expansion northwards* Moose contraction northward*	Deer Migratory bird Moose Small game	* Thompson et al. (1998)
Recreational fishing	southern Ontario	?	Longer season Lower water levels Cold water species reduction* Coolwater species unknown change Warmwater species increase** Exotic species increase**	Recreational fishing	* Minns and Moore (1992) * Jones et al. (2006) ** Dove and Lewis (in prep)
Recreational fishing	northern Ontario	↑	Longer season Lower water levels Coldwater species reduction* Coolwater species increase** Warmwater species increase*** Exotic species increase***	Recreational fishing	* Minns and Moore (1992) * Jones et al. (2006) ** Government of Canada (2004) *** Dove and Lewis (in prep)

a – not all references provide support for each specific activity

5.5.3. Snow and ice-based activities

For winter activities, the negative effects of climate change will start in the short term and will continue into the long term. Participation decreases are expected in all winter sports including alpine skiing, snowmobiling, cross-country skiing, ice fishing, snowmobiling, and skating due to reduced opportunities. This reduction will vary by region and by activity and will depend on the length of the initial season and the length of the new season. If a season becomes too short or unpredictable, thresholds could be reached whereby individuals no longer consider investing in the equipment necessary to participate or the infrastructure necessary to provide supply.

Adaptation, both by suppliers and individuals, has the potential to mitigate forecasted negative effects of climate change on winter recreation and tourism. For some winter tourism and recreation activities, technological adaptation methods have already been implemented. Ski resorts, both alpine and cross-country, in Ontario have made multi-million dollar investments in snowmaking technology to offset climate variability and to lengthen the skiing season (Scott and Jones 2006a), while smoothing terrain or developing runs on north-facing or shady slopes can provide skiing with less snow cover (Scott 2006). The modification of business practices has helped minimize the effects of climate change on Ottawa's Winterlude festival (Scott et al. 2005). The amount of adaptation required to respond to climate change will depend on the location. For example, the need to increase snowmaking in southern Ontario will be greater (e.g., 47% to 66%) than in northern Ontario (e.g., 28% to 52%) (Scott and Jones 2006a).

The price of participating in winter nature-based tourism and recreation activities can be expected to increase. Price increases may result from costs of adaptive measures, shorter seasons for recouping investment and scarcity of opportunities. For non-market recreation, participants may be subject to higher non-market costs, such as crowding, or travel costs in cases where the scarcity of sites increases. Under climate change many downhill ski areas in eastern North America could see a doubling of their snowmaking expenses by 2050 (under a high impact scenario). This increase in snowmaking costs could increase overall operating expenses by 5%, which could jeopardize the financial viability of some operations (Scott et al. 2006). For those activities where adaptation is necessary for continued supply, the costs of adaptation will increase participation costs. If the demand and willingness-to-pay are sufficient, increased costs could be passed on to consumers, but some businesses may close. Under mandatory adaptation (e.g., the need for snowmaking to offer alpine skiing opportunities), the long-term change in demand will determine whether alpine skiing opportunities continue to be offered at higher cost to consumers (either through higher admission prices or higher travel costs), or whether these opportunities simply cease to exist.

For some winter activities, adaptation within the sport may not be practical. For example, the use of snowmaking equipment on long snowmobile trail networks would be expensive and impractical (McBoyle and Scott 2006). In such cases, areas dependent on these activities may experience negative economic impacts. The economic impact of snowmobiling in Ontario could be halved, falling from C$ 932 000 in 1998 to between C$ 354 000 and C$578 000 as soon as the 2020s (McBoyle and Scott 2006). However, activity substitution may offset this loss. Current trends show that recreationists may already be switching to all terrain vehicles (ATVs). In the early 2000s ATV sales and registrations in the United States increased while snowmobile sales dropped (McBoyle and Scott 2006).

5.5.4. Hunting

Climate change is not expected to affect hunting in the short term while the long-term effects are unknown. As moose populations retreat northward in the long term, many hunters will incur increased travel costs and times, which will decrease moose hunting participation. Resource-based tourism outfitters now offering moose opportunities may lose an important product[12]. Although operators may be able to substitute moose with deer, it is questionable whether demand for deer hunting rivals that for moose hunting[13]. On the other hand, moose tourism could represent an economic development opportunity for the most northern residents of Ontario. Government regulations and mandates relating to natural resource management will also influence the supply of these tourism and recreation opportunities. Little if any information is available about potential impacts to migratory bird or small game hunting opportunities.

5.5.5. Recreational fishing

The expected net effect of climate change on recreational fishing differs between northern and southern Ontario. In northern Ontario, the net effect should be positive because increases to walleye productivity are expected as lakes warm from cold water habitat to cool water habitat (Government of Canada 2004). Effects of climate change on walleye in southern Ontario are not certain.

[12] Moose and bear are the primary species of interest to tourists who visit Ontario to hunt (Browne et al. 2003).
[13] There were nearly twice as many non-resident moose hunters (approximately 2900) as deer hunters (approximately 1500) in 1997 (OMNR 2002).

Walleye is by far the most important fish species to northern Ontarians as almost 80% of Thunder Bay and Wawa area anglers prefer this species (Hunt 2006). Walleye is also an important part of the resource-based tourism industry bringing in a premium in the year 2000 of about $40 to $84 per guest at float plane accessible lodges and outpost camps (Hunt et al. 2005). Although anglers may target other fish species when walleye catches are low (Hunt et al. 2002a), any change to the availability and abundance of walleye will significantly affect fishing participation.

Climate change will also reduce cold water (e.g., lake trout, brook trout) fishing opportunities. Unlike Walleye these cold water species are vitally important to only a small percentage of resource-based tourism operations (Hunt et al. 2002b, Browne et al. 2003). However, loss of cold water fishing opportunities may result in large changes to economic welfare of anglers (Hunt and Moore 2006). Climate change will increase warm water fishing opportunities. Currently only a small percentage of resource-based tourism operators and northern Ontario resident anglers pursue these species (Hunt et al. 2002b. Browne et al. 2003, Hunt 2006), therefore under current demand patterns there will be little change in welfare.

Other effects of climate change on fishing relate to season, precipitation and reduced water levels. Warmer temperatures should correspond to an increased season for open water fishing and reduced precipitation in northwestern and southern Ontario should increase angling participation (Hunt and Moore 2006). Fishing, however, may suffer from reduced water levels, affecting water body accessibility, navigation, and opportunities.

