



Adapting forest and range management to climate change

in the Thompson-Okanagan 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 Thompson-Okanagan region, in the southern interior of the province, includes the Thompson-Okanagan plateau as well as portions of the Coast and Cascade mountains to the southwest and the Columbia Ranges to the northeast. The topography is incised by several large lakes, including Okanagan and Shuswap, and rivers, including the Thompson, Shuswap and Fraser. Lying in the rain shadow of the Coast and Cascade Mountains, this region has some of the warmest and driest ecosystems in BC.

At the broadest scale, the region can be divided into three sub-regions: eastern portions of the Coast and Cascade Mountains, the central Thompson plateau, and a western portion of the Columbia Ranges. These divisions, defined by ecoregion boundaries, represent enduring features that will shape ecosystems in any climate. The leeward western sub-region is mostly dry, although some moist Pacific air travels through low passes. The rolling plateau includes north-south valleys associated with large river systems that carry warm dry air from the Columbia Basin. Pacific air brings high precipitation to the mountainous eastern sub-region. For information on weather systems for BC, visit [BC Weather](#)⁵.

Vegetation communities form an intricate mosaic in the Thompson-Okanagan, varying with latitude and elevation from open bunchgrass steppes in the hot, dry valleys of the south, through transitional parkland with widely-spaced ponderosa pines and Douglas-firs, to inland temperate rainforests of western redcedar and western hemlock at low elevations in the Columbia Ranges and dense coniferous in the cold, wet higher elevations. For information on biogeoclimatic (BEC) zones in this region, visit [BEC WEB](#).

Because of landscape complexity, climate adaptation will require dividing the mountain ranges and plateaus into finer-scaled units. Climate vulnerability analyses of the Kamloops TSA, in the northern

portion of the region, can provide guidance⁶. In the Kamloops TSA, analyses were based on five “ecozones” (groups of BEC subzones representing broad landscapes with similar climates, vegetation and ecological processes)⁷: **dry Douglas-fir and ponderosa pine ecozone** (e.g., IDFxh, PPxh subzones in southern valleys); **dry lodgepole pine ecozone** (e.g., MSxk, IDFdk subzones in the south of the district); **transitional ecozone** (e.g., ICHmw, ICHdw, IDFmw subzones along valleys running from the Columbia Highlands to the Thompson-Okanagan Plateau); **plateau ecozone** (e.g., MSdm, SBSmm and ESSFdc subzones); and, **cool and wet ecozone** (e.g., ESSFwc and ICHwk subzones in the Columbia Highlands and Mountains) (Figure 1).

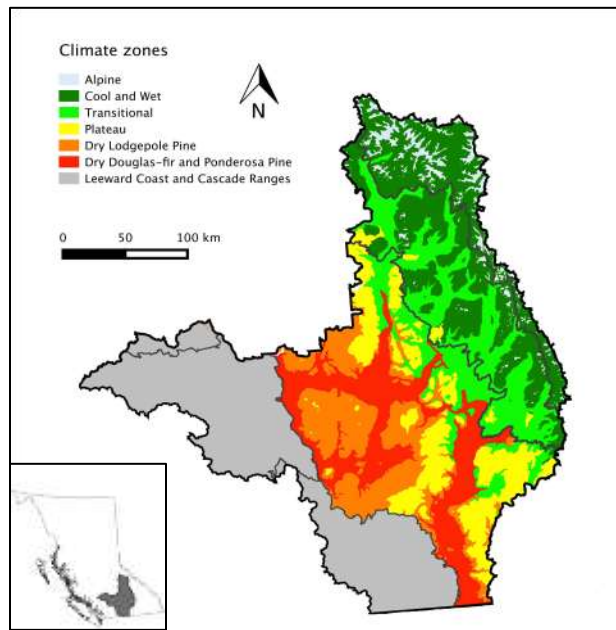


Figure 1. Climatically-relevant sub-regions within the Thompson-Okanagan Region. The grey portion of the map includes a broad division based on ecoregions; the coloured portion shows division into ecozones based on analyses in the Kamloops TSA and extrapolated to similar ecosystems in the south. Spatial 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 Thompson-Okanagan Region](#), its [Plan2Adapt](#) tool for projecting future climate conditions, and [ClimateBC](#)⁸.

