



Adapting forest and range management to climate change in the Cariboo Region:

Considerations for planners and practitioners

1. About this Series

Climate change will fundamentally change ecosystems in British Columbia. Therefore, adapting forest and range management to climate change is necessary to foster resilient¹ ecosystems that continue to provide the services, products and benefits society relies on.

This extension note is part of a series that uses current climate change research² to summarize, for each region, projected climate changes, impacts to ecosystems, and adaptation strategies. Where regional information is limited, information is drawn from provincial-scope research.

This extension note is intended to help planners, practitioners and decision-makers with planning under the *Forest and Range Practices Act*, assessing cumulative effects, developing climate change action plans, and monitoring the effectiveness of adaptation practices. Endnotes provide references and further sources of information.

2. Provincial Overview³

Climate: BC has become warmer and wetter over the last century. Winter has warmed the most. Extreme rainfall and dry conditions have increased and snowpacks have decreased. These warming trends will continue. By the end of this century, mean annual temperature in BC could be at least 1.7 to 4.6°C warmer than it was in the last few decades⁴. More winter precipitation will likely fall as rain rather than snow, resulting in lower snowpacks, earlier and more rapid snowmelt, and longer fire seasons.

Regional differences: Northern and southern regions of BC are expected to warm more than coastal BC and parts of central BC. Winter precipitation is expected to increase in all regions, but summer precipitation is expected to increase in northern BC and decrease in southern and coastal BC.

Impacts: Ecosystems will likely undergo both predictable and unpredictable ecological shifts. Climate envelopes (the climate associated with an ecosystem today) for subalpine and alpine areas will diminish in most locations while those for grasslands, shrub-steppe and dry forested ecosystems are expected to expand. In response, ecological communities will disassemble and reassemble—sometimes into novel combinations—as populations decline, move or adapt. Many species, including trees, will not be able to migrate quickly enough to keep pace with shifting climate. During this transition, ecosystems will be strongly influenced by disturbances and invasive plants. **Natural disturbance** dynamics will change:

likely changes include increased fire and drought in southern and coastal BC, increased storms and windthrow on the coast, and more frequent and extensive mortality due to bark beetles, defoliators and diseases across BC. Invasive species will increase. **Hydrological regimes** will shift due to increased evaporation, altered vegetation communities, increased storm frequency and magnitude, decreased snow accumulation, seasonal changes to precipitation, and accelerated ice melt followed by diminished glacier extent.

Adaptation: Many adaptation strategies are similar across BC. With the exception of assisted migration, most strategies are not novel, but are elements of ecosystem management that require broader application. Strategies to reduce risks to forest ecosystems include **promoting resilience** by maintaining or increasing diversity at all scales, **guiding ecological transformation** by maintaining landscape connectivity and assisting migration, **combating detrimental change** by controlling invasive plants and excessive disturbance, and **limiting cumulative effects** of multiple land-use activities. Strategies to reduce risks to forestry-dependent communities include **increasing monitoring** of change, **increasing capacity** to respond to change (e.g., by economic diversification), **strategically harvesting** at-risk forests, managing fire in wildland-urban **interfaces**, and increasing capacity of **infrastructure** to withstand extreme events.

3. Description of Region

The Cariboo Region includes the Fraser Plateau nestled between the Coast Mountains to the southwest and Columbia Mountains to the northeast. Precipitation is highest in the mountains and lowest in the rainshadow of the Coast Mountains. At the broadest scale, the physiography divides the region into three portions with different climatic regimes. These divisions represent enduring features that will shape ecosystems in any climate regime. Valleys associated with large river systems, including the Fraser, Chilcotin and Quesnel, cut through the plateau. For more information on weather systems for BC, visit [BC Weather](#)⁵.

Current ecoregion boundaries represent a reasonable division of the Cariboo region into three climatically-relevant portions, with the mountains on each side of the central plateau (Figure 1). Ecosystems vary tremendously over the region, with eight biogeoclimatic (BEC) zones⁶ represented. At the broad scale, current BEC zones match the three sections reasonably well: the **Plateau** sub-region is dominated by IDF in the south, with BG along the Fraser Canyon, and by SBPS, MS and SBS in the north; the mountainous **Chilcotin Ranges** sub-region is mostly MS and ESSF with IDF in the valleys, and the wetter **Columbia Highlands** sub-region is mostly ESSF with ICH in the valleys. Alpine ecosystems are present at high elevations. For more information on BEC zones in this region, visit [BEC WEB](#).

Because of landscape complexity, finer-scaled units, dividing mountain ranges and plateaus might be useful for future work.

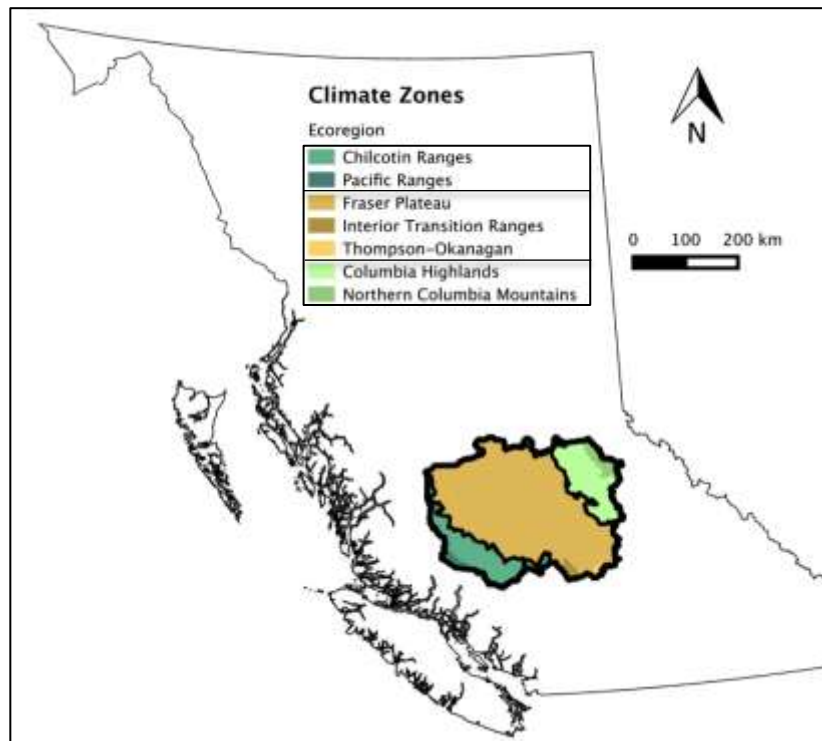


Figure 1. Three climatically-relevant sub-regions within the Cariboo Region based on groups of Ecoregions. Spatial data from [DataBC](#).

4. Climate Change Projections

Our understanding of climate change is adjusting continually as models are improved with new research and methods. Projections in this document are derived from the Pacific Climate Impacts Consortium's regional climate summary for the [Cariboo Region](#), its [Plan2Adapt](#) tool for projecting future climate conditions, and [ClimateBC](#) ⁷.

