FOREST MANAGEMENT AND CLIMATE CHANGE[1]

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OVERVIEW

Forest management decisions made now will effect forests many decades into the future. Thus it is important for managers to take account of how forests may respond to future climatic conditions. Unfortunately, the picture of what the climate will be at specific locations and times in the future is not clear. Even less clear is the picture of how organisms will respond. Consequently, management actions to address climate change must be flexible and such that they do not compromise the health of the forest should the climate not change as predicted. Actions will further be complicated by differing values placed on forests by society, disagreement on whether impacts of climate change are positive or negative, and the priority of governments for addressing other impacts. Also, there will be increased pressure to manage forests to offset emissions from the burning of fossil fuel and to moderate the effects of climate change on non-timber resources.

This task of planning for the unknown is not as daunting as it may seem. The first step requires policy makers and resource managers to accept that change is probable and that responses can be developed. Incorporating responses into forest management planning requires:

- A clear definition the problem, that is, the level of change at which action is needed.
- The determination of the sensitivity of forest organisms to changing climate.
- The development of management responses to be implemented when the changes occur, and implementation of actions needed now.
- Monitoring of forests to assess if and when changes are occurring.

Disturbances of forests, such as harvesting and forest fires, provide opportunities for forests to adjust to the changing climate. The success of adjustment will depend on factors such as the sensitivity of species to climate change and the availability of alternate species. We may be capable of aiding managed forest and commercial tree species to adjust to a changing climate; however, in parks and wilderness areas we will probably have to 'let nature take its course'. Forest management already addresses many of the problems, such as fire, disease, insects and reforestation failures, that are will occur under a changed climate; it is the location and extent of the problems that will change. New species cannot be planted in anticipation of future climatic conditions because the current conditions would not be suitable. It may be possible to plant now ecotypes that grow well under a range of conditions and thus produce forests that can tolerate a changing climate.

We need to improve our knowledge of the sensitivity of species and ecosystems to climate, to continue provenance trials in different climatic regimes, and to develop adaptive management strategies. Physiologically based models of plant and animal response to weather should be linked to ecosystem level models to predict impacts. Current initiatives to ensure healthy forests, maintain biodiversity and minimize fragmentation of habitat will help buffer the effects of climate change. Some impacts of climate change will be easier to deal with than others, and there will be surprises ahead. However, established forests are resilient, and there should be time to adapt to many potentially negative impacts. Social changes will be significant. Society will need to revise its expectations of, and demands on, forests, and there may be adjustments required by groups who's livelihood is based on the use of forests.

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INTRODUCTION

Can we manage forests to help them adapt to future climate changes? We have only a hazy picture of what climate changes may occur and an even less clear understanding of their impacts on forests (Waterstone, 1993; Houghton et al., 1996; Michaels, 1996; Loehle and LeBlanc, 1996). This uncertainty probably discourages most forest managers from even considering the issue, even though the decisions they make now will have repercussions many decades in the future. A previous symposium on Forest Management and Climate Change (Wall, 1992) concluded that forest managers can and must respond to possible future changes in climate. The delegates recommended that managers:

- Accept that climate change is probable, and that actions have benefits now.
- Maintain healthy, diverse forest ecosystems, and develop adaptive management techniques.

What would pro-active responses by forest mangers involve? I describe a framework for response (based on that in Spittlehouse, 1996) and give some examples. These thoughts are preceded by a section describing the environment under which responses would be developed.

FACTS & ASSUMPTIONS

I believe that we will see the equivalent doubling of the atmospheric carbon dioxide concentration in the next 50 to 100 years. The importance of fossil fuel use to the global economy means that we are unlikely to see significant reductions in emissions in the near future (Waterstone, 1993). The Intergovernmental Panel on Climate Change (Houghton et al., 1996) concluded that a 2 to 4° C warming of British Columbia and the Yukon's climate and accompanying changes in precipitation and weather patterns are likely to occur by the end of the next century. However, we are uncertain of the timing, magnitude, spatial distribution and variability of the changes. Some people believe that we are already experiencing human induced changes in climate.

