CLIMATE CHANGE: IMPLICATIONS FOR FOREST ECOSYSTEMS AND FOREST MANAGEMENT IN EASTERN ONTARIO

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Introduction

There exists strong scientific consensus that the global climate will warm significantly within the next century, primarily in response to increased concentrations of greenhouse gases in the atmosphere (Houghton et. al., 2001). The projected warming will be accompanied by changes in precipitation as well as greater variability in global weather patterns. Forests and woodland, which cover approximately 4,000 million ha globally will certainly be affected (Gitay et al., 2001). The manner in which we manage our forests will play a critical role in reducing impacts of climate change on forests, and adapting and responding to ongoing changes.

Extensive reviews of the implications of climate change for global forests have been undertaken as part of the Intergovernmental Panel on Climate Change (IPCC) third assessment report on the state of climate change knowledge [Gitay et al., 2001]. In Canada the implications of climate change for Ontario's forests and forest management was a significant component of the Canada Country Study (Saporta et al., 1997) and have been described and reviewed more recently by Colombo et al (1998), Parker et al (2000) and Papadopol (2000). Related reviews for Eastern Canada and the US northeast have been undertaken by Stewart (1993) and Davis and Mauri (1998), respectively. This paper summarizes the implications of climate change for eastern Ontario's forests and forest management outlining why forest managers and woodlot owners should be concerned about climate change, what climate change means for forest ecosystems, and what it means for forest management.

So why should we be concerned about climate change? The answer to this is quite simple: the climate projections are not trivial, the impact on forest ecosystems could be severe, and the potential implications for the economy of Ontario are significant.

How Important Are Forests To Ontario's Economy?

In Ontario forests occupy an estimated 58 million hectares, or roughly 65% of the provinces land area (CCFM, 2002). In 2001, 400,000 ha of forest were harvested representing a wood volume of 28.1 million

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cubic metres. Economically the value to the economy was approximately $15.8 billion accounting for about $3.7 billion of Canada's net balance of trade. Agro-forest products such as maple syrup and Christmas trees are also major industries contributing $10.8 million and $50.6 million annually to Ontario's economy (AAFC, 2003). At the same time approximately 83,500 people (1 in 16 jobs) are employed directly or indirectly in forest related industries. Many northern communities are economically dependent on forest industries for their existence. In addition, to direct forest benefits Ontario's forests also provide important recreational opportunities and a source of resources for indigenous groups. It is evident from these figures that changes in the growth and productivity of the forest as a consequence of climate change could have significant socio-economic impacts in terms of peoples livelihood and the economy in general.

Why Should We Be Concerned About Future Climate Projections?

Simply put - the changes being projected for Canada are not trivial by any sense of the imagination. Significant global warming and other climatic changes are forecast to occur by the middle of this century. The Canadian global climate model for example projects the following for the period 20040-2069 (CICS, 2003; National Atlas of Canada, 2003):

<u>Temperature:</u>

- annual temperature will to increase by 2 to 3C with winters warming more than summer

What does this increased temperature mean in biological terms?

- in response to the increased temperature the frost free season is expected to increase by 15 to 20 days; the growing season start will occur 7 to 10 days earlier and the growing season will end 7 to 10 days later than at present;
- heat accumulation during the growing season will increase 15 to 20% (i.e. growing degree days $>$ 5C (dd) will increase 350 to 450 dds, or Corn Heat Units will increase 500 to 700 units above present values.

<u>Moisture:</u>

- annual precipitation is projected to increase by 3 to 5% with growing season moisture staying about the same as today

What does a slight increase in moisture mean in biological terms?

- eastern Ontario will be drier as the slight increase in precipitation will not offset the moisture demands of increasing temperature; as well,
- more of the precipitation received in winter will occur as rain, freezing rain or sleet in conjunction with warmer, near freezing temperature;
- more precipitation may be received in fewer, but, more intense events both in winter and summer; leading to

- more runoff during winter and an advance in spring peak flow dates coincident with earlier spring thaws; and
- later fall freeze up.