The climate in the Thompson-Okanagan Region has changed over the past century and is expected to continue to change. On average over the region, over 1°C of warming has occurred during the 20th century, with warming occurring in all seasons; by the 2050s, temperature is projected to warm an additional 1.8°C (1.1 – 2.7°C). Projections suggest the region may warm, on average, by about 1.6 to 4.4°C by the end of this century, similar to moving from Williams Lake to Merritt or Princeton to Kamloops (3.3°C warmer). Summer is projected to warm more than other seasons.

Precipitation is fairly uniform over most of the region relative to other regions in BC, but varies considerably among years. Over the entire Thompson-Okanagan, annual precipitation has increased over the past century, although winter precipitation has decreased from 1951 – 2009. Projected changes

are modest, with about a 10% decrease in summer by the 2080s and a 10% increase in other seasons. In a region with such high topographical variation, high variability in future precipitation is likely at smaller scales.

Summary of climate projections for the Thompson-Okanagan for the 2050s*

Climate variable	Change in Thompson-Okanagan ⁹	Variation within region
Temperature		
Mean (°C)	+1.8 (1.1 to 2.7)	Slightly higher in south
Summer (°C)	+1.9 (1.3 to 2.7)	Slightly higher in south
Winter (°C)	+1.6 (0.8 to 3)	Slightly lower in south
Precipitation (%)		
Annual	+6 (-1 to 11)	Consistent over region
Summer	-9 (-19 to 1)	Biggest decrease in north
Winter	+7 (-4 to 15)	Consistent over region
Snowfall (%)		
Winter	-11 (-20 to 0)	Biggest decrease in south
Spring	-55 (-75 to -12)	Consistent over region
Snowpack	Decrease	Become intermittent or disappear at lower elevations
Frost-free days	+24 (14 to 35)	Greater increase at lower elevations and in south
Growing Degree Days	+319 (183 to 482)	Greater increase at lower elevations and in south
Extreme weather	More heat waves ¹⁰	Particularly at lower elevations

* Based on 1961-1990 baseline. Projected changes in temperature continue to increase past 2050. Source: PCIC [Plan2Adapt](#) tool. Median of 30 projections with range (in brackets) showing the 10th to 90th percentile of projected changes.¹¹

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, heatwave) can become a 1 in 10 year event.¹²

5. Impacts to Ecosystems

Ecosystem Climate Envelopes

Climate envelopes describe the climatic conditions associated with currently mapped biogeoclimatic (BEC) subzone/variants¹³. 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 generally projected to shift upslope and northward across BC¹⁴, resulting in expansion of some existing lower valley and plateau ecosystems as well as creation of novel ecosystem assemblages. By the 2050s, climate envelopes for current Thompson-Okanagan BEC zones are predicted to shift about 85 – 250 m upward in elevation and up to 175 km northward (Figure 2). Dry subzones are vulnerable, as the hotter, drier climate becomes less suitable for lodgepole pine and Douglas-fir. In these sites, forests may shift to grassland on south aspects and at lower elevations due to reduced moisture and increased fire frequency. The transitional subzones face moderate to high vulnerability due to drought stress and increased disturbance¹⁵. Although the ICH climate envelope is projected to expand, some subzones may come to resemble a combination of IDF and ICH, and dry sites may shift to shrubby or grassland ecosystems¹⁶. The plateau subzones are less likely to shift to grassland, but the current MS zone could shift to a new state comprised of a variety of communities. The wet cool subzones will be least impacted by drought and, in the absence of fire, could develop into a novel community including cedar and grand fir.