The climate in the Cariboo Region has changed over the past century and is expected to continue to change. Averaged across the region, over 1°C of warming has occurred during the 20th century, with most since 1950. Projections suggest the region may warm, on average, by about 1.6 to 4.3°C by the end of this century, similar to moving from Quesnel to Merritt (2.3° warmer).

Precipitation trends are more complex and vary between plateau and mountainous sub-regions. Over the entire Cariboo Region, annual precipitation has increased slightly over the past century, although winter precipitation has decreased from 1951 – 2009. Precipitation is projected to increase modestly in all seasons but summer where it is predicted to decrease.

Summary of climate projections for the Cariboo for the 2050s*

Climate variable	Change in Cariboo	Variation within region
Temperature		
Mean (°C)	+1.8 (1.1 to 2.6)	Fairly consistent
Winter (°C)	+1.7 (0.6 to 2.8)	Fairly consistent
Summer (°C)	+1.8 (1.3 to 2.6)	Fairly consistent
Precipitation (%)		
Annual	+6 (-1 to 13)	Fairly consistent
Winter	+7 (-15 to 5)	Fairly consistent
Summer	-7 (-3 to 14)	Less decrease in Columbia Highlands
Snowfall (%)		
Winter	-8 (-15 to 3)	Less decrease in Columbia Highlands
Spring	-54 (-74 to -12)	Consistent
Snowpack	Decrease	Consistent, except may be no change or slight increase in Chilcotin Ranges ⁸
Frost-free days	+23 (13 to 34)	Greater increase in lower elevations
Growing Degree Days	+283 (162 to 444)	Greater increase in lower elevations
Extreme weather	More heat waves, summer drought, wildfires, heavy precipitation ⁹	

* Based on 1961-1990 baseline. Projected changes in temperature continue to increase past 2050. Source: PCIC [Plan2Adapt](#) tool. Projections are based on a combination of A2 and B1 emissions scenarios, where A2 represents roughly business as usual and B1 represents a more optimistic scenario with about ½ of emissions of business as usual. Median of 30 projections with range (in brackets) showing the 10th to 90th percentile of projected changes.¹⁰

Increased Variability and Extremes: Focusing on mean changes in temperature and precipitation can obscure important changes in climate variability and extremes. Climate projections are based on mean temperature and precipitation per season and do not reflect potentially large changes in variability. Even with constant variability, the frequency of extreme events will increase much more than a small change in mean temperature or precipitation would suggest.

Climate Variability and Extreme Events

Seemingly small increases in mean values of climate variables can substantially increase the probability of an extreme event. For example, increasing the mean by one standard deviation can lead to a more than 10-fold increase in extremes so that a 1 in 100 year event (e.g. flood) can become a 1 in 10 year event.¹¹

5. Impacts to Ecosystems

Ecosystem Climate Envelopes

Climate envelopes describe the climatic conditions associated with currently mapped biogeoclimatic (BEC) subzone/variants¹². These envelopes help ecologists and foresters integrate climate variables and

visualise the potential extent and implications of climate change, but they **do not** predict what future ecosystems will look like for several reasons. First, ecosystems do not move as a unit; second, current climate projections are based on average climate values, ignoring the extreme events that can shape ecosystem structure and composition; third, climate envelopes do not capture site-scale shifts well. Nonetheless, projections can help estimate the relative stress that climate change poses to an ecosystem and its potential to recover to a new functional state.

Climate envelopes are projected to shift upslope and northward across BC. By the 2050s, climate envelopes for current Cariboo BEC zones are predicted to shift about 100 – 250 m upward in elevation and up to 175 km northward (Figure 2). The cold, dry SBPS and high elevation MS and ESSF will likely experience the highest stress: all are projected to lose over two-thirds of their current area by the 2050s¹³. Conversely, the IDF, BG and ICH climate envelopes are projected to lose little current area and to expand inland and upslope. More detailed analyses in the Thompson-Okanagan region to the south suggest that some ICH subzones may come to resemble a combination of IDF and ICH, that dry sites may shift to shrubby or grassland ecosystems, and that the current MS zone could shift to a new state comprised of a variety of communities¹⁴.