Climate projections for the period 2040-69 imply longer, warmer and somewhat drier growing seasons with greater temperature extremes; milder winters with potentially fewer extremes in minimum temperatures; and somewhat drier conditions. However, the timing, magnitude, spatial distribution and variability of the changes are very uncertain. Overall, the climate for eastern Ontario will be similar to the current climate of Windsor in south western Ontario the warmest area of Canada, or equivalent to the climate some 200 to 400 km south and west. This is an enormous change in environment that will put major stress on our forest ecosystems to change and adapt.

Has the Climate Changed Over the Last 50 Years?

The above illustrates what the climate modelers are suggesting the average climate may look like in 50 years. The big question is – has the climate shown signs of change and if so how has it been changing? Tables 1 and 2 outline the observed changes for Ottawa over the last 50 years in the context of 30 year normal periods for temperature and moisture in relation to what the climate modelers are projecting for the period 2040-69. A number of things are quite apparent. First, both the annual and growing season temperatures have been increasing over the last 50 years. Second, in response to the warming the length of the growing season has been getting longer – it is about 15 days longer today than 50 years ago. The surprise here is that the change in growing season length has largely changed by an increase in the growing start date. The end date

Table 1: Changes in Growing Season Temperature Characteristics In Eastern Ontario Over the Last 60 Years in Relation to Projections for 2040 to 2069.

30 Year Normal Period	Growing Season Length (days)	Growing Season Start Date	Growing Season End Date	Growing Degree Days >5C°	Corn Heat Units	Growing Season Tmean (C°)	Annual Tmean (C°)
1941-70	145	May 13	Oct 5	1822	3012	16.99	5.79
1951-80	155	May 7	Oct 8	1949	3218	16.97	5.87
1961-90	159	May 4	Oct 9	1955	3243	16.95	5.96
1971-20	160	May 2	Oct 8	1989	3298	17.16	6.25
2040-60	175	April 24	Oct 16	2387	3874	18.63	8.73

Table 2: Changes in Growing Season Moisture Characteristics In E. Ontario Over the Last 50 Years in Relation to Projections for 2040 to 2069.

30 Year Period	Variable	Annual Total (mm)	Winter (Oct. to Mar.)	Summer (April to Sept.)	Summer GSMI 1-(PE-P)/PE
1951-80	Precipitation PE	846 579	448 71	398 508	0.78
1961-90	Precipitation PE	870 580	451 71	419 511	0.82
1971-20	Precipitation PE	916 586	481 70	436 517	0.84
2040-60	Precipitation PE	892 641	471 88	376 562	0.75

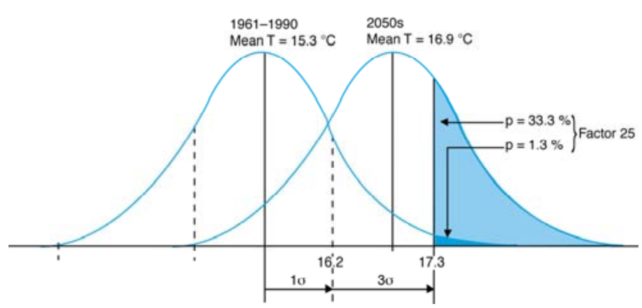
GSMI – Growing Season Moisture Index and PE – Potential Evapotranspiration has increased only slightly. In response to the increase in growing season length the growing season mean temperature and heat accumulation has increased as well. Overall, the observed changes over the last 50 years are consistent with what the climate modelers are projecting for temperatures in the future.

