Report #9

Moving Towards Adaptation Strategies in Forest Management - a Starting Place for the West Kootenays

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Contents

1.0 INTRODUCTION

Recent reports by the International Panel on Climate Change (IPCC) confirm that global climate change is underway, and likely to accelerate over the coming decades unless humans make drastic cuts to global greenhouse gas emissions (IPCC 2007). In British Columbia, analysis of the last hundred years of climate data confirms that parallel climatic changes are also occurring in this province (Spittlehouse 2008), and in the Columbia Basin (Murdock et al. 2007). Visible evidence of changes in climate is also becoming increasingly apparent to local people – witnessed through a wide range of changes in a broad variety of different indicators.

Results from downscaled global climate models illustrate the range of potential climate changes for BC over the next century, depending on what assumptions are made about future greenhouse gas emissions. Potential changes for southern British Columbia include increases in annual temperatures and precipitation, decreases in summer precipitation, decreases in snowpack at low elevations, increases in annual and inter-annual climate variability and increases in the frequency and magnitude of extreme weather events.

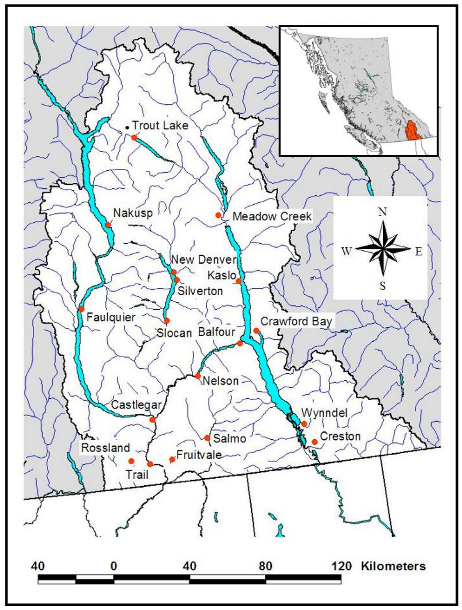

Figure 1. Study area.

The British Columbia government has recognized that the uncertainties associated with climate change demand a forest management approach that differs from the traditional (MoFR 2008). With the establishment of the Future Forest Ecosystems Initiative (FFEI) in 2006, the province began a move toward looking for ways to adapt the forest and range management framework with respect to potential future climates. The province established the Future Forest Ecosystem Scientific Council[1] (FFESC) in 2008 to deliver research grants to support the objectives of the FFEI. This report summarizes some of the findings of one project[2] that was among those funded by the FFESC under their 2009 call for proposals.

This report is #9 in a series of reports for the West Kootenay Climate Vulnerability and Resilience Project (see Figure 1 for study area location). It focuses on a first approach to considering adaptation actions for West Kootenay forest practitioners – what, if anything, can be done to reduce the ecosystem vulnerabilities identified in Report #7, minimize the risks to achieving management objectives and producing the desired goods and services from these ecosystems, and address the barriers in the socio-economic portion system to adaptation? We emphasize that this report should be considered a very first step to initiating adaptation in this area, and we urge that it is used to spark conversation and debate moving forward.

It became apparent to the project team during the two years of interaction with West Kootenay practitioners that there is a high level of variability in terms of understanding the need for adaptation, especially across different branches of forest management. For example, impacts have already prompted changes in practices in strategies around community wildfire protection and more generally within Wildlife Management Branch. However, other members of the forest management community were largely uninformed about the need for change, and the extent of the change that may be required. Adaptation - changes in practices and perceived measures of success - will likely be required across the full range of forest management practices and management strategies including:

[1] Further information on FFESC: http://www.for.gov.bc.ca/hts/future_forests/council/index.htm

[2] Resilience and Climate Change: Adaptation Potential for Ecological Systems and Forest Management in the West Kootenays. For further information on the project: http://kootenayresilience.org

adjusting operational decisions about when to harvest, changing prescriptions for what species to reforest, revising management objectives, and reconciling the allowable annual harvest levels with these changes. Creating the understanding and willingness to engage in this process will be a key part of effective adaptation (see Report # 8, Pearce 2012).

Working to identify potential adaptation actions to reduce vulnerabilities to climate change is the end point of the West Kootenay Climate Vulnerability and Resilience project. However, this report is simply a starting point upon which further work should be developed. Report #7 (Utzig and Holt 2012) identifies the potential range of ecological vulnerability for West Kootenay "ecosystems". These vulnerabilities are likely to significantly impact the availability of ecological goods and services that society depends upon, and each forest manager will need to respond to those changes. Each forest management organization and the other users of the forests in the management unit will value these goods and services differently. Consequently, each forest management organization will need to make their own choices about the best adaptation options to address the specific climate change impacts in their forest management unit.

This report (Report #9, Pinnell et al. 2012b) summarizes the research and participant input on choosing adaptation actions for the West Kootenay area, including a summary of how to approach the problem, adaptation actions at different scales, and how to approach 'deciding what to do'.

What is Adaptation?

Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist:

- anticipatory – implemented before climate change impacts are experienced; or
- reactive – occurs after the initial impacts become evident;
- autonomous - not a conscious response to climatic, but is triggered by ecological changes in natural systems; or
- planned – deliberate decisions based on the awareness that conditions have changed, or are expected to change.

Based on IPCC, (2007)

1.1 Methods

Various phases of this project have contributed to the development of the preliminary adaptation actions , including:

- We use the results from the ecosystem Vulnerability Assessment to guide where changes may be occurring and their ecological significance (Report #7, Utzig and Holt 2012). This information alone is inadequate to set priorities for action, but it does provide guidance on where ecological factors may play most readily into the need for changes to current management planning. For example, predicted changes in ecologically appropriate tree species, or changes in natural disturbance regime, have significant implications for determining appropriate management strategies such as suitable species and stocking standards.
- Content also came from workshop participants – from exercises in the 1st, 2nd and 3rd practitioner workshops (refer to Report #10, 2012b). This included impact charts, scenario discussions where we considered incorporating climate change information in four forest management decision scenarios: fire management, landscape scale management of conservation areas, harvest to free-growing decisions, management decisions for forests between free-growing and to mature ages and the structured-decision making exercises for road management, silviculture prescriptions and management of forests between free-growing and to mature ages.
- Brief literature review.

