Background for a Conversation on Climate Change in the Nadina Forest District[1]

British Columbia's forests already have experienced the possible effects of climate change, from the mountain pine beetle outbreak in the interior, to *Dothistroma* needle blight in the northwest, to extreme windstorms on the coast. These types of events are expected to become the norm. Due to lag effects of global climatic systems, significant climate change will take place despite current efforts to reduce greenhouse gas emissions. Government agencies charged with managing forest ecosystems have begun the task to understand how to adjust our management systems to prepare for and adapt to dynamic, complex, ecological and climatic systems.

The workshop "Adapting Nadina Forest Management to Climate Change" is intended as a step in an ongoing dialogue among scientists and forest managers about preparing for and adapting to climate change in the Nadina Forest District. Workshop exercises will address a list of potential climatic and ecological changes. To help participants envisage the potential "net effect" of the various individual changes that are being anticipated (e.g. reduced precipitation, increased facilitated migration), workshop participants will be presented with two stories (scenarios). Scenario-based approaches are being used increasingly as a technique to help decision makers consider options in the face of uncertainty.

These two scenarios do not predict what **will** happen. Instead, the narratives depict what **could** possibly happen given a set of assumptions about how the climate could change, how people locally, as well as globally, may react, and how ecosystems may respond. The future will likely contain elements of both scenarios, and even more likely, other unforeseen events or outcomes. They are written from the perspective of someone in the year 2050 looking back over the previous 50 years of climate change and describing how events have played out. The scenarios were built using the known science relevant to climate change and to impacts on species, ecosystems and human communities. They are intended to read like a true history of major environmental and social events and trends. The Intergovernmental panel on Climate Change's (IPCC) climate scenarios informed the human dimension and social assumptions in the scenarios.

Additional background information about the scenario approach s provided at the end of the narratives.

[1] The material presented has been adapted from Morgan, D.G. 2009. Exploring the Future: Policy Workshop Information Package. Workshop background package to Future Forests Ecosystem Initiative policy workshop. March 11, 2009, Victoria, B.C.

Year 2050
Implications of the last 50 years of climate change on British Columbia's Forest and Range Ecosystems

Scenario 1: Managing for Resilience

Scenario Summary

Climate	Moderate climate change
Rate of Change	Gradual
Future	Some uncertainty, limited predictability
Temperature	2º C warming globally
Precipitation	Mixed: wetter winters, drier summers in south, wetter summers in north
Extreme Events	Moderately increased frequency of extreme events
IPCC Global	
World	Extensive international co-operation
Economy	Service and information focus; moderate economic growth
Population	Peaked in 2050 and then declined
Governance	Global solutions to economic, social and environmental sustainability
Technology	Clean and resource efficient
Management	
Management Emphasis	Ecological resilience, water and carbon
Economic Emphasis	Flexibility, lots of redundancy
Mitigation	Extensive carbon emission reduction and efforts to store carbon
Adaptation	Risk management strategy adopted
Integration	Integrated adaptation/mitigation strategies
Timber Harvesting Landbase (THLB)	Increase in non-productive forest area due to grassland expansion and planting failures.
Forest Industry	AAC = 30 M m3/year, mostly salvage from natural forests. No harvesting of green old growth since 2020. Industry competiveness weak due to cheap timber from developing world.
Range	Forage supply has increased mostly in the central part of the province.
Ecological Processes	
Pests/Pathogens/Disturbance	Moderate increase in disturbance frequency and extent
Ecosystem Productivity	Mixed: improved in north, reduced in south due to reoccurring drought and loss of soil biotic community.
Hydrology	Impacted by droughts in south
Geomorphology	Increased landslide and mass wasting frequency and extent especially on the coast.
Ecosystem Components	
Ecosystems	Some grassland expansion
Soils	Some loss of diversity and productivity
Water	Increased sedimentation and reduced flows in south
Genetics	Reliance on assisted migration - generally successful
Aquatic Biology	Salmon restricted to north
Wildlife	Increase in number of species at risk, range changes, increased disease outbreaks
Biodiversity	Shifts in diversity, decline of specialists, increase in opportunists, increase in alien invasive species
Carbon balance	Increased uptake in the north and reduced decay rates in the south due to drought were mostly offset by increased disturbances resulting in a carbon-neutral forest.