What about moisture? Table 2 shows the changes over the last 40 years in annual winter and summer precipitation totals, and a simple growing season moisture index. The later represents the ratio of precipitation to potential evapotranspiration. Observations suggest annual and growing season precipitation over the last 40 years has been increasing. Combining the increased precipitation with increased temperature in the context of potential evaporation eastern Ontario appears to be getting wetter as opposed to drier as suggested by the climate modelers. This discrepancy is a bit of a surprise and a positive one if the trend continues to hold (where the increased heat is being more than offset by the increase in precipitation). However, if the modelers are correct and the trend does not hold, it could indicate forest ecosystems could be vulnerable to some severe drying in the future. At the present time modelers' confidence in the precipitation projections are considerable less than that for temperature, so considerable uncertainty exists in terms of which way precipitation trends are likely to go. As it stands now increased dryness does not appear to be an increasing problem.

Extremes – Have They Changed Over The Last 50 Years?

Tables 1 and 2 show changes in average conditions and provide no indication of what changes might be in store in terms of extremes of temperature and precipitation. Using averages can be very deceptive and misleading in the context of extremes as relatively minor shifts can have significant effects. Figure 1 (Francis and Hengeveld, 1998) illustrates this point nicely using the mean summer temperature as an example. In this example they use 15.3C as the current mean temperature and then compare it to a climate that has been increased by 1.6C to an average of 16.9C. The key thing to note is that an event that under the current climate has a 3 standard deviation from the mean, under the new climate norm lies within 1 standard deviation. What this means is an extreme event with a risk factor of 1 in a 100 under the current climate has increased to 1 in 30 under the new climate. This implies – todays extremes may be tomorrows norm. The implications of this are enormous for our forest ecosystems and forest management.

Figure 1: Effect of Change in Mean Temperatures on Extremes



(From Franics and Hengeveld, 1998)

So Have temperature Extremes Changed Over The Last 50 Years?

Table 3 illustrates the changes in winter, spring, summer and fall maximum and minimum temperature extremes over the last 50 years in relation to what the climate modelers are projecting for the year 2040-

2069. Observations suggest that extreme minimums are declining and extreme maximums are increasing slightly. Again the observations are consistent with what the modelers are projecting. Reductions in extreme minimums bode well for increased winter survival in the context of extreme killing temperatures. However, increased maximums don't bode well in the context of increased heat stress.

Table 3: Changes in Temperature Extremes (C°) In Eastern Ontario Over the Last 50 Years in Relation to Projections for 2040 to 2069.

30 Year Period	Variable	Jan	April	July	Oct
1951-80	Tmax Tmin	10.0 -37.2	30.0 -16.1	36.7 5.6	26.7 -7.2
1961-90	Tmax Tmin	10.0 -35.0	31.2 -15.0	35.6 5.0	26.7 -7.2
1971-20	Tmax Tmin	11.4 -35.0	31.2 -15.0	35.0 5.0	27.0 -7.2
2040-69	Tmax Tmin	12.5 -28.0	33.7 -14.0	37.4 7.4	29.0 -4.8

Overall the modelers are projecting warmer and drier conditions and an increase in both temperature and moisture extremes. What this translates into is long warmer growing seasons with increased periods of drought and dryness. At the same time we are going to see warmer winters with reduced extreme minimums, with not appreciably greater moisture overall than today. The warmer winter temperatures suggest a shift in precipitation from snow to more rain, sleet and freezing rain. The modelers also suggest we will see more of our precipitation being received both in winter and summer in the form of more intense storms.