Note that this work commenced at the very end of the West Kootenay Climate Vulnerability and Resilience project, and should be considered the foundation for moving forward. Additional work will be required to discuss, modify and build upon the ideas presented here.

2.0 HOW TO APPROACH THE PROBLEM?

2.1 Adaptation principles

As adaptation is a relatively new response to climate change, the selection and implementation of adaptation actions is a new endeavor. Few forest management adaptation initiatives have advanced through the steps of evaluating adaptation options, deciding on the best options, implementing these options and learning through monitoring. Consequently the current advice regarding selecting adaptation options provides principles for approaching this task. There are a large number of recent papers summarizing approaches to developing appropriate adaptation options (e.g., Kolstrum et al. 2011, CCSP 2008) – many are very general and tend to focus on changing the mind-set for how to make management decisions. The following three papers offer some succinct advice:

2.1.1 US Forest Service

The US Forest Service has developed four general climate change adaptation strategies based on the experiences of pilot adaptation assessments in national forests (Petersen et. al., 2011). These broad strategies are helpful to consider when brainstorming adaptations.

- **Promote resistance to climate change**—This strategy includes actions and treatments that enhance the ability of species, ecosystems, or environments (including social) to resist forces of climate change and that maintain values and ecosystem services in their present or desired rates and conditions. For example, where steep slopes have been altered by road construction, resisting erosion and landslides is always an objective, especially if increased saturation and/or runoff accompanies climate change. Resisting change is often appropriate for situations and resources associated with high social or ecological value that are vulnerable to direct or indirect effects of climate change.
- **Develop resilience to climate change**—As discussed in Report #2 (Holt et al. 2012), in a climate change context, resilience refers to the capacity of a system or environment to withstand or absorb increasing impact without changing state. Examples of resilient ecosystems include conifer forests that regenerate to forest rather than to shrub lands or grasslands after repeated wildfire (e.g., Ponderosa pine forests). Adaptation treatments with a goal of increasing resilience will reduce species or system vulnerability to acute or chronic stress such as by reducing forest densities, thereby minimizing water stress, fire hazard, and some types of insect outbreaks.
- **Assist response to climate change**—The most proactive strategic actions are those that work directly with the changes that climate is creating; that is, they assist transitions to future states by mitigating and minimizing undesired and disruptive outcomes. Examples include assisting migration, through which species are moved to locations currently outside native ranges, but projected to be favorable future habitat, or planting novel species mixes in regeneration projects to expand forest diversity and thus resilience.
- **Realign highly disturbed ecosystems**—When ecosystems have been disturbed beyond historical ranges of natural variability, restoration can be implemented to return structure, composition, process, and ecosystem services to historical states. This approach makes sense where disruption has been so severe and projected climate changes are within the historical climatic range.

2.1.2 UK Climate Impacts Program (UKCIP)

The United Kingdom Climate Impacts Program (UKCIP) was one of the first initiatives globally to focus on supporting adaptation decisions. This program identifies the following types of adaptation actions[3]:

- **accepting the impacts**, and **bearing the losses** that result from climate risks (e.g., increasing loss estimates from wildfires, insects and diseases in allowable annual cut decisions);
- **off-setting losses** by **sharing or spreading the risks or losses** (e.g., through insurance or reallocating operating areas in a TSA after a large wildfire);
- **avoiding or reducing** exposure to **climate risks** (e.g., harvesting climate sensitive stands, building roads to higher peak flow standards); and,
- **exploit new opportunities** (e.g., assisted migration).

Identification of 'robust' climate change adaptation options – actions that make sense across a range of climate change scenarios is emphasized. For example, selecting a tree species for reforestation that is suitable if the climate changes minimally, but entirely unsuitable if large changes happen, would not be a robust choice.

2.1.3 BC Adaptation Principles

Simon Fraser University's ACT Program (Harford 2008) identifies a series of broader principles that increase the chances of leading to effective adaptation actions:

- **Promote smart adaptation – through knowledge mobilization and outreach -** which includes:
  - strategic communications and organizational development , with a focus on multi-disciplinary team building;
  - develop institutional capacity and encourage broad stakeholder engagement; and
  - understand economic implications of 'not adapting'.
- **Mainstream -** adapt existing mechanisms of change, and incorporate climate change as central feature.
- **Build or foster development of the right tools -** create tools and practices that lead to effective adaptation. This includes practical tools (understanding where and how to manage) and changing legislation to respond appropriately.
- **Build Expertise -** this includes increasing existing capacity by training people in multi-disciplinary programs, and developing capacity within organizations to be more aware of, and technically capable of adapting to, climate change information and implications.

2.2 Considering uncertainties

Considering uncertainties is a key part of any management strategy. There are a vast number of uncertainties that climate change brings to the forest management realm. We discuss one aspect of these uncertainties below – which climate future am I managing towards?

The range of climate predictions for the West Kootenays generated through this project provide some quite solid direction on future trends in climate: In general, the models are projecting that by the 2080s, winters, springs and falls will be warmer by 1 to 5^{o}C and 10-25% wetter, and that summers will be 2 to 7^{o}C warmer, with precipitation that may be similar to today or decreased by up to 30%. In summary then, it is not the direction of change that is

[3] See http://www.ukcip.org.uk/wizard/wizard-4/4-1/

questioned, but the rate of change and the magnitude of those changes over time. That climate change will create significant changes in the structure and dynamics of West Kootenay forested ecosystems is not uncertain.

In an attempt to start to deal with the range of potential futures, we used three climate scenarios in the vulnerability assessment, so resulting in three sets of impact and vulnerability ratings. This range can be used to get some understanding of the potential range of futures that could be expected. Where it is more clear (though by no means certain) in what direction the ecosystems are headed, then it becomes easier to incorporate the assessments of impacts and vulnerability into management adaptation decisions. Where the three scenarios result in quite different potential outcomes it makes translation into management direction more difficult, with the need to concentrate on robust options, rather than optimal options.

In terms of consistency of the projections from the three scenarios, the vulnerability assessment results for the low elevation forests in the North Subregion and mid elevation forests in the Mid Subregion are most consistent – and are predicted to have the highest vulnerabilities. These areas should therefore become a high priority for further assessment (in relation to the specific adaptation actions, using principles as outlined above).

