Management of British Columbia's Forests in Response to Climate Change

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Abstract

Climate change is an undeniable global event. Widely believed to be caused by human activities that release greenhouse gases, this change in climate will occur over a very short period of time when it is compared to natural climate variations. The effect the change will have on environments is somewhat unknown and any predictions are best guess scenarios. In British Columbia the mountain pine beetle has destroyed millions of pine trees but the infestation is not yet done. This may be one of the early symptoms of global warming on the British Columbia environment. Climate change will warm temperatures in BC and increase the annual precipitation. These warmer temperatures allow for longer growing seasons and in many cases, more favorable growing conditions. Studies on Sitka Spruce have found increases in volume growth by as much as 20% and growth in the boreal has been found to increase with higher CO_2 levels and warmer temperatures. Climate change does not have to mean beetle epidemics and dying ecosystems. With proactive management British Columbia may actually find benefits in a warming climate.

Keywords: global warming, climate models, adaption, migration, ecosystem, silviculture, management.

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Introduction

Forests in British Columbia cover 60 million ha of the land base. These forests provide numerous benefits for the people of the province including, recreation, food gathering, employment, and much more. The world is experiencing a change in climate which will affect global temperatures, precipitation, and general weather patterns. The extent to which the climate will actually change is unknown but estimates of global changes have been created using climate models. British Columbia, which is influenced by temperate and northern climates, is expected to have temperature changes greater than the global average. These changes will affect the biotic communities leading to large changes in ecosystems. Vegetation and their predators (pests and disease) will be affected differently and will need to be closely monitored to ensure ecosystem balance is retained.

The first part of this paper is background information to ensure full understanding of the latter part. Climate change is going to happen. The extent to which it occurs is unknown and the affects it will have are just as uncertain. By creating proactive solutions, forest managers in the province may not only be able to lessen the negative effects that may fall upon the forests, but to harness positive effects of climate change. British Columbia has a relatively cold climate with short growing seasons. If warming brings higher temperatures and longer growing seasons, with careful planning, forest productivity may actually increase. The paper will begin with an overview of what climate change is.

Climate Change Overview

Climate Change Worldwide

Climate change is a worldwide phenomenon of changing climatic conditions. The extent of the change would be variable throughout the world though it is generally accepted that the largest changes will be in continental areas of higher latitudes (Bernstein, 2007). Though the extent of the potential change is unknown, even a small change in global average temperature is expected to have significant consequences including receding glaciers, melting ice packs, and a rising level of the worlds' oceans. Historically, climates do vary but the changes occur over thousands of years. This particular occurrence of climate change is widely accepted to be caused by human activities, particularly through the release of greenhouse gases and is expected to occur within this century. "The rate of warming will be faster than has occurred in the past and there will be an increase in the frequency and intensity of extreme temperature and precipitation events" (Spittlehouse, 2007). Greenhouse gases include carbon dioxide, methane, nitrous oxide and others. These gases "absorb [the sun's] infrared radiation and trap the heat in the atmosphere" (Administration, 2008). Higher concentrations of these gases mean more heat is trapped, thus contributing to a rise in global temperatures (Figure 1).

There are many models representing the potential change in global temperatures. The models do not always agree which tends to project a high level of uncertainty. As climate change is believed to be closely linked to greenhouse gas emissions, particularly CO_2, changing the global emissions regime changes the models' results. In the next century, models are predicting a change of 0.5 to 4 degrees Celsius in global mean temperature (Spittlehouse, 2007). An increase of 0.5 degrees is based on a complete cut in CO_2 emissions whereas an increase of 4 degrees is based on current trend CO_2 emissions. Examining global changes does little to aid in an analysis of specific areas. For more relevant changes let's look at expected changes in British Columbia (BC).