Public policy has to consider more than just climate impacts. Population changes, economic growth, health, education and safety have the highest priority. Society has a large financial and social investment in the status quo and may view the cost of doing nothing as less than the cost of responding. Whether changes are positive or negative depends on society's values (Watson et al., 1992; Waterstone, 1993). An important time frame for forest management is the rotation age of the stand. However, forestry activities are driven by current economics, and a five-to-ten year time horizon may be the major factor in decision making (Sandenburg et al., 1987). Thus, support will be limited for forest management actions targeted to adapting to climate changes that may occur 50 years from now.

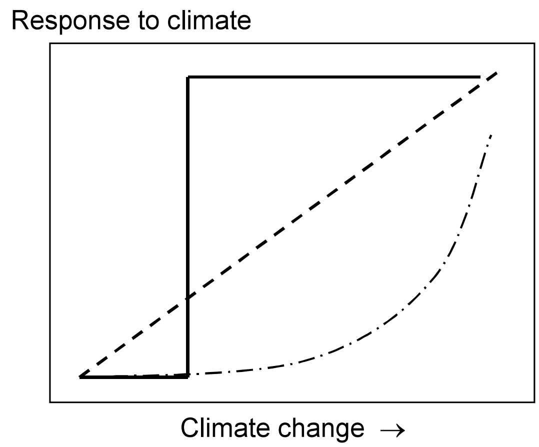
Information on past climates and associated vegetation communities (paleoclimatology and paleobotany) and computer simulations have been used to predict impacts of future climate change on forests. The paleo-studies are useful for showing the kind and magnitude of changes that could occur. However, different variables are driving future climate change, and there is a much different landscape (e.g., disturbance regime) than existed centuries ago. Much of the work modelling the response of vegetation to climate change is inadequate. A major concern is that most models are not physically or physiologically based. Henderson-Sellers (1994) shows that although simple vegetation/climate models agree on present vegetation regimes, they produce widely different responses to the same climate change scenario. Loehle and LeBlanc (1996) believe that ecologically based models are, among other concerns, programmed to make forests overly sensitive to climate change. Eamus and Jarvis (1989), de Bruin and Jacobs (1993) and Friend and Cox (1995) show the need to consider physiological responses of the vegetation over short time steps and interactions between variables. For example, increasing atmospheric carbon dioxide induces partial closure of stomata, thus reducing transpiration and increasing water use efficiency. Spittlehouse (1996) showed how, over a few kilometres, site factors could produce quite different responses of tree growth to reduced rainfall. Most simulations of vegetation response are driven by a specific climate scenario. Therefore, they are of limited use for forest management if this climate scenario does not occur, or, if significant response is likely to occur before the new climate is achieved. Bonan et al. (1990), Clark (1991), Clark and Reid (1993), Working Group II (1995) and Spittlehouse (1996) note the need to assess sensitivity to changes in climate.

Sensitivity will vary with species, ecosystem and climate variable. For example, Figure 1indicates that different management actions would be required depending the sensitivity to climate change (shape of curve) and the degree of climate change (distance along the x-axis).

Despite their limitations, paleobotany and the computer models can be used to get a broad view of the impacts of climate change on British Columbia's forests (Leverenz and Lev, 1987; Pollard, 1991; Working Group II, 1995; Hebda, 1997). The rate of climate change will be one of the most important criteria in determining how well organisms adjust. There will be changes in the frequency of weather induced disturbances, e.g., fires and pests. There will be shifts in ranges of organisms northward, and upward in elevation. Forests at the edge of their range are likely to be effected first, giving us an opportunity to assess changes and responses before more productive forests are negatively affected. Because species rather than ecosystems move, we could see new mixes of species (Leverenz and Lev, 1987; Bonan et al., 1990; Clark, 1991; Working Group II, 1995; Hebda, 1997). There could also be significant impacts on forest based communities in terms of changes in access time to sites for harvesting, appropriate harvesting methods, species to be harvested, and allowable annual cuts (Pollard 1991; Working Group II, 1995; Rothman and Herbert, 1997).