Alternatively, the highest elevation bands in the South, North and to a slightly lesser extent the Mid Subregion, have consistently Low and Very Low vulnerability ratings. As a result, these areas become a relatively lower priority for further exploration of adaptation actions. However, monitoring to detect any unanticipated changes will remain important in these areas.

It is most difficult to know how to interpret the vulnerability assessment for the 'intermediate' areas – those with either intermediate vulnerability, or with a high diversity of vulnerability ratings. For example, the mid elevation band in the North which has Low, Low and Very High vulnerability ratings – depending on scenario, and the South mid elevation band has ratings of Very Low, Very Low and High ratings, resulting in significant uncertainty about potential outcomes. For these systems, choosing ecologically appropriate adaptation strategies will be particularly challenging. The principles laid out in Section 2 of this report can help focus management strategies – by looking at ways to promote resilience across the range of potential futures. However, the time, effort and information required to undertake this process should not be under-estimated.

2.3 When to act?

The ecosystem vulnerability ratings outlined above are based on the potential changes that may occur by the 2080s (2070 – 2099). Although this seems distant, in terms of forest management this timeframe is well within the usual planning horizon, and decisions made today (e.g., reforestation) that are incompatible with the future climate will have significant implications. One aspect of determining how to approach such changes is to assess whether management should 'anticipate' the predicted changes today, or whether to allow them to occur and 'respond' to them when they have occurred. Many factors play into these decisions including consideration of:

- **certainty -** how 'certain' are we that the changes will occur? Is there evidence existing today that the changes are ongoing. Without management actions what are the implications?
- **urgency -** urgent actions could be those relating to key risks or vulnerabilities such as to important values (e.g., wildlife habitat), human health (e.g., fire risk), infrastructure, or timber supply for example. Analysis of risks and timeframes will be a key need moving forward. An evaluation of urgency requires more information than the ecosystem vulnerability analysis undertaken here. A risk approach – considering ecosystem vulnerability in the context of the broad spectrum of consequences to values and likelihood of those consequences may be an appropriate next step (ASRD 2010).
- **possibility of resistance -** although ecosystem changes are expected everywhere (see Report # 5, Utzig 2012), the mechanisms of change may be quite different from one another. Different types of forest may 'resist' change differentially – for example existing wetter ICH forest types, though predicted to be highly vulnerable to catastrophic ecosystem shifts, are specifically vulnerable immediately after a disturbance event. Large fires in this system are therefore likely to warrant immediate management actions to prevent

the system from entering a successional stall. However, in the interim (before a fire), wetter ICH forests also maintain values – e.g., they effectively dampen the effects of broader climate change through microclimate effects more effectively than open drier forest types. In the short-term then, before a fire occurs, the values supported by these systems are likely to be maintained. Adaptive management – in particular, monitoring of the rates of individual tree mortality for example – should be an important component to signal whether changes are beginning to happen that require consideration in management decisions.

- **opportunity for success -** without management action, what are the implications? Forest practitioners have the opportunity to influence certain types of ecosystem structures or processes in the immediate term. Harvest occurs over a relatively limited portion of the landbase at any one time, while other management strategies – e.g., planning, wildfire management – differentially affect different portions of the landbase over differing time periods. Determining what scale is most appropriate for tackling anticipated changes will be a key decision in preparation for climate change adaptation. For example, 'decline syndrome' (mortality of trees attributable to a combination of factors) is predicted for a significant area of the West Kootenays. Mechanisms of mortality are likely to be a combination of drought, insects and disease - at the individual tree level, and fire at the landscape level. The potential to combat decline syndrome can occur at the planning level (e.g., determining where to harvest first), at the cutblock level (e.g., by designing partial harvesting systems that retain climate appropriate trees and remove those likely to decline). However, the effectiveness of each strategy will depend on the location of 'at risk' stands and the proportion of the 'at risk' trees within those stands. In some cases, especially due to the resilience afforded by the natural diversity of West Kootenay forests, management for decline syndromes may only be relevant in specific areas of the landscape.

Taking time to identify the types of changes and the locations that can be dealt with effectively using management tools will be helpful.

3.0 SUBREGION-SPECIFIC ADAPTATION CONSIDERATIONS

The West Kootenay study area has been separated into north, mid and south geographic subregions representing regional landscapes with relatively homogenous regional climates (Figure 2). In this report, for each subregion we provide a brief description of historic disturbance regimes and resulting ecosystems, predicted climate change, predicted changes to disturbance regimes and resulting ecosystems, and finally issues to consider when selecting adaptation strategies.

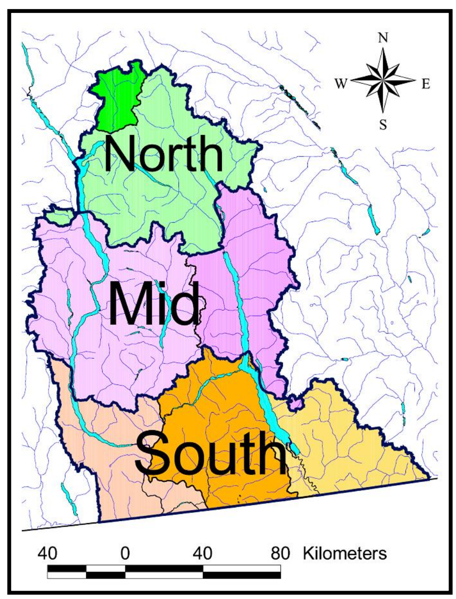

Figure 2. Subregions.

3.1 North Subregion

Historically, ecosystems in the North subregion have been old-growth western redcedar/ western hemlock forests at low elevations and Engelmann spruce/subalpine fir forests at high elevations, with both experiencing gap replacement disturbances at long intervals. Seral species such as Douglas-fir, western larch and white pine are infrequent on dry, warm aspects. Moist conditions in these Interior Cedar-Hemlock (ICH) and Engelmann Spruce –Subalpine Fir (ESSF) ecosystems have for the most part kept fires small.

Climate change is predicted to cause warmer temperatures, higher annual total precipitation, but with drier conditions in the summer

(Report #3, Utzig 2011). These changes along with more frequent extreme weather events are predicted to change stream flow regimes and likely reduce channel stability. Frequent large stand-replacing fires are predicted to replace gap replacement disturbances (Report #4, Utzig et al. 2011). Growing conditions on the warmest, low elevation sites are expected to be more supportive of grassland-steppe, grand fir and dry MS ecosystem types (Report #5, Utzig 2012). The warmer moist sites will be more suitable for coastal western hemlock (CWH) ecosystem types. Conditions suitable for ICH species will move upslope into current ESSF ecosystems.