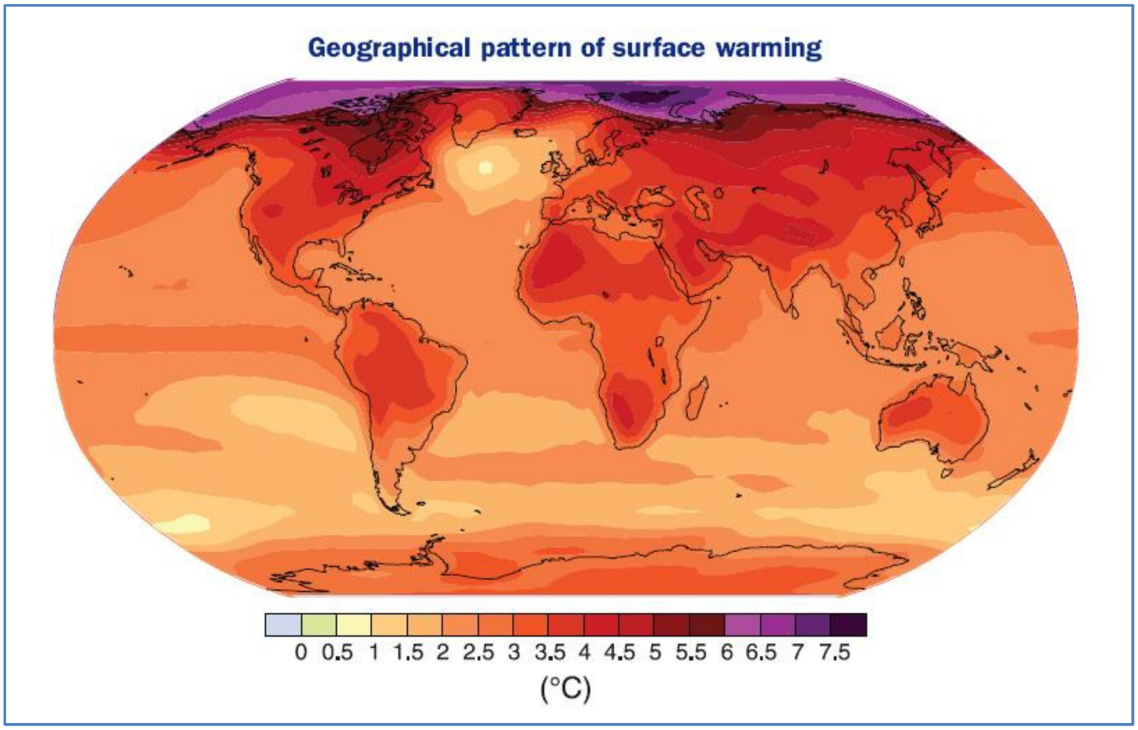

Figure 1: Projected surface temperature increases for the late 21st century (2090-2099) as compared to the late 20th century (1999- 2000) (Bernstein, 2007).

Climate Change in British Columbia

British Columbia is rich in diverse landscapes and ecosystems. The landscape largely affects the climate in the province which creates the many ecosystems. "British Columbia will have greater warming and changes in the precipitation regime than the global average. All models and emissions scenarios predict an increase in winter and summer temperature. Warming would be greater in northern British Columbia than southern British Columbia" (Spittlehouse, 2007). Changes would be more severe in the winter months; winter minimums in the future may be as high as 9 degrees warmer than current winter average minimums. The smallest changes will be seen on the coast where temperatures are moderated by the ocean. Figure 2 demonstrates the changes in temperature between present day and periods throughout the next 100 years.

