Climate Change: Impacts and Adaptation in Forestry

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Abstract

Current changes in climate are already affecting forest species. Future climate change will bring greater changes in range of occurrence, forest disturbance and growth rates. These changes in turn will affect society's ability to use forest resources. We already take account of climate in forest management; in the future we will have to apply these techniques with a greater intensity and in different areas. Climate change adaptation strategies for the forest management sector should be based on the application of vulnerability assessment or risk management concepts. An adaptation plan must address biophysical and socio-economic impacts and include policy and institutional considerations. We will need to evaluate current vulnerability, speed recovery after disturbance, and reduce vulnerability to further climate change. The adaptation plan should include monitoring the state of the forest to detect change to aid determining when to intervent. An example of using this framework to adapt to changing forest productivity is presented. Many forest ecosystems and species will have to adapt autonomously because management can only influence the timing and direction of forest adaptation at selected locations. In general, society will have to adjust to however forests adapt. Sustainable forest management already embodies many of the activities that will be required to respond to the effects of climate change on forests. Including adaptation to climate change as part of forest planning does not necessarily require a large financial investment now with an unknown future payback time.

Introduction

By the end of the 21st century, the mean annual temperature for western North America could be 2–5°C above the range of temperatures that have occurred over the last 1000 years (Houghton *et al.* 2001). An increase in winter precipitation and a decrease in summer precipitation may also occur. These changes would significantly affect forest ecosystems and their utilization by society (McCarthy *et al.* 2001; Spittlehouse and Stewart 2003). Predicted changes include the movement of species ranges northward and up in elevation with new assemblages of species occurring in space and time (Hebda 1997; Kirschbaum 2000; Hansen *et al.* 2001). Forest management decisions are usually based on the assumption that the climate will remain relatively stable throughout a forest's life. This may have worked well in the past, but future climate change challenges this assumption. Canada's natural resources and associated industries and communities are vulnerable to climate change and there is a need for the forestry community to be proactive in adapting to climate change (Davidson *et al.* 2003; Standing Senate Committee on Agriculture and Forestry 2003; Spittlehouse and Stewart 2003).

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Adaptation to climate changes refers to adjustments in ecological, social, and economic systems in response to the effects of changes in climate (Smit *et al.* 2000; Smit and Pilifosova 2001; Davidson *et al.* 2003). The development of adaptation measures for some time in the future, under an uncertain climate, in an unknown socio-economic context is bound to be highly speculative (Burton *et al.* 2002). Some people may view responding as a greater risk than doing nothing, or that adaptation is not a feasible option. Although forest ecosystems will adapt autonomously, their importance to society means that we may wish to influence the direction and timing of this adaptation at some locations. In other cases, society will have to adjust to whatever change brings.

This paper is based on Spittlehouse and Stewart (2003). My objective is to encourage the forestry community to begin assessing its vulnerability to climate change and develop adaptation strategies. I will present a brief summary of current and possible future changes in the environment and forest ecosystems and then present a framework for determining options to adapt to climate change.

Current and future changes in BC

Globally there has been an increase in mean annual air temperature of over 0.5°C in the last 100 years. British Columbia has also seen similar or greater changes, particularly in winter minimum temperatures, and with the increase being greatest in northern regions (Anon 2002). There has not been a consistent long-term change in precipitation. Possible responses to these changes in temperature include retreating of glaciers, shift in the annual hydrograph, permafrost melt and increase in landslides in the north, and changes in fire occurrence (Anon 2002; Leith and Whitfield 1998; Clague 2003, Gillet *et al.* 2004). There are no long-term measurements to allow assessment of biological response in BC’s forest ecosystems to these changes. However, world-wide there are reports of earlier start to the growing season, earlier arrival of migratory birds, increase in boreal forest productivity, earlier breeding of animals and genetic adaptation in resident populations (Stewart *et al.* 1998; Stenseth *et al.* 2002; Walther *et al.* 2002; Climate Change Impacts and Adaptation Directorate 2002, Real *et al.* 2003).