Issues specific to the North Subregion that must be considered when selecting adaptation options are:

- harvesting, reservoirs, agriculture and settlement have severely fragmented ecosystems at elevations <1500m;
- there is a lack of seed source for fire adapted species;
- mountainous terrain limits lateral connectivity/ movement; and
- driest sites (low elevation/ warm aspects) and interface areas require attention first.

The three climate scenarios used in the vulnerability assessment consistently predicted that the low elevation areas in the North Subregion have high vulnerabilities (Utzig and Holt 2012). Therefore careful consideration about climate change impacts should be incorporated into landscape and operational planning in these areas.

3.2 Mid Subregion

Historically, high elevation ecosystems in the Mid Subregion consisted of old-growth Engelmann spruce and subalpine fir (ESSF) forests with gap replacement and infrequent stand replacing fires, interspersed with insect outbreaks, typically bark beetles. Mid to low elevation forests were a patchwork of old-growth western redcedar / western hemlock forests interspersed with diverse seral forests of Douglas-fir, western larch, lodgepole pine and western while pine, with minor amounts of western redcedar and western hemlock. The mid elevation forests developed through moderate to long return interval fire regimes, with some gap replacement disturbance and the lowest elevation forests disturbance regime was mainly short to moderate return interval mixed fire regimes. General climate change predictions are the same as those described for the North Subregion and are expected to result in shorter fire return intervals, moving toward frequent stand initiating or maintaining fires (Report #4, Utzig et. al. 2011). Growing conditions in the drier low and mid elevation forests will be more suitable for grassland-steppe, Ponderosa Pine (PP) or dry ICH ecosystem types (Report #5, Utzig 2012). Moist aspects will become more suitable for dry montane spruce (MS) and transitional CWH ecosystem types. The driest mid to upper elevations may provide growing conditions suitable for PP species while mesic to moist sites may resemble conditions found in ICH, ESSF, dry MS or transitional CWH ecosystems. Over time, it is expected there will be a gradual loss of Engelmann spruce.

Issues specific to the Mid Subregion that must be considered when selecting adaptation options are:

- harvesting, reservoirs, agriculture and settlement have severely fragmented elevations <1500m;
- there is a lack of downslope seed sources for elevations <1000m and dry areas between 1500 and 2000m;
- there is a high risk of invasive plant spread <1500m in elevation;
- mountainous terrain limits lateral connectivity/movement; and,
- shallow/coarse soils may limit upward movement of plant species at elevations >1500m.

The three climate scenarios used in the vulnerability assessment consistently predicted that the middle elevations (1000-2000m) areas in the Mid Subregion have high vulnerabilities (Report #7, Utzig and Holt 2012). Therefore careful consideration about climate change impacts should be incorporated into landscape and operational planning in these areas.

3.3 South Subregion

Historically, high elevation forests were often old-growth Engelmann spruce and subalpine fir with extensive areas of lodgepole pine. Gap replacement disturbances interspersed with long interval stand-replacing fires created this landscape mosaic. Seral forests consisting of Douglas-fir, western larch, lodgepole pine and western white pine with some western redcedar and western hemlock have been common at low to middle elevations and were shaped by wildfires occurring at short to moderate fire return intervals. Some very dry sites and south aspects at low elevation had open stands of Ponderosa pine, Douglas fir and western larch, and experienced frequent low intensity stand maintaining fires. Some scattered old-growth patches occurred at mid elevations.

General climate change predictions are the same as those described for the North and Mid Subregions and are expected to result in a more intense fire season with greater area burned. Growing conditions at low elevations can be expected to become more suitable for grassland-steppe or PP ecosystem types. On moist low and middle elevation sites, growing conditions will become more suitable for grand fir, dry MS or Interior Douglas fir (IDF) ecosystem types. Growing conditions in mesic upper elevations will move toward ICH conditions; whereas, moist sites will resemble transitional CWH ecosystems. Climate at very dry high elevation sites will be more suitable for IDF, PP or grassland-steppe ecosystems.

Issues specific to the South subregion that must be considered when selecting adaptation options are:

- harvesting, reservoirs, agriculture and settlement have severely fragmented elevations <1000m;
- harvesting has moderately fragmented mid to high elevation forests;
- lack of downslope seed sources for elevations <1000m;
- high risk of invasive plant spread <1500m;
- fragmentation limits lateral species shifts at elevations >1500m and lakes limit lateral species shifts at lower elevations; and
- coarse soils limit upward movement of species at elevations >2000m.

The three climate scenarios used in the vulnerability assessment resulted in high variability in the results for the 1000 - 1500m elevation ecosystems, with very low vulnerability for two scenarios and high vulnerability for the very hot/dry scenario (Utzig and Holt 2012). Therefore careful consideration should be given to selecting “robust’ options when incorporating climate change impacts into landscape and operational planning in these areas.

4.0 LANDSCAPE SCALE ADAPTATIONS

Landscape scale adaptation refers to actions taken beyond the scale of individual forest types or cutblocks. In many ways, landscape scale adaptation will be more effective to reducing vulnerabilities than adaptation at the ecosystem or stand level. In part this is because the relevant disturbances (e.g., wildfires and insects) occur at the landscape scale and are best managed at this scale. As well, successful range shifts of species will be facilitated by retaining ecosystem connectivity at the landscape scale, from low to high elevations and north/south.

This section outlines potential landscape scale adaptation for consideration by West Kootenay forest practitioners. beginning with adaptations that are likely to be relevant to most ecosystems across all subregions, followed by recommendations for each subregion in Tables 1-3. As described in earlier sections, these are suggestions that must be considered a first step that should be improved through conversations, pilots and further research.

Landscape scale adaptation is currently challenged by the current absence of ongoing landscape scale planning and monitoring for public forest lands in BC. Given the public ownership of most BC forest lands; the large number of forest tenures and other tenures; the wide range of interest groups and number of communities who have interests in these forests; and the potential range of climate change impacts that require changes in practices, leadership in landscape adaptation by BC government agencies is essential.

