Applying Climate Change Information in Resource Management
User Needs Survey

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BRITISH COLUMBIA

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ABSTRACT

Climate change information, with estimates of natural disturbance and projected ecosystem shifts, can support research and inform decision-making for a wide range of values within the purview of the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development. In recent workshops, a need for Ministry-supported climate projections was identified. Evaluating how users apply climate projections should guide content; understanding their skills can help in designing effective delivery and support. We built a survey to solicit information on climate data needs and applications, preferred delivery of information, and respondents' skills. Between November 2018 and February 2019, we collated 45 responses from Ministry staff who were working in a variety of areas, including ecology, fisheries and wildlife, forestry, aquaculture, hazards, water stewardship, land permitting, planning, and engineering. Respondents requested clear indications of climate trends and extremes, where possible, including estimates of uncertainty. Two distinct user-groups differed in their needs: researchers preferred easy access to raw information for manipulation, and close communication with other specialists, including climatologists; decision makers preferred interpreted data that clearly show trends and uncertainty based on consensus projections. Recommendations include developing an endorsed set of climate projections, models, and tools; building web-based access to that information using multiple layers; providing support at regional and provincial levels; and tailoring training to user needs and skills.

EXECUTIVE SUMMARY

Climate change information, with estimates of natural disturbance and projected ecosystem shifts, can help support research and inform decision-making for a wide range of values. In recent Climate Change Integration Workshops and Climate Action Plans, a need for Ministry-supported recommendations for climate change projections to inform impact assessment, adaptation, and natural resource decision-making was identified. Defining user needs is critical because relevant information varies with business area and decision type. Evaluating how users apply projections will drive content. Understanding user skills will help in designing effective delivery and support.

Our survey solicited information about climate change needs, application, and delivery from British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development personnel between November 2018 and February 2019. We collated 45 responses from staff who were working in a variety of areas, including ecology, fisheries and wildlife, forestry, aquaculture, hazards, water stewardship, land permitting, planning, and engineering. This report summarizes the results of the survey and presents preliminary recommendations to address user needs.

Information needs varied by business area:

- Ecosystem and Wildlife Conservation: Projected shifts in Biogeoclimatic Ecosystem Classification climate envelopes can help in estimating changes in habitat suitability, location of climate refugia, potential distribution of rare ecosystems, areas of high vulnerability, and suitability of currently reserved areas.
- Water and Fisheries Management: Climate-driven changes to streamflow and water temperature can inform stream and fisheries management (e.g., water licensing in low-flow, sensitive, or heavily allocated systems; riparian buffers; habitat supply; fisheries-sensitive watersheds).
- Forest Management: Climate change projections can help in determining appropriate tree species, provenances, and densities for planting, and in refining growth-and-yield estimates for Timber Supply Reviews.
- Range Management: Improved drought modelling with climate change can allow seasonal forage supply and variability in water availability to be estimated.
- Infrastructure Design: Climate change information can be used to improve infrastructure resilience; for example, updated estimates of extreme flood risk can improve dam and spillway design and culvert standards.
- Safety: Projected wildfire and flood threats associated with climate change can facilitate event preparation and response. Flood and landscape hazard assessments can benefit from the inclusion of climate variability and extreme events.

Respondents requested clear indications of climate trends and extremes where possible, including estimates of uncertainty. Two distinct user-groups differed in their needs: researchers preferred easy access to raw information for manipulation, and close communication with other specialists, including climatologists; decision makers and technical advisors preferred interpreted data that clearly show trends and uncertainty based on consensus projections.

Requests to meet these needs included the following:

- easy access to specific variables and recommended data sources
- sufficiently fine spatial and temporal scales for basic climate variables
- projected probability of extremes
- projected forest disturbance frequency and magnitude
- projected hydrological consequences of climate change
- projected species- and ecosystem-specific climate envelopes
- projected impacts on ecological services, human settlements, and socio-economic systems

The following recommendations address user needs for climate change information:

1. Develop a recommended set of climate projections, models, and tools.
2. Improve ClimateBC's flexibility and accessibility.
3. Provide easy access to requested variables, such as extremes and streamflow.
4. Build a single web-based framework with multiple layers that link to interpreted data.
5. Provide technical and topic expert support at regional and provincial levels.
6. Tailor training to users.

Respondents provided considerable information related to their specific needs. Integrating climate change into decision-making requires further feedback from decision makers, and ongoing evaluation and improvement.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

Climate change projections support impact assessment, adaptation, and natural resource decision-making. The British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) plans to integrate climate change into daily business. In Climate Change Integration Workshops held across British Columbia, and in Climate Action Plans developed for regions and branches of the Ministry, a need for Ministry-supported recommendations for climate-related projections was identified. Previous guidelines for selecting and using projections in British Columbia (Murdock and Spittlehouse 2011) were based on the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (IPCC 2007). The IPCC's *Fifth Assessment Report* (IPCC 2014) provides many more climate projections and types of data than the 2007 report. Consequently, it is timely to produce new guidelines on climate projections and recommendations for their use.

Defining user needs is critical in developing guidance about using climate projections. Relevant information will vary with business area and decision type. Evaluating how users apply projections and which specific variables are most useful should drive content. Understanding user skills will help in designing effective delivery mechanisms, training, and technical support frameworks.

This report presents the results of a user-needs survey completed by FLNRORD staff, which describe current and potential uses of climate change data, and preferences for data delivery and training needs.

2 METHODS

This project builds on a foundation laid by participants in Climate Change Integration Workshops and by the Climate Action Plan Community of Practice by interviewing potential users of climate change projections within FLNRORD. In September 2018, we compiled a list of participants in Climate Change Integration Workshops held across British Columbia in 2017. This list of approximately 350 people was filtered down to approximately 100 high-priority target respondents, including all members of the Climate Action Plan Community of Practice. We delivered a questionnaire (Appendix 1) via email, which asked people

- what climate change information they currently use
- what information they would like to use
- how they plan to apply climate information
- how they would like information delivered
- what they need for technical support

After following up with individuals to clarify responses, we sent a second request to targeted individuals to fill gaps in business areas.

Because language and terminology varied with respondents' experience and business area, we combined similar responses to minimize redundancy while retaining original wording as much as possible; however, some redundancy remains.

3 RESULTS

3.1 Respondents

We received 45 responses, mostly from individuals, but including a few team responses from business groups (Table 1). Many responses were received from people who were not on the original list, possibly because target respondents directed the questionnaire to other appropriate team members.

The response rate was very high for researchers, who formed almost one-quarter of respondents in total across several business areas. Ecologists and ecosystems biologists were well represented with nine responses. Six responses addressed fisheries and wildlife issues. Forest management responses included three researchers (tree improvement and pathology) and one analyst. Six responses addressed hazards, including flooding, geohazard, and wildfire.

TABLE 1 *Number of respondents by business area*

Business area	No. of respondents
Ecology (all researchers)	5
Terrestrial and aquatic ecosystems	4
Fisheries and wildlife (one researcher)	6
Forest management (three researchers)	4
Aquaculture	1
Climate change	1
Hazards (one researcher)	6
Water stewardship and licensing	4
Land permitting	2
Land use planning and rural policy	5
Engineering	5
Mining reclamation	1
Economics	1