Disturbance, 'natural' or anthropogenic, provides an opportunity to adjust to a changing climate (Franklin et al., 1992; Veblen and Alaback, 1996). Non-commercial forests, such as parks and wilderness areas, will be extremely difficult to manage for change to meet society's expectations because intervention is not usually part of the management strategy (Pollard, 1991; Peters and Lovejoy, 1992). In this case, society may have to 'let nature take its course'. This will also be the case for non-commercial species in managed forests. Most tree species occupy a wide climatic range, and, although the reforestation stage can be extremely sensitive to climate, established forest trees are resilient and already withstand large interannual variations in weather conditions. Site conditions, e.g., soil depth and topography, moderate the above-ground climate thus extending plant ranges. A patchwork of age classes and ecosystems over the landscape will aid adaptation. Competition by species more suitable to the new climate will not

Figure 1. Hypothetical responses of organisms and ecosystems to climate change. The dashed line shows a linear response to climate. The dotted and dashed line describes a non-linear response, with sensitivity increasing as the change in climate increases. The solid line describes a catastrophic response to climate change.



be immediate because it will take many years for them to migrate to new areas. The lighter seeds of many hardwood and non-woody species are likely to disperse further and faster than the heavier conifer seeds. In some situations, there will be an improvement over existing conditions. For example, a gain in productivity through warmer temperatures in presently cold areas may more than offset increased losses to disease and fire. The increased carbon dioxide concentration may result in an increase in water use efficiency and growth of plants (Eamus and Jarvis, 1989; Bonan et al., 1990, Spittlehouse, 1996: Loehle and LeBlanc, 1996).

The importance of moderating the rate of increase in the atmospheric carbon dioxide concentration has implications for forest management (Pollard, 1991). There will be increased pressure to manage forest to offset emissions from the burning of fossil fuel, and forestry will be required to minimize net losses of carbon dioxide and other greenhouse gases to the atmosphere through harvesting and wood processing. Unlike the rest of the developed world, most of British Columbia's harvest is in old-growth forests with the potential for a net loss of carbon dioxide from these sites over the next rotation. British Columbia's forested estate is presently a sink for carbon, but the rate of gain in carbon is decreasing as a result of natural and anthropogenic disturbances, and the aging of the forests (Kurz et al., 1996). Management options may be further complicated by the need to manage forests to moderate the effects of climate change on non-timber resources such as fish habitat and domestic water supplies.

MANAGEMENT RESPONSE FRAMEWORK

Do we just react to changes when they occur, or prepare now to respond to these changes? We are planning for the unknown - we do not know when changes will occur but have some general idea of what to expect. Policy makers and forest managers must accept that climate change is probable and that it can be addressed. Policy makers can create an environment to manage for change and direct research towards aiding adaptive management. Forest managers have to develop and apply plans for responding to climate change. Assessments will be important and aid targeting of limited resources (Sandenburg et al., 1987).

Development of a response plan requires a framework for the analysis (Spittlehouse 1996):

- Identify the issue of concern and the degree of change in forests that would be considered a serious problem.
- Determine the sensitivity of forests to changes in climate, and the impacts of potential future climate changes.
- Develop management responses which include actions to be taken in the future, and actions required now to facilitate future response.
- Monitor forests to determine if changes are taking place, and if thresholds for intervention have been reached.

Global climate model simulations can be used as a guide when defining the problem, e.g., what will happen if the future climate is warmer and drier. Given such a scenario, the management concern is what to do after disturbances such as harvesting, fire, disease, or a drastic reduction in productivity have occurred. These disturbances provide an opportunity for adapting the forest to the new climate. Decisions must be made as to which changes can be managed and which must be left to work themselves out. It is probable that the latter situation will be the case in much of British Columbia.