Implications for Forest Ecosystems in Eastern Ontario

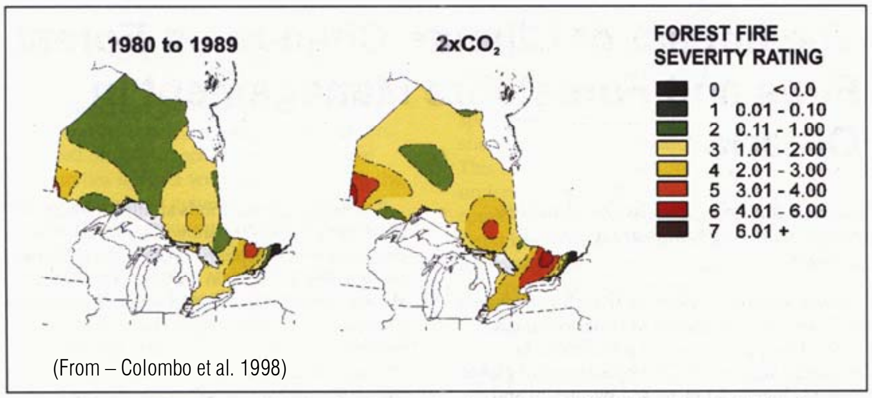
Over the next 50 to 100 years, if the above climate projections occur what does it mean for forest ecosystems? Globally, the IPCC suggests:

- the greatest impacts on global forests will occur in high latitudes – Canada is a high latitude country so the impacts are expected to be significant;
- mortality rates will increase 30 to 40% above current rates;
- the preferred geographic range of species may shift approximately 300 to 500 km north;
- the rate of climate change is expected to occur faster than forest species can migrate (i.e. grow, reproduce or re-establish themselves);
- implications of extreme weather are largely unknown;
- synergistic effects of atmospheric pollution and deposition are unknown although it is known that increased exposure to atmospheric pollutants increases the susceptibility to stresses related to freeze-thaw, drought, biotic agents and extreme weather; and
- productivity in some areas and for some species will increase while in other areas and for many existing species it will decrease.

The results of the IPCC assessment suggest the effects of climate change on forest ecosystems in eastern Ontario over the next 50 to 100 years could be quite severe with significant changes in

- growth rates – temperate and deciduous species will increase while boreal species will decline;
- increased and changed competition between existing and new species (vegetation, insects, diseases) – many existing species will likely be out competed;
- regeneration – rates for boreal species will see increasing problems while temperate and deciduous problems will be less;
- fire disturbances - increased area burned, shorter return periods, and increased intensity – in eastern Ontario work by Columbo et al (1998) suggest a significant increase in fire severity rating (Figure 2);
- insect and disease disturbances – increases in frequency and intensity of outbreaks;
- extreme weather problems – increased damage associated with windthrow, ice storms, drought, and heavy rainfall.

Figure 2: Change in Fire Disturbance Severity Rating for Ontario for a Doubled CO_2 Climate

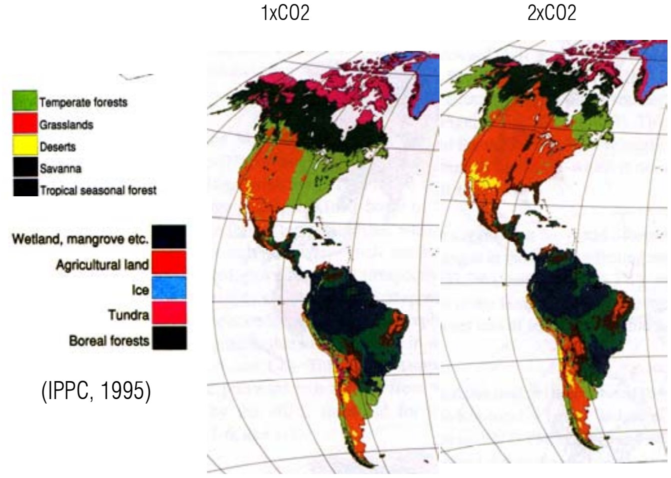


(From – Colombo et al. 1998)