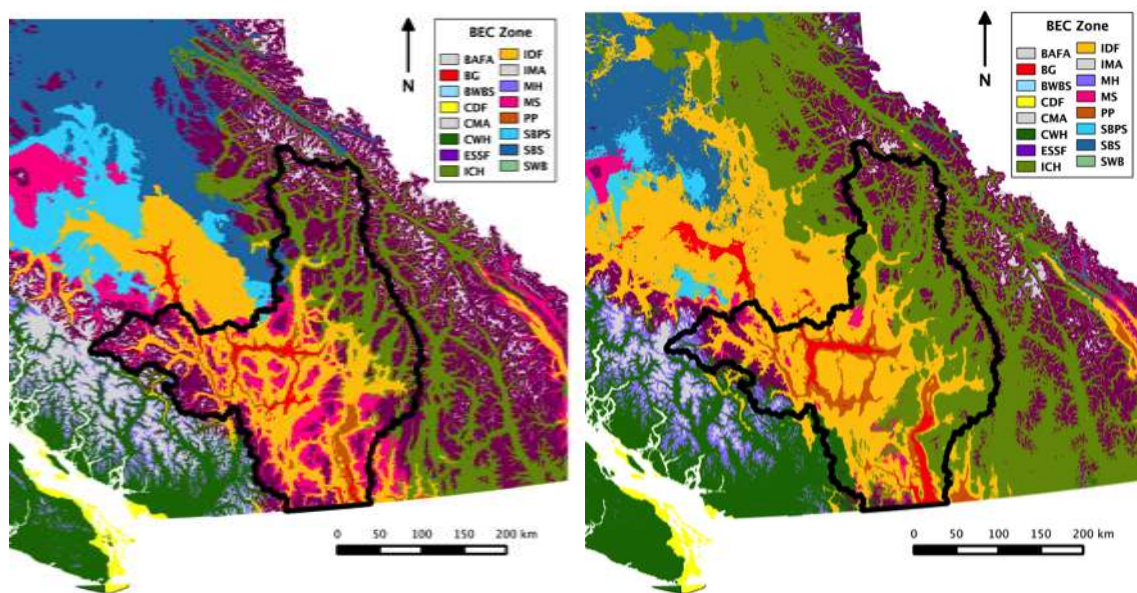


Figure 2. Current (BEC version 8) and projected future (2041-2070) BEC zone locations. Future map shows consensus of multiple projections. Maps from [ClimateBC](https://climatebc.ca/).

Natural Disturbance

The most profound changes to BC's forests in this century will be the result of more frequent and severe natural disturbances¹⁷. In the Kamloops TSA, the area influenced by natural disturbances could double

over the next century, with drought, fire and insects expected to be primary disturbance agents¹⁸. 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. In the Thompson-Okanagan, hotter, drier summers, coupled with increased mortality due to drought stress and insects, will increase fire hazard. Fires are projected to be larger, more intense and more frequent. Forested ecosystems in the region are already undergoing massive shifts in structure due to loss of mature lodgepole and ponderosa pines to mountain and western pine beetles. Mortality due to Armillaria root rot will likely decrease in dry ecozones and increase in the transition ecozones. Douglas-fir will likely experience increased mortality from the tussock moth and the bark beetle. Drought will also impact grasslands.

The increased prevalence of disturbance will vary by climatic sub-regions, elevation and forest type, with the biggest changes projected for dry forested ecosystems at low elevations.