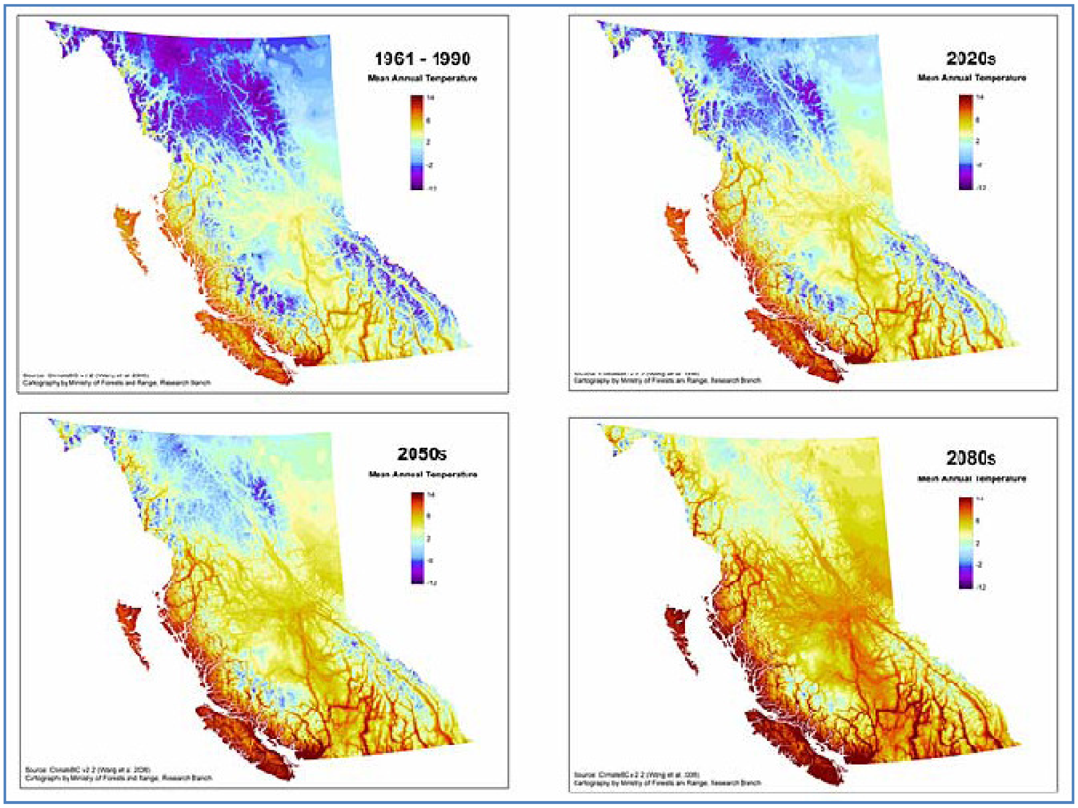

Figure 2: Mean annual temperature for BC for current climate (1961–90 average) and that predicted for BC in 2020s, 2050s and 2080s for the A2 scenario (Spittlehouse, 2007)

Large changes in climatic conditions will make many forest species that are adapted to their current conditions maladapted for the future conditions of the same site. A basic measure of suitability can be completed by viewing the distribution of biogeoclimatic ecosystem classification (BEC) zones in BC. The BEC zones incorporate climate, soil, and vegetation data to map ecosystems throughout the province. Each BEC zone is divided into subzones each with their own variants that help distinguish ecosystems. BEC zones are often associated with some unique ecosystems and vegetation. The zones themselves are generally named after the species that occurs on zonal sites in climax ecosystems (Meidinger, et al., 2005). As the "climate is the most important determinant of the nature of terrestrial ecosystems," a change in climate would most certainly result in a change in ecosystem development (Meidinger, et al., 2005). It is uncertain exactly what will happen to regional climatic conditions during climate change, however, figure 3 demonstrates potential BEC zone shift in BC by the year 2080.