A combination of climate, soil and disturbance conditions control forest growth and distribution. As these change so will the range and zonation of forest species and ecosystems in eastern Ontario. Present research suggest that climatic conditions suitable for much of the existing boreal mixed-wood forest ecosystem in eastern Canada will be replaced by conditions more suitable for temperate deciduous forests located to the south (Rizzo and Wicken, 1992). Results from the IPCC second assessment report suggest the changes could be even more severe with much of forest in the Great Lakes area being replaced by grasslands (Figure 3). Figure 4 illustrates the effect of climate change on the climate suitability range for eastern hemlock (Davis, 1992) a major species in eastern Canada. If climate changes occur as projected the optimum climatic conditions for hemlock will shift considerably north of its present boundary. Similar shifts in climatic suitability can be expected for all existing vegetation and insect species and diseases. This means the future climate for eastern Ontario is going to be much more conducive to temperate and deciduous species and much less

Figure 3: Implications of Doubled CO2 Climate Change for Global Forest Ecosystems (IPPC, 1995).

There will be large shifts in the eventual distribution of global ecozones.

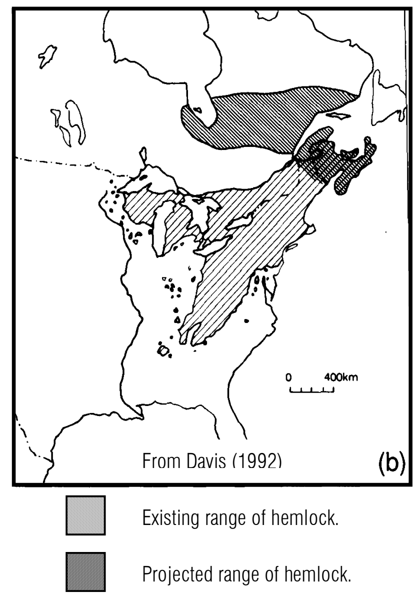


(IPPC, 1995)

suitable for existing coniferous species. A major concern is whether the soils will accommodate or hinder the change in species and ecosystems?

Implication for Forest Management

Figure 4: Impact of Climate Change on the Range of Eastern Hemlock (Davis, 1992)



Assuming the range of current climate change projections is correct, there are likely to be significant changes to forest ecosystems in Ontario. This has major implications in the management and use of our forests. What can forest management do to mitigate potential unwanted effects of climate change and take advantage of those that may be desirable?

First and foremost, forest management is all about adaptation. Literally everything forest managers do in managing their lands is aimed at maximizing fibre production, biodiversity, or agroforestry products (maple syrup) of some sort. Managers have been developing and adapting their management practices since forestry began to take maximum advantage of the local climatic and environment conditions. Protection systems have been developed and mitigation options and strategies devised and implemented to overcome climatic and other environmental problems.

Second, in the context of tools needed to adapt and respond to climate change forest managers are not starting from scratch. Most of the problems that climate change will pose related to silviculture, regeneration, fire, disease and insects disturbances are ongoing problems in forest management and are presently being addressed in one form or another by industry, university and government research programs. Subsequently, many of the research and management activities required to adapt and respond to climate change are already part of current actions.

What Can Forest Managers Do About Climate Change?

Forest managers have many tools at their disposal to assist forest ecosystems in mitigating and adapting to climate change including:

- species/provenence control in both natural and artificial regeneration;
- density and thinning controls and programs;
- harvesting and planting strategies;
- breeding and genetic programs;
- protection systems for fire, insects and diseases;
- forest inventory and monitoring programs; and
- forecasting tools for planning and scheduling interventions.

All are in place and being used in varying degrees today and are being worked on to improve forest management in the future. Most are being worked on in the context of sustainable forest development. However, few are being looked at in the context of adapting or responding to climate change.

Given this vast array of tools it has led many to wonder what the problem is with climate change in the context of forest management? So what is the problem for forest management?