Drivers

Climate Change
The rate of climate change over the last 50 years has been relatively gradual, unfolding in a way that has been consistent with the more optimistic estimates made early in the century. Overall, the mean winter temperatures have been milder, glaciers and snow packs have been reduced; we now have hotter and drier summers in the southern part of the province and warmer conditions in the north. The climate is more variable year to year with an increase in frequency of extreme weather events over that recorded in the previous century. The coast has warmed less than the interior, is wetter in winter and has more storms than were the case historically.

Global Context
The carbon incentive programs implemented in the 2010s, based on the 2009 Copenhagen Agreement (which paved the way for broad global agreement on drastically reducing carbon emissions), have been recognized as being key to the reorganization of the global economy over the past 40 years. Economic development is far more focused on ecological and human sustainability, with carbon management as its primary goal. Social and environmental consciousness was ignited in the 2010s when the global implications of run-away climate change became more evident Rapid changes in policies were precipitated by the extensive forest die-back due to large insect outbreaks (e.g., the boreal forest-wide mountain pine beetle (MPB) epidemic of 2013), intense forest fires, in particular the Australian bush fires of 2009, and the collapse of portions of the western Antarctic ice sheet in 2015 which led to severe coastal flooding in Asia displacing more than 25 million people.

Since the beginning of the 21st century, British Columbia's population has increased by almost 50%, with the majority of the population now living on the east side of southern Vancouver Island, Vancouver, Kamloops and the Okanagan. British Columbians take pride in their wilderness and as the population increased so too did the visits to wilderness areas. Although skiing in the south has declined with the last 50 years' warming - Whistler/Blackcomb had to close the lower half of their resort in 2025 - it has thrived in the north, particularly the world-class destination resort in Atlin.

In British Columbia, huge investments in technology, coupled with environmental protection to minimize disturbance of existing carbon stores, and more efficient use of resources, has led to modest economic development, a significant change from the rates of growth seen early in the century. A large portion of our current economic productivity is directed to transitioning to post-fossil-fuel technologies. As well, a larger component of a family's budget is now allocated to food, compared to previous generations, due to high cost, low-input, low-impact agriculture, and the maintenance of large areas of wilderness. Bioenergy, considered to be a promising new energy source early in the century, proved uneconomical except as an energy source for mills. Greater efficiency, hydro, renewables and the Princeton Nuclear plant are able to meet the energy demands of the province.

Responses

Terrestrial Ecosystems and Wildlife
Ecosystems are far more stressed than they were historically, particularly at the edge of their distributions. Efforts to enhance the resilience of forests to environmental stress - through mixed planting and an expanded reserve network - have been recognized as being critical to keeping forests within their bounds of adaptability. There has been a gradual decline in some tree species that were once commercially important, such as western red cedar on the coast, while Douglas-fir and grasslands have expanded throughout much of the drier portions of the interior. The grassland expansion has resulted in a reduction of the land available for timber harvesting; economically this has been somewhat offset by an increase in land for grazing. Extended growing seasons appear to be increasing annual

growth increment in some regions, particularly in northern climes and at higher elevations. Climate-change impacts have had less of a negative impact on forest productivity than previously anticipated back in 2010. In north-central British Columbia productivity has increased as a result of longer growing seasons and milder winters. Where natural regeneration may have been previously encouraged, particularly for those species lacking tree breeding programs, it is now strongly discouraged in most regions of the province. For the past 20 – 25 years, reforestation and rehabilitation efforts depended largely on "Assisted Migration" to move climatically-adapted genotypes into ecosystems outside their species' and/or natural range. This program was fast-tracked back in 2015, despite the failure of early trials. As a climate-change strategy it has been an overall success and has also been extremely beneficial for increasing the storage of carbon in forests.

By comparing conditions 50 years ago with today's ecosystems, recent research has revealed reductions in the diversity and abundance of critical soil biota, such as mycorrhizal fungi, and a proliferation of 'weedy' species in those ecosystems exhibiting the greatest symptoms of decline. This pattern is echoed in plant and animal populations, heightening ongoing concerns about the influence of landscape fragmentation on the ecological integrity of managed forests and grasslands. As some the worst effects of climate change were realized, the potential for reduced soil fertility resulted in the development and enforcement of minimum-debris-retention guidelines, and the identification of sensitive site types where all timber harvesting has been restricted. On a somewhat positive note, the decline in abundance of soil biota and increased drought has, in some places, reduced carbon losses from soils.