5.6. Overall effects on societal welfare

We expect that warm weather activities will benefit from climate change in the short term. Water-based and snow- and ice-dependent activities may be negatively affected. In the long term, winter activities and water-based warm weather activities are expected to be increasingly negatively affected. Since most tourists with an outdoors interest visit Ontario during the summer months (55%) (OMTR 2006), the positive effects on warm weather tourism and recreation should outweigh the negative effects of reduced winter opportunities. This expected outcome is consistent with past research in the United States that suggests climate change will result in a net benefit for outdoor recreation (Loomis and Crespi 1999). Researchers also agree that demand for tourism and recreation combined with the perceived positive aspects of climate change on supply (e.g., warmer temperatures for longer periods) are expected to increase participation in nature-based tourism and recreation across North America (Loomis and Crespi 1999, Mendelsohn and Markowski 1999, Richardson and Loomis 2004, Scott and Jones 2006b). With increased participation in tourism and recreation, we expect increased welfare and positive economic impacts. Adaptation may moderate the effects of climate change on recreation and tourism. Adaptation both by suppliers and individuals will determine the degree to which societal welfare changes.

Not all people will gain from climate change. Benefits to individuals may be reduced through increases in travel costs, the loss of special places, or increased crowding. Since climate change is likely irreversible there will also be a loss of ‘option values’ or the loss of settings and species available for potential future recreation development. The distribution of gains and losses among individuals may be socially unacceptable.

Changes in ecosystem types and their distribution will affect the allocation of benefits from many tourism and recreation opportunities. Jones et al. (2006) speculate that resort operators in Canada may benefit from the northward shift in species distribution as United States anglers travel north to fish the species they have always targeted. The northward movement of the peak angling and moose hunting resource in Ontario could increase travel costs for recreational anglers and hunters. Not only could travel distances increase as the distribution shifts, but the prices associated with transportation may increase. Policy efforts to mitigate climate change may result in taxation of air transport and other carbon emitting forms of transportation (Gyimothy 2006), resulting in increased access costs to tourism and recreation participants.

Value of new opportunities and preferences (i.e., demand) not yet considered will also determine the net social and economic impact of climate change. This may include the benefits accrued due to the development of tourism and recreation markets not yet conceived.

5.7. Management implications

Proactive planning by tourism industry associations and governments will help the tourism and recreation sectors adapt to climate change. Governments and industry associations should continue to research the potential impacts of climate change and communicate findings to nature-based tourism and recreation suppliers. Similarly, research into future demand trends and motivations for recreation may provide useful information to tourism operators looking to diversify opportunities that may be negatively affected by climate change. Knowing which resources and activities are substitutable (e.g., alpine skiing and downhill mountain biking) could help suppliers proactively adapt with minimal loss of revenues.

The possibility of reduced water levels will have important implications for recreation management. Tourism operators, conservation authorities, provincial parks, tourism associations, recreation associations, and others involved in the construction and maintenance of Ontario's water access points (e.g., boat launches) should plan for low water levels when sites are constructed or renovated. Such proactive strategies will ensure the continuity of water-based recreation opportunities.

Resource managers and suppliers of warm weather tourism and recreation opportunities should anticipate increased demand. For provincial parks and golf courses, where climate change has extended the warm weather

Resource Management in Ontario

Resource management plays an important role in the tourism and recreation sectors. In Ontario, much nature-based tourism and recreation occurs on Crown lands and laws and regulations related to the management of Crown resources may affect recreational uses.

Regulations that can affect components of nature-based tourism and recreation in Ontario include:

Crown Forest Sustainability Act
- Governs forestry activities
- Provisions for tourism and recreation

Endangered Species Act

Fish and Wildlife Conservation Act
- Conservation and management of wildlife and fish resources
- Licensing of hunters and anglers
- Regulations for hunting and angling

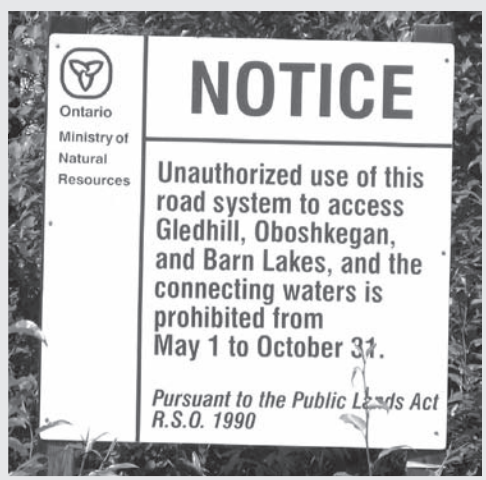
Forest Fires Prevention Act
- Restricted fire zones
- Restricted travel zones

Ontario Water Resources Act

Provincial Parks Act
- Establishment and management of provincial parks

Public Lands Act
- Land use, resident, non-resident camping
- Forest roads
- Dams

Tourism Act
- Commercial lodges and outposts



These acts, while possibly flexible in the long term are expected to remain fixed in the short term. As such, the supply and demand for tourism and outdoor recreation are heavily influenced by these different systems. In some cases, these systems may hinder ways to mitigate the effects of climate change.

season for camping and golfing respectively, operating seasons could be extended. Increased revenues may be generated by taking advantage of increased demand. Operators may also want to consider increasing infrastructure to cope with increased demand during the warm season. However, increased demand combined with longer seasons could strain resources.

Winter tourism operators in Ontario should start preparing now for the long-term potential loss of winter tourism. Diversifying to other activities is one option. Operators should also consider long-term investment carefully and with explicit consideration of climate change. In the short term, operators should consider marketing strategies that target winter sports participants in locations that are already seeing severe reductions in the season length. For example, reductions in the alpine ski season have already occurred in the northern United States. Ski areas in Michigan and Vermont may have a greater likelihood of being closed during key economic periods such as Christmas and Spring Break than areas in Ontario (Scott et al. 2006). These closures provide an opportunity to attract individuals to Ontario.

Governments could potentially aide adaptation and expansion by considering the effects of climate change on new and existing regulations. For example, fishing and hunting seasons are based on the numbers, distribution, and life cycles of the species, which may change in the future. Management agencies can also help anglers adapt to climate change by refocusing angling effort onto new species that will benefit from climate change (e.g., small mouth bass ([*Micropterus dolomieu*]). Policy changes, including changes in the fishing regulations to maximize the benefit of the increase in population and distribution of certain species, will help maximize the benefits to anglers, while ensuring that these fisheries are not over-exploited. Increased incidents of forest fires could negatively affect recreation through fire bans and travel restrictions. This may be an important consideration for businesses offering canoe trips, ecotourism opportunities, and other activities in the forest.