Simply, it comes down to:

1. the rate, magnitude or intensity of future climate change – these are not known precisely;

2. uncertainty about current projections – these are very uncertain because the modelers don't have a very good understanding of many of the processes involved;

3. separating climate change from natural variability – this is a very difficult problem because climate varies naturally from day-to-day, year-to-year, to decades to centuries. Because of the uncertainties in the current state of science and our short observational record there is considerable debate as to whether the observed changes over the last century are anything more than natural variability. Evidence over the last 5 years, however, is just now enabling scientists to separate natural from human induced change at the global level. At the regional and local levels, however, we have a long way to go in separating these; and

4. extreme weather – because of the scale that existing global models function at, we have very imprecise understanding of how extremes in temperature, precipitation, drought or severe storms will be affected by future climate change. Many of the processes related to these climatic features are just now being built into the next generation models. Computer power and resolution have been and will likely continue to be a constraint in resolving the problems of extremes for some time to come.

Climate modelers' confidence in terms of current projections is highest at the global level and falls off considerably as you move to the regional and local scales. For eastern Ontario just exactly what the future climate will be is known only vaguely in terms of broad climate features. It is not known well in terms of the details forest managers require to make decisions in the context of major changes. The risks are simply too high at the moment and surprises can not be ruled out.

For forest managers the inability of climate modelers to project the rate, magnitude or intensity of climate change with a high degree of certainty poses a significant dilemma. The forest life cycle ranges from decades to centuries. Hence, decisions being made today are being made on the assumption the climate and environment will remain suitable throughout the trees' lifecycle. This assumption has worked pretty well over the last two hundred years. Climate change, however, poses a very serious threat and challenge to this assumption because of the time frame involved and the changes being projected. It is no longer a safe bet for forest managers to assume the environment they plant their trees in today will be the same 50 to 100 years from now. At the same time it is too risky to begin making wholesale changes because the uncertainties are large and the climate has not changed enough to put the forests beyond todays climate limiting factors.

At the same time the broad suite of tools available has led some forest managers to believe that the degree to which forest managers will be able to cope with adverse impacts of climate change on the forests will be directly related to the current and future intensities of management. This may be true, however, these same tools if used unwisely or without a good knowledge of the biophysical implications could exacerbate rather than mitigate the potential implications of climate change (Stewart, 1993; Davis and Mauri (1998), Stewart et. al, 1998; Papadopol (2000), Parker et al (2000).

Given the uncertainties associated with climate change, forest managers are largely planning for the unknown - they have an idea of what to expect but don't know precisely what changes are going to take place, where they will take place, or the rate at which the changes will occur. Given these circumstances what can or should forest managers be doing now to prepare for climate change?

What Should Forest Managers Being Doing?

As a means of planning for climate change forest managers need to accept that change is probable and that responses need to considered now. Factoring climate change into their ongoing short, medium and long term management planning is an essential aspect. To begin the process forest managers need to:

- identify the issue of concern and the degree of change in forests that would constitute a serious problem;
- determine the sensitivity of their forests to changes in climate, and weather extremes;
- identify degrees of change that would pose a serious problem;
- update their short, medium and long terms plans with responses and actions to address these changes;
- monitor the health of the forest – determine if changes are taking place and identify thresholds for intervention;
- upgrade their inventory – know what is on the ground; and
- find out about climate change and what it means for them – the best defense is knowing and understanding the enemy. If understood and anticipated climate change could be a major opportunity; whereas if misunderstood and not anticipated – it could be a major disaster.

In planning, developing and implementing adaptive actions and responses toward climate change forest managers should not be planning or proceeding to make wholesales changes at the moment. The uncertainties are simply too great for drastic measures at the moment. Instead forest managers should use and apply "the precautionary principle" in the planning and implementing of all potential actions. This principle suggests taking steps to adapt and mitigate aspects of climate change now in order to avoid future losses even though the exact probability of the loss is uncertain. Because climate change projections are so uncertain at the present time only actions that reduce future risk and make sense in terms of today's economics should be implemented now.

What Actions Can Forest Managers Take?