Large landscape-scale disturbances continued to occur more often in the 21st century, starting with the MPB outbreak back in 2000-2015, then the spruce beetle outbreaks in the north in the 2020s, followed by a series of bad fire years in the 2030s, similar to that seen 100 years earlier. As well, there has been substantial degradation and fragmentation of terrestrial wildlife habitat through the combined effects of past land management practices and increased rates and extent of disturbance. This has been particularly devastating for old-forest-dependent species, such as Woodland Caribou and Spotted Owl. Despite expensive last ditch efforts, the last Spotted Owl died in captivity in 2028. Although Mountain Caribou have been largely extirpated from the south, the habitat set-asides from early in the century have proved valuable for maintaining other species.

It had been assumed that species would shift their ranges north and upwards in elevation following their preferred climatic conditions. This did occur for some species of plants, birds and coyotes. However, most species lacked the ability to disperse to new range, particularly if it was not adjacent to their historic range and did not have suitable habitat, or was already occupied by a competing species. The species that were at the southern part of their range were the most challenged, while those in the northern part of their range, in some cases, have expanded, including several species that were historically listed as at risk.

Overall, there has been a 20% decline in species abundance across the province compared to the turn of the century. Furthermore, the list of species at risk has steadily increased over the last 50 years, in some cases severely limiting timber harvesting and has lead to the constant debate about the amount of effort to preserve a species in a place that is no longer climatically suitable. The final demise of the Vancouver Island Marmot was attributed to a climate change-related short term increase in snow depth that occurred earlier in the century, corresponding to the time when the marmots emerged from hibernation to forage. In general the snow depth now is far below that typically recorded in the last century. As well, over the past 50 years, an increasing number of birds seem to arrive earlier every year. There has been a steady decline in waterfowl populations due to shrinking wetlands, especially wetlands that were historically sustained by snow pack. There has been a disruption in pollination of some vascular plants due a combination of factors: changes in arrival time of migrating pollinators, the invasion of non-local insects displacing historic pollinators, and expansion of pathogens causing disease in certain pollinators. This is causing great concern among ranchers and farmers. As well,

there have been a number of cold-injury events for plants associated with the variable weather. Certain plants have prematurely sprouted in early warm weather, and then died when the weather turned cold again.

Invasive species have become extremely difficult to manage over the past several decades and are currently threatening the integrity of several major ecosystems. Several new human health hazards, including West Nile virus, have become common in B.C., but are being controlled with reasonable success. Other wildlife disease outbreaks have had negative effects on populations of once common game species, including Moose and Bighorn Sheep.

Watershed Processes & Aquatic Biology
Over the past 50 years, there has been major hydrological change, including increased stream and lake temperatures, decreased snow accumulation, an accelerated winter thaw, and ongoing recession of glaciers. In addition, there has been a moderate increase in the frequency of storm events. These hydrological changes have resulted in severe flooding compared to historical conditions. In some areas all infrastructure has been removed from active floodplains, and in others millions of dollars have been spent on upgrading dikes and other flood control structures.

Past increases in landslide rates have continued particularly in Haida Gwaii, Vancouver Island, and along the coast. The rates are now comparable to the rates that were observed in the last century when logging and road-building on steep terrain first became commonplace. The trend of increased rates of major landslide events in northern BC, first observed in the early 2000's, has continued with ongoing rising temperatures. In the north-east of the province melting permafrost areas have caused major localized issues – in fact maintaining infrastructure in many places has become so difficult and costly that forest management activities have been severely restricted.

Sea-level rise has been fairly modest along BC's coastline. The most problematic area has been the Fraser River delta. Additional coastline areas have been subject to increased erosion, particularly in Haida Gwaii.

Because of rising water temperatures, we have seen temperature barriers to fish migration, delayed spawning, and changes in overall aquatic biological productivity. Furthermore, insect and fire landscape-scale disturbances led to dramatic increases in sediment production and subsequent impacts to water quality and fish habitat in affected watersheds. Salmon in the southwest, southern interior and central interior all went into serious decline and the southern stocks became extirpated in 2035. There are growing concerns regarding the introduction of parasites and invasive species into arctic watersheds in the north. Further, rainbow trout eventually displaced the remaining bull trout populations in 2020. However, all is not bad news as the most northern salmon stocks increased slightly from 2015 to 2025 and have been relatively stable since. The small-mouth bass stocking of the 2020s was a huge success and has supported a thriving game fishery in the southern part of the province.