4.1 Adaptation actions applicable to all ecosystems

4.1.1 Strategic landscape planning

- Reduce non-climate stressors where possible to maintain existing ecosystem resilience. For example, identify barriers to movement (for tree and other species) and take action to reduce these effects. Look for opportunities to actively increase existing connectivity from low to high elevation and from south to north.
- Regionally, assess which stands are most vulnerable to wildfire, insects, disease or decline syndrome in the short, mid and longer term.
- Identify areas of high value for reasons other than timber – e.g., biodiversity, wildlife habitat, rare ecosystems, water provision (community watersheds and otherwise), and recreational values. Cross-reference high vulnerability ecosystems identified in Report #7 (Utzig and Holt 2012), and stands most vulnerable to wildfire, insects, disease or decline syndrome, with ecosystems that produce high value goods and services. Analyze whether current management strategies are likely to be effective with climate change. Evaluate likelihood of success associated with strategies for 'resistance' to climate change in the short to midterm. "Resistance" can potentially provide the 'time' needed for other species to adapt or move in response to climate changes. Adjust management practices if needed.
- Plan for landscape diversity, with varying ages, species, and genetics.
- Incorporate new information and support development of more information on changes to disturbance regimes, key ecosystem functions, etc., for the most common projected climate envelopes.

4.1.2 Biodiversity management

- Identify and assess climate risks to habitats of species at risk and keystone species. Where needed, identify and implement changes in practices to retain habitats, or plan connectivity for migration.
- Assess vulnerabilities in existing reserves (e.g., OGMAs or critical wildlife habitat), and consider opportunities for reducing vulnerabilities (e.g., create buffers with reduced fire hazard; identify as 'high priority' area in fire suppression).
- Assess representativeness of existing reserves and plan for reserves where gaps are identified.

4.1.3 Timber harvesting

- Focus harvest in stands that are highly vulnerable to significant disturbance in the short and midterm, and where resistance (buffering, maintaining existing cover, etc.) is unlikely to be an effective response.
- Salvage damaged trees to maintain current and mid-term harvest levels and reduce fire hazard.
- Reassess terrain stability mapping and practices in light of changing peak water flows and changing harvest seasons (i.e., less dependable snowpack for winter harvesting).
- Reduce harvesting in domestic and community watersheds to protect water quantity during summer droughts and water quality that can decline when stream water temperatures increase.

4.1.4 Reforestation

- Evaluate projected tree species range shifts and review and adjust stocking targets and standards and suitable species by area.
- Enhance landscape scale diversity, with varying ages, species, stand structure and genetics.
- Develop and use climate-based seed selection systems.
- Evaluate potential for new provenances. This could include movement from lower elevations and drier aspects, or assess those from the US and NW coastal transition areas, based on projected climate envelopes.
- Promote natural regeneration where ecologically suitable for projected climate changes. Consider the broader requirements of species (other than trees) with respect to assisted migration strategies.

4.1.5 Access planning / management

- Maintain access in areas with high fire risk.
- Decommission roads in high risk stability locations.
- Reduce area in permanent access structures to reduce erosion and sedimentation risks, and to minimize movement of invasive species.
- Increase road inspection and maintenance to account for increased heavy rain events.
- Reassess road construction standards to accommodate climate change (e.g., increase culvert size and bridge clearance; increase use of swales and outslope roads).
- Monitor roads during storms and fast thaws to avoid damage, and to improve information to guide revised road construction standards and maintenance guidelines

4.1.6 Wildfire management

- Support and participate in wildfire risk mapping.
- Plan wildfire fuel breaks where needed around infrastructure and communities – e.g.,
    - Plant / manage to encourage aspen.
    - Plan landscape level mosaics (diversity in age classes and species) to provide fuel breaks (also good for reducing insect/disease risk and enhancing biodiversity).
- Participate in FireSmart education programs.
- Increase cooperation between forest managers (e.g., wildlife management, licensees, BC Timber Sales, etc.) to broaden the area over which 'fuelSmart' prescriptions are written. Ensure short, medium and long-term implications of prescriptions are considered in light of climate futures.

4.1.7 Insect and disease management

- Participate in systematic long-term monitoring of at-risk forests to detect changes in growth and mortality.
- Participate in development of hazard and risk rating systems for insect and disease attack, and mapping that accounts for climate change.
- Identify and harvest susceptible types first (also listed under timber harvesting).
- Actively manage small outbreaks: e.g., remove damaged trees, pheromone traps, trap trees, etc.

4.1.8 Monitoring

- Support an evaluation of the existing climate monitoring instrumentation in the region to identify any gaps and changes needed.
- Monitor occurrence of late spring frosts, frozen ground and snow depths, and impacts on operations and ecosystems.
- Improve forest inventories (e.g., improving accuracy, incorporating changes – e.g., MPB), particularly for stands between free-growing to maturity, to support wildfire, insect and disease risk mapping.
- Participate in the development and use of soil moisture/drought indices measurement.
- Monitor forest ingrowth into alpine.
- Explore ways that 'citizen scientists' can participate in monitoring to gather local information efficiently (e.g., NatureWatch Canada[4]).

4.1.9 Timber supply:

- Support inclusion of climate change in growth and yield modeling as adequate information is available.
- Over the long-term, reduce AAC to account for future loss of low elevation growing sites in some portions of the region.
- Conduct sensitivity analysis in timber supply reviews to include the full range of potential gains and losses associated with climate change.

4.1.10 Research:

- Analyze past and projected climate information to better understand the potential range of extremes (e.g., drought, heat waves, high intensity storms, peak flows, fire frequency, fire intensity, lightening distribution and frequency, winter minimums - for affect on insects and other pests).
- Implement provenance trials for resistance to drought, insects, and disease.

4.2 North Subregion

At the landscape level the North Subregion is projected to experience an explosion of wildfires as the climate warms, in part due to the heavy fuel accumulations in these highly productive forests, where fire has not been a dominant factor historically. Greater risks of hemlock looper outbreaks are anticipated, as well as an increase in foliar diseases and stem rusts in young forests. The following actions are presented only as a starting point for further research and discussion.

[44] http://www.naturewatch.ca/english/

Table 1. North Subregion – landscape level adaptation actions.