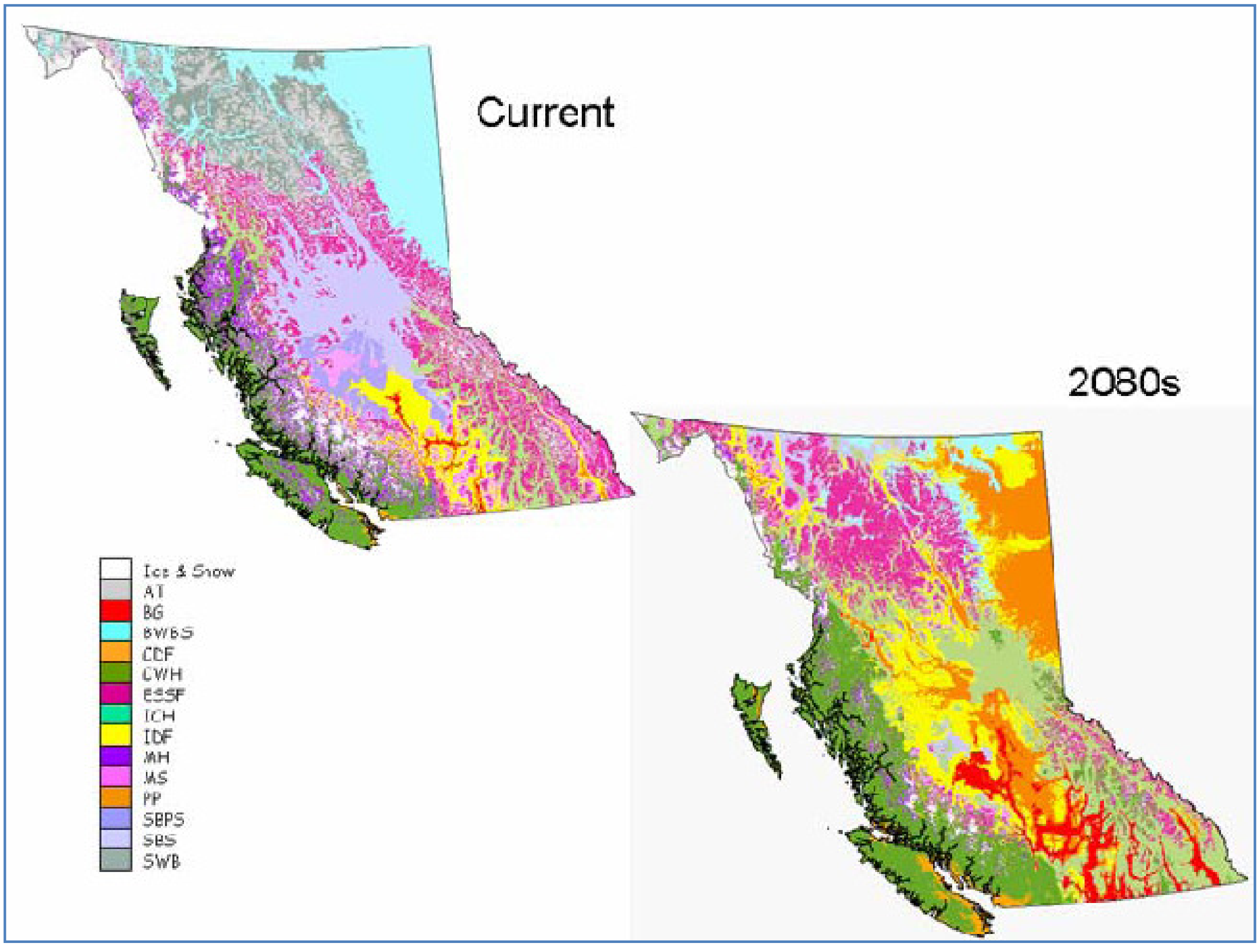

Figure 3: Biogeoclimatic zones in BC and where their climates might occur in the 2080s under the A2 climate change scenario (Spittlehouse, 2007).

Some trends that can be noted in figure 3 are that the shift of BEC zones tends to be northward and uphill. In this model it is apparent that some BEC zones will increase in size, whereas, others will essentially disappear. The Bunch Grass, Ponderosa Pine, Interior Douglas Fir, and Interior Cedar Hemlock are the most notably expanded zones; whereas, the Mountain Hemlock, Spruce-Willow-Birch, Sub Boreal Pine-Spruce, Sub Boreal Spruce, and Boreal White and Black Spruce will all but disappear. The Engelmann Spruce Sub-alpine Fir will still be a dominant BEC zone; however, it will have shifted northward to occupy most of what were once the Spruce-Willow-Birch and Boreal White and Black Spruce zones. The shift in BEC zones does not necessarily mean that species that currently occupy these areas will die; however, it will mean that many of them will become maladapted.

