Actions to Promote Climate Resilience in Forests of British Columbia

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Abstract

Climate change has introduced major uncertainties into the planning and practice of forestry. We recommend seven broad actions that would help to make our forests more climate resilient: avoiding entrapment, emphasizing the future, adopting a policy of no regrets, seeking the right species at the right place, encouraging connectivity, nurturing acceptance and adaptation, and reducing carbon emissions. Some actions are specific to British Columbia; all actions attempt to address the major sources of uncertainty.

KEYWORDS: Climate change; forest management; resilience

Introduction

There are three broad forms of uncertainty in predicting what British Columbia's forests will become and how well they will meet the products and ecosystem services we seek: (1) predicting climate, (2) predicting tree species' responses to climate, and (3) predicting effects of factors modifying trees' responses (e.g., pathogens, fires).

Generally, workers are more confident in projections of temperature than in projections of precipitation (Mote et al. 2005; Dawson et al. 2008; Pike et al. 2008; Spittlehouse 2008). Much of how our forests will respond depends on the amount and timing of precipitation. Predictions of precipitation range from general increases in annual precipitation over most of the province, with summer drying in south and central British Columbia (Spittlehouse 2008), to most areas showing increases even during summer (Mote et al. 2005; Pike et al. 2008). Mote et al. (2005) reported that from the 1920s to present, precipitation has increased for almost all areas of the province during all seasons. All of these estimates are uncertain. Moreover, increased precipitation can be offset by warmer temperatures to reduce available soil moisture. Problems in down-scaling projections of precipitation in British Columbia (or other regions of Canada) are apparent (e.g., Flannigan et al. 2005; Wotton et al. 2010). Mbogga et al. (2010) used analysis of variance to partition variance and found that methods of downscaling the climate had strong effects, particularly at higher elevations and in the north. A major cause is the lack of weather stations in these regions and will not be easily overcome.

Predicting responses of individual tree species to climate is challenging because the species will be competing under a climate regime we have not seen before and the species may not have experienced before. This challenge is increased by the differential response

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of pathogens and effects of changes in fire frequency (Bunnell et al. 2011b). We should anticipate both error and uncertainty in climate projections for the province and additional uncertainty in projections of tree species' responses to climate change. This, in turn, suggests we recognize the limitations of our ability to predict in our preparation and responses.

We recommend seven broad actions that would help to make our forests more climate resilient. Some actions are specific to British Columbia; all actions attempt to address the major sources of uncertainty.

Becoming climate resilient

The long list of ecosystem services provided by forests (Millennium Ecosystem Assessment 2005) emphasizes that maintaining healthy forest cover is critical from both economic and ecological perspectives. Bunnell (2009) observed that it is impossible to make ecosystems "climate proof," so we must work to make them "climate resilient." The literature tends to use "ecological resilience" and "ecosystem adaptability" interchangeably (e.g., Gunderson & Holling 2002; Puettmann et al. 2009). Common adaptation strategies proposed in Canada, England, Mexico, and the United States are intended to work towards ecosystem resilience (review of Mawdsley et al. 2009). Campbell et al. (2009) reviewed the theory and features of ecological resilience. We intend the term "resilience" to incorporate three features common in the literature on resilience and ecosystem adaptability:

1. capacity of an ecosystem to resist change,
2. amount of change a system can experience and retain typical controls over its structure, and
3. ability of an ecosystem to reorganize after disturbance.

Forests are complex systems with many parts interacting over a large range of scales (Bunnell & Huggard 1999) with most interactions non-linear (Bunnell & Dunsworth 2004). These features make their trajectory in response to changing climate difficult to predict but also expose mechanisms for increasing resilience. Campbell et al. (2009) reviewed how concepts of resilience and complexity suggest two key points relative to forest management (here paraphrased):

1. complexity over a range of scales is desirable, and
2. the inherent complexity of forests means outcomes in response to external conditions are poorly predictable.

We concur with both points. Two other broad points influence actions to maintain or increase climate resilience of forests.

First, the dominant species of forests cover more extensive areas and are much longer lived than species in most other ecosystems. This implies large changes can occur suddenly if extensive areas of broad age classes become vulnerable (e.g., to pathogens). Second, dominant trees of a forest typically show little functional redundancy but greatly influence the character of the forest (Ebenman & Jonsson 2005; Ellison et al. 2005). The long-lived nature and pronounced effect of dominant tree species on the character of forests means we need to refine our ability to predict future distribution of tree species. The future distribution will depend on far more than the species' autecology, including how climate regime affects fungi, insects, and competitors.