Assm't Unit	Potential Vulner-ability	Regime Shift (RS)	Harvest Planning	Biodiversity Planning	Wildfire Management	Insect and Disease Management
<1000m	VH-H-VH	RS very likely; likely catastrophic	In conjunction with FireSmart, actively plan harvesting to reduce fire risk in interface areas	Increase connectivity along climatic gradients (upslope, north-south and key low passes) Re-evaluate representation in OGMA and PAs[5]	Reduce fuels in high risk areas (esp. interface areas) Increase fire suppression capabilities Clearly identify suppression priorities, including biodiversity values Develop protection strategies for key values (e.g., fire guards, access, spp/age landscape modification)	Monitor for changes in Hemlock looper Monitor for changes in foliar disease and stem rusts in regenerated stands
1000-1500m	M-M-VH	RS likely to very likely; likely to be catastrophic	Harvest priorities based on susceptibility and maintaining connectivity	Same as above	Clearly identify suppression priorities, including biodiversity values	Same as above
1500-2000m	L-L-VH	RS unlikely, but if so, likely catastrophic	Harvest priorities based on susceptibility and maintaining connectivity	Same as above	Same as above	Monitor for mortality in Engelmann spruce and subalpine fir
>2000m	L-VL-L	RS unlikely; very unlikely to be catastrophic	N/A	No change	No change	No change

4.3 Mid subregion

Forests located on dry aspects at 1000-2000m have the greatest vulnerability in this subregion. Projected increases in drought conditions are expected to increase wildfire risk and susceptibility to beetle attack. Larch is an important species in these forests and foliar disease may create greater risks for this species. The following actions are presented only as a starting point for further research and discussion.

[5] Old Growth Management Areas and Protected Areas

Table 2. Mid Subregion landscape level adaptation actions.

Assm't Unit	Potential Vulner-ability	Regime Shift (RS)	Harvest Planning	Biodiversity Planning	Wildfire Management	Insect and Disease Management
<1000m	M-M-M	RS likely; unlikely to be catastrophic	In conjunction with FireSmart, actively plan harvesting to reduce fire risk in interface areas	Increase connectivity along climatic gradients (upslope, north-south and key low passes) Re-evaluate representation in OGMA and PAs Monitor invasive plants	Reduce fuels in high risk areas (esp. interface areas) Increase fire suppression capabilities Clearly identify suppression priorities, including biodiversity values Develop protection strategies for key values (e.g., fire guards, access, spp/age landscape modification)	Suppress Douglas-fir bark beetles Monitor foliar diseases (esp. in larch)
1000-1500m	H-H-VH	RS likely to very likely; about as likely as not to be catastrophic		Re-evaluate representation in OGMA and PAs	Same as above	Same as above
1500-2000m	H-H-VH	RS likely to very likely, likely to be catastrophic	Actively plan on drier aspects	Assess and increase connectivity on warm aspects	Same as above	Monitor western balsam and spruce bark beetles
>2000m	L-VL-M	RS unlikely; very unlikely to be catastrophic	N/A?	No change	No change	Same as above

4.4 South subregion

Forests located in dry ecosystems, and on dry sites in this subregion are most vulnerable as the climate changes. Increased wildfire risk and expanding beetle populations are anticipated. In the lowest elevations, declining summer water flows are expected to limit water available for domestic use, prompting less harvesting to maintain streamflows. At higher elevations, warm sites are expected to limit spruce growth. The following actions are presented only as a starting point for further research and discussion.

Table 3. South Subregion landscape level adaptation actions.

Assm't Unit	Potential Vulner-ability	Regime Shift (RS)	Harvest Planning	Biodiversity Planning	Wildfire Management	Insect and Disease Management
<1000m	L-L-M	RS likely to very likely (localized); unlikely to be catastrophic	In conjunction with FireSmart, actively plan harvesting to reduce fire risk in interface areas Prioritize harvesting for areas shifting to grassland climates	Manage reserves to reduce identified vulnerabilities Identify and protect any dry ecosystem OG Monitor and control invasive plants	Reduce fuels in high risk areas (esp. interface areas) Increase fire suppression capabilities Clearly identify suppression priorities, including biodiversity values Develop protection strategies for key values (e.g., fire guards, access, spp/age landscape modification)	Monitor Douglas-fir beetle and actively control
1000-1500m	VL-VL-H	RS about as likely as not; about as likely as not to be catastrophic	Reduce harvesting in domestic and community watersheds Minimize fragmentation during development planning	Identify and protect any dry ecosystem OG Look for opportunities to improve connectivity to lower elevations (i.e., new reserves) Monitor and control invasive species		
1500-2000m	L-L-M	RS unlikely, but if so, about as likely as not to be catastrophic (localized risk)	Reduce Se on warmest aspects	Increase connectivity along climatic gradients		Monitor and actively control western balsam and spruce bark beetles Monitor any remaining mountain pine beetles
>2000m	VL-VL-L	RS likely; very unlikely to be catastrophic	N/A	No change	No change	No change

5.0 ECOSYSTEM/STAND LEVEL ADAPTATIONS

Some impacts, vulnerabilities and adaptations are best addressed at the ecosystem or forest stand level (e.g. silvicultural system selection, microsite identification and management). This section provides a listing of potential adaptations that generally apply to West Kootenay forests, followed by more detailed suggestions for specific West Kootenay ecosystems in Tables 4-6.

5.1 Adaptation options applicable to all subregions

The following adaptation options apply generally to most ecosystems at elevations across all subregions.

5.1.1 Silvicultural systems

- Select silvicultural systems to maximize vigour and decrease susceptibility to insects and disease over the long term.
- Increase use of partial cutting on drought susceptible sites to increase survival and growth of mature leave trees as well as new regeneration.
- Use partial cutting to create structural diversity to discourage certain insects and diseases (e.g., spruce leader weevils).
- Enhance biodiversity through partial cutting (e.g., connectivity for wildlife habitat and movement, retain multiple tree species and age classes).

5.1.2 Stand level biodiversity

- Protect microclimate refugia and diversity (e.g., maintain shade in gullies and ravines).
- For sites expected to experience frequent drought, increase coarse woody debris retention (i.e., abundance and piece size).
- Increase riparian buffers for smaller and high elevation streams to moderate stream temperature to protect habitat for temperature sensitive aquatic species and to increase landscape connectivity.
- Increase riparian buffers in domestic and community watersheds to protect water quality (i.e. water temperature) and to increase landscape connectivity.
- Increase wildlife tree patches to contribute to landscape connectivity.