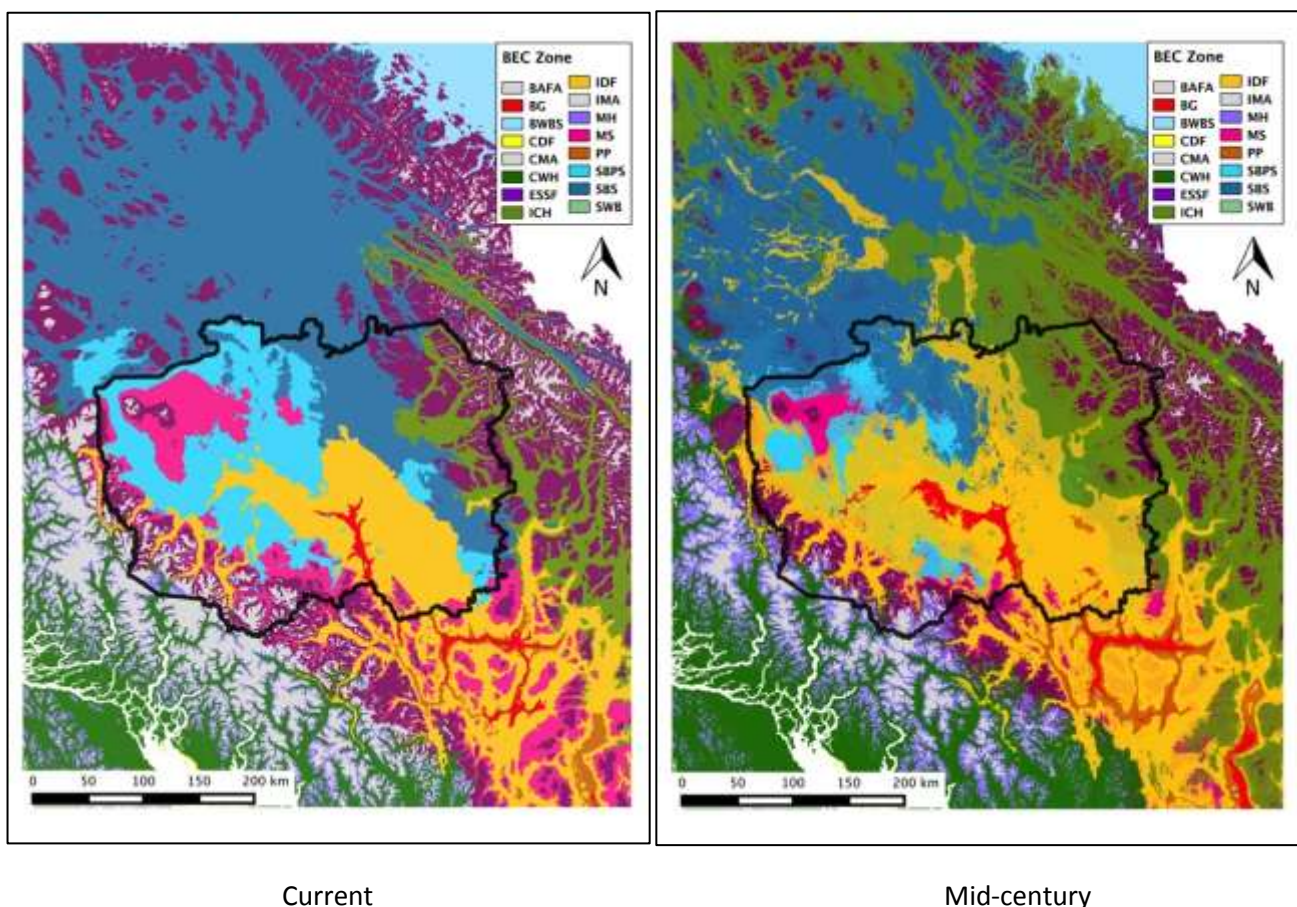


Figure 2. Current (BEC version 8) and projected future (2041-2070) BEC zone locations. Future map shows consensus of multiple projections. Maps retrieved from [ClimateBC](https://climatebc.ca/).

Natural Disturbance

The most profound changes to BC's forests in this century will likely be the result of more frequent and severe natural disturbances¹⁵. In the Cariboo, drought, fire and insects are expected to cause the most disturbances. Disturbances can cascade as, for example, drought-stressed trees are more susceptible to insects and disease, leading to increased mortality and relatively open stands with ladder fuels that support large wildfires. Changes in climatic conditions support range expansion of forest pests that are currently limited by climate. Fewer extreme cold events will occur to inhibit insect outbreaks. Cariboo ecosystems are already undergoing massive shifts due to loss of mature lodgepole pine to the mountain pine beetle. Douglas-fir will likely experience continued and increased mortality from the tussock moth, the Douglas-fir bark beetle and the Western spruce budworm.

The increased prevalence of disturbance will vary by climatic sub-region, elevation and forest type.

Disturbance	Projected changes
Fire and drought	<ul style="list-style-type: none">• Drought will increase in all but the coolest, wettest subzones; drought is expected to cause mortality to Douglas-fir, spruce and subalpine fir.• Fire size and intensity will increase, particularly in the southerly areas of the plateau, due to decreased summer precipitation.
Mass wasting	<ul style="list-style-type: none">• Increased seasonal soil moisture due to snowmelt and rainfall may increase mass movement in steep terrain.• Loss of forest cover (due to fire or drought) may increase chance of mass wasting.• Loss of snow and ice at high elevation may increase mass wasting from increasing freeze-thaw of exposed rock.
Insects and disease	<ul style="list-style-type: none">• Mountain pine beetles have already caused substantial mortality in pine in dry subzones and in the plateau subzones.• Western spruce budworm will continue to expand to the north of the region.• Douglas-fir beetles may increase with increased fire frequency and severity.• Douglas-fir tussock moths may expand northward.• Stem rusts may increase in young pines depending on changes in precipitation.

Hydrology and Fish

The Cariboo Region is expected to follow projected provincial trends in hydrology, although the effects will vary with location, elevation and aspect¹⁶. Hydrology in the region will be substantially influenced by warmer annual temperatures with increased evaporative demand, wetter winters with less snow and more rain, wetter springs and falls, and drier summers, combined with more frequent and severe extreme weather events. Smaller winter snowpacks that melt more rapidly will reduce late summer stream flow over most of the region. In wet cool subzones within the region, increased peak flows due to increased winter precipitation in some high-elevation watersheds could lead to increased scour, sediment transport and mass wasting. Annual water flows are expected to decline in the south of the region. Altered flow patterns could disrupt seasonal habitat use by fish.

In southern parts of the plateau, domestic and agricultural water use is expected to grow. Competition for limited water resources will increase as seasonal water flow decreases.

Loss of vegetation through natural or anthropogenic disturbance, combined with climate change, creates cumulative effects. Cumulative effects may decrease the capacity of a landscape to buffer rainfall, increase stream flashiness and potentially increase sediment delivery and channel instability. Snow accumulation and melt patterns are projected to change considerably following moderately severe fires, but little following unsalvaged mountain pine beetle outbreak. Effects are difficult to predict, however, given projections for less snow.

Earlier thaws and changed peaks pose hazards to infrastructure.

Increased water temperatures, reflecting warmer summer air and reduced flows, can impact salmonid populations. In addition, smaller snowpacks in the ESSF may contribute less cool water to streams.

Feature	Projected changes
Hydrological regime	<ul style="list-style-type: none"> Projections include earlier onset of spring peak and reduced late summer/fall flows, particularly in drier subzones. Flows may vary more across sub-regions depending on changes to late winter rains.
Peak flows	<ul style="list-style-type: none"> Spring peak discharge will change; within the region, in wet, cool northern subzones, peaks will likely increase; in drier, southern subzones, peaks may decline. Shift from snow-driven to hybrid rain/snow-driven regime could lead to more frequent and flashy high flows during fall. These flows could disturb the streambed and spawning habitat.
Spring recession	<ul style="list-style-type: none"> Decreased snowpack could reduce the magnitude and duration of the spring recession (a relatively stable period of moderate flow and temperature), affecting the sorting and deposition of sediment and profoundly impacting aquatic habitat.
Low flows ¹⁷	<ul style="list-style-type: none"> Smaller spring snowpack and earlier spring freshet will lower summer low flows, lengthen the low-flow period, and decrease groundwater storage. Some perennial streams may become intermittent or ephemeral. Loss of glacial meltwater over the long term will reduce summer low flows. Temperature will increase in some streams and lakes, posing risk to temperature sensitive fish; many low elevation streams in warm subzones could reach lethal temperatures for salmonids.
Variability	<ul style="list-style-type: none"> Variability in peak flow will likely increase, leading to unstable stream morphology in some systems. Mid-winter melt events will likely increase.

Biodiversity

Climate shapes species distributions and ecological communities¹⁸. Populations faced with a changed environment can die out, move, or adapt to the new conditions. Many species that are adapted to projected future climates currently live several hundred kilometres distant from that area; only the fastest dispersers will be able to keep up with the pace of change. Most invasive plants and generalist weedy species are well-adapted for broad movement. For some ecosystems, potentially irreversible regime shifts may follow intense disturbances, particularly if invasive plants colonise and block historical successional paths. Southern parts of the Cariboo are particularly vulnerable to such regime shifts.

Mountain ranges are particularly important for conservation of biodiversity. Relative to gentle terrain, mountains accommodate more climatic zones within close proximity; thus, as the climate changes, populations in lower elevation zones may find suitable climatic conditions by migrating upwards.