Biotic Responses

Vegetation

"Vegetation responds gradually to climate change" (Chapin, et al., 2004). This may be expected as climate changes in the past have been 'gradual'. The change in global mean temperatures that may occur over the next century will be much faster than most changes in the past. This will result in large populations of vegetation that will be maladapted to their local climate. "Species will respond to these climate changes either by adapting in place, migrating, or going extinct" (Gayton, 2008); (Aitken, et al., 2007). "Trees usually adapt to changing climatic pressures through natural selection or gradual movement of seeds to more hospitable regions" (Group, 2008). Commercial tree species, which are long lived and late to mature, will not be able to naturally adapt to the rapid changes. Findings from interpreting fossil pollen data shows tree species, responding to post glacial warming, moving north at a rate of up to 1000 metres per year (Pearson, 2006). Further studies have shown that the "actual migration rate estimates [are] less than 100 m per year" (Aitken, et al., 2007). These were unfortunate findings as the estimated migration rates required for plant species to follow the climate trends would be in the order of 1000 meters or more per year (Aitken, et al., 2007); (Pearson, 2006).

Though species may become maladapted, it does not mean that they will die. Species can be quite resilient and often survive in sub-optimal conditions. Usually, under these circumstances, competition between species for light, water, and nutrients, leads to one species out-competing another and thus dominating in a landscape. *Most* trees will grow in *most* places; they may not grow well, but without competition they will persist. Forests stands we see are comprised of specific species, and genotypes of a species, that were successful at establishing themselves better than others. With the climate shifts being so drastic and at large magnitudes, it is expected that no species currently existing in an area will be well suited for that same area in the future. "As all tree species will be suffering... interspecific competition may weaken, facilitating persistence under sub-optimal conditions" (Aitken, et al., 2007).

Pests and Diseases

Compared to warmer places in the world, BC has relatively few pests and diseases in their forests. This is mostly due to the fact that cold winter climates found in BC is not accommodating for many species. As temperatures begin to increase many pests will be able to survive winters, allowing them to establish stable/expanding populations. These ‘pests’ may come in a wide variety including foliar diseases, root diseases, defoliating insects, bark beetles, wood borers etc.

“Of all forest life, insects, which are cold blooded, are probably best equipped to adapt to climate change” (Service, 2003). “Increased warming would most likely increase the diversity of insects at higher latitudes. Insects typically migrate much faster than trees. “Many temperate tree species are likely to encounter non native insect herbivores that previously were restricted to subtropical climates” (Dale, et al., 2001). The effects of non native pests on native species are unknown; however, the potential for it to be devastating is a possibility. Native species that are usually held below epidemic levels by climatic conditions will be able to thrive in the warmer temperatures. One bold example of this is the mountain pine bark beetle that has recently devastated the pine forests of the BC interior. Scientists uncovered a substantial shift in climatically suitable habitats for the mountain pine beetle in the latter half of the 20th century. The shift, northward and toward higher elevations, has been followed by mountain pine beetle populations” (Service, 2003). It’s widely accepted that early winter temperatures in the past decade have been too warm to alleviate beetle populations, allowing them to reach their epidemic numbers.

Climate Impacts on Vegetation, Pests, and Disease

For the existing vegetation, the outlook is somewhat grim. The vegetation will be encountering stress as a direct result of the changing climate in the form of droughts, extreme temperatures, high winds, heavy rains and other weather phenomenon. “Different effects result in combinations of problems such that drought may weaken tree vigour, resulting in an increased susceptibility to insect infestations” (Dale, et al., 2003). Such combinations may prove devastating on the forests of BC. As previously noted, most species will experience adverse conditions that will weaken interspecies competition; essentially the whole province will become highly prone to insect and disease infestations.

Trees are an extraordinarily hardy group of species that can withstand great deals of stress and other adverse problems. This “resilience can lead [people] to expect current vegetations to persist indefinitely” (Chapin, et al., 2004). Under normal circumstances this may be true; trees can handle short term stresses very well. With climate change in mind, however, the poor conditions are long term. The local conditions that the tree is adapted for will change. The tree will be placed in a near-constant state of stress making it highly susceptible to insects and other diseases.