Some examples of actions that could be taken by forest managers include:

<u>Extreme Actions:</u>

- pre-emptive salvage cuts – that is a “use it” or “lose it” approach, and
- replace existing species with new species – anticipatory approach.

Both represent an all or nothing strategy in terms of dealing with climate change. Both are very risky and premature on the basis of current information and few if any foresters or forest organizations would recommend these approaches at present in terms of adapting or responding to climate change.

Less Extreme Actions:

Applying the “precautionary principle” is more appropriate in terms of determining what actions should be implemented now. Examples, of appropriate actions that could be taken now include:

- thinning and partial harvest (i.e. take out older, weaker or more susceptible trees/stands);
- shorten the rotation length (reduces the exposure time);
- identify and test more appropriate and adapted species/clones/provenances;
- improve access to the forest to facilitate salvage, protection, monitoring and inventorying operations;
- improve, test and adapt various protection systems (i.e. - fire, insect and disease);
- improve monitoring of the condition and state of health of your forest to detect problems early;
- upgrade and improve your inventory –it is difficult to know what to do if you don’t know what is in your forest or what is happening in it.

Actions of these sorts are cost effective in terms of todays economic realities but would go a long way toward reducing the risk of undesirable climate change and providing the means of taking advantage of potential opportunities.

Conclusions

The IPPC Third Assessment Report [Gitay et al, 2001] indicates that forest ecosystems in high latitude countries such as Canada will be severely affected by climate change. Over the next century, conditions suitable for boreal, temperate and deciduous ecosystems will migrate northward. In responding to current climate projections, forest ecosystems in eastern Ontario are likely to shift from the current mixed boreal-temperature deciduous mixture, to more temperate deciduous. Climate change is also expected to affect many of the features contributing to the functioning of existing ecosystems. Growth and regeneration will be affected – for temperate and deciduous species it will increase while for boreal species it will decrease. As well, natural disturbances related to fire and insects are expected to increase significantly and play a considerable role in contributing to ecosystem changes. However, the timing, location, and rate of projected changes remain very uncertain. As well, the potential benefits of elevated CO_2 and atmospheric pollution in terms of increasing growth and productivity and mitigating potential undesirable effects remains inconclusive.

In determining and evaluating the implications of climate change on forests and the forest sector, forest managers have many tools at their disposal that will enable them to adapt to and mitigate most of the unwanted impacts of climate. Many of the necessary actions to be taken to respond to climate change are already part of ongoing forest management. The action required now in preparing for pending climate change is deciding the degree of change in the forest that constitutes a problem, determining and testing possible solutions, and initiating monitoring programs to determine when intervention is required. The key is accepting that climate change is real, improving their tools, recognizing the problem, having a plan, and taking timely action. These will all contribute to reducing the risk and vulnerability to surprises or unforeseen climate changes and take advantage of potential opportunities.

Additional Sources of Information

Additional information on climate change projections for Canada can be obtained from the following Web sites:

- Canadian Institute For Climate Studies
  http://www.cics.uvic.ca
- Environment Canada – Climate Change site
  http://www.msc.ec.ca/saib/climate/FAQ_2002/index_e.html
- National Atlas of Canada
  http://atlas.gc.ca

For additional information on the implications of climate change for forest ecosystems and management can be obtained from the following Internet Web sites:

- Government of Canada – Climate Change site
  http://www.environmentandresources.ca
- Ontario Ministry of Natural Resources
  http://www.mnr.gov.on.ca/MNR/
- Canadian Forest Service – Climate Change site:
  http://www.nrcan-rncan.gc.ca/cfs-scf/science/resrch/climatechange_e.html
- Canada Country Study – Environment Canada site
  http://www.ec.gc.ca/climate/ccs/ccs_e.htm
- Intergovernmental Panel on Climate Change site
  http://www.ipcc.ch
- Climate Change Impacts and Adaptation Research Network (CCIARN) – Forest Sector site
  http://www.forest.c-ciarn.ca/index_e.php

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