The demand for inbound tourism may also increase. Resource managers and tourism suppliers should consider this and plan appropriately.

6. Social and Economic Effects of Climate Change on Forestry in Ontario

Climate is of primary importance for the forest products industry in Ontario since it helps determine the type and productivity (e.g., growth rate) of forest species. Using the conceptual model presented in section 3.1, we explore the potential effects of climate change on commercial forest activities in Ontario for the short (centred on the 2020s) and long terms (2050s and beyond). Within each term, we examine the expected effect of climate change on supply of and demand for Ontario's forest products. Then we discuss the economic and social implications for the Ontario forest products industry and for the citizens of Ontario. Because of the large economic benefit derived from traditional harvesting of Ontario's forests, we focus on traditional wood products, which we term 'forest products'.

6.1. Short-term demand for Ontario forest products

The demand for forest products depends on consumer's preferences, constraints, and to a lesser extent awareness of alternatives (See Figure 5). The price of a product, the price and availability of substitute and complementary products, as well as social and governance factors also influence demand. We assume that while climate change will not affect the short-term demand for Ontario's forest products, other factors may affect demand.

Forecasts predict increased global demand for forest products in the short term due to global population and economic growth, especially in developing countries such as China. The Food and Agriculture Organization of the United Nations predicts global demand for industrial wood to increase by 1.8% per annum until the year 2010 (Lee and Lyon 2004). Worldwide demand for pulpwood is also expected to grow rapidly (Lee and Lyon

2004). Despite these macro-scale demand trends, short-term demand for Ontario's forest products will fluctuate in response to market-specific factors such as the value of the Canadian dollar, the United States economy, and trade regulations between Canada and the United States.

Traditional timber products such as lumber, pulp, and paper, which are primarily exported to the United States, are the focus of demand for Ontario's forest products. Exports of traditional forest products totaled $8.4 billion in 2005 (NRCan 2006). Non-timber forest products (NTFPs), including foods, medicines, cosmetic products, and decorative items, accounted for only a small fraction of Ontario's forest product export market (NRCan 2006, Mohammed 1999). Ontario's forests also provide tourism and recreation opportunities to thousands of visitors each year.

In recent years, the export value of Ontario's forest products has declined. In 2005, Ontario exported $8.4 billion worth of forest products representing a steady decline from $9.7 billion in 2000 (in year 2000 dollars) (NRCan 2001, 2006). This decline is attributable to reduced demand in Ontario's export markets (e.g., the United States), increased global supply, and more substitute products. For example, paper product exports from Ontario have declined over the last five years, due to the increase in electronic media in the United States (Turner et al. 2005), increased supply of recycled fibre (Irland et al. 2001), and increased virgin fibre production capacity in Russia, Asia, and South America (NRCan 2006). Demand for Ontario's softwood lumber is also declining, in part due to technological advances that allow the use of low quality fibre from other countries (NRCan 2006), and due to the use of plastics and vinyl in house siding and decking.

While the overall value of exports and the demand for some products is falling, engineered wood products such as oriented strand board (OSB) are becoming increasingly popular and represent a new manufacturing opportunity. These products use less wood fiber and can be manufactured from currently under-utilized species such as aspen (Schuler et al. 2001).

Although we expect climate change to have minimal influence on short-term demand, an increase in extreme events (e.g., fires, hurricanes) could result in a concurrent increase in demand for wood products to replace destroyed structures. For example, the predicted annual increase in demand (between 2005 and 2010) for structural panels following Hurricane Katrina in the United States is equivalent to 2.4% of North American capacity (APA the Engineered Wood Association 2005).

6.2. Short-term changes in Ontario's fibre supply

We expect climate change to start affecting the short-term supply of forest products. Since we do not expect demand to change significantly, we consider changes to the supply of traditional forest products and the ability of Ontario forests to provide these products.

Climate change may affect forest products markets in two ways. First, it will affect the primary input, wood fibre, in terms of quantity (i.e., the number of cubic metres of wood), quality (e.g., the straightness or number of knots), and type of wood fibre available for harvest. These changes will occur as trees and ecosystems respond to changes in climate. Second, climate change will affect factors of production (e.g., labour, capital, other natural resources) used to produce forest products.

The quantity of wood fibre available for harvest depends on the amount of standing stock (i.e., trees) and its productivity (i.e., the growth rate as measured by net primary productivity). Climate change may reduce the quantity of wood fibre through increased incidence of extreme weather events (ice storms, wind storms, thunder storms, fire) (Francis and Hengeveld 1998). The inability of forested ecosystems to adapt quickly to climate change may result in reduced vigour (Parker et al. 2000) and possibly premature mortality (i.e., dieback) of trees (NRCan 2004, Hengeveld et al. 2005). Even with salvage harvesting, the amount of wood obtained from a stand will be less than if the forest reached optimal rotation age.

Backgrounder: The Forest Industry in Ontario

The forest industry plays a significant role in the economy of Ontario. In 2005, there were 84 500 direct jobs in the forest industry in Ontario (NRCan 2006). Assuming a multiplier effect similar to the national average (2.54) this resulted in approximately 130 000 additional person years of indirect and induced employment (NRCan 2006).

The forest industry exported $8.4 billion worth of forest products in 2005. These exports comprised primarily paper and paperboard (21.7%), wood panels (waferboard, plywood, fibreboard, veneer and particleboard) (15.4%), newsprint (13.4%), wood pulp (10.1%), and softwood lumber at (8.7%) (NRCan 2006). Major markets for Ontario exports are the United States with 96.4% and the European Union with 1.1% of exports.

Approximately 64% of Ontario's land area is forested with 91% of this owned by the Crown. In Ontario, 31% of the Crown forest is classified as production forest and is managed for timber production along with other uses (OMNR 2003). The two main forest regions in which forest harvesting occurs are the Boreal forest, which contains 59% of Ontario's forests and the Great Lakes-St. Lawrence forest, which contains 20% of Ontario's forests (OMNR 2003). The major commercial species in Ontario are: spruce (*Picea sp.*), balsam fir (*Abies balsama*), jack pine (*Pinus banksiana*), poplar (*Populus sp.*), white birch (*Betula papyrifera*), red (*Pinus strobus*) and white pine (*Pinus strobus*), and tolerant hardwoods (maple (*Acer sp.*), yellow birch (*Betula alleghaniensis*), hemlock (*Tsuga canadensis*); OMNR 2004). Mills in Ontario consume about 20,000,000 cubic metres of Crown wood annually (OMNR 2003).