In the past, occurrences of climate change have altered the distribution of ecosystems and the life that was found within them. These alterations took place over long periods of time with species migrating, evolving, adapting, or dying. In a natural environment the changes are somewhat predictable. Modern climate change has another variable contributing to unknown outcomes. “Human activity combined with climate change can precipitate ecological changes of much greater magnitude than climate change alone” (Chapin, et al., 2004). An example of human influence on ecological change in past can be found in the boreal regions. At one time, vast steppe-grasslands covered much of the north. These grasslands supported many large “animals [that] disturbed and fertilized the ground sufficiently to, in turn, maintain productive steppe-grassland” (Chapin, et al., 2004). The grasslands and the large animals coexisted, each supporting the other. When humans began migrating north, they hunted heavily causing many of the animals to disappear. Consequently the vegetation changed from steppe-grassland to moss-shrub tundra, a much less productive ecosystem (Chapin, et al., 2004). Human impact on the environment is far greater than it was in the past. This is shown best by the fact that the current change in climate has been caused by human activity. It is known that humans can largely affect the outcome of environmental situations, but in this particular case, will the outcome be positive or negative?

Managing for Climate Change

Much of the world will face climate extremes that may severely harm ecosystems and the way of life of the people who live in these regions. Fortunately, BC is in an area that has relatively cooler temperatures than the rest of the world and some warming may not be a terrible thing. Much of the interior and northern parts of BC have cold winters and relatively short growing seasons. If approached in the correct way, the warming caused by climate change may come as an opportunity for BC. Figure 3 demonstrated that both the Coastal Western Hemlock and Interior Cedar Hemlock zones increase significantly in size. Given that these are the two most productive BEC zones in the province, an increase in their size is very good news for commercial tree growers.

Managed Stands

Forestry is one of the oldest and most important industries in BC. There are communities throughout the province that were built around and rely on the forests for their livelihoods. With the negative impacts that the forests are facing with climate change the outlook for these communities is grim.

To ensure the continued viability of commercial forests some actions will need to be taken. Forests will face many problems including phenotypic responses and insects and disease. The maladaption that trees will develop can be deviated by applying certain treatments to stands. Certain aspects of trees and stands make them susceptible to various pests and diseases. By removing the characteristics of the stand that make them susceptible to the most imminent pests and diseases, the life span and viability of the maladapted forests will be maximized.

There are some measures that can be taken to overcome abiotic stresses. In stands that may suffer from drought, thinning treatments may help prevent excess evapotransporation from the site. In coping with increased fire frequencies, fire fuel reduction programs could be created to reduce fire risks. Using shelter wood silvicultural systems may increase the likelihood of successful regeneration in dryer and hotter times. Members of the Alex Fraser Research Forest use this method in the dryer portions of the Interior Douglas-fir biogeoclimatic zone to regenerate Douglas-fir. Without this method, direct sunlight on hot days heats the soils too much for seedlings to survive. Shelter wood systems may also help with off season frosts. Though the general trend of climate change is warming, there will be events of extreme weather which may include early or late frosts. Canopies of trees can hold enough heat in that, at night, temperatures can remain above freezing, even when temperatures outside of the stand may drop below zero. Careful attention should be given to cutblock design when considering climate change. Extreme weather events may also include heavy winds or precipitation. Cut blocks should be designed to minimize the effect of winds on reserves and adjacent stands. For example designers of blocks should avoid long narrow cuts that winds can funnel through creating high destructive potential. As well, when constructing roads it is important that culverts and ditch lines are adequate to accommodate potential greater than average rain events. Long stretches of ditch line should be avoided to minimize water damage to roads, and to avoid siltation of water resources.