Feature	Projected changes
Cumulative effects	<ul style="list-style-type: none"> Past human activities have altered, degraded and fragmented habitat, making dispersal in response to climate-related disturbance more difficult for specialist species. Human response to increased disturbance (e.g. extensive salvage harvesting following insect infestations and fire) can exacerbate impacts of climate change. Old forest will decline due to disturbance and harvesting, threatening associated species. Over-grazing and trampling impacts grasslands and forest understory by changing the plant community, destroying the biological crust and opening soil to invasive plants.
Communities	<ul style="list-style-type: none"> Communities will reassemble, often into new combinations, as some established species decline or disappear, new species colonise and interactions change. Ecosystems may undergo regime shifts (e.g. from forest to shrubs or grassland).
Interactions	<ul style="list-style-type: none"> Ecological processes and relationships among species (e.g. predation, pollination, mutualism) may uncouple as the timing of events changes and becomes more variable (e.g., if migration depends on day length, but prey abundance depends on temperature).
Invasive species	<ul style="list-style-type: none"> Invasive species (plants and other organisms) are expected to increase as temperatures and disturbance increase. Current indigenous species may be less competitive in the new climate and disturbance conditions, facilitating invasive plant population expansion. Parts of the Cariboo already have many invasive plant species. Grasslands and dry forest types are particularly impacted and will provide a source of invasive plants following disturbance, facilitating regime shifts.
Wildlife ¹⁹	<ul style="list-style-type: none"> Wildlife and trophic interactions (e.g. predation) will be particularly affected by changes in snowpack and freeze-thaw regimes. Impacts vary by species. Increased fire could impact caribou habitat negatively and moose habitat positively. Increased disturbance (and salvage harvesting) of old-growth management areas will result in decline of old seral forest and affect the character of reserved areas. Wildlife tree patches face increased risk of tree mortality that will affect their value.

Cumulative Effects

Cumulative effects are changes to an ecosystem over time caused by a combination of **human activities, natural variability** and **climate change**. Assessment of cumulative effects integrates the effects of past, present and foreseeable future events and processes. FLNR has a [framework in place to guide assessment of the cumulative effects of resource management and climate change](#). Such a framework provides the context for informed decisions about which management actions are most likely to succeed.

Trees

Tree species distributions will shift gradually in response to climate change due to physiological tolerances, natural disturbance, and competition²⁰. Fires and harvesting will shift the age-class distribution towards younger stands. Most tree species (and populations) will be unable to migrate quickly enough to follow the climate envelopes to which they are adapted.

Uncertainty about climate projections leads to uncertainty about which trees may be best-suited to changing conditions, particularly in the coast/interior transition at the west of the region. Suitable trees at any given point in time may become maladapted by rotation age, creating additional uncertainty and complexity for management.

Response class	Projected changes
Physiological tolerance	<ul style="list-style-type: none">• Some tree species, including interior spruce, lodgepole pine, Douglas-fir, ponderosa pine and Western red cedar, will face drought stress and regeneration challenges in drier ecosystems.• In dry subzones, young stands with abundant lodgepole pine have high vulnerability.• The landscape may become climatically suitable for grand fir and western white pine.
Productivity	<ul style="list-style-type: none">• Tree growth will likely increase in moister, cooler areas due to elevated CO₂ coupled with warmer temperatures.• Growth potential, however, may not be realised because of limited nutrients, because populations are not adapted to increased extreme events, or because maladaptation increases susceptibility to insects and disease.
Natural disturbance	<ul style="list-style-type: none">• Fires and drought stress will cause increased tree mortality. Pulses of mortality will coincide with warmer, drier climatic cycles and follow insect and disease outbreaks.• Insect and pathogen outbreaks could increase mortality, even in healthy rapidly-growing trees.• Stressed trees are more susceptible to insects and pathogens.• Tree mortality in transitional subzones will be heightened by warmer, seasonally drier conditions.• Several deciduous and coniferous species will likely suffer diebacks.
Competition	<ul style="list-style-type: none">• Competition will occur after natural disturbance; shrubs may be favoured.

Range

Grassland ecosystems will also shift in response to climate change due to increased drought, loss of forest due to disturbance, and competition. Grasslands are projected to increase in the region, but community composition will likely be low in native grassland diversity and dominated by invasive species²¹. Cumulative effects of increased invasive species and decreased precipitation could decrease the chance of recovery.

Forage supply could increase in the IDF as the forest canopy thins. Earlier spring plant growth and a longer growing season will translate into a longer grazing season.

Response class	Projected changes
Productivity	<ul style="list-style-type: none"> At lower elevations, productivity will depend on the plant community, with deep-rooted perennial grasses performing best. Early seral communities dominated by shallow-rooted grasses, annual grasses, and invasive forbs will have lower productivity due to drought, particularly if grazing levels remain unchanged. Productivity will increase at higher elevations. Frequent drought may lead to fluctuating herd sizes.
Competition	<ul style="list-style-type: none"> Many desirable species, including bunchgrass and rough fescue, may be unable to migrate quickly enough to follow the climate envelopes to which they are adapted, and will not out-compete faster-dispersing invasive plants such as cheatgrass. Needlegrasses and some warm season (C4) grasses are better adapted to rapid migration. Invasive plants may be particularly favoured following fire in forests with little understory.
Water	<ul style="list-style-type: none"> Dispersed surface water sources available for livestock will decrease with reduced snowpack and spring snowfall.
Infrastructure	<ul style="list-style-type: none"> Fencing and water developments may need to be relocated to realign with a shifting forage resource.

Ecological Surprises

Current vulnerability modelling does not include ecological surprises or complex climate-ecological relationships. For example, in a warmer climate, decreased snowpack might increase susceptibility to late frosts. Simplistic predictions in complex systems cannot replace long-term interdisciplinary research and monitoring.

6. Adaptation—modifying management to account for climate change

It is necessary to modify management activities – planning, practices, and monitoring - to address the impacts of climate change on ecosystems. Adaptation strategies will vary depending on the ecosystem, the direction of anticipated climate change, the degree of certainty in projected changes, the urgency (risk and vulnerability), and the likelihood of adaptation practices achieving desired outcomes. Hence, management activities under a changing climate will need to be flexible and proactive.

This section includes adaptation strategies to address the current and anticipated impacts to ecosystems described above. These strategies reflect regionally-important ‘best available information’ drawn from research and the input of regional specialists. Practitioners and decision-makers should consider these adaptation strategies as voluntary guidance to inform operational planning and practices.

Many of these adaptation strategies are existing elements of good forest management that require broader application. As with current policy guidance, some adaptation strategies may conflict with each other (e.g., maintaining downed wood to sustain biodiversity may conflict with minimizing forest fuels to reduce catastrophic wildfire risks), requiring decisions that trade-off resource values depending on the

priorities for the area in question. Trade-offs will likely become more common and challenging over time.