The forest products industry in Ontario has an extensive supply chain. This chain includes forest nurseries (supply seedlings for replanting), the forest owner (may be the province (Crown land), a company (patented land), or a private landowner (woodlot)), loggers, and primary and secondary processors (Gravelines 2005).

The forest sector plays a dominant role in northern Ontario's economy. In 1996, six Ontario census sub-divisions had greater than 30% employment from the forest industry. These census divisions were Dubreuilville with 63.2% forest industry employment, White River with 48.4% forest industry employment, Terrace Bay with 45.1%, Red Rock with 33.6%, Smooth Rock Falls with 32.1%, and Iroquois Falls with 31.4% (Econometric Research Ltd. 2001).

In recent years, Ontario's forest industry has faced a number of competitive challenges that have led to the closure of production facilities and the concentration of manufacturing in cost-efficient operations. Between April 2005 and March 2006, 12 mills closed with three other mills cutting capacity. At the same time, only two mills announced investments in their facilities (NRCan 2006).

From OMNR (2003)

General vegetation models (GVMs) such as BIOME3 (Haxeltine and Prentice 1996) and MAPSS (Neilson et al. 1992) predict changes in species distribution and productivity. Because of the long lifespan of most tree species in Ontario little noticeable short-term change in species composition will likely occur. However, trees may start responding to climate change through changes in productivity. Climate change may affect productivity in three main ways: through increased temperature, increased atmospheric CO_2, and increased precipitation (northeastern Ontario) or decreased precipitation (southern and northwestern Ontario) (Parker et al. 2000).

The effects of climate change on productivity are complex and vary by species and region. Colombo (In prep) discusses the effects and interactions of these changes on productivity.

Climate change may also affect wood quality; boards from trees with erratic growth rates (e.g., due to periods of drought) may warp and twist (Nyland 1996). Extreme wind events can cause sweep or crook (the bending of the tree trunk) making the tree less useful for the production of lumber. Increased incidence of insects and disease may also reduce wood quality (Parker et al. 2000). For example, timber infected with mountain pine beetle is more resinous, more permeable, more susceptible to cracks and splits, and is stained blue (NRCan 2006).

Because of the uncertainty over how climate change will impact wood fibre, researchers have developed two divergent scenarios for economic modelling; dieback and the regeneration scenarios (Sohngen et al. 2001). The forest dieback scenario assumes that existing forests subjected to unsuitable growing conditions suffer mortality (Lee and Lyon 2004). In the regeneration scenario, standing trees do not suffer early mortality, but are replaced (after some time) by better-adapted species upon their death (Sohngen et al. 2001). These two extreme scenarios bound the range of climate change effects on standing global wood fibre stocks.

6.3. Short-term effects on forest products

Changes to factors of production is a second way that climate change may affect forest products markets. Climate-induced changes to forests, resulting in changes in wood quantity and quality, will change the amount and type of processing (e.g., growing, tending, extracting, transporting, and milling) needed to produce products from wood fibre. Climate change will also affect the supply and cost of factors of production (i.e., other resources, labour, and capital) needed for processing.

We expect the short-term costs of growing and tending Ontario's forests to increase. Increased forest fire severity will likely increase the cost of fire suppression (Wotton et al. 2005) and increased incidence of disease and insect infestation may result in additional costs associated with pesticide treatments. The cost of fibre extraction may also increase due to reductions to winter harvesting seasons. This will either reduce extraction possibilities or require the construction of more costly summer roads (Colombo in prep).

Besides affecting the amount of processing required, climate change will affect the availability and cost of factors of production. For example, a hypothetical climate change mitigation program that taxes the use of non-renewable carbon-based fuels could drive energy prices higher. In such a case, we could see an increase in the costs of energy intensive extraction, transportation, and milling.

Because of the possibility of adaptation, climate change will not necessarily result in changes to the quantity or the quality of Ontario's forest products. In the production of most consumer goods, many factors of production are substitutable. Within this concept of substitutability, the possibility of short-term adaptation to climate change arises (i.e., decreases in the quantity and the quality of forest resources could be compensated by increased use of labour or capital). In the short term, significant technological advances are unlikely. Therefore, adaptation is limited to innovations involving existing technology or changes to business practices. Several past innovations have allowed the forest industry to adapt to changing conditions and to become more efficient. For example, tree planting uses labour to decrease the time needed for forest regeneration. Business agreements whereby pulp mills in northern Ontario purchase waste wood chips from lumber mills reduces dependence on raw fibre (OMNR 2004). Similar innovations and substitution of factors of production should allow the forest industry to adapt to short-term changes in supply caused by climate change. However, possibilities are not limitless and assuming suppliers are already allocating factors of production to minimize costs, substitution is likely to cause a decrease in output and/or an increase in price.

6.4. Short-term effects on global supply

Since Ontario competes in an international market, the impact of climate change on the world's forests will affect Ontario's forest economy (see Figure 6). Changes to the global supply of forest products are considered in terms of changes to the forests and in terms of changes in the ability to produce forest products.

Models show that the global supply of wood fibre will increase from climate change (Sohngen et al. 2001, Perez-Garcia et al. 2002)[14]. Global gains in wood fibre will result from an increase in net primary productivity, an increase in the amount of land area supporting forests, and an increase in land area supporting short-rotation (i.e., faster growing) species (Sohngen, et al. 2001, Lee and Lyon 2004). However, the amount of increase in wood fibre will depend on if forests adapt to climate change with or without dieback (Sohngen et al. 2001).

Most researchers agree that wood fibre production in South America and Oceania will increase in the short term. Lee and Lyon (2004) suggest that with climate change, the emerging region (South America, Oceania, India, Africa), followed by the East Siberian region, and then the southern United States will dominate timber production in the next 30 years. Sohngen et al. (2001) concur that mid to low latitude countries will see increases in wood fibre under climate change, but suggest that high latitude regions such as Siberia are not likely to see near-term increases due to dieback, and lags associated with the adaptation of long-rotation species. Areas in low to mid latitudes are expected to suffer little dieback, while fast-growing trees with short rotation periods allow forests to quickly adapt to climate change (Perez-Garcia et al. 2002, Sohngen and Sedjo 2005).