Forest and Range Industry Implications
The timber harvesting industry is prominent in northern interior communities, but has nearly vanished from other parts of the province. The dominant silvicultural systems used in the north are based on salvage of trees recently killed by climate-related stresses (sometimes in clearcuts of several thousand hectares) and replanting the timber harvest land base with better-adapted genetic stock. In most of the southern interior, timber harvests are restricted to selective harvest systems to minimize hydrological impacts. Inter-planting with appropriate species and genetic stock is widespread on both the timber and non-timber harvest land base to maintain tree cover where possible. On the coast, second growth (on the most productive sites) is being managed for long rotations to maximize carbon storage, with minor harvests in the form of commercial thinning only. In 2020, much of the former timber harvested land-

base that had old growth was considered best-suited for carbon storage and various co-benefits, and was officially removed from that land designation.

Forage supply and productivity have changed from year to year. Generally, there has been stable productivity in the south and increased productivity in the north of BC. Some of the increased productivity was due to increased water use efficiency and longer growing seasons. Forage supply and quality in some areas is challenged by an increase in annuals and invasive plants.

In summary, we have managed to modify our forestry and range practices and expectations to adapt to the modern climate with some success. Through our continued participation in international efforts, there is hope that our forest and range ecosystems will be able to continue to provide services for future generations.

Year 2050
Impact of the last 50 years of climate change on
British Columbia's Forest and Range Ecosystems

Scenario 2: Reacting to Chaos

Scenario Summary

Climate	Extreme climate change
Rate of Change	Rapid
Future	Uncertain, unpredictable
Temperature	3 – 5º C warming globally
Precipitation	Wetter winters - more rain and a lot less snow, drier summers in south, wetter summers in north
Extreme Events	Greatly increased in frequency
IPCC Global	
World	Very little international co-operation
Economy	Protectionist; very low economic growth
Population	Still increasing
Governance	Self-reliance with preservation of local identities
Technology	Slow fragmented development
Management	
Management Emphasis	Reacting to chaos - forced adoption of water and carbon management
Economic Emphasis	Maximum short-term gain
Mitigation	Very little reduction in carbon emissions
Adaptation	Crisis management
Integration	None
Timber Harvesting Land-base (THLB)	Dramatic reduction in total area of THLB due to grassland expansion, planting failures and demands for water.
Forest Industry	AAC = 20 M m3/year, half salvage, half short-rotation plantations No harvesting of green old growth since 2020
Range	Forage supply has decreased and become unpredictable from year to year.
Ecological Processes	
Pests/Pathogens/Disturbance	Considerable loss of timber and wildlife due to recurrent natural and human disturbance
Ecosystem Productivity	Generally poor - trees stressed by shifting climate, increased rates of mortality
Hydrology	Drought in south, frequent flooding on coast and parts of north, intense water competition
Geomorphology	Mass-wasting common, significant infrastructure losses.
Ecosystem Components	
Ecosystems	Lots of ecosystem degradation
Soils	Rate of change outstripping adaptation, overall loss of soil
Water	Lack of water, poor quality
Genetics	Reliance on assisted migration - mixed results
Aquatic Biology	Loss of salmon
Wildlife	Loss of specialist species
Biodiversity	Loss of diversity, opportunists, pests and invasive species thrive
Carbon balance	Forest is a net source of carbon to the atmosphere.

Drivers

Climate Change
Over the last 50 years the climate has changed dramatically. The rate and magnitude of change even exceeded some of the most pessimistic projections discussed at the turn of the century. We have seen many novel and unpredictable climatic events in British Columbia such as the increasing incidence of tornados in the central plateau. Having now crossed the 2 ^{o}C increase in global temperature threshold, feedback mechanisms, such as melting of the Siberian permafrost and reductions in the Greenland and Antarctic ice sheets, have become a reality. Overall, the mean winter temperature is considerably warmer than at the dawn of the century leading to a reduction of the snow pack over large parts of the province. As well, the southern part of the province has experienced two decade-long summer droughts. The climate has become extremely variable from year to year. Extreme weather events are common leading to flash flooding, landslides and forest blowdown, with the most severe occurring on the coast.