There is a large literature, often on individual practices, offering suggestions on how to maintain resilience in forests (Campbell et al. 2009; Secretariat of the Convention on Biodiversity 2009; Heineman et al. 2010; Johnston et al. 2010). We take a broader approach, providing some illustrative examples, but emphasizing the broad kinds of action appropriate to maintaining a healthy forest cover and conditions specific to British Columbia.

Actions to promote climate resilience

We note seven broad actions to promote climate resilience: avoiding entrapment, emphasizing the future, adopting a policy of no regrets, seeking the right species at the right place, encouraging connectivity, nurturing acceptance and adaptation, and reducing carbon emissions.

Avoid entrapment

By avoiding entrapment we mean entrapment by historical ways of doing things. Planning must change to match the changing climate. Some well-intended concepts in regulatory and certification systems no longer apply. For example, guidelines intended to maintain proportions of stand types on the landscape over time are usually derived from present distributions, or those from some time before intensive forest operations and certainly from a time before effects of climate change became so evident. Historical data remain important for understanding how trees and forests have responded to historical climate variation but are less valuable as targets.

Forest composition has never been static, but it also has never been so fluid during our history. Projected climate change favours shifts in species' ranges and regional composition that will alter stand types and stand dynamics in a given area. Failure to recognize this could lead to management approaches that are expensive and difficult because they are at odds with nature. Because the rates of change differ regionally, there can be no province-wide approach. Accepting changes in species composition of some stands with time, while maintaining a variety of stand types across the landscape, should increase resilience. Such flexibility will be more critical where rates of change are greatest (e.g., in the boreal rather than on the mid- or north-coast).

Flexible standards that allow stands to change composition between and during rotations require developing a broader suite of yield curves and targets within forest management plans, and a broader range of silvicultural practices (e.g., partial cutting, understorey protection, underplanting) to help create resilient stands. Appropriate techniques depend on the species present today and those predicted to be there in the future. Climate change will make some targets and variances required by regulatory or certification systems "unnatural" and difficult to meet. Increased fire frequency negates historical estimation of amounts of early seral; changes in species composition alter expected amounts of dead wood and understorey. Perhaps most important from a regulatory perspective is that expected volumes will change and should be based less on historical performance and more on predicted future performance, which could be lower.

Emphasize the future

The future will be different. By avoiding entrapment, we do not intend doing whatever we want, but instead invest in forecasting the future so that we utilize future conditions as best we can. At the least, this requires better early warning systems for insects and pathogens and better understanding of ongoing changes in stand composition (e.g., Change Monitoring Inventory plots; B.C. Ministry of Sustainable Resource Management 2002). We must be prepared to respond quickly to the arrival of new pests or sudden expansion of current pathogens; we may have to better understand their biology and learn how to control them quickly. Monitoring is a key and common element in adaptation strategies (Mawdsley et al. 2009). Much of our current monitoring focusses on meeting regulatory standards that are being made obsolete by climate change. The problem is that change already is under way and is likely to speed up, so that almost everything is changing, and this means difficult choices in allocating monitoring funds. Features such as species composition, pathogen distribution, and fates of smaller streams are likely to be more informative than amounts of down wood (provided most dead wood does not become biofuel). Similarly, the apparent effectiveness of a range of efforts to induce resilience needs monitoring. Likewise, our estimates of volume and productivity must change to allow for uncertainties wrought by climate change. Improving our abilities to predict both climate and tree species' responses are key to management emphasizing the future.

A different aspect of emphasizing the future arises from the concept of emerging ecosystems (review in Bunnell et al. 2011a). Forests in British Columbia not only will contain different mixes of tree species but of other organism groups as well. Although we need to anticipate dominant species as best we can, it will become increasingly important to manage ecosystem function rather than focus on species doing the functioning. Bunnell et al. (2011a) noted some consequences of such a shift and the need to learn how we can distinguish emerging species that replace useful waning functions from those that negatively modify functions.

Adopt a policy of no regrets

Considering wetlands, Bunnell et al. (2011a) recommended a policy of no regrets. By this they meant acknowledging the variance, but consistent direction, of climate projections and avoiding focus on a specific climate outcome by developing responses that seem reasonable regardless of realized outcomes. Forest planning and practice can either exacerbate or mitigate consequences of climate change. Practitioners have ample experience encouraging tree growth and seedling survival, controlling competition, and directing successional processes. Specific tools may change little, but their relative use is likely to shift. The broad goal is to reduce vulnerability and increase complexity. There are ample examples. Buffers around smaller streams and some wetlands would help conserve water (e.g., Bunnell et al. 2011a). Shelterwoods may prove a useful tool to reduce frost damage and shade fragile regeneration from more intense radiation (Örlander 1993; Sagar & Waterhouse 2010). In many areas, clearcuts may exacerbate climate change effects of higher temperatures in summer and greater frost heaving in early spring (Sagar & Waterhouse 2010). Thinning to increase vigour of overstorey trees may prove not only an incremental silviculture option but a necessary step to grow trees to maturity.