The forest products market is dynamic and global supply of forest products is constantly changing in response to the availability and prices of factors of production, governance factors, technology, and demand. Climate change is not expected to affect the latter three factors in the short term (as per our model) but will affect factors of production. Presently, regions such as Russia, Asia, and South America have cheaper labour, newer mills, and lax social and environmental standards (NRCan 2006). With climate change expected to enhance wood fibre supplies in these regions (this is debatable for Russia depending on whether dieback or regeneration occurs), they are likely to increase their supply of forest products to the global market. Under such conditions, producers in the southern hemisphere will dominate the global timber market (Perez-Garcia et al. 2002).

An important consideration is the type and quality of wood fibre supplied to the global market. Despite increases in wood fibre and low processing costs, we expect increases in production of solid wood in the emerging region to be minimal because the fast-growing trees in this region typically do not have the density and strength of slower growing trees (Lee and Lyon 2004).

6.5. Short-term effects on societal welfare

5.5.1. Exchange indicators

Globally, we expect wood fibre and forest product prices to decrease due to increases in supply. This increase may result from climate change and the entrance of emerging regions into fibre markets (Perez-Garcia et al. 2002, Sohngen et al. 2001, Lee and Lyon 2004). The change in wood fibre prices will vary by product and region. For solid wood, supply increases in the emerging region are expected to be minimal (Lee and Lyon 2004). If such predictions hold true then the price of solid wood products and the amount supplied by Ontario to the global market could hold steady. Perez-Garcia et al. (2002) predict that the prices of sawlogs in Canada will change less than one percent.

Perez-Garcia et al. (2002) predict that by 2040 Canada will have reduced its harvest of wood fibre because of negative climate effects to supply (e.g., fibre is not available for harvest), and because of lower market prices.

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[14] Some models (e.g., the LLH climate scenario used by Perez-Garcia (2002)) actually predict a decrease in available wood fibre worldwide with an increase in price.

Costs of producing forest products in Ontario may also increase due to increases in silvicultural costs, forest protection costs (e.g., from fire and insects), and transportation costs. A combination of high extraction costs and low market prices will reduce the profitability of harvesting Ontario's wood fibre.

Even in the short term, changes in the quantity and price of Ontario's forest products are uncertain. Predictions given above assume perfectly competitive economic markets. The existence of imperfect markets (e.g., oligopolies), trade regulations, and social policies will influence the amount of Ontario forest products produced and the price they command. For global models, we cannot assume that all areas will respond in an economic fashion to changes in prices (e.g., the former Soviet Union and Eastern European countries) (Perez-Garcia et al. 2002).

6.5.2.Economic welfare and impact

A global increase in wood fibre produces a net increase in economic welfare (Perez-Garcia et al. 2002). The extent of this increase will depend on how global forests adapt to climate change (i.e., with dieback effects or with no loss in standing stock).

The change in welfare resulting from climate impacts will be location specific. Globally, if the price of timber drops, consumers will benefit through increased consumers' surplus. Benefits will be concentrated in areas that are net importers of forest products while areas producing forest products will see losses from a decrease in producers' surplus. Perez-Garcia et al. (2002) predict that by 2040 the forest products industry in Canada (net exporter) could see up to a $17.4 billion loss in producer welfare with a net welfare loss (consumers' surplus minus producers' surplus) of $9.5 to $14.3 billion. This net loss of welfare also applies to Ontario since Ontario is a net exporter of wood products, and the losses of producers' surplus can be expected to exceed any gains in consumers' surplus due to lower forest product prices. Losses will have implications for governments through lost stumpage revenues (for the province) and reduced tax revenues (for municipalities) if forest products processing centres close.

Increases in catastrophic disturbances that affect supply (e.g., fire) or demand (e.g., hurricanes) will play an interesting role in market dynamics and will have differing welfare implications for different sectors of society and for different regions (see Prestemon and Holmes (2004) for an example). By examining an analogue event such as the 1998 ice storm in Eastern Ontario, we can estimate the impact of extreme events on the forest industry in Ontario. For example in 1998, damage to red pine (*Pinus resinosa*) stands, measured as a loss of net present value, was between $21.2 million to $33.1 million. The damage to eastern white cedar (*Thuja occidentalis*) stands was between $3.56 million and $39.6 million (Heigh et al. 2003). Losses in the maple syrup industry in eastern Ontario were between $6.7 million and $7.5 million (Heigh et al. 2003).

Because most forest products are produced in northern Ontario, there will be greater welfare losses in this region. However, government policies and the distribution of current investment could determine the economic impact and the change in economic welfare in Ontario. Current social mandates and government policies provide support for the forest industry and help mitigate the negative impacts of downturns in the economy (e.g., by providing tax incentives or loan guarantees). Similar support may become available to help the forest industry cope with climate change. In a declining industry, producers will likely keep newer and more cost effective mills open, resulting in no change in welfare for those areas, while areas with less cost effective mills may see closures and negative welfare effects. The effects of climate change on the forest products industry will result in changes in spending, changes in employment levels or changes to tax revenues. The cost of fire suppression across Ontario may increase by 16% by 2040 (Wotton et al. 2005). Although this increase in cost will strain government resources, it could also result in increased employment and economic activity in northern Ontario from fire fighting activities.

6.5.3. Social impacts

Climate change effects on the forest industry may decrease the viability of communities that depend on it. The proximity of these communities to forested lands increases the likelihood that community residents will experience negative effects from any physical changes to the forest (e.g., forest fires) resulting from climate change. The economies of forest-dependent communities may be negatively affected if climate change results in a decrease in forest harvesting. Quality of life, community cohesion, and the socio-economic status of residents of forest-dependent communities may also be negatively affected (Hauer et al. 2001).

An increase in forest fires could threaten lives and property if the fires are not quickly contained, and fires could disrupt lifestyles in forest-based communities (Davidson et al. 2003). Forest fires can be harmful to human health through smoke pollution and can have devastating psychological effects on residents who suffer the loss of a residence, the loss of cultural heritage, the loss of recreational areas (NRCan 2004) or even the loss of loved ones. With an increase in fire frequency, small northern communities (e.g., First Nation communities) may need to evacuate to larger centres more frequently resulting in the disruption of residents' lives. Remote communities that find themselves frequently evacuated may eventually suffer a loss of cultural integrity (NRCan 2004). Even without the actual occurrence of fire, the quality of life of community dwellers that depend on the forest for employment and recreation opportunities will be affected. Increased temperatures combined with reduced precipitation could increase the frequency of fire bans and travel restrictions in parts of Ontario. These could result in work stoppages and a disruption or loss of income for those working in the forest. Mill closures or workforce reductions are not likely to be directly attributable to climate change in the short term.