Disturbance	Projected changes ^{19*}
Fire and drought	<ul style="list-style-type: none"> • Drought will increase in all but the coolest, wettest ecozones; drought is expected to increase mortality in many tree species, including lodgepole pine, Douglas-fir, spruce, subalpine fir and trembling aspen. • Fire size will increase; the risk of large wildfires is particularly high in dry ecozones with lodgepole pine. • Fire intensity will increase with more intermittent to full crown fires. • Fire frequency will increase; for example, in the Okanagan, the area experiencing fires every 50 years or less may expand from 34% to over 90% by 2085. • Fire refugia will decrease; for example, in the Okanagan, refugia may decrease from 41 to 2% of the landscape by 2085.
Insects and disease	<ul style="list-style-type: none"> • Insects are projected to increase substantially in dry and transitional subzones. • Mountain and western pine beetles have already caused substantial mortality in lodgepole and ponderosa pine in dry and plateau ecozones; this risk will continue if lodgepole pine trees survive. • Spruce beetles may increase throughout the region in the short term. • Armillaria root rot will likely decline in dry subzones and increase in transitional ecozones as ecosystems dry.

* Studies cover different portions of the region.

Hydrology and Fish

The Thompson-Okanagan Region is expected to follow projected provincial trends in hydrology, although the effects will vary with location, elevation and aspect²⁰. 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 northern subzones, 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.

Particularly in the Okanagan basin, domestic and agricultural water use is substantial and expected to grow. With a semi-arid climate, water levels are already below low-flow thresholds in some streams. Competition for limited water resources will increase as seasonal water flow decreases; water allocation challenges will increase with climate change.

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 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.

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 stream systems.

Earlier thaws and changed peaks pose hazards to infrastructure.

Feature	Projected changes ²¹
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. Increased flashiness 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.
Summer flows	<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. 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 (some are already affected) without adaptation.
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 at lower elevations.

Biodiversity

Climate shapes species distributions and ecological communities²². Populations faced with a changed environment can die out, move, or adapt to the new conditions. Many species that are adapted to projected climates currently live tens or even hundreds of 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. The Thompson-Okanagan region is more vulnerable to such regime shifts than most of BC.

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 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, which reduces large dead standing and downed wood) can exacerbate impacts of climate change. Old forest will decline due to increased disturbance and harvesting, threatening associated species; e.g., in the Kamloops TSA, old growth patches are projected to decline by 30 – 50% with an 80% reduction of large (>1,000 ha) patches. 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). Deciduous trees, including trembling aspen and paper birch, that provide critical habitat for many birds and other species, may be lost from dry ecosystems. In the Okanagan, over two-thirds of faunal species are classified as medium to high risk, particularly species requiring late-successional forest²³.
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 bird migration depends on day length, but their insect 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. The Thompson-Okanagan already has many invasive plant species, including knapweed and cheatgrass. Grasslands and dry forest ecosystems are particularly impacted and will provide a source of invasive species following disturbance, facilitating regime shifts.
Wildlife ²⁴	<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 affect 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 competition²⁵. Fires and harvesting will shift the age-class distribution towards younger stands. Most tree species will be unable to migrate quickly enough to follow the climate envelopes to which they are adapted. Uncertainty about climate projection leads to uncertainty about which trees may be best-suited to changing conditions. 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">• Many tree species will face unprecedented drought stress and regeneration challenges at lower elevations beyond 2050.• In dry ecozones, risk to lodgepole pine establishment and survival will be very high.• Parts of 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 ecosystems due to elevated CO₂ coupled with warmer temperatures.• Growth potential, however, may not be realised because of limited moisture or nutrients, because populations are not adapted to changed seasonality and increased extreme events, or because maladaptation increases susceptibility to insects and disease.• Some dry ecosystems may shift from productive forest to grassland.
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.• Drought-stressed trees are more susceptible to certain insects and pathogens; e.g., lodgepole pine is susceptible to a range of disturbance agents when stressed.• Tree mortality in transitional subzones will be heightened by warmer, seasonally drier conditions.• Several deciduous and coniferous species will likely suffer diebacks. The current trend of birch die-back is expected to worsen.
Competition	<ul style="list-style-type: none">• Competition will occur after natural disturbance; shrubs may be favoured.