5.1.3 Regeneration

- Increase species and genetic diversity in plantations.
- Explore opportunities for assisted migration of tree species into new sites (O'Neill, et. al. 2008) especially for areas where there is no downslope seed source.
- Underplant with other species or genotypes where growth and survival of current regeneration (or forest) is at risk.
- Closely monitor plantation and natural regeneration success during drought years and promptly take action to establish successful regeneration.
- Evaluate opportunities to include western white pine when planting due to its ability to tolerate a wide range of moisture conditions. Promote and participate in blister rust progeny trials.

5.1.4 Stand tending

- Increase growth and vigour through stand tending to reduce rotation and risks compared to longer rotations.
- Fertilize to enhance growth, reduce rotation and improve insect/disease resistance.
- Manage species composition, density and stand structure to improve diversity and increase growth/reduce rotations.
- Control vegetation to reduce drought stress.

5.2 North subregion

Special attention will need to be paid to forests on ecosystems below 1500m in this subregion where regime shift is likely/very likely and likely to be catastrophic, particularly on the warmest/driest sites. Adaptations to reduce water stress and wildfire risk and promote biodiversity are suggested. The following actions are presented only as a starting point for further research and discussion.

Table 4. North Subregion – ecosystem/ stand level adaptation actions.

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
<1000m	VH-H-VH	RS very likely; likely catastrophic	Thin from below mature stands retaining fire adapted species in interface areas and along highways Partial cut for oldgrowth recruitment in moist sites	Increase riparian buffers to provide additional connectivity	Increase proportion of drought resisting species, esp. Fd, Lw and blister rust resistant Pw on mesic to dry sites	Space to retain maximum fire adapted species on warm aspects
1000-1500m	M-M-VH	RS likely to very likely; likely to be catastrophic	On warm aspects thin from below mature stands retaining fire adapted species On moist to wet sites partial cut for oldgrowth recruitment	Same as above	Emphasize Fd, Lw and Pw on dry sites	Same as above on warm aspects
1500-2000m	L-L-VH	RS unlikely, but if so, likely catastrophic		Increase large CWD on warm aspects Increase riparian buffers on small streams	Investigate opportunities for assisted migration of Fd, Lw and Pw on driest sites	

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
>2000m	L-VL-L	RS unlikely; very unlikely to be catastrophic	No change	No change	No change	No change

5.3 Mid Subregion

In forests at mid to higher elevations (1000-2000m) in this subregion, forests are likely to very likely to experience regime shifts, and as likely as not to be catastrophic. Management for spruce is expected to be challenged due to moisture stress, leader weevils and bark beetles (see Report #6, Pinnell 2012a). The following actions are presented only as a starting point for further research and discussion.

Table 5. Mid subregion – ecosystem/stand level adaptation actions.

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
<1000m	M-M-M	RS likely; unlikely to be catastrophic	Thin from below to promote fire resistant species on warm / dry aspects in interface areas	Actively monitor and control invasive species Increase riparian buffers to increase connectivity	Minimize soil disturbance during site prep to reduce invasive species Promote Fd, Lw and blister rust resistant Pw Reduce densities on dry sites	Retain fire adapted species on dry to mesic sites
1000-1500m	H-H-VH	RS likely to very likely; about as likely as not to be catastrophic	Create multi-storied stand for Sx regen to reduce losses to leader weevils	Same as above	Minimize soil disturbance during site prep to reduce invasive species On driest aspects plant more Fd, Lw, blister resistant Pw Monitor Lw foliar diseases in young stands	During spacing favor Fd and some healthy Pw on dry sites

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
1500-2000m	H-H-VH	RS likely to very likely, likely to be catastrophic	On moist aspects, partial cut for oldgrowth retention favoring Cw Create multi-storied stand for Sx regen to reduce losses to leader weevils		Establish Pl in mixed species stands Phase out use of spruce except on coldest sites Consider use of Cw and Hw in trials on moist sites (assisted migration)	On warmest and driest sites space retain deciduous on Sx sites to reduce losses to leader weevils
>2000m	L-VL-M	RS unlikely; very unlikely to be catastrophic				

5.4 South Subregion

In this subregion, water stress at low and mid elevations is anticipated to limit species success on the drier sites to very drought tolerant species at the lowest elevations, and remove spruce as a suitable species, except on the coldest sites at higher elevations. The following actions are presented only as a starting point for further research and discussion.

Table 6. South subregion – ecosystem/stand level adaptation actions.

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
<1000m	L-L-M	RS likely to very likely (localized); unlikely to be catastrophic	Partial cut to open forest structure	Retain high levels of large CWD Increase riparian buffers Actively control invasive species	Minimize soil disturbance during harvesting/ site prep to reduce invasive species Plant Py, Fd and Lw on dry sites at low density	Regular prescribed fire to maintain low stocking
1000-1500m	VL-VL-H	RS about as likely as not; about as likely as not to be catastrophic	Same as above on driest aspects	Increase stand structure diversity	Same as above on driest aspects	Same as above on driest aspects

Assm't Unit	Potential Vulnerability	Regime Shift (RS)	Silvicultural System	Stand level biodiversity	Regeneration	Stand Tending
1500-2000m	L-L-M	RS unlikely, but if so, about as likely as not to be catastrophic (localized risk)	Increase species diversity on warmer aspects (Fd, Lw, Py)		Phase out use of Se except on coldest sites Consider use of Cw and Hw in trials	
>2000m	VL-VL-L	RS likely; very unlikely to be catastrophic	No change	No change	No change	No change

6.0 OPERATIONAL ADAPTATIONS

Several aspects of climate change in the West Kootenays are expected to impact day-to-day and annual forestry operations in the West Kootenays. The operational adaptations listed below have been suggested to offset these impacts:

- Use seasonal weather forecasts[6] to understand probable conditions and plan seasonal operations appropriately.
- Reduce soil disturbance during harvesting and site prep to:
  - reduce invasive plant spread (esp. important in low elevations, dry sites); and
  - reduce compaction and forest floor displacement to retain soil water holding capacity.
- Anticipate changing harvesting seasons as snowpack and frozen soils are already becoming less dependable and longer summer shutdowns due to high fire hazard will be likely.
- Prepare for early seasonal planting start-ups and forecasted summer droughts.
- Shift to cable versus ground-based harvesting to reduce soil compaction and forest floor displacement (reduce invasive plant spread, maintain maximum site productivity).
- Chip debris for mulch (improve soil moisture holding capacity and add nutrients).