Forest management already addresses problems such as fire, disease, insects, and reforestation failures that are likely to occur under a changing climate. It is the location and extent of the problems that will change. Consequently, many of the forest research and management activities required to address climate change are useful now and are part of current actions. Management prescriptions must be flexible and not compromise the health of the forest if the climate does not change as predicted (Pollard 1991). Greater emphasis may be placed on managing so as not to limit the options for the non-timber resources. Alternate tree species cannot be planted now in anticipation of future climatic conditions because the current conditions are not suitable. However, it may be possible to plant ecotypes that grow well under a range of conditions and thus produce forests that can tolerate a changing climate. Human adaptations to climate change include changing our expectations and demands on forests. Leaving migration corridors and reserve areas may be the only way to address unmanaged ecosystems and wildlife within a managed landscape. Existing forest health, tree growth and biodiversity monitoring programs may need to be modified so as to be able to discern the impacts of climate change (Sandenburg et al., 1987; Peters and Lovejoy, 1992; Working Group II, 1995; Spittlehouse, 1996).

We must ensure that research provides information that will help in managing for climate change. Genetic variability of tree species needs to be evaluated in terms of the climate of the seed source and the climate of provenance trials (e.g., Rehfeldt, 1995; Carter, 1996). The ecological limits of species in managed (limited competition) and unmanaged situations needs to be determined. Process-based models should be used to assess ecosystem sensitivity to changes in climate, and they should be linked to ecological models that account for such factors as inter-species competition and tree death. The models should be based on short time steps because plants and animals respond to day-to-day weather conditions not average annual conditions. We should be assessing impacts of changes in intensity and frequency of extreme events, e.g., repeated years with summer drought (Spittlehouse, 1996).

EXAMPLES OF USING THE FRAMEWORK

The following are four brief examples of possible responses to the many questions that can be asked about managing for climate change. I address only a change to warmer and drier conditions.

Changes in fire frequency

Problem: Warmer and drier conditions may increase the frequency of fires, resulting more areas with a high fire hazard.

Responses: High quality fire monitoring and attack capabilities. Increased salvage logging of burnt areas, though the volume of wood per hectare may decrease because the increased fire frequency would reduced the average age of the forest (Rothman and Herbert, 1997).

Actions now: We already have an extensive fire monitoring network. We should increase fire-safety consciousness and fire-proofing of buildings in rural areas. There may be opportunities to improve the utilization of wood salvaged after fires. Changing stand structure and species mix may make the forest less vulnerable to extensive fires (Franklin et al., 1992).

Changes in growth and yield of forests

Problem: Warmer and drier conditions may result in reduced growth rates of existing forests in some areas and increased rates of growth in other areas (Working Group II, 1995; Hebda, 1997). This will effect timber availability, and may also affect international sales through greater competition from countries were tree growth has increased.

Responses: Harvest trees earlier in the rotation where growth is declining, and prepare to use small diameter logs (Working Group II, 1995; Rothman and Herbert, 1997). After harvest, sites would be replanted with alternate ecotypes or species. Increased growth rates in some areas may mean an increase in the allowable annual cut and employment, offsetting reductions elsewhere in the province, but requiring relocation of the labour force.

Actions now: Determine climatic regimes of various ecotypes and compare growth capabilities under a range of climates, e.g., provenance testing program. Develop growth and yield models that explicitly assess the effect of climate on tree growth.

Reforestation problems

Problem: Warmer and drier conditions may result in poor survival and growth of seedlings in certain areas.

Responses: Plant drought tolerant stock. Utilize harvesting and site preparation techniques already developed for existing dry environments to improve the regeneration microclimate. Consider planting alternate species.

Actions now: Development of drought tolerant stock (Farnum, 1992). Review provenance trials for drought tolerance of ecotypes. It may be prudent to plant an ecotype that grows well under a range of conditions, or plant stock from a range of genetic sources at a site (Ledig and Kitzmiller, 1992).

Wildlife, non-commercial plant species, wilderness areas and parks

Problem: Forest habitats will change as the forests adjust to the new climate. We cannot expect to have the knowledge and resources to readily establish noncommercial species of organisms in areas where the climate may be more suitable. Intervention through intentional disturbance and reforestation is not a normal activity in wilderness areas and parks.