Range

Grassland ecosystems will shift in response to climate change due to increased drought, and a decline in forests due to disturbance and competition. Earlier spring plant growth and a longer growing season may translate into a longer grazing season for livestock. Grasslands are projected to increase in the region, but community composition will likely change and may be dominated by invasive species²⁶.

Response class	Projected changes
Productivity	<ul style="list-style-type: none">• Productivity will decrease at lower elevations due to increased drought and resultant increase in invasive plants, particularly if grazing levels remain unchanged. Deeply rooted perennial grasses will perform best.• Productivity will increase at higher elevations.• Frequent drought may lead to fluctuating herd sizes.
Competition	<ul style="list-style-type: none">• Many desirable plant 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.• Invasive plants may be particularly favoured following fire in forests with little existing understory vegetation.
Water	<ul style="list-style-type: none">• Dispersed surface water sources available for livestock will decrease.
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 resilience²⁷. 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.

Uncertainty²⁸

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 to mitigate flood impacts should take into account the higher probability of flooding associated with climate change plus climate oscillations. Planners may need more flexibility to handle regime shifts (e.g. if forested ecosystems lose viability). Best management practices for ecosystem management²⁹ provide an excellent resource.

Practices

Hydrology

To protect aquatic ecosystems, water availability and infrastructure near watercourses, adaptation consists of managing water removal to ensure sufficient flow, 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 • Manage livestock grazing levels 	<ul style="list-style-type: none"> • Drought guidance³⁰ • <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 watersheds³¹</i>
<ul style="list-style-type: none"> • Maintain ditches and deactivate roads <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 table 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>

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
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 • Design roads and drainage structures to accommodate increased peak flow and sediment transport in areas likely to become seasonally 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 <ul style="list-style-type: none"> ◦ Maintain roads and drainage structures adequately • Manage grazing to maintain functional riparian ecosystems; maintain sufficient riparian vegetation to control grazing 	<ul style="list-style-type: none"> • Interior watershed assessment • Stream quality crossing index • Identify “flashy” watersheds³²; monitor precipitation and runoff • Updated riparian retention guidance to address risk of increased sedimentation • 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 the hydrological implications of salvaging disturbed stands ◦ Account for increased runoff from burned sites in ECA calculations • Manage roads to minimize impacts to flows • Protect stream sources from timber harvesting and compaction by livestock and machinery • Leave live standing vegetation and downed wood barriers next to all riparian areas on rangeland 	<ul style="list-style-type: none"> • Interior watershed assessment • Post disturbance watershed effects³³ • Landscape fire management planning • Water quality and livestock grazing BMPs

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.

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 	<ul style="list-style-type: none"> • Biodiversity Guidebook • Updated land use plans • Climate-based timber supply analysis

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
<ul style="list-style-type: none"> ○ Include strategically placed landscape-level fuel breaks ○ Manage OGMA's flexibly to address changing conditions (e.g., it may be necessary to build in extra areas of old forest across landscape to maintain old forest network) 	
<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 management³⁴
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 (i.e., retain partial overstory for shelter) in dry ecozones and in dry sites in other ecozones • Recognise sites where reforestation may fail and adjust stocking standards accordingly (e.g., do not attempt to reforest sites that are predicted to shift from PP to BG) 	<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 downed wood in a relatively undisturbed state <ul style="list-style-type: none"> ○ Particularly important on dry sites and in riparian ecosystems 	<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) <ul style="list-style-type: none"> ○ Particularly important on dry sites 	<ul style="list-style-type: none"> • See Trees section
Loss of diversity and vigour in young and maturing forests due to maladaptation to changing climate	
<ul style="list-style-type: none"> • Plant climatically-suited species and genotypes (i.e., facilitate migration) 	<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 • Encourage deciduous trees <ul style="list-style-type: none"> ○ Avoid removing aspen in dry and transition ecozones ○ Maintain deciduous species in moist transition ecozones ○ Encourage deciduous species in cool and wet ecozone 	<ul style="list-style-type: none"> • Climate change stocking standards³⁵
<ul style="list-style-type: none"> • Use stand tending to influence succession 	<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) • Establish competitive vegetation in ditches, on side slopes and other disturbed soil as soon as possible • Undertake 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>