7.0 DECIDING ON ADAPTATION ACTIONS

The 'right' adaptations will depend on the characteristics of the forests in the management unit; the legal and policy framework for those forests, including the values and roles of all tenure holders, user groups and the public; and the preferences, particularly about risk management, of the organization and individuals responsible for managing the area. There are two steps needed to figure out what adaptations should be implemented:

1. Assess how forest management is most vulnerable and likely to be impacted by projected climate changes, to decide on where to focus adaptation efforts (e.g., which sites, which forest management activities).

[6] http://cses.washington.edu/cig/fpt/cloutlook.shtml

2. Decide what adaptation actions to take to reduce the vulnerabilities that are deemed to be unacceptable to the manager.

There are many ways to conduct these two steps – each organization will need to decide how they will reach these decisions. Vulnerability assessments or risk assessments can be used to decide where to focus adaptation efforts (See Report #2, Holt et al. 2012). Simple screening tools have also been designed for businesses to assess their 'climate risks' (see Figure 3). Risk management can also be used to guide decision-making about what adaptation actions to take. Structured decision-making is a recommended approach (Ohlsen, et al. 2005) for combining vulnerability and risk assessments into a logical series of steps to create a transparent process that illustrates trade-offs across management objectives (See Report #2, Holt, et al. 2012 and workshop example in Report #10, Pinnell 2012b).

The following aspects of the process are important, regardless of the specific process that is used:

- more than one scenario of future climate change must be considered, to reflect the uncertainty and prompt decision makers to seek 'robust' options that have benefits across a range of future climates; and,
- organizations and individuals who might be affected by changes in practices, including those who will need to implement new practices should be involved enough in the decision process to understand the projected climate changes, impacts and options so that they support the resulting decision.

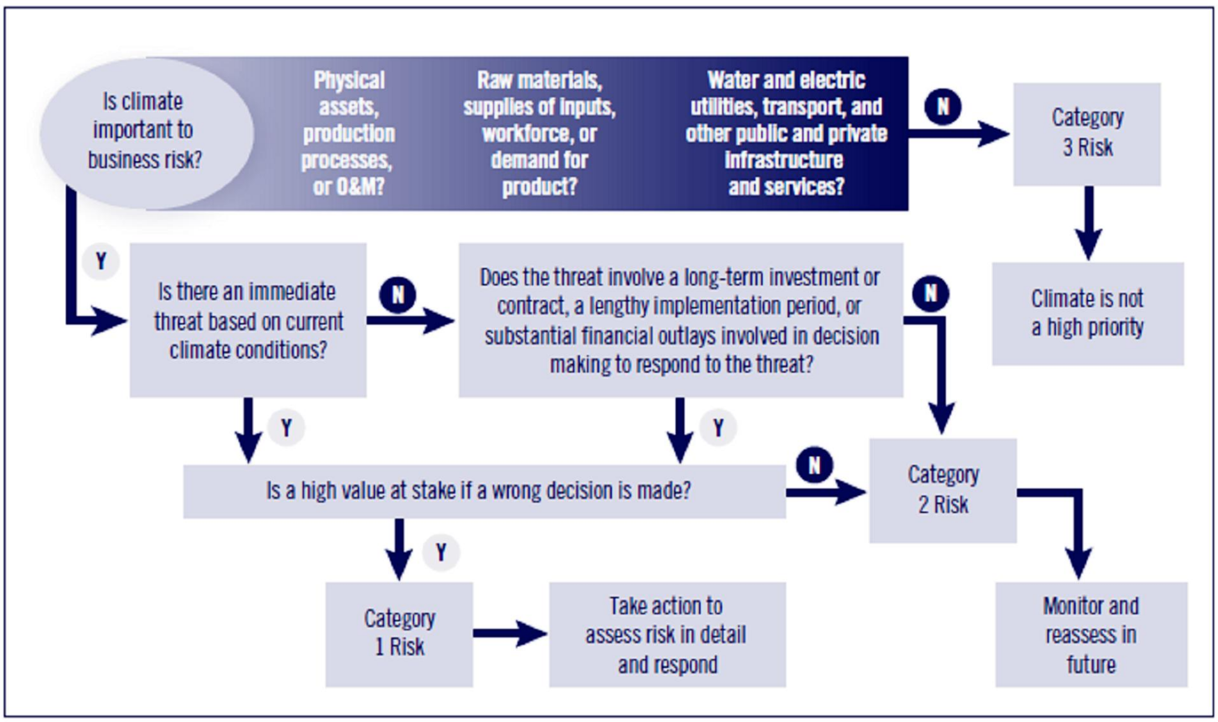

Figure 3. Screening for climate risks (from Sussman and Freed 2008).

8.0 CONCLUSIONS

This project and this report provide a starting place for deciding on appropriate forest management climate change adaptation actions in the West Kootenays. From our interaction with forest practitioners during this project we understood that some forest practitioners in the West Kootenays are observing climate change impacts (examples in appendices in Report #10, Pinnell 2012b). Some of these (particularly those who attended the workshops) feel they have enough info about climate change and now they need to know more about 'what to do' before they are ready to implement adaptation actions to reduce ecosystem vulnerability.

This paper offers some ideas that are offered as a starting point for the next phase of climate change adaptation in the West Kootenays. Immediate steps could include:

- Further development of some of the 'planning' adaptation actions needed.
- Use these first steps as the basis for discussion at Climate Change Conversation Forums planned by and for West Kootenay practitioners. Practitioners have contacted the project team indicating their interest in this next step, and their willingness to be involved to move this forward. Note the need to identify a funding and (at least one) champion. .
- Conduct pilot adaptation action planning with one or two representative licensees or landowners to explore the tools and challenges to identifying priority adaptations.
- Possible adaptation actions in this report, or other ideas, can be fed into a decision-making process and priorities can be established as to what to do where first.
- Monitoring, continuous learning and some form of adaptive management must be prioritised in all key areas of climate change adaptation - especially since climate change and its impacts is a complex issue with high uncertainty and significant implications for all aspects of society.

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