Thinning reveals the interactions and necessity of acknowledging responses of individual tree species. Thinning and reducing stocking rates of trees so that moisture stress does not worsen the impact of pathogens and possibly fire, appears to be a policy of no regrets; there should be benefits, regardless of the rate or degree of climate change. In some instances, however, thinning would not benefit forest productivity. For example, although thinning enables trees to better resist beetles and other pathogens, it creates a thicker phloem, which in lodgepole pine makes trees more attractive to bark beetles. Nevertheless, this is an issue only where large expanses of pine trees exist, a condition that could possibly sustain attacks. Another example of a policy of "no regrets" is avoiding harvest of all species in a stand without regard to maintaining existing regeneration. Although harvesting with care for understorey trees is more difficult, it likely will be better to allow what's growing to continue to grow, than to rely on conditions being favourable enough to allow successful new regeneration. We already know that a variety of age classes and suitable species increases resistance to insects and pathogens (Woods et al. 2005, 2010; Johnston et al. 2009). Encouraging greater complexity in stands may increase costs, but such actions may be our best insurance that stands are available to harvest in the future.

Some policies could lead to regrets. For example, identifying stands that may be vulnerable to climate change and harvesting them first will likely be inadequate. Aggressive pre-emptive strikes or post-disturbance salvage may not leave enough live (or dead) structures and seed sources to allow trees (and other species) to respond to change. It is also unlikely that we can harvest the same volumes as we have historically and still have resilient ecosystems.

Other workers have suggested other beneficial changes in practice (e.g., Campbell et al. 2009; Heineman et al. 2010; Johnston et al. 2010). The diversity of environments in British Columbia and uncertainty about climate outcomes emphasizes three points.

1. A policy of no regrets will be beneficial.
2. We cannot do the same thing everywhere.
3. Monitoring a variety of initiatives will be necessary.

Right species at the right place for future growth

It already is clear that many tree species will be unable to migrate at a pace equivalent to the rate of climate change (Iverson et al. 2004; Aitken et al. 2008). This emphasizes the importance of connectivity (see below) and the establishment phase of forest management. We have spent decades of research trying to match species and genotypes to environments for which they are optimally adapted and can regenerate well. The favourable environments are now moving, exposing a clear need to rethink concepts of local gene pool and seed tree zones. Scruffy groups of krummholz and black spruce at current extremes of range may become the source of new forests. It is difficult to overemphasize the importance of anticipating the future and acting now, despite limitations in understanding. The growth rate of trees ensures that playing “catch up” will not work. Acting quickly is not as daring as it sounds. Genetic studies indicate that most tree species are non-optimal for their current environments and in a state of “adaptational lag” (e.g., Namkoong 1969; O’Neill et al. 2008).

British Columbia has proceeded farther and faster than most jurisdictions in anticipating how to get the right species in the right place (e.g., Wu & Ying 2004; Ying & Yanchuk 2006). Tools to help guide assisted migration or colonization have been developed (e.g., Wang et al. 2010). Small changes in seed transfer standards that address elevational lags in trees species adaptability are under way, including assisted migration trials (O’Neill et al. 2008; Johnston et al. 2009). Because the uncertainty is high, several approaches are necessary. Species at the edges of their ranges (both latitudinal and elevational edges), but near areas that are predicted to become favourable, should be encouraged as regeneration or retained as future seed sources. Local gene pool and seed tree zones should allow for increasing regional genetic diversity by using tree seed sources from southern or lower-elevation seed zones in some regeneration efforts. Perhaps more important will be allowing natural regeneration from lower-elevation or southerly areas to migrate by retaining seed sources and protecting existing regeneration to maintain useful genetic variability, especially at edges of ranges. To inform management, such new approaches should be included among high priority elements of monitoring intended to emphasize and expose the future. Monitoring to allow early detection and reaction to regeneration or stand establishment problems will be critical.