Biotic factors will also contribute greatly to the health and well being of forest stands. As the stands become stressed from abiotic factors, they also become more susceptible to insects and disease. Often, insects are attracted to stands by a few sick trees. Once they are established, they then attack the healthy trees nearby. In managed forests, active monitoring may find susceptible trees than can then be removed. In areas where there are existing beetle infestations, there are various methods which have proven effective when pest populations are below epidemic levels. The most effective methods are preventative ones (Schmitz, et al., 1996). When managing for Douglas-fir bark beetle “prompt detection of blow down or other stand disturbances, timely removal of threatened or infested trees, and maintenance of a vigorous stand” are key (Schmitz, et al., 1996). A reactive approach that has been used is to create susceptible trees by cutting them down and making piles. When beetles from surrounding stands come to infest the logs, they are burned. This can be risky; if the logs are left to long, the beetles may spread in greater numbers than they were previously. Realising that maintaining a vigorous stand under the influences of climate change is difficult, these precautions are to allow these stands to reach an age when they can be harvested. A method called ‘fall and burn’ is used in parts of the province in efforts to slow the spread of mountain pine beetle. Infected trees are cut down and then piled and burned, killing the beetles and their young.

Eventually, the effects of climate change will make existing stands unproductive. The goal of these activities is not to maintain stands for long periods, but to allow them to reach an age they can be harvested and effectively utilized. Upon harvesting they will be regenerated; this process will described be under the heading Future Stands.

Future Stands

The greatest potential for increasing stand yields in BC forests is in the future stands. With careful planning through scenario analysis and predictions of future climates, it may be possible to take advantage of warmer climates and longer growing seasons. There are many restrictions to increased growth potential that need to be addressed; some of which are politics (can be controlled) and others are environmental factors other than temperature (cannot be controlled).

There are political safeguards in the province of BC to ensure the forest resource is managed in the best known possible manner. One safeguard is that in order to practice forestry in BC a person must belong to the Association of BC Forest Professionals. These personnel are trained and experienced in forest management and no major decisions are to be passed without first passing through these people. This ensures actions in the forest are first approved by the most qualified people. Another safeguard is the presence of the Ministry of Forest. This government body oversees large companies that operate on crown land to ensure the forest resource is protected. The most relevant safeguard to this paper is the presence of seed use and transfer standards. These standards have been developed based on years of study with provenance trials.

"The purpose of [the] standards [are] to maintain the identity, adaptability, diversity and productivity of [BC]'s tree gene resources" (Snetsinger, 2004). Created using data collected from many years of provenance testing, seed transfer zones are areas of similar climate where trees can be moved around within. With only very special exceptions are trees moved across seed transfer zone boundaries when they're destined to be planted on crown land. Fortunately, provenance testing, which determines what tree families perform best in stable environments, can provide information for population response curves. "Population response curves should be used to predict the maximum extent to which seed can be moved from milder to colder climates for reforestation in the short term and tree growth in the longer term, and seed transfer guidelines should be changed accordingly" (Aitken, et al., 2007). Transfer guidelines would need to be changed to accommodate assisted migration. By moving tree families northward or uphill it may be possible to match their environmental requirements with the environment, ensuring maintained optimum stand growth.

The uncertainty associated with climate change is great. Even though modelling may allow predictions to be developed on which trees to plant and where, if the models are wrong, the results could be devastating from an economic perspective. To assist in overcoming this potential pitfall planting a large diversity of species may curb any issues. A large diversity of species will minimize the potentials for large outbreaks of pests and disease as they are often specialized to one or two species. Traditionally, forestry in BC has been dominated by the harvest of conifers, and re-introducing deciduous components into commercial forests may help fill gaps caused by misplacement. Deciduous trees tend to be more tolerant of varying climates and have better potential for being productive. To further add to the diversity of species choices, but perhaps complicate some political rules, is to introduce species that are not yet native to BC. These would be species south of BC, that currently do not have range within the province, but which the climates may one day support in BC. An example would be introducing the Redwood or Giant sequoia to forests in the southern portions of the BC coast. Small projects on private land have shown that these species can compete with and in places outperform the local species in a stand environment.