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
<ul style="list-style-type: none"> • Manage grazing to maintain late seral vegetation communities <ul style="list-style-type: none"> ◦ Adjust stocking rates and distribution ◦ Particularly important near susceptible ecosystems (e.g. grass and wetlands, saline areas, dry, open forested ecosystems and riparian areas) 	<ul style="list-style-type: none"> • Managing rangeland invasive plants • Updated range policy
<ul style="list-style-type: none"> • Minimize site disturbance, especially multiple disturbances <ul style="list-style-type: none"> ◦ Particularly important on susceptible (e.g., steep warm forested slopes, grasslands, saline ponds, wetlands, rock outcrops) sites ◦ Minimize off-road vehicle access in grasslands, wetlands, riparian areas and 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

Trees

Adaptation strategies for trees are designed to increase 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 decreases in projected beetle-related tree mortality over the long term, modest decreases in disease, and modest increases in tree growth in areas with sufficient moisture. Decreases in projected beetle-related mortality are, however, partly attributable to a changing forest age-class structure (i.e. there are fewer old trees).

In the Kamloops TSA, analyses suggest that reducing reliance on lodgepole pine for reforestation would be a simple change that would increase resilience significantly³⁶. Other useful adaptation strategies include targeting harvesting towards stands that are vulnerable to natural disturbance, partial cutting to assist regeneration, and incremental silviculture to increase fire resistance.

Adaptation may have limited success in reducing fire disturbance because losses due to wildfire are expected to double in the next 40 years, and effective fire control in average-weather years can be negated by large disturbances 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	
<ul style="list-style-type: none"> • Plant climatically-suited species and genetic stock <ul style="list-style-type: none"> ◦ For example, increase ponderosa pine in dry sites dominated by Douglas-fir, increase Douglas-fir in dry lodgepole pine sites • Establish operational trials to test survival and growth • Monitor select plantations to test survival and growth annually 	<ul style="list-style-type: none"> • Kamloops Future Forest Strategy • Tree species selection tool • FFT assisted species migration guidance • Chief Forester standards for seed use³⁷ • Climate-based seed transfer interim policy measures • Seed zone maps

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
	<ul style="list-style-type: none"> • <i>Measures to address cost and risk</i>
Increased drought stress	
<ul style="list-style-type: none"> • Reduce reliance on lodgepole pine <ul style="list-style-type: none"> ○ Avoid stand conversions to lodgepole pine across lower elevation and plateau landscapes (e.g. do not consider lodgepole pine a “preferred” species in the dry lodgepole pine ecozone, dry sites in the transition ecozone, or the plateau ecozone) ○ Promote Douglas-fir and ponderosa pine in these lower elevation and plateau ecozones ○ Fertilize existing young lodgepole pine stands to shorten rotation and replace with more resilient species mixture, if cost effective • Reduce reliance on spruce in moist transitional ecozone <ul style="list-style-type: none"> ○ Encourage species mixture including Douglas-fir, ponderosa pine, western larch and western white pine • Target harvest of stands that are vulnerable to natural disturbance 	<ul style="list-style-type: none"> • Kamloops Future Forest Strategy
<ul style="list-style-type: none"> • Partially cut stands on dry subzones and sites to retain shelter and moisture to protect fragile regeneration <ul style="list-style-type: none"> ○ Especially on vulnerable sites such as south-facing slope or areas prone to frost • Promote more open conditions, particularly at lower elevations, to maintain and promote vigour • 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"> • 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 ○ Balance fuel reduction with biodiversity objectives • 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 standards³⁸ • Fire and fuel management guidelines³⁹ • Kamloops Future Forest Strategy
<ul style="list-style-type: none"> • Reduce human-caused fires 	<ul style="list-style-type: none"> • Wildfire Management Branch prevention strategy