Responses: Maintain conditions that allow forest organisms the opportunity to respond as best they can (Peters and Lovejoy, 1992). Seed areas with non-commercial species in areas where the climate has become suitable (Working Group II, 1995).

Actions now: Leave migration corridors in managed areas. Maintain healthy and diverse managed forest ecosystems (Pollard, 1991). We should not rely on only protected areas to maintain biodiversity (Franklin et al., 1992).

CONCLUSIONS

I believe that it is possible to develop forest management responses to future unknown climates. This does not mean that we will be able to manage for all negative impacts, or take full advantage of any positive impacts. It is likely that we will have to allow most of British Columbia's forests to adjust to climate change as best they can, and it is only on the more productive, harvestable sites that intervention will be feasible. It will be important to ensure that management activities do not compromise the ability of unmanaged areas to adjust. Managers must accept that climate change is probable and that actions have benefits now. Responses include deciding the degree of change in the forest that constitutes a problem, determining possible solutions, and initiating monitoring programs to determine when intervention is required. Research is needed to identify species and forest ecosystems at greatest risk, and to better quantify the eco-climatic limits and sensitivity of commercial species. Impact analyses should be done using physiologically based models with short time steps, and should determine the impact of changes in intensity and frequency of extreme events. Many actions for responding to climate change are part of current forest management. Provenance trials where trees are grown 100's of kilometres from their source provide information on a species ability to grow under a wide range of conditions. Management to ensure sustainable forestry, maintain biodiversity, reduce fragmentation and preserve habitat also aids adaptation for climate change. The most difficult adjustment will be society's need to revise expectations of, and demands on, forests.

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REFERENCES

Bonan, G.B., Shugart H.H. and Urban, D.L. (1990). The sensitivity of some high-latitude boreal forests to climatic parameters. Climatic Change 16, pp. 9-29.

Carter, K.K. (1996). Provenance tests as indicators of growth response to climate in 10 north temperate tree species. Canadian Journal of Forest Research 26, pp. 1089-1095.

Clark, J.S. (1991). Ecosystem sensitivity to climate change and complex responses, in R.L Wyman (ed.), Global Climate Change and Life on Earth, Chapman and Hall, New York, pp. 65-98.

Clark, J.S. and Reid, C.D. (1993). Sensitivity of unmanged ecosystems to global change, in J. Darmstadter and M.A. Toman (eds.), Assessing Surprises and Nonlinearities in Greenhouse Warming, Resources For the Future, Washington, DC, pp. 53-89

de Bruin, H.A.R. and Jacobs, C.M.J. (1993). Impact of CO_2 enrichment on the regional evapotranspiration of agro-ecosystems, a theoretical and numerical modelling study. Vegitatio 104/105, pp. 307-318.

Eamus, D. and Jarvis, P.G. (1989). The direct effects of increase in the global atmospheric CO_2 concentration on natural and commercial temperate trees and forests. Advances in Ecological Research 19, pp. 1-55.

Farnum, P. (1992). Forest adaptation to global climate change through silvicultural treatments and genetic improvement, in G. Wall (ed.), Implications of Climate Change for Pacific Northwest Forest Management, Occasional Paper No. 15, Department of Geography, University of Waterloo, Waterloo, ON, pp. 81-84.

Franklin, J.F. and 12 others. (1992). Effects of global climatic change in Northwestern North America, in R.L. Peters and T.E. Lovejoy (eds.), Global Warming and Biological Diversity, Yale Univ. Press, New Haven, pp. 244-257.

Friend, A.D. and Cox, P.M. (1995). Modelling the effects of atmospheric CO_2 on vegetation-atmosphere interactions. Agricultural and Forest Meteorology 73, pp. 285-295.

Hebda, R.J. (1997). Impact of climate change on biogeoclimatic zones of British Columbia and Yukon, in, Future Climate Change in British Columbia and the Yukon, Environment Canada, Vancouver, B.C. (this publication).