By addressing the above concerns progress can be made by utilizing the longer growing seasons and increased concentrations of CO_2 in the atmosphere. As can be expected, longer growing seasons and increased temperatures, so as they are not extremely hot, would mean increased stand yields. Studies have found that "growth responses of boreal species to elevated CO2 ... increase with temperature" (Aber, et al., 2001). In this particular case, both the cause and the effect of climate change are benefiting to the productivity of boreal forests. Effects of drought may be deceased as increases in CO2 concentration increase water use efficiency and thus reduce water stress (Aber, et al., 2001). Other studies on Sitka Spruce have shown that increased temperature and growing season may increase volume gain by up to 20% (Krakowski, et al., 2004). These results would only be found in areas that receive a certain amount of water, but the regions where Sitka Spruce is commercially grown on a large scale have seasonal averages well above the minimum required. These are just a few examples of the growth potential associated with climate change and well managed forests in the future.

Natural Stands

Whereas managed stands now and in the future can be ecologically 'reset,' the large part of the province that is parks and other non industrial forests must face climate change alone. Species in natural stands may react to climate change in three possible ways: migrate to a more suitable location, adapt to the conditions at their current location, or be extirpated from their current location (Aitken, et al., 2007). Some select populations may purely persist.

Species migration can occur in several ways. One way is through long distance dispersal where species migrate towards areas with preferred climate. In the current shift of climate, the natural migration capacity of species (approximately 100meters per year) is less than the required distance (greater than 1000meters per year) to be successful. Another method of migration is through 'local migration'. The term 'local migration' seems like an oxymoron but the implication is that members of a particular genotype that live at the edges of their natural range are able to reproduce locally. The climate in these areas may have been borderline at one time; changes may have created favourable conditions. "In some cases, at high-latitude or high-elevation tree limits, advanced colonization may have already created islands of stunted ''krumholtz'' individuals that can develop into erect tree form and become reproductively capable with climate warming" (Aitken, et al., 2007). Finally, there is assisted migration. When climate change moves favourable conditions many kilometres from a site the existing tree species will not be able to migrate fast enough. When this happens humans can assist in the migration of species. This does not mean planting entire areas with more suitable species and genotypes. Assisted migration can be accomplished by simply creating patches of climatically suitable vegetation in the new area. With time they will mature and produce offspring that can colonize the nearby areas. This could be completed in parks where the conservation of generally a priority. As for the rest of the non-industrial forest in the province it is uncertain whether anything could be done for them. An assisted migration project would probably be very expensive and would be focused on the most important areas, including parks, and rare or endangered ecosystems.

Human involvement in the natural forests is limited to assisted migration and forests will adapt through natural processes. Stands that will be most successful in adapting will be those that have high genetic diversity, high populations, and high reproductive rates (Aitken, et al., 2007). Selective breeding of trees may produce offspring that are more suitable for local sites than their parents. This may create a form of 'assisted adaption'.

Vegetation that does not successfully migrate or adapt may be extirpated from the local environment. In extreme cases where the entire species has very limited geographic locations, extinctions may occur.

There is a possibility that some populations may not react to climate change and they may simply persist. They may not perform at their optimal levels, but there is an ability to persist. The most likely species to accomplish this are the 'adaptive generalists'. Adaptive generalists have limited genetic diversity but are often able to grow in extensive environments. Species such as Western White Pine are adaptive generalists and can grow in many different areas. For this reason it has no transfer limits set by the seed transfer standards. Species such as Douglas-fir that have very high genetic diversity are less likely to persist, but have high probabilities to adapt.

Conclusion

Climate change is almost always presented as being a bad event, probably because such a large change in global climates is being caused by human actions. In BC, where it is on average cooler than other places in the world, some warming does not have to be a bad thing. So long as the negative effects are realized and measures are taken to overcome them, forests will be able to migrate or adapt, and hopefully extirpated populations can be minimized. It has been demonstrated that higher levels of CO_2 and warmer temperatures can actually increase volume growth in different species throughout the province. More effort should be put into capitalizing on the future potential of climate change. Climate change is bringing with it an opportunity for higher yielding forests or more diverse species. This opportunity should be embraced.

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