Projected ecosystem changes and adaptation strategies	Existing policy guidance and <i>policy or knowledge needs</i>
<ul style="list-style-type: none"> • Manage fire hazard around communities • Reduce risk in interface areas <ul style="list-style-type: none"> ○ within 2 km of communities, critical infrastructure and high environmental and cultural values, wildfire risk reduction is the primary consideration) 	<ul style="list-style-type: none"> • Strategic wildfire prevention initiative⁴⁰ • Fuel hazard assessment and abatement • FireSmart program • FireSmart communities
Increased disease-related mortality	
<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
<ul style="list-style-type: none"> • Increase stand-scale species diversity (e.g., retain and plant a variety of species, including broadleaf) <ul style="list-style-type: none"> ○ Expand breadth of “acceptable” species in young stands • Increase landscape-scale species diversity by planning retention and reforestation at the landscape level <ul style="list-style-type: none"> ○ 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 responses⁴¹ • Stocking standards reference guide • Climate change stocking standards • <i>Free-growing policy that allows variation for local conditions</i>
Increased beetle-related mortality	
<ul style="list-style-type: none"> • Plant climatically-suited species and stock <ul style="list-style-type: none"> ○ Reduce reliance on lodgepole pine and spruce 	<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 2-4 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 conditions⁴². 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. Steps towards adaptation include revising expectations for rangelands to include climate dynamics, expecting higher variability in productivity, maintaining late seral native perennial grass species, and adjusting stocking rates to reflect changing productivity.

Projected ecosystem changes and adaptation strategies	Existing policy guidance and policy or knowledge needs
Changes to forage supply	
<ul style="list-style-type: none"> Reduce allocation where forage supply is projected to decrease (e.g., some low elevation grasslands) <ul style="list-style-type: none"> 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 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 guidance⁴³ Forage use regulations that adapt to changes in forage supply (e.g. updated tenure replacement policy) Range ecosystem descriptions Range management principles
Changes to water supply	
<ul style="list-style-type: none"> Control access to water with strategic fencing, barriers and troughs <ul style="list-style-type: none"> 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 Thompson-Okanagan, trend monitoring should include:

- Climate: temperature, precipitation, snowpack, glacial melt and extreme weather.
- Disturbance: fire weather index⁴⁴, mass earth movements, insect and disease prevalence by seral stage, and soil moisture.
- Hydrology: stream flow by watershed, water temperature, channel stability, forest cover, erosion, suspended sediment.
- Biodiversity: regime shifts, seral stage, habitat supply, species health, connectivity, 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 Thompson-Okanagan 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)