Global Context
The failure of international efforts to maintain free trade and to agree on carbon emission targets led to the formation of the economic regions that we see today. British Columbia, as part of the North American economic region, has, in relative terms only, faired far better than many jurisdictions. Coastal flooding and loss of arable land in Asia and South America, has meant that those areas continue to suffer extreme poverty. A breakdown in governance has led to atrocities committed by those regions' various warlords as they fight over the remaining arable land. Central Europe has been put in an untenable situation. There is severe flooding in the north, drought and heat waves in the south, and a huge influx of refugees resulting from widespread famine in north Africa. Europe is being pushed beyond its ability to cope.

With an influx of environmental refugees from Latin America and Asia, British Columbia's population has almost doubled over the past 50 years. Although Vancouver, Victoria, Nanaimo, Kelowna and Kamloops are still the most populous cities, northern towns have increased at an amazing rate, particularly along the Highway16 corridor, including Terrace, Smithers, Prince George and McBride, and the more northerly towns of Atlin, Dease Lake and Fort Nelson. The Peace River area has become more important for agriculture, although the productivity is limited due to unpredictable water availability.

The province has successfully deployed hydro-electric technologies, such as tidal and run-of-river electric projects, to reduce its dependence on fossil fuels. However, the continued investment in bridges and roads early in the century encouraged continued automobile use. Moreover, the heavy early investment in biofuels, to make some profit from the decaying forest, delayed the de-carbonization of the BC economy.

Despite the amount of environmental change of the last 50 years, British Columbia is still better off than most places on the planet and as a result is under immense global pressure to preserve its remaining natural refuges. The province is one of the few places with remnant Woodland Caribou and Grizzly Bear populations, although they are highly managed and restricted to the northern part of the province, most notably the Spatsizi plateau.

Responses

Terrestrial Ecosystems and Wildlife
Efforts early in the century to enhance the resilience of forests to environmental stress were overwhelmed with more and more forest disturbances. Large landscape disturbances became more frequent starting with the Mountain Pine Beetle (MPB) outbreak early in the century. This was quickly

followed by widespread die-back of mature trees and then the 2018 spruce beetle outbreaks in the north. Large fires have become beyond our capacity to suppress, leading to the expansion of grass and scrublands to their current extent beyond Quesnel. The highly disturbed forests of British Columbia have continued to be a source of carbon, despite our early attempts to restore them to being sinks.

Large tracts of forest and range in British Columbia, including both managed and unmanaged lands, are exhibiting significant die-back and mortality. Stands with mostly dead trees have much wetter soils and the risk of physically damaging soils due to winter logging is high. However, the desperate need for biomass and jobs has led the government to turn a blind eye to harvesting-related soil disturbances and extreme levels of debris removal. As a result, many regions of the province are experiencing losses in soil productivity, increased erosion rates, and reductions in water quality. The remaining live trees have become increasingly maladapted to their current climate.

The vigour and productivity of forests planted in the 1980s to 2000s (including the most extensive planting programs in the history of British Columbia forestry) remain inconsistent. Part of the problem appears to be a simplification of soil biotic communities caused by the cumulative stresses of climate change, repeated natural and man-caused disturbances, rapid migration of 'host' species and the invasion of many soils by exotic species, such as earthworms. In fact earthworms are pushing formerly coniferous ecosystems toward deciduous-dominated open woodlands. In many regions of the province, half of these forests were regenerated with seedlots at the lower (warmer, drier) limits of their seed transfer range and these trees have been dead for two to three decades. There is hope that these earlier plantation failures are becoming less common because of the development of a North America-wide program for the assisted migration of tree species and genotypes - much of the most successful seed stock in British Columbia's new climatic conditions originated in the forests of the USA. But the climate is now changing so rapidly due to global feedback mechanisms, it is difficult to know what to plant, period. Forest productivity has risen considerably in the far north and at higher altitudes, where moisture deficits have not been as extreme. The majority of new industrial investments are focussed on fibre farming and biofuel licenses in the Dease Lake and Fort Nelson areas, which are providing desperately needed jobs for the growing population of climatic refugees flooding into the north.

Dry summer conditions and major fuel loading from the MPB led to a series of major fires in the British Columbia Interior throughout the 2010's and 2020's. The most notable of these fires was the Quesnel fire in 2015 and the Vanderhoof fire in 2023 – killing over 200 people and destroying much of the town. A major water treatment plant had to be built in Quesnel to deal with the sediment-laden water due to the fire. After the Vanderhoof fire, the Nechako sockeye run was almost completely decimated due to habitat loss from sediment production in the watershed.