Encourage connectivity

Mawdsley et al. (2009) found commitment to increasing connectivity common among strategies for adaptation to climate change. Managers, purposefully or not, plan landscapes in patterns that either enable species to move or put obstacles in their way. The importance of doing what is possible to facilitate migration of tree species is noted above. To sustain healthy systems, it is equally important that other species can migrate as well, including those birds and mammals that disperse tree seeds. Currently, the province exhibits little co-ordination of landscape planning approaches. This is a grievous lack because both the non-harvestable and harvestable land bases have roles in creating resilience (examples in Campbell et al. 2009). Landscape disturbances will increase with climate change and landscape planning should be able to respond and adjust to these changes. The relegation of planning to companies and "professional reliance" seriously undermines planning at the scale needed to confront the challenges of climate change.

The lack of a province-wide vision and failure of broad-scale planning almost certainly will cause future grief. We can, however, attempt to facilitate species movement necessary to maintain healthy systems by landscape planning. More mobile species can choose to move significant distances quickly (Bunnell et al. 2008); other species move more passively by gradual establishment of dispersing seeds or being nudged by shifting sources of food and shelter. Given the uncertainty, the prudent approach is to leave more of stands and landscapes behind after harvest. More or larger retention patches enable animal species to move and provide areas where trees, shrubs, herbs, and other organisms can live and subsequently migrate. Retention across the landscape provides the same services over a larger area. Not planning for retention, removing retention because it might die, or reducing planning for old-growth patches because disturbance may kill them, all ignore future uncertainty and reduce our future ability to respond. Areas for retention can be chosen so that these have the greatest likelihood of persistence; replacement areas can be planned. Any successful landscape planning requires co-operation with neighbouring tenures.

Nurture acceptance and adaptation

Some of the changes recommended, such as relaxing regulatory standards on species composition, could startle the public. We need education to encourage changes in society's expectations about future forest values and the management practices and policies intended to increase resilience. The list of potential topics is long but includes more flexible standards, changes in rotation length and practices, expected directions of regional species change, regional reductions in harvest, approaches to wood salvage and processing (including biofuels), associated changes in other resource values, and public water use. Campbell et al. (2009) noted that only about 1% of the harvestable land base is harvested annually, greatly constraining our ability to introduce policy and practices to increase resilience. Harvesting more will not help; emphasizing the urgency in formulating approaches and nurturing acceptance will. Public values will likely shift to emphasize the production and protection of water in our forests, sequestration of carbon, and (possibly) protection of biodiversity, so focussing primarily on timber is not appropriate.

Reduce carbon emissions

Reduction of CO_2 emissions is clearly key. It also will happen, if for no other reason than youth will become aggrieved enough to demand a future. There are numerous ways the practice of forestry, from stand establishment through milling operations, can reduce emissions (e.g., Jandl et al. 2007; Campbell et al. 2009; Daniels 2010). A major problem, however, is that the largest source of CO_2 equivalents for dimensional lumber is transportation from the sawmill to the consumer (94% in studies of White et al. 2005). There will be greater need for fire prevention and control and likely rethinking of policy and practice in areas adjacent to current communities. A key point is that anticipating species' responses and assisting those to increase resilience has the significant consequence of encouraging carbon sequestration over carbon release.

Conclusions

There is little doubt that the climate will become warmer. We are less certain how regional patterns of precipitation will change. This is unfortunate because moisture stress strongly influences tree growth and resistance to pathogens. We are still less certain about the rates of change for either temperature or precipitation. The only certainties are that change has begun, forests are beginning to respond, change will continue, and current directions are unfavourable for many current tree species. Forests will change; experience to date indicates that the seven broad actions described here can help to make changing forests more climate resilient.

We note seven broad actions to promote climate resilience:

- avoiding entrapment,
- emphasizing the future,
- adopting a policy of no regrets
- seeking the right species at the right place
- encouraging connectivity
- nurturing acceptance and adaptation
- and reducing carbon emissions.

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Test Your Knowledge

How well can you recall the main messages in the preceding article?
Test your knowledge by answering the following questions.

Actions to Promote Climate Resilience in Forests of British Columbia

1. The authors argue that we should pursue ecosystem resilience because:
   a) It is cheaper to pursue than is mitigation
   b) Change is inevitable; we cannot "climate proof" a natural system, so must confront change
   c) It is becoming faddish and we should not be left out

2. The authors note seven actions that should increase resilience. Among these seven, the province has done best at:
   a) Seeking the right species at the right place and encouraging acceptance and adaptation
   b) Embracing new approaches and reducing opportunities for regret
   c) Encouraging connectivity and reducing carbon emissions

3. The authors interpret major impediments to creating resilient forests to be:
   a) The lack of a province-wide vision and failure of broad-scale planning
   b) Lack of experience in monitoring
   c) Insufficient funding

ANSWERS: 1=b; 2=a; 3=a