6.6. Long-term demand for Ontario's forest products

Demand for products derived from Ontario's forests has the potential to change significantly over the long term. Changes in social and governance factors will define a new set of consumer preferences, awareness, and constraints. Based on current trends, we speculate that Ontario will see future demand for three types of products: carbon capture and storage, bio-products, and traditional forest products.

Under current international atmospheric carbon reduction strategies, a country can obtain carbon credits by using forests to capture and store atmospheric carbon (Bhatti et al. 2003). This concept is based on the fact that an increase in forest biomass will create a sink for atmospheric CO_2. Carbon can be sequestered by afforestation (e.g., converting non-forested lands to forested lands) and by intensive forest management (Colombo et al. 2005). In addition, the use of forest products instead of more energy-intensive products avoids the release of greenhouse gases into the atmosphere.

Carbon markets, wherein polluters (i.e., individuals or industries) exchange money for carbon credits, may help determine demand for carbon capture and storage. Carbon markets offer a means by which individuals or industries can off set the amount of CO_2 they emit by purchasing carbon credits. Government incentives, policies, and regulations, based on society's desire for reductions in CO_2 emissions will affect demand for carbon capture and storage.

We could also see future increases in the demand for bio-products (i.e., products made from renewable, biological resources). Bio-products include fuels, adhesives, solvents, plastics, paints, fabrics, pesticides, pharmaceuticals, nutraceuticals, and NTFPs (non-timber forest products) (Duchesne and Wetzel 2003). Demand for bio-fuels could increase as reserves of fossil fuels diminish (Duchesne and Wetzel 2003). Forest bio-fuels can reduce CO_2 emissions and, combined with afforestation and recycling activities, can reduce greenhouse gas accumulation in the atmosphere.

Much uncertainty exists about the future demand for traditional forest products. Future population levels, economic status, and the availability of substitute products are likely key factors affecting demand. Demand will vary for products produced in Ontario depending on availability from other suppliers (e.g., the emerging region). One area where demand may increase in Ontario (assuming available supply) is for certified wood products (i.e., wood products grown and harvested in an environmentally and socially sustainable manner). Studies have shown that some consumers are willing to pay a premium for environmentally certified wood products (see Ozanne and Vlosky (1997) and Spinazze and Kant (1999) for examples).

6.7. Long-term effects on supply

In the long term, climate change will alter the amount, quality, and type of wood fibre available. Due to the long rotation age of Ontario's forests, the forest products industry may not experience some effects of climate change (e.g., increases or decreases in productivity or changes in forest composition) until the long term. In this section, we consider the long-term changes to wood fibre in conjunction with changes to products (e.g., carbon capture and storage, bio-products). Producing new products will require factors of production, which climate change may affect in the long term. Forest product suppliers will also be operating in a business environment governed by changed governance structures and technology.

The type (i.e., forest species composition), quantity and quality of wood fibre will likely change in the long term. The ability to use a tree for a specific product depends not only on the characteristics inherent to the species (e.g., the wood density, fibril orientation, chemical composition, grain patterns) but also on the quality of the individual tree (e.g., the size, presence of knots, sweep and crook). Growing conditions help determine the quality of the wood (e.g., slow-growing trees may have shorter branch free lengths and trees from dense forests tend to have less knots) (Nyland 1996). If we suppose that forests in Ontario will be managed primarily for lumber, we must consider the effects of climate change on quality, future forest composition, and growth rate.

We expect changes in forest composition as trees respond to climate change. Ideal climatic ranges of species now present in Ontario are predicted to move between 100 and 500 km northward; however, entire ecosystems will not simply shift northward (Parker et al. 2000). Therefore, the process of adapting to climate change is expected to be disruptive (Hengeveld et al. 2005). New species combinations will occur (i.e., new ecosystems) as species migrate based on their climate and soil preferences. Scientists expect generalist species, species adapted to disturbance, species with high migration rates, and species with early sexual maturity to dominate future forests (Parker et al. 2000, Gray 2005). One prediction for northwestern Ontario includes the conversion of the boreal forest to aspen parkland due to increased fire frequency. This forest is expected to be open and comprise trembling aspen and balsam poplar (*Populus balsamifera*) (Gray 2005). Proactive forest management, whereby regeneration efforts (e.g., after a harvest or forest fire) focus on planting more southerly forest types could significantly speed up the change in forest composition in Ontario's forests.

The expected long-term productivity of Ontario's forests varies across the province. In northeastern Ontario, productivity may increase, however, reduced levels of precipitation in the northwest and southern regions of Ontario will likely counter any increase in growth rates due to higher temperatures and increased CO_2 concentrations (Parker et al. 2000). Increases in forest fire activity (Parker et al., 2000, Wotton et al. 2005) may act to reduce the net amount of wood fibre available at any given time. While it is necessary to consider dieback and regeneration scenarios in the short term, we follow the lead of other researchers (e.g., Lee and Lyon 2004) and assume that forests will reach a new equilibrium in the long term[15].

On a provincial scale, the supply of traditional forest products is expected to decline. Only the northeastern region is expected to increase its supply of traditional forest products.

6.7.1. Carbon capture and storage and bio-products

The ability of Ontario forests to supply carbon capture and storage opportunities and bio-products are also important long-term considerations. The boreal forest (with present species composition) may only be able to supply limited carbon capture and storage opportunities (Bhatti et al. 2003). In 2000, the 100 000 most productive hectares in Canada would only provide an 8.7% return on investment if they were afforested (Boyland 2006). The future value of carbon will play an important part in determining the amount of carbon sequested in Ontario. Short-rotation hybrid poplar plantations may provide a way to remove CO_2 from the atmosphere (Bhatti et al. 2003) and be economically beneficial at $20/tonne of carbon sequestered (Van Kooten 2000).

[15] The extent to which this is true will depend on greenhouse gas mitigation actions undertaken in the short term. However, equilibrium is a useful assumption for modelling future scenarios.

Carbon captured in forests is not permanently stored. Captured carbon can be lost to the atmosphere through fire and decay (Boyland 2006). Climate change, with predicted increases in temperatures, drought, and fire severity increases the risk of loss of carbon stored in forests. However, expanding the intensive fire management zone in the boreal forest could result in the retention of an additional 4.1 million tonnes of carbon during the period 2008-2012 (Colombo et al. 2005).

6.8. Long-term effects on global supply

The long-term global yield of harvested wood fibre is expected to increase due to increases in net primary productivity and due to the northward expansion (natural and human aided) of the range of more productive species (Sohngen et al. 2001). The east Siberian region, followed by the southern United States and the emerging region (South America, Oceania, India, and Africa) are expected to dominate timber production in the next 90 years (Lee and Lyon 2004). Emerging low-cost producers in Russia, Asia, and South America not only have fast growing plantations to harvest but also newer, more efficient mills and lower labour costs (NRCan 2006).