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- ⁶ [Adapting forest management in the Kamloops TSA to address climate change: Kamloops Future Forest Strategy](#) (also known as K1) (2009); [Validating impacts, exploring vulnerabilities and developing robust adaptive strategies under the Kamloops Future Forest Strategy](#) (also known as K2) (2011)
- ⁷ BEC subzone acronyms: IDFxh = Very Dry and Hot Interior Douglas-fir; PPxh = Very Dry and Hot Ponderosa Pine; MSxk = Very Dry and Cool Montane Spruce; IDFdk = Dry Cool Interior Douglas-fir; SBPS = Sub-boreal Pine and Spruce; ICHmw = Moist Warm Interior Cedar Hemlock; IDFmw = Moist Warm Interior Douglas-fir; MSdm = Dry Mild Montane Spruce; SBSmm = Moist Mild Sub-boreal Spruce; ESSFdc = Dry Cold Engelmann Spruce Sub-alpine Fir; ESSFwc = Wet Cold Engelmann Spruce Sub-alpine Fir; and ICHwk = Wet Cool Interior Cedar Hemlock
- ⁸ The sites provide definitions and calculation details for indices
- ⁹ Median and range (10th – 90th percentile) from a standard set of Global Climate Model projections ([Plan2Adapt](#))
- ¹⁰ Based on trends for all of BC
- ¹¹ Details of the ensemble PCIC30 are given in Murdock and Spittlehouse, [Selecting and using climate change scenarios for British Columbia](#) (2011)
- ¹² 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
- ¹³ BECWeb includes information on [BEC and climate change](#)
- ¹⁴ Wang et al, [Projecting future distributions of ecosystem climate niches: uncertainties and management implications](#) (2012)
- ¹⁵ See Footnote 6
- ¹⁶ 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)
- ¹⁷ For more information, see [Chapter 2c \(Natural Disturbance\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*, Haughian et al, [Expected effects of climate change on forest disturbance regimes in British Columbia](#) (2012), and Footnote 16
- ¹⁸ See Footnote 6
- ¹⁹ See Footnotes 6, 166 and 17
- ²⁰ 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
- ²¹ See Footnote 200
- ²² For more information, see [Chapter 2e \(Forested Ecosystems\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests*, and Footnote 6.
- ²³ See Footnote 166
- ²⁴ For more information, see [Chapter 2f \(Wildlife\)](#) of *A Climate Change Vulnerability Assessment for British Columbia's Managed Forests* and Footnote 16
- ²⁵ For more information, see Hamann and Wang, [Potential effects of climate change on ecosystem and tree species distribution in British Columbia](#) (2006) and sources in Footnote 222
- ²⁶ For more information, see [Climate Change and BC Range](#)
- ²⁷ Dymond et al, [Diversifying managed forests to increase resilience](#) (2014)
- ²⁸ Fletcher, *Towards a framework to support working with uncertainty in natural resource management (a discussion paper)* (2015); [link to be added prior to publication](#)
- ²⁹ For example, see Leech et al, [Ecosystem management: A practitioners' guide](#) (2009)
- ³⁰ [BC Drought Response Plan 2010](#) (being updated) and [Dealing with Drought \(a Handbook for Water Suppliers in BC\)](#) (2009)
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- ³¹ Wilford and Lalonde, [A framework for effective watershed monitoring](#) (2004)
- ³² Flashy watersheds respond rapidly to changes in precipitation
- ³³ Redding et al, [Natural disturbance and post-disturbance management effects on selected watershed values](#) (2012)
- ³⁴ Gayton and Almuedo, [Post-disturbance management of biodiversity in BC forests](#) (2012)
- ³⁵ Updates to the Chief Forester's reference guide for FDP stocking standards based on climate change projections (2014)
- ³⁶ Nelson et al, [Guidance to adapt forest management for climate change in the Kamloops TSA](#) (2012)
- ³⁷ Refer to Section 8, Page 15
- ³⁸ Guidance for designing fire management stocking standards is anticipated for release in June 2015
- ³⁹ [Silvicultural regimes for fuel management](#); [Interim guidelines for fire and fuel management \(ABCFP, 2013\)](#)
- ⁴⁰ This web site includes guidance for Community Wildfire Protection Plans, Fuels Management Prescriptions, and Operation Fuel Treatments
- ⁴¹ Swift & Ran, [Successional Responses to Natural Disturbance, Forest Management, and Climate Change in British Columbia's Forests](#) (2012)
- ⁴² Recent research shows effects in coastal ecosystems. Kranabetter, Stoehr, and O'Neill, [Ectomycorrhizal fungal maladaptation and growth reductions associated with assisted migration of Douglas-fir](#) (2015)
- ⁴³ For more information on managing the effects of climate change on BC rangelands, refer to: (i) L. Fraser et al, [Climate Change and BC Range](#) (2013); (ii) 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, (iii) Range Branch's *Range Management Responses to Climate Change* (to be published in summer 2015)
- ⁴⁴ [Provincial fire research and monitoring needs](#)