Although some of these adaptation strategies may incur incremental costs or land base constraints, the long-term economic benefits of adaptation to the productivity of timber, forage and other resource values are predicted to outweigh short-term costs. For example, studies in the Alex Fraser Research Forest, and in the Merritt and Kamloops TSAs, indicate the economic viability of diversifying managed forests to reduce forest health risks and increase resilience²². And, designing and maintaining roads and bridges to a higher standard will likely minimize repair and compensation costs after flood events. Some adaptation strategies are also potential climate change mitigation or carbon storage strategies (e.g., networks of reserves, retaining downed wood).

Adaptation strategies in this section reference related policy guidance and policy or knowledge needs.

Planning

Climate change poses at least three broad challenges for planners:

- Existing management **objectives** may be inappropriate because they were developed without considering climate change and do not generally include objectives for mitigation or resilience.
- Existing management **strategies** are unlikely to achieve existing objectives under a changing climate.
- **Uncertainty** about the effectiveness of management strategies will increase.

In addition, regulatory or administrative change may be too slow to prompt timely management responses to changing conditions. At a broader scale, market forces may pose barriers.

Uncertainty²³

The impacts of climate change are already present on the landscape. However, projecting the impacts of climate change into the future is fraught with uncertainty due to incomplete ecological and climate models, and to alternative plausible emissions scenarios. Ecological processes that reflect multiple interactions (e.g. shifting species distributions) are more uncertain than processes that correlate strongly with a single variable (e.g. fire hazard and temperature).

Managing in the face of uncertainty requires:

- Recognition of uncertainty (known and unknown sources)
- Information gathering (via monitoring) to reduce uncertainty where possible
- Recognition that uncertainty increases with time span considered
- Acceptance that uncertainty will remain and a decision to either use precaution to maintain a desired value or to put a value at risk

Adaptation requires planning that includes new objectives, new strategies and increased consideration of uncertainty. For example, objectives to maintain biodiversity or timber could be modified to maintain ecological resilience, and strategies should take into account the higher vulnerability of monocultures. Planners may need more flexibility to handle regime shifts (e.g., if forested ecosystems lose viability). Best management practices for ecosystem management²⁴ provide an excellent resource.

Practices

Hydrology

To protect aquatic ecosystems and infrastructure near watercourses, adaptation consists of managing water removal to ensure sufficient flow in areas with drought, limiting increases in stream temperature, limiting sediment input (from surface erosion, streambank collapse and landslides), and limiting increases in peak flows where they are projected. Strategies vary with latitude and elevation.

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
Decreased flow in summer and longer low-flow period	
<ul style="list-style-type: none"> • Manage water allocations/use to maintain water supply during low flow periods • Maintain diversity in stand composition and age-classes across watersheds to vary snow accumulation and loss and desynchronise run-off • Retain sufficient riparian cover to maintain stream flow • Minimize establishment of invasive species in riparian areas • Manage level of livestock grazing 	<ul style="list-style-type: none"> • Drought guidance²⁵ • <i>Climate-based policy guidance for water allocation/use</i> • <i>Monitor impacts of forest disturbance on run-off</i> • <i>Updated riparian retention guidance for small streams</i> • Water quality and livestock grazing BMPs
Increased stream temperature	
<ul style="list-style-type: none"> • Retain adequate riparian vegetation next to streams and wetlands <ul style="list-style-type: none"> ○ Particularly important in temperature sensitive watersheds and along headwater areas 	<ul style="list-style-type: none"> • <i>Inventory and monitor temperature sensitive watersheds</i>²⁶
<ul style="list-style-type: none"> • Maintain ditches and culverts on active roads and deactivate roads to restore drainage as soon as possible <ul style="list-style-type: none"> ○ Important on segments that discharge directly into streams, particularly in temperature sensitive watersheds 	<ul style="list-style-type: none"> • <i>Monitor and manage road drainage</i>
<ul style="list-style-type: none"> • Avoid harvesting sites with high water tables <ul style="list-style-type: none"> ○ Important for sites with high water tables that feed streams, particularly in temperature sensitive watersheds 	<ul style="list-style-type: none"> • <i>Inventory potential warm water sources (e.g. standing water)</i>
Increased risk of landslides and surface erosion (that affect streams or infrastructure)	
<ul style="list-style-type: none"> • Avoid locating roads and cutblocks on or above unstable terrain • Manage grazing to maintain functioning condition of riparian areas • Design roads and drainage structures to accommodate increased peak flow and sediment transport in areas likely to become wetter: e.g., improve surface on high hazard roads; seed erodible cut slopes; build adequate ditches; replace selected culverts with bridges; limit road density in erosion-prone areas • Manage grazing to maintain functional riparian ecosystems; maintain sufficient riparian vegetation to control grazing 	<ul style="list-style-type: none"> • Interior watershed assessment • <i>Regional guidance for gentle-over-steep terrain</i>²⁷ • Water quality evaluation²⁸ • <i>Inventory “flashy” watersheds; monitor precipitation and runoff</i> • <i>Updated riparian retention guidance to address risk of increased sedimentation</i> • Forest road engineering guidebook

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
	<ul style="list-style-type: none"> • Guidelines for managing terrain stability • Water quality and livestock grazing BMPs
Increased peak flows and flashiness	
<ul style="list-style-type: none"> • Maintain diversity in stand composition and age-classes across watersheds to vary snow accumulation and loss and desynchronise run-off • Limit Equivalent Clearcut Area (ECA) to 30 to 50% of THLB • Anticipate increased natural disturbance and manage harvest to stay within ECA limits <ul style="list-style-type: none"> ○ Evaluate hydrological implications of salvaging disturbed stands ○ Account for increased runoff from burned sites in ECA calculations • Assess flood risk and increase design criteria for infrastructure • Manage roads to minimise impacts to flow • Protect stream sources (springs, seepages) from timber harvesting and compaction by livestock and machinery • Leave live standing vegetation and debris barriers next to all riparian features including seepages, non-classified drainages and S6 streams 	<ul style="list-style-type: none"> • Interior watershed assessment • Post disturbance watershed effects²⁹ • Landscape fire management planning • Road and bridge design guidance to address increased peak flows • Guidance on natural range barriers

Biodiversity

Adaptation strategies for biodiversity are designed to achieve two objectives: (1) reduce the existing anthropogenic pressures that compound the negative effects of climate change on biodiversity (e.g., reduce harvesting and road access where sensitive values exist, , and (2) promote resilient ecosystems at stand and landscape scales (e.g. manage grazing to maintain or achieve late seral plant communities).