Further complicating predictions of long-term changes in global wood fibre supplies are changes to the land area under forest cover. This will result from changes to the human footprint (e.g., areas covered by settlement and under agriculture) and climate-induced changes in biome types.

6.9. Factors affecting supply

Technology will help forest products suppliers adapt to climate change. Technological advances could enhance the supply of natural resources directly. Genetic engineering could aide tree species in adapting to climate change by making them more resistant to drought, floods, and/or insect and disease infestations (Canadian Forest Service 2005). Advancements in processing over the past 70 years have enabled the forest industry to become more competitive and more efficient. We expect forest products producers worldwide to benefit from additional technological advances over the next 70 years.

Policies on CO_2 reductions, carbon capture and storage, environmental standards, and land use may affect the global supply of wood fibre or forest products. For example, governments may set targets for amounts of carbon to be captured and stored, offer subsidies on carbon credit prices or require specific areas be set aside for ecosystem and species protection. Multilateral trade policies will determine whether multinational firms move production to areas where the supply of fibre is more abundant, labour is cheaper, or regulatory conditions are less stringent (Nelson and Vertinsky 2003).

6.10. Long-term effect on societal welfare

In the long term, Ontario's forests may provide a range of products to the global market in accordance with demand trends and the province's desire to maximize social welfare. Where multiple products are produced from Ontario's forests, the quantity and price of each product exchanged will depend on supply and demand for that particular product and the supply and demand for all other products produced from Ontario's forests. This complicates any attempt to forecast the quantity and price of each product.

For traditional forest products, Sohngen et al. (2001) predict that producers in mid to high latitude regions of the world (e.g., Ontario) will on average benefit in the long term, once the long-lived species in these areas adapt to climate change and the producers take advantage of increases in productivity. However, effects will vary by region.

In Ontario, the short-term economic effects will likely continue beyond 2050. Stand productivity is expected to increase in the northeastern region of the province with corresponding increases in the timber supply in that region. Stand productivity in northwestern Ontario will likely decrease with negative effects on the regional timber supply. For example, in the 2060s wood supplies in the Dog River-Matawin forest management unit (east of Quetico Park) may be too scattered for harvesting to be viable (Munoz-Marquez Trujillo 2005). Therefore, climate change is likely to reduce the contribution of the forest products sector to that region's economy.

A potential impact of climate change on the forest harvesting industry is the closure of mills. The potential economic impacts of the shutdown of a mill due to climate change effects are estimable from an analogue event (i.e., a recent mill shutdown). When Domtar closed a pulp mill, a paper machine, and a sheeter at its Cornwall Ontario operation in March 2005, 1384 direct, indirect and induced person years of employment were lost in MNR's Kemptville District (Gravelines 2005). The mill closure also resulted in a loss of $52 million in tax revenues across all levels of government (Gravelines 2005).

The economic impacts of carbon capture and storage projects and the production of bio-fuels are difficult to predict. The production of bio-products could increase welfare in northern regions of Ontario and provide new opportunities for forest-dependent communities (Duchesne and Wetzel 2003). For example, Northern Biodiesel, a company selling bio-diesel in the Thunder Bay market, has a long-term goal of opening a bio-diesel manufacturing plant in northwestern Ontario (Northland Bio-Diesel 2006).

If proactive adaptation strategies are taken in the short term, long-term economic impacts to forest-dependent regions may be less severe. Additionally, as climate stabilizes at a new equilibrium, the economic system should follow.

6.10.1. Long-term social implications for Ontario

Residents of forest-based communities will feel the long-term impact of climate change in two ways: (i) through physical losses (e.g., property) and (ii) through socio-economic impacts. However, unlike in short term, in the long term individuals and groups will have the opportunity to adapt.

The composition of the landscape will change in the long term. Many people in forest-based communities, as well as in Aboriginal communities have a strong connection to the land. This attachment-to-place is an emotional sentiment that goes beyond the objective value of the land (Eisenhauer et al. 2000). Climate, scenery, pristine state, and the presence of wildlife are major factors contributing to attachment to special places. If these special places are negatively affected by climate change, local people may experience stress and discomfort at the loss (Eisenhauer et al. 2000). As climate deviates from traditional patterns, people may lose their sense of the continuity and meaning of life (Norgaard 2006). First Nations communities have cultural ties to the land that climate change could negatively affect. Cultural integrity, social cohesion, and community stability may be affected as culturally important traditions and activities are lost (Hauer et al. 2001, Davidson et al. 2003).

In northwestern Ontario where wood fibre is expect to decrease, climate change may indirectly cause mill closures in forest-dependent communities[16]. As mills reduce their workforce or close, populations may decline as people leave to find employment. Because of out-migration, community cohesion may be lost and a decline in community services (e.g., schools may close) will result (CBC 2002). A reduced timber supply could generate conflict among stakeholders and community members over the use of this scare resource (Ahmad and Ahmed 2000, Munoz-Marquez Trujillo 2005). Increased competition for employment in communities may result in lower wages and resentment towards individuals who receive employment. Housing prices will likely fall with a reduced population and lower demand. Disaffected and disillusioned residents may take recourse in crimes or other anti-social behaviour (Ahmad and Ahmed 2000). Residents of forest-dependent communities may also find themselves the target of or in conflict with environmental organizations who may perceive their livelihoods as contributing to deforestation and hence climate change (Davidson et al. 2003).

[16] Decreases in forest harvesting are likely to be only partially attributable to climate change. Global demand (non-climate change-related) and changes in technology will also be major determinants of the amount of harvesting that is conducted in Ontario forests.

The development and production of new forest products such as bio-fuels and carbon capture and storage have the potential to create jobs in forest-dependent regions. This could be important in those areas negatively affected by climate change effects on the traditional forest products industry.

6.10.2. Distribution of economic and social effects

In 50 to 100 years, the supply of wood fibre in northwestern Ontario is predicted to decrease while the supply in northeastern Ontario will increase (Parker et al. 2000). As supplies of wood fibre start to decline in the northwest region, milling operations will be scaled back, resulting in negative economic impacts. Stand productivity in the northeastern region of the province is expected to increase with corresponding positive increases in the forest product supply. However, this increase in supply does not suggest that the region will experience a net economic benefit from climate change since forest product prices are expected to decline as global supply increases.