The fires in the interior also led to heavy loss, degradation and fragmentation of forest-dependent terrestrial wildlife habitat. Most specialist species, such as Woodland Caribou, have pretty much disappeared save the few heavily managed remnant populations. The species at risk designation has almost become meaningless given how extensive the list has become; it seems like every native species is at risk with the exception of crows and deer.

It had been assumed that species would shift their range north and upwards in elevation. This did occur for some species of plants and birds. However, most species lacked the ability to disperse to new areas, particularly if they were not adjacent to their historic range. Even where species were able to migrate, they often failed to establish due to insufficient habitat and patch size, competition with other species, or because the habitat was already occupied by active agricultural, urban or industrial development. Furthermore, the rate of change was too fast for most species to adapt to and it is clear that many are still in flux, occupying unsuitable historic range and in decline. Overall, there has been a 50% decline in species abundance across the province since the climate started to radically change.

Birds, hibernating mammals and plants requiring external pollinators have declined significantly over the last 50 years. These declines have been attributed to climate-related environmental shifts that have decoupled the seasonal timing of species and their habitat requirements. For example, although some years have been "normal," in other years wildlife emerge or arrive on site only to find that they cannot rear their young because of unusual snow packs. Similarly, plants may flower before insects hatch or deharden prematurely and then suffer heavy mortality when the temperature drops.

Invasive species (plants, mammals, amphibians and especially insects and diseases) have become established over extensive areas and changed whole ecosystems to the point where an ecologist from 2000 would not recognize them as native ecosystems. Several significant public health risks associated with invasive species continue to plague much of the province. West Nile virus, which became the major public health problem in the 2020s and 2030s and is still prevalent, it is now considered a minor nuisance compared to the combined impacts of several new pests that established in the 2040s.

Watershed Processes & Aquatic Biology

The frequency of storm events has increased dramatically over the past 50 years. This has led to more severe flooding. We have seen many more landslides, particularly in Haida Gwaii, Vancouver Island, and along the coast. Landslide rates have even surpassed those observed in the previous century, which at that time were due to logging and road-building on steep terrain. The trend to increasing rates of major landslide events in northern British Columbia, first observed in the early 2000's, has continued as temperatures continued to warm. Logging road maintenance now consumes fully half of the forestry budget, even as more and more roads are closed and deactivated. In the northeast of the province, melting of permafrost areas has caused major issues, severely affecting infrastructure in areas which once supported commercial timber production.

Starting in 2015, the drastically rising water temperatures in the southern part of the province became a barrier to salmon migration, leading to the extirpation of those populations in 2025. Despite the modest increases in the northern salmon stocks from 2015 to 2025, they are now on the brink of extinction. The small-mouth bass stocking in the 2020s was initially a success but with the rising water temperature, those populations succumbed to disease and only persist in isolated pockets.

The demand for domestic and irrigation water in south-central British Columbia has become so extreme that existing lakes and rivers in the Okanagan and Thompson basins are now managed strictly as human water sources. All objectives for aquatic ecosystem management have been abandoned. Balancing human uses (domestic, irrigation, and hydro-electric) and basic aquatic ecosystem requirements has become a critical and high profile issue in parts of the Columbia, Fraser and Peace watersheds as well.

Sea-level rise has been a growing concern along our coastline. The most problematic area will be the urban areas of the Fraser River delta – most of Delta and Richmond will likely be under water by the end of the century. Severe erosion has begun around Naikoon Park in Haida Gwaii. Much of Vancouver Island, the Gulf Islands, Haida Gwaii and areas around Prince Rupert are already subject to increased erosion.

Forest and Range Industry Implications

The timber harvesting industry is struggling to survive in northern interior communities, and has essentially vanished from other parts of the province. In the southern interior and on the coast, timber harvests are restricted to niche harvesting systems that provide wood for speciality products only, primarily wood art and furniture. Our forests seem to go from one disturbance crisis to another and we are left with far younger and more degraded forests as time goes by. The variability in natural disturbances has led to an inconsistent wood supply, both in terms of quality and quantity. This has been a problem for both traditional milling and the burgeoning biomass energy sector. Half of the harvest is from salvage of trees recently killed by climate-related stresses (sometimes in clearcuts of

several thousand hectares). The other half is from short-rotation plantations that provide a relatively stable, although limited, supply of fibre for the feedstock for bioenergy and bioplastics industries. Logging has become increasingly challenging because the window of time during which forests can safely be cut has shrunk dramatically. Drier, hotter summers limit summer logging due to fire hazard; warmer, wetter winters limit the period when the ground is frozen.