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
Loss of old forest habitat and connectivity, due to increased tree mortality	
<ul style="list-style-type: none"> • Create a network of reserves and corridors at multiple scales <ul style="list-style-type: none"> ○ Include riparian areas, wildlife tree patches, and old growth management areas in reserves ○ Include corridors crossing elevation gradients ○ Include habitat for specialized species, communities at risk ○ Manage OGMA's flexibly to address changing conditions 	<ul style="list-style-type: none"> • Biodiversity Guidebook • Updated land use plans • Climate-based timber supply analysis
<ul style="list-style-type: none"> • Limit salvage in reserve network (e.g., partial cut or avoid harvest) <ul style="list-style-type: none"> ○ Particularly important where stands buffer microclimate or provide large structure 	<ul style="list-style-type: none"> • Chief Forester's retention guidance • Post-disturbance biodiversity management³⁰

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
Loss of suitable microclimate and soil conditions to re-establish historic ecosystem following harvest (e.g., potential regime shift from forest to grassland)	
<ul style="list-style-type: none"> • Avoid harvesting sensitive sites <ul style="list-style-type: none"> ○ Particularly important on dry sites • Partially-cut stands on dry sites (i.e., retain partial overstory shelter) • Recognize sites where reforestation may fail and adjust stocking standards accordingly 	<ul style="list-style-type: none"> • Drought risk assessment tool • Enhancing biodiversity through partial cutting • <i>Inventory sensitive sites</i>
<ul style="list-style-type: none"> • Retain large downed wood <ul style="list-style-type: none"> ○ Particularly important on drier sites and in riparian ecosystems ○ Particularly important to reduce vulnerability of saproxylic (wood-feeding) species to harvesting combined with climate change 	<ul style="list-style-type: none"> • Wildlife trees and coarse woody debris policies • FREP CWD backgrounder • CWD management
<ul style="list-style-type: none"> • Promote rapid site recovery to appropriate species (e.g., reforestation of dry sites; retain deciduous trees on moist sites) <ul style="list-style-type: none"> ○ Particularly important on dry sites 	<ul style="list-style-type: none"> • See Trees section
Loss of vigour and diversity in young and maturing forests due to maladaptation from changing climate	
<ul style="list-style-type: none"> • Plant climatically-suited species and genotypes (i.e., facilitate migration) • Preserve phenotypic and genetic diversity in regenerating stands to facilitate natural selection and to take advantage of phenotypic plasticity 	<ul style="list-style-type: none"> • See Trees section
<ul style="list-style-type: none"> • Retain naturally-occurring and regenerating species (including deciduous trees and shrubs) and plant a diverse species mix. Avoid monocultures. • Encourage deciduous trees <ul style="list-style-type: none"> ○ Avoid removing aspen in dry and transition subzones ○ Maintain broadleaves in moist transition subzones 	<ul style="list-style-type: none"> • Climate change stocking standards³¹
<ul style="list-style-type: none"> • Use stand tending to influence successional pathways 	<ul style="list-style-type: none"> • See Trees section
Increased spread of invasive plants following disturbance	
<ul style="list-style-type: none"> • Minimize roads <ul style="list-style-type: none"> ○ Especially important in currently unroaded areas and susceptible ecosystems • Minimize road use (e.g., gates, deactivation) • Rehabilitate abandoned roads • Establish competitive vegetation in ditches, on side slopes and other disturbed soil as soon as possible • Wash equipment to remove seeds and plants prior to moving into new areas • Follow best management practices for invasive plants 	<ul style="list-style-type: none"> • Invasive plant management practices • Invasive species council of BC • Invasive species working group; IAPP Map, E-Flora BC • <i>Access management policy</i> • <i>Increase monitoring and controlled experiments</i>
<ul style="list-style-type: none"> • Manage grazing (appropriate level, time, duration and distribution of use, planned rest and recovery time) to maintain late seral grasslands and improve resilience <ul style="list-style-type: none"> ○ Adjust stocking rates and distribution 	<ul style="list-style-type: none"> • Managing rangeland invasive plants • <i>Updated range policy</i>

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
<ul style="list-style-type: none"> ○ Particularly important near susceptible ecosystems (e.g. grass and parkland ecosystems and riparian areas) 	
<ul style="list-style-type: none"> • Minimize site disturbance, especially multiple disturbances <ul style="list-style-type: none"> ○ Particularly important on susceptible (e.g., dry, grassy) sites ○ Minimize off-road vehicle access in harvested areas • Minimize summer logging on susceptible sites (e.g. dry, grassy sites) • Account for invasive plants in site plans 	<ul style="list-style-type: none"> • Map distribution of invasive species
<ul style="list-style-type: none"> • Weed-proof existing stands <ul style="list-style-type: none"> ○ Promote forest stands with weed-resistant understory plant communities ○ Maintain the integrity of mycorrhizal networks to resist invasion, minimize soil disturbance, and maintain high C/N ratio environments where they exist 	<ul style="list-style-type: none"> • Ecological restoration policy

Trees

Adaptation strategies for trees are designed to increase tree establishment success, survival and growth potential, and to reduce the negative impacts of natural disturbance resulting from climate change.

Adaptation strategies have the potential to shift overall climate-induced impacts on timber supply from negative to positive or neutral. Adaptation could lead to large decreases in projected beetle-related tree mortality over the long term, modest decreases in disease, and modest increases in tree growth. Large decreases in beetle mortality are, however, partly attributable to a changing forest age class structure.

Adaptation may have limited success in reducing fire disturbance because effective fire control in average-weather years can be negated by large fires in very dry years. Landscape fire management planning is aimed at reducing these losses as much as possible.

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
Increased tree growth potential on sites with sufficient moisture	
<ul style="list-style-type: none"> • Plant climatically-suited species and genetic stock <ul style="list-style-type: none"> ○ Especially on dry sites or sites facing drought • Adjust stocking standards to reflect site capabilities • Establish operational trials to test survival and growth 	<ul style="list-style-type: none"> • Tree species selection tool • FFT assisted species migration guidance • Chief Forester standards for seed use³² • Climate-based seed transfer interim policy measures • Seed zone maps • Measures to address cost and risk
<ul style="list-style-type: none"> • Fertilize sites that have limited nutrients but sufficient moisture <ul style="list-style-type: none"> ○ Consider risks of increased invasive species 	<ul style="list-style-type: none"> • Benefit/cost analysis • Guidance on suitable sites
<ul style="list-style-type: none"> • Partially cut stands on dry sites to retain shelter and moisture and increase fire resiliency 	<ul style="list-style-type: none"> • Drought risk assessment tool