Possible future climates for BC are presented in Table 1. The range of values reflects the uncertainty in future greenhouse gas emissions and differences in how the various models simulate the climate. All projections show a warming that tends to be greater in northern areas and larger in winter and spring. Winter precipitation is expected to increase and summer precipitation may increase or decrease. A number of factors will control biological responses to these climate changes. They include the rate and magnitude of the climate change, species and population sensitivity to climate, fecundity, life span, habitat requirements, current distribution, frequency, timing and size of disturbance (fire, disease, insects, harvest), competition, barriers to movement and human adaptive actions. Climate change impacts for BC include: species ranges moving northward and up in elevation (Hebda 1997), increase in the frequency, intensity, and timing of disturbances such as fire (Stocks *et al.*1998) and pests (Sieben *et al.* 1997; Carroll 2003), change in forest productivity (Spittlehouse 2003) and change in biome distribution (Scott *et al.* 2002). For example, by 2080 there would be a significant expansion of true grassland and the forest/grassland transition climates in southern BC (Hebda and Spittlehouse unpublished data); though how rapidly such changes may translate into movement of species is uncertain (Loehle 2003). Species ranges may be reduced if the current warmer/drier end of a range becomes unsuitable and species are unable to move into areas where the climate is suitable because of slow

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migration rates, unsuitable growing substrate or lack of habitat (Stewart *et al.* 1998). Some species will adapt better than others will. Harding and McCullum (1997) suggested that in BC and Yukon about 70% of the bird and ungulate species and 20% of fish species would have an increase in habitat under climate change, while the remainder would have a loss.

Forest management activities will not be immune for the effects of climate change. We already take account of climate in forest management, in the future we will have to apply these techniques with a greater intensity and in different areas. Fire management is an obvious example and we may need to focus on the protection of areas with high economic or social value, while in other areas fire is allowed to run its course (Stocks *et al.* 1998; Parker *et al.* 2000). Increasing winter precipitation will affect water management in forests. An increased risk of sediment transport to streams threatens water quality and fish spawning habitat. Warmer winters will reduce the opportunities for winter logging in areas where the frozen surfaces of forest roads and ice bridges are essential for site access, and where a snow pack is necessary to protect the land during harvesting (Pollard 1991). Harvesting restrictions could increase due to the increased risk of landslides under heavy rainfall. There will be changes in wood quality and timber supply locally and globally, and market impacts will not be uniformly distributed (Perez-Garcia *et al.* 2002). A changing climate means that the geographic extent of seed transfer zones will change. Thus we need to determine the limits of transferability of species and genotypes and develop new regeneration strategies (Ledig and Kitzmiller 1992; Rehfeldt *et al.* 1999; Parker *et al.* 2000). We will need to re-evaluating conservation and recovery programs because rare and endangered plant species usually have specialized environmental requirements and low genetic diversity (Peters 1990; Hansen *et al.* 2001). Attributes that parks and wilderness areas were designed to protect may no longer exist within the protected area (Halpin 1997; Scott *et al.* 2002), and a 'hands-off" approach to wilderness management may not be an appropriate response.

Adaptation to climate change in forestry

Forecasting impacts is difficult because of our limited knowledge about the vulnerability of ecosystems and species, and the poor spatial and temporal resolution of the future climate. Although we do not have a clear view of the future climate and forest, it is critical to begin the process of developing adaptation strategies now. Adaptation to climate change in forest management requires a planned response well in advance of the impacts of climate change. Evaluating vulnerability is critical for developing adaptation strategies. Vulnerability is the degree to which a system (organism, ecosystem, company, or community) is susceptible to, or unable to cope with, adverse effects of climate change. It depends on the magnitude and rate of climate change, sensitivity to climate and the system's adaptive capacity. Adaptive actions reduce the risks (decrease vulnerability) by preparing for adverse effects and capitalizing on the benefits. However, intervention will be selective and there will be impacts that cannot be prepared for or anticipated. Spittlehouse and Stewart (2003) presented an extensive list of adaptive actions proposed in the literature for forest managment.

Adaptation requires (Dale *et al.* 2001; Spittlehouse and Stewart 2003) that the forestry community:

- Establish objectives for the future forest under climate change.
- Increase awareness and education within the community about adaptation to climate change.
- Determine the vulnerability of forest ecosystems, forest communities, and society.
- Develop present and future cost-effective adaptive actions.