Range ecosystems have had changes in species composition leading to changes in forage quality and composition and forage supply. In general, there has been reduced productivity in the south and increased productivity in the north. However, the forage supply is unpredictable from year to year because of extreme weather events. There has been local extinction of some plant communities - due to fragmentation and displacement by invasive plants.

In summary, we can only hope for some relief from the constant change of our forest and range ecosystems. Without more aggressive atmospheric decarbonising technologies and international co-operation, the warming and variable weather looks to be intensifying. Currently, plans are underway to create more biospheres to isolate agricultural land from the effects of a worsening climate so that they can provide a relatively stable supply of food.

Technical Background on the Use of Scenarios in Climate Change and Forest and Range Policy Discussions

Don Morgan
March 11, 2009

How climate will change and how British Columbia's forest and range ecosystems will be affected is fraught with uncertainty. Participants at the April 12th, 2011 Nadina Vulnerability workshop will explore two scenarios that have been constructed to illustrate possible futures for B.C.'s forest and range ecosystems under climate change.

The use of scenarios has its roots in strategic planning and war games. More recently, they have been used to explore the supply of ecosystem services (e.g. timber, water and wildlife) in the context of climate change and the uncertainty and complexity of human and ecological system dynamics (Peterson et al. 2003, MA 2005, IPCC 2007).

Scenarios reflect alternative dynamic stories to capture the essence of our understanding of how systems function, the uncertainty about the future of any system, and our ability to control or influence change. Scenarios are based on "a coherent and internally consistent set of assumptions about key relationships and driving forces" (Nakicenovic and Swart 2000). They are designed specifically to lend insight into system drivers and to explore uncertainties in system behaviour. They do not predict the future. They enable people to explore the consequences of alternative decisions and how these may play out across a range of possible futures. Scenarios do not advocate one particular future.

Complex systems are dynamic and the interactions among the elements are non-linear. As a result, the outcomes are uncertain and we cannot predict what will happen over time. Because of the extent of uncertainty associated with ecosystems, optimizing approaches to decision-making are considered unworkable (Peterson et al. 2003, MA 2005). Furthermore, ecological predictions that include the role of humans become confounded by people changing their behaviour when presented with new information. Methods that include both qualitative and quantitative approaches for examining the future are being shown to be the most useful for planning (MA 2005), especially under climate change (IPCC 2007).

The two scenarios were constructed based on the definition of scenarios used by Peterson et al. (2003) and by the Millennium Ecosystem Assessment (MA 2005). They are written as a "future history", i.e., they are told from the perspective of someone in the year 2050 looking back over the time from 2009 to the present (2050). The assumptions, the social environment and the science are based on the following sources:

- IPCC's fourth assessment (IPCC 2007),
- IPCC Emissions Scenarios (Nakicenovic and Swart 2000),
- Canadian Sustainable Forest Management Network (http://www.sfmnetwork.ca/html/forest_futures_e.html),
- Millennium Ecosystem Assessment (MA 2005),
- FFEI's Integrated Ecological Impact Assessment background report (Utzig and Holt 2009), and
- Narratives written by government scientists and discipline experts based on their perceptions of the potential future of the various components and processes of B.C.'s forest and range ecosystems, under moderate and extreme climate change.

The first scenario – "Managing for Resilience" – is the more optimistic of the two. It is based on the IPCC's B1 climate scenario which assumes successful global efforts to minimize greenhouse gas emissions and climate change. It results in British Columbia's ecological and human systems showing sufficient resilience to adapt, although not without significant difficulties. This scenario reflects the

amount of climate change already in the system (Weaver et al. 2007). The second scenario – "Reacting to Chaos" – is based on the IPCC's A2 climate scenario which reflects a future where there has been little international co-operation on mitigating emissions and the world is experiencing extreme climate change. This scenario is consistent with observed climate change trends and in some people's view the second scenario may not be "extreme" enough. Recent observations by climate specialists involved in the IPCC suggest that the rates of greenhouse gas emissions and climate-related changes occurring since 2005 (e.g., melting of Arctic sea ice) exceed those predicted by the IPCC's A2 climate scenario (Candadell et al. 2007).

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