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
Increased drought stress	
<ul style="list-style-type: none"> • Reduce reliance on lodgepole pine especially in dry subzones <ul style="list-style-type: none"> ◦ Promote Douglas-fir and ponderosa pine in these subzones ◦ Target harvest of susceptible pine stands • Ensure that species mix will provide a harvestable stand (e.g. in some sites, higher densities of lodgepole pine may be appropriate providing that landscape diversity is maintained) 	<ul style="list-style-type: none"> • Kamloops Future Forest Strategy
<ul style="list-style-type: none"> • Adjust stocking standards to reflect lower site capabilities • Partially cut or thin stands on dry subzones and sites to retain shelter and moisture <ul style="list-style-type: none"> ◦ Promote open conditions • Adjust stocking standards to reflect lower site capabilities 	<ul style="list-style-type: none"> • Drought risk assessment tool • Kamloops Future Forest Strategy
Increased fire hazard	
<ul style="list-style-type: none"> • Increase fire resilience at the landscape level by creating strategic fuel breaks, prescribing fire, and allowing ecologically appropriate fires in suitable locations to burn under appropriate conditions <ul style="list-style-type: none"> ◦ Work with range managers to create fire breaks 	<ul style="list-style-type: none"> • Landscape fire management planning
<ul style="list-style-type: none"> • Assess fire hazard • Increase fire resilience at the stand level by managing surface fuels, species composition, density, crown base height, crown bulk density and age-class of forest stands • Reduce post-harvest fuels as necessary (e.g., biomass recovery, broadcast burning, pile and burn, mulching, chipping) <ul style="list-style-type: none"> ◦ Choose appropriate season and weather for fuel-reduction ◦ Consider using grazing to manage fine fuels • Do not reforest areas where climate change creates conditions where there is a low probability of producing commercial timber 	<ul style="list-style-type: none"> • Landscape fire management planning • Fire management stocking standards³³ • Fire and fuel management guidelines³⁴ • Kamloops Future Forest Strategy
<ul style="list-style-type: none"> • Reduce human-caused fires <ul style="list-style-type: none"> ◦ Control access during fire season (e.g. by gates) 	<ul style="list-style-type: none"> • Wildfire Management Branch prevention strategy
<ul style="list-style-type: none"> • Manage fire hazard around communities • Use grazing to manage fine fuels • Reduce risk to structures in interface areas 	<ul style="list-style-type: none"> • Strategic wildfire prevention initiative³⁵ • Fuel hazard assessment and abatement • FireSmart program • FireSmart communities
Increased disease-related mortality (mainly younger stands)	
<ul style="list-style-type: none"> • Plant climatically-suited species and genetic stock 	<ul style="list-style-type: none"> • Forest health and species selection • TSA forest health strategies

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
<ul style="list-style-type: none"> • Increase stand-scale species diversity (e.g., retain and plant a variety of species, including broadleaf); expand breadth of “acceptable” species in young stands • Increase landscape-scale species diversity by planning retention and reforestation at the landscape level; vary species mix and density 	<ul style="list-style-type: none"> • Long-term forest health and stocking standards • Guidance on species composition • Guidance on broadleaves • Guidance for FSP stocking standards • Mixed species options for FFT • Successional responses³⁶ • Stocking standards reference guide • Climate change stocking standards • <i>Free-growing policy that allows variation for local conditions</i>
<ul style="list-style-type: none"> • Plant higher initial densities to account for losses to biotic (and abiotic) damage; i.e. build in redundancy 	<ul style="list-style-type: none"> • See above • TSA forest health strategies
<ul style="list-style-type: none"> • Minimize mechanical damage from wind, snow and ice 	<ul style="list-style-type: none"> • BCTS windthrow manual
Increased beetle-related mortality (mainly mature/old stands)	
<ul style="list-style-type: none"> • Plant climatically-suited species and stock <ul style="list-style-type: none"> ◦ Reduce reliance on lodgepole pine 	<ul style="list-style-type: none"> • See above
<ul style="list-style-type: none"> • Increase stand-scale diversity 	<ul style="list-style-type: none"> • See above
<ul style="list-style-type: none"> • Shorten rotations <ul style="list-style-type: none"> ◦ Especially for relatively productive sites most susceptible to disturbance 	<ul style="list-style-type: none"> • <i>Benefit/cost analysis that considers timber supply</i>
<ul style="list-style-type: none"> • Monitor and control beetle population sources (e.g., sanitation harvesting) <ul style="list-style-type: none"> ◦ Focus on stands where benefit of control outweighs cost to non-timber values 	<ul style="list-style-type: none"> • Regional & TSA forest health strategies • Provincial bark beetle management strategy • Mountain pine beetle action plan • Chief Forester’s retention guidance

Assisted Migration

When trees are harvested 60-120 years after they are planted, the climate could be 3-5 degrees warmer, exposing the trees to maladaptation and health risks. Moving populations of trees today (assisting migration) from their current provenance is one potential solution; growth and health are better when seeds are transferred to follow the climate in which they evolved. However trees have complex symbiotic relationships with many ectomycorrhizal fungal species in the soil and in some cases these bonds are tightly linked to local nutrient and climate conditions³⁷. Improved understanding of these interactions in specific ecosystems may increase success. Government is leading a large, long-term [Assisted Migration Adaptation Trial](#) to understand tree species’ climate tolerances. Findings are helping inform [Climate Based Seed Transfer policy](#) and tree species selection guidance.

Range

Adaptation strategies for rangelands aim to capitalize on opportunities (e.g., longer grazing season) and to reduce negative impacts (e.g., increased invasive plants and drought stress) of climate change and cumulative effects. The first step towards adaptation will be to maintain preferred native perennial grass species on site in late seral communities. Stocking rates need to be adjusted to reflect lower productivity in dry sites, and levels and timing of use need to be designed to facilitate desired plant communities. Assisted migration of preferred native perennial grasses (bluebunch wheatgrass, rough fescue, Idaho fescue) may be necessary.

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
Changes in forage supply	
<ul style="list-style-type: none"> • Reduce allocation where forage supply is projected to decrease (e.g., some low elevation grasslands); manage for conservative stocking rates that allow recovery • Increase allocation where forage supply is projected to increase (e.g., higher elevation forested pastures) • Investigate assisted migration of selected species forage species (e.g., bluebunch wheatgrass or rough fescue as understory species as forest canopies open) • Relocate infrastructure such as fences and water developments to align with the shifting forage resource • Plan for changing conditions; for example, prepare for increased drought events with contingency forage 	<ul style="list-style-type: none"> • Range climate change guidance³⁸ • <i>Forage use regulations that adapt to changes in forage supply (e.g. updated tenure replacement policy)</i>
Changes to water supply	
<ul style="list-style-type: none"> • Provide controlled access to surface drinking water sources by strategic fencing, barrier placement and the use of pumps and troughs • Use off-stream watering to limit livestock access and impacts to streams • Protect springs and seepage areas from livestock trampling 	<ul style="list-style-type: none"> • Water quality and livestock grazing BMPs
Increased invasive species	
<ul style="list-style-type: none"> • Maintain aggressive control program for high priority weeds <ul style="list-style-type: none"> ○ Especially in areas projected to lose perennial herbaceous species 	<ul style="list-style-type: none"> • See invasive plants under Biodiversity section

Monitoring

To develop adaptation strategies that are more likely to achieve management objectives, practitioners and decision-makers need to understand the direction and magnitude of changes in climate and key ecological responses at relevant spatial scales. In the Cariboo, trend monitoring should include:

- Climate: temperature, precipitation, snowpack, glacial melt and extreme weather.