Henderson-Sellers, A. (1994). Global terrestrial vegetation 'prediction': the use and abuse of climate and application models. Progress in Physical Geography 18, pp. 209-246.

Houghton, J.T., Miera Filho, L.G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K. (eds.). (1996). Climate Change 1995 The Science of Climate Change, Cambridge Univ. Press, Cambridge, U.K., 572 pp.

Kurz, W.A., Apps, M.J., Comeau, P.G. and Trofymow, J.A. (1996). The carbon budget of British Columbia's forests: 1920-1989. Preliminary analysis and recommendations for refinements. FRDA Report No. 261, B.C. Ministry of Forests, Victoria, B.C. 62 pp.

Ledig, F.T and Kitzmiller, J.H. (1992). Genetic strategies for reforestation in the face of global climate change. Forest Ecology and Management 50, pp. 153-169.

Leverenz, J.W. and Lev, D.J. (1987). Effects of carbon dioxide-induced climate changes on the natural range of six major commercial tree species in the western United States, in W.E. Shands and J.S. Hoffman (eds.), The Greenhouse Effect, Climate Change, and U.S. Forests, The Conservation Foundation, Washington, DC, pp. 123-155.

Loehle, C. and LeBlanc, D. (1996). Model-based assessments of climate change effects on forests: a critical review. Ecological Modelling 90, pp. 1-31.

Michaels, P.J. (ed.). (1996). State of the climate report. Western Fuels Association, Inc., Arlington, VA, 28 pp.

Peters, R.L. and Lovejoy, T.E. (eds.). (1992). Global Warming and Biodiversity, Yale Univ. Press, New Haven.

Pollard, D.F.W. (1991). Forestry in British Columbia: planning for the future climate today. The Forestry Chronicle 67, pp. 336-341.

Rehfeldt, G.E. (1995). Genetic variation, climate models and the ecological genetics of *Larix occidentalis*. Forest Ecology and Management 78, pp. 21-37.

Rothman, D.S. and Herbert D. (1997). The socio-economic implications of climate change in the forest sector of the Mackenzie Basin, in S. Cohen (ed.), Final Report of The Mackenzie Basin Impact Study, Environment Canada, Toronto, ON, (in press).

Sandenburgh, R., Taylor, C. and Hoffman, J.S. (1987). How forest products companies can respond to rising carbon dioxide and climate change, in W.E. Shands and J.S. Hoffman (eds.), The Greenhouse Effect, Climate Change, and U.S. Forests, The Conservation Foundation, Washington, DC, pp. 247-257.

Spittlehouse, D.L. (1996). Assessing and responding to the effects of climate change on forest ecosystems, in R.G. Lawford, P.B. Alaback, and E. Fuentes (eds.), High-Latitude Rainforests and Associated Ecosystems of the West Coast of the Americas, Springer-Verlag, New York, pp. 306-319.

Veblen, T.T and Alaback, P.B. (1996). A comparative review of forest dynamics and disturbance in the temperature rainforests of North and South America, in R.G. Lawford, P.B. Alaback, and E. Fuentes (eds.), High-Latitude Rainforests and Associated Ecosystems of the West Coast of the Americas, Springer-Verlag, New York, pp. 173-213.

Wall, G. (ed.). (1992). Implications of Climate Change for Pacific Northwest Forest Management, Occasional Paper No. 15, Department of Geography, University of Waterloo, Waterloo, ON, 221 pp.

Waterstone, M. (1993). Adrift in a sea of platitudes: why we will not resolve the greenhouse issue. Environmental Management 17, pp. 141-152.

Watson, H.L., Bach, M.C. and Goklany, I.M. (1992). Global vs climate change, in G. Wall (ed.), Implications of Climate Change for Pacific Northwest Forest Management, Occasional Paper No. 15, Department of Geography, University of Waterloo, Waterloo, ON, pp. 97-109.

Working Group II. (1995). Climate Change 1995 Impacts, Adaptations and Mitigation of Climate Change: Scientific and Technical Analysis. Cambridge Univ. Press, Cambridge, U.K.