Warming climates in the boreal region could have positive economic implications for northern communities (e.g., communities north of the current limit of forest harvesting) aspiring to use industrial forestry to create economic welfare. A warmer climate could mean a faster tree growth rate and hence a shorter rotation in the northern part of the province. However, reduced summer and winter precipitation in some areas of the region may offset any gains in forest growth from a warming climate.

6.11. Management implications

Because of the potential effects of climate change on the forestry sector, proactive planning by forest managers, industry, and community leaders will be essential for helping to minimize the negative effects of climate change and maximizing any positive effects. This report is part of the first step of preparing for climate change: describing research and gathering information. Although the exact effects of climate change on Ontario's forest products sector remain uncertain, we know that the future will be different and that planning is required.

In-depth research on localized climate change and potential impacts on Ontario's forests is a key building block in helping the forest industry adapt to climate change. Communicating risks and opportunities to forest industry leaders will help to motivate autonomous adaptation. Due to expected increases in global fibre supplies, combined with lower production costs in the emerging region, Ontario producers may find opportunities for forest exports in niche markets.

Management agencies could also invest in research and management strategies to help Ontario's forest industry adapt to climate change. For example, considering the long rotation age of Ontario's commercially harvested tree species, forest managers may consider planting tree species better adapted to future climate. Experiments should be undertaken to assess the potential risk and benefits of such a strategy.

Fire management planning will require careful consideration of changing fire regimes. Expected future lengthening of the fire season will require advanced preparedness and training. Fires may also be more severe requiring a greater number of resources (Wotton et al. 2005). If reductions in stumpage revenues occur, funding for fire suppression and forest management activities may have to be supplied from elsewhere.

The types of products demanded from Ontario's forests will likely change, and forest management planning strategies and land use planning strategies may need to be flexible. Land-use and forest management planners should anticipate the potential demand for products such as bio-fuels and carbon capture and storage, and prepare a regulatory framework in advance.

Communities dependent on the forest industry should start planning now for climate change effects. Communities should educate themselves on the potential effects of climate change and respond appropriately. Economic diversification, development of human capital, and development of infrastructure will all help to improve community resiliency.

7. Discussion and Conclusions

We developed and applied a conceptual model to illustrate the social and economic effects of climate change on three natural resource-based product sectors. Climate change will affect the type and availability of Ontario's natural resources, which in turn will affect tourism, recreation, and forestry activities. We expect supplies of natural resources to change in both the short and long term. In the long term, we also expect variations in the goods demanded from Ontario's natural resources. Potential new products include bio-products, carbon capture and storage opportunities, and sunbird tourism.

Climate change will affect tourism and recreation in Ontario. Generally, warm weather tourism and recreation activities will benefit from climate change while winter-based activities will suffer. Since most tourism and recreation participation in Ontario occurs in the summer months, we expect a net benefit due to climate change.

Participants of warm weather tourism and recreation will be able to take advantage of increased opportunities due to longer seasons. For water-based warm weather tourism, impacts to hydrological systems may diminish gains associated with warmer temperatures. Participants of winter-based activities are expected to either see a reduction in their opportunities due to shortened seasons, or see increased costs associated with necessary adaptation. The magnitude of effects on supply can be expected to be greater in the long term, but will potentially be moderated by adaptation strategies.

The indirect effects of climate change on Ontario's ecosystems including changes to recreationally valuable flora and fauna will have a considerable affect on Ontario's nature-based tourism industry in the long term. Increases in walleye productivity may benefit recreation and tourism centred on fishing while any decline to moose populations may result in losses to recreation and tourism centred on moose hunting. The MNR may need to carefully consider potential effects of climate change on fish and wildlife populations and modify management strategies and regulations accordingly.

Ontario forest product producers are expected to lose more than gain from climate change and its ensuing effects. Supplies of wood fibre in Ontario are expected to decline while the costs of tending, extracting, and milling are expected to increase. These effects will be combined with an expected decrease in global prices for forest products.

Climate change will affect the supply of Ontario's forest products in two ways: i) through changes to the quantity, quality, and type of available wood fibre and ii) through changes to factors of production. In the short term, an increase in extreme events such as fire, windstorms, insect infestations, and ice storms could negatively affect the quantity and quality of wood fibre. Because of changes to Ontario's wood fibre supply, changes in the amount and type of processing needed to produce consumer goods will ensue.

Species type, quantity, and quality of wood fibre in Ontario's forests will change in the long term. New ecosystem types will appear. The quantity of wood fibre is expected to be reduced across the province although there will be regional variations. In the northwest, drought may decrease productivity, result in more open forest types (e.g., aspen parklands), and reduce the volume of wood fibre. Forest productivity may increase in northeastern Ontario, but the increased costs of production and decreased product prices may offset any benefit of increased productivity.

In the long-term, we expect consumers to demand products such as bio-products and carbon capture and storage opportunities from Ontario's forests. The long-term changes in technology and changes in governance structures and policies will determine whether Ontario can offer such forest products to international markets.

Adaptation to the effects of climate change on the tourism, recreation, and forest industries is possible. Adaptation strategies should maximize the potential benefits to individuals or groups while minimizing the negative effects. Individual consumers likely have the most flexibility for adapting to climate change through behavioural changes. Producers are less able to adapt to climate change than consumers, due to fixed investments. However, producers that embrace and adapt to climate change may profit.

Some types of adaptation are best implemented at the institutional level. Forms of adaptation that are considered public goods or common pool resources are two types of adaptation that may not occur in optimal quantities without government intervention.

For resource managers, the challenge of climate change is to manage resources in an ever-changing world. Managers should take care to understand the potential impacts of climate change on different services and products provided by or from natural systems. Research can help to forecast these effects of climate change. With these forecasts, managers could encourage development of resources that will benefit from a changing climate. For resources that are likely to decline, managers should develop approaches that make full benefit of any adaptation measure. Proactive and flexible management may be key to helping Ontario maximize the benefits of climate change while minimizing negative effects. Flexibility should be incorporated into resource management regulations, to allow autonomous adaptation by tourism and forestry suppliers to occur unimpeded. In some cases, governments may wish to directly implement or supply adaptations.

The potential social and economic effects of climate change on natural resources are under-researched. As more detailed climate change information becomes available, more in-depth and quantitative analysis should be undertaken. Analysis of the potential impacts to the forest and tourism industries could be especially useful for northern Ontario where these industries are main economic drivers. A social and economic analysis of new opportunities such as carbon capture and storage opportunities would be useful to determine the benefits to local communities from these programs.

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