- Hydrology: stream flow by watershed, water temperature, channel stability, forest cover, erosion, suspended sediment, trampling.
- Disturbance: fire weather index³⁹, wildlife, mass earth movements, insect and disease prevalence by seral stage, and soil moisture.
- Ecosystem state: regime shifts, connectivity, mature and old forest cover, habitat supply, invasive species and distribution shifts.
- Tree growth and health.
- Range: plant communities and condition, drought conditions.

Some of these data are already collected, but are not analysed regularly. A climate network that covers sub-regional variability with sufficient weather-monitoring stations will be important.

Moving Forward

Successful regional adaptation will require innovation and collaboration. Shared learning among practitioners, decision-makers and communities has the best potential for developing suitable adaptation strategies for the Cariboo Region that foster resilient ecosystems and sustain natural resources into the future. This document could be a helpful catalyst in collaborative efforts.

Contact for More Information

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2. Provincial specialist – Kristine Weese, Sustainable Forest Management Specialist, Resource Practices Branch, Kristine.weese@gov.bc.ca (250-558-1760).

¹ Ecological resilience is the capacity of an ecosystem to absorb, recover from and adapt to disturbance or stress caused by agents of change (such as climate change and natural resource management)

² Current research outcomes are primarily derived from projects under the [Future Forest Ecosystems Scientific Council](#) (FFESC) research program, but also including related regionally-relevant research

³ See the report [A Climate Change Vulnerability Assessment for British Columbia's Managed Forests](#) (Morgan and Daust et al, 2013) for more insight into how climate change is expected to impact BC's forest ecosystems

⁴ Projections are based on a combination of A2 and B1 emissions scenarios, where A2 represents roughly business as usual and B1 represents a more optimistic scenario with about ½ of emissions of business as usual (Trevor Murdock, Pacific Climate Impacts Consortium)

⁵ Moore et al, [Chapter 3 \(Weather and Climate\)](#), Compendium of Forest Hydrology and Geomorphology in British Columbia (Pike et al, editors)

⁶ BEC zone acronyms: IDF = Interior Douglas-fir; BG = Bunchgrass; SBPS = Sub-Boreal Pine – Spruce; MS = Montane Spruce; SBS = Sub-Boreal Spruce; ESSF = Engelmann Spruce Subalpine Fir; ICH = Interior Cedar Hemlock

⁷ The sites provide definitions and calculation details for indices

⁸ Rodenuis et al, [Hydro-climatology and future climate impacts in British Columbia](#) (2009)

⁹ Based on trends for all of BC

¹⁰ Details of the ensemble PCIC30 are given in Murdock and Spittlehouse, [Selecting and using climate change scenarios for British Columbia](#) (2011)

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- ¹¹ Wigley, The effect of changing climate on the frequency of absolute extreme events (2009) (Climatic Change 97:67-76; DOI 10.1007/s10584-009-9654-7) gives a theoretical analysis; Kharin et al, Changes in temperature and precipitation extremes in the CMIP5 ensemble (2013) (Climatic Change 119:345-357; DOI10.1007/s10584-013-0705-8) gives an analysis based on global climate models
- ¹² BECWeb includes information on [BEC and climate change](#)
- ¹³ Wang et al, [Projecting future distributions of ecosystem climate niches: uncertainties and management implications](#) (2012)
- ¹⁴ Nitschke and Innes, [Integrating climate change into forest management in South-Central British Columbia: an assessment of landscape vulnerability and development of a climate-smart framework](#) (2008)
- ¹⁵ For more information, see [Chapter 2c \(Natural Disturbance\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*
- ¹⁶ For more information, see summary in [Chapter 2b \(Hydrology and Aquatic Ecosystems\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*, and [Chapter 19 \(Climate Change Effects on Watershed Processes in BC\)](#) in the Compendium of Forest Hydrology and Geomorphology
- ¹⁷ An analysis of streamflow trends in the Skeena is underway (contact Scott Jackson at scott.jackson@gov.bc.ca for more information)
- ¹⁸ For more information, see [Chapter 2e \(Forested Ecosystems\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*
- ¹⁹ For more information, see [Chapter 2f \(Wildlife\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*
- ²⁰ For more information, see Hamann and Wang, [Potential effects of climate change on ecosystem and tree species distribution in British Columbia](#) (2006)
- ²¹ For more information, see [Climate Change and BC Range](#)
- ²² Dymond et al, [Diversifying managed forests to increase resilience](#) (2014)
- ²³ Fletcher, *Towards a framework to support working with uncertainty in natural resource management (a discussion paper)* (2015); [link to be added prior to publication](#)
- ²⁴ For example, see Leech et al, [Ecosystem management: A practitioners' guide](#) (2009)
- ²⁵ [BC Drought Response Plan 2010](#) (being updated) and [Dealing with Drought \(a Handbook for Water Suppliers in BC\) \(2009\)](#)
- ²⁶ Wilford and Lalonde, [A framework for effective watershed monitoring](#) (2004)
- ²⁷ Grainger, [Terrain stability field assessments in "gentle over steep" terrain of the Southern Interior of British Columbia](#) (2001)
- ²⁸ [FREP water quality effectiveness evaluation indicators and protocols](#); [stream quality crossing index](#)
- ²⁹ Redding, Lapp and Leach, [Natural disturbance and post-disturbance management effects on selected watershed values](#) (2012)
- ³⁰ Gayton and Almuedo, [Post-disturbance management of biodiversity in BC forests](#) (2012)
- ³¹ Updates to the Chief Forester's reference guide for FDP stocking standards based on climate change projections (2014)
- ³² Refer to Section 8, Page 15
- ³³ Guidance for designing fire management stocking standards is anticipated for release in June 2015
- ³⁴ [Silvicultural regimes for fuel management](#); [Interim guidelines for fire and fuel management \(ABCFFP, 2013\)](#)
- ³⁵ This web site includes guidance for Community Wildfire Protection Plans, Fuels Management Prescriptions, and Operation Fuel Treatments
- ³⁶ Swift & Ran, [Successional Responses to Natural Disturbance, Forest Management, and Climate Change in British Columbia's Forests](#) (2012)
- ³⁷ Recent research shows effects in coastal ecosystems. Kranabetter, Stoeher, and O'Neill, [Ectomycorrhizal fungal maladaptation and growth reductions associated with assisted migration of Douglas-fir](#) (2015)
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³⁸ For more information on managing the effects of climate change on BC rangelands, refer to: (i) Newman et al, [Managing for the ecological and socioeconomic effects of climate change on BC rangelands: developing strategic Range Use Plans, Range Stewardship Plans, and range management strategic documents](#) (2013); and, (ii) Range Branch's *Range Management Responses to Climate Change* (to be published in summer 2015)

³⁹ [Provincial fire research and monitoring needs](#)