- Manage the forest to reduce vulnerability and enhance recovery.
- Monitor to determine the state of the forest and identify when critical thresholds are reached.
- Manage to reduce the impact when it occurs, speed recovery, and reduce vulnerability to further climate change

I focus here on a framework for planning adaptive actions. It is a format for risk analysis of which there are many examples in the literature (Kelly and Alger, 2000; Davidson *et al.* 2003; Spittlehouse and Stewart 2003; Turner *et al.* 2003). A plan for facilitating adaptation in forestry must address biophysical and socio-economic impacts and will include policy and institutional considerations. First we need to identify the issue of concern. Next comes the assessment of the vulnerability (sensitivity, adaptive capacity) of the forest, forest dependent communities, and society in general to climate change. This assessment facilitates the development of adaptive actions to be taken now and those required for the future as change occurs. Current activities include those that facilitate future responses to reduce vulnerability. Adaptation options must include the ability to incorporate new knowledge about the future climate and forest vulnerability as they are developed. Until climate change has had sufficient impact to warrant intervention it is likely that that in many situations there is a not much that is to be done 'on the ground, in the forest' for a few decades. However, we need to have a suite of options ready to go when we do wish to intervene; thus there is work to do now.

The following is an example of using the framework noted above on the effect of climate change on a managed forest. Other examples can be found in Spittlehouse and Stewart (2003). This example is in the detail required for a full analysis but is presented to show how the risk analysis might take place.

- *Issue:* A managed forest under climate change.
- *Vulnerability:* Lower summer precipitation and increased temperature - reduce growth rates, change wood quality, increase the risk of disturbance by fire, insects and disease, change in species suitability, change in wildlife habitat, recreational opportunities.

  Increased winter precipitation and temperature – increase risk of erosion, increase in streamflow, reduced winter logging opportunities
- *Options for the future:* Adjust rotation ages, utilise small logs, increase salvage after disturbance by fire and insects, modify seed transfer zones, upgrade culverts.
- *Actions to do now:* Replace geographically defined seed transfer zones with zones defined by climate, identify policy and knowledge barriers to implementation, develop harvesting and wood processing technology to meet future fibre supply.

Climate change adaptation strategies can be viewed as the risk management component of sustainable forest management plans. Actions can be taken that are useful now, but would also reduce the risk of unacceptable losses in the future. As can be seen in the above example, many actions required in adapting to climate change benefit the present as well as the future. Spittlehouse and Stewart (2003) proposed a number of questions that need to be addressed to facilitate adaptation planning. These included: what are the research and educational needs; what are barriers to the implementation of adaptation in forest management; what forest policies need to be in place to facilitate adaptation; and are current monitoring systems adequate to spot problems induced by climate change soon enough to allow implementation of an acceptable response?

Conclusions

Current forest utilization and preservation is based on how forests developed under past climatic conditions. Policy-makers and forest managers must accept that climate change in the near term is probable and that forests and forest dependent communities face significant challenges. Planned adaptation will reduce vulnerability for commercial tree species at selected sites. However, many forest species will have to adapt autonomously and society will have to adjust to the result. Until climate change has had sufficient impact to warrant intervention it is likely that that in many situations there is a not much that can be done in the forest for at present. However, it is necessary to start assessing forest vulnerability to climate change and developing adaptation strategies. Sustainable forest management already embodies many of the activities that will be required to respond to the effects of climate change on forests. Including adaptation to climate change as part of forest planning does not necessarily require a large financial investment now with an unknown future payback time.

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Table 1. Future climate scenarios for 2020 and 2080 for southern and northern British Columbia presented as changes from current conditions. Data encompass predictions from eight global climate models, though there are outliers outside the ranges presented. Data are available from the Canadian Institute for Climate Studies (http://www.cics.uvic.ca/scenaros/index.cgi?Scenarios).

	2020		2080	
	Temp. °C	PPT %	Temp. °C	PPT %
Southern				
Winter	0 to 2	-5 to 15	2 to 6	0 to 25
Spring	0.7 to 1.7	-3 to 10	2 to 6	-5 to 15
Summer	1 to 2	-25 to 5	3 to 7	-45 to 5
Fall	0.7 to 1.5	-5 to 5	2 to 6	-5 to 15
Northern				
Winter	0 to 2	0 to 15	3 to 10	5 to 45
Spring	0.5 to 2.5	2 to 20	2 to 8	5 to 50
Summer	0.5 to 1.5	-10 to 17	2 to 6	-10 to15
Fall	0.5 to 2	-5 to 10	2 to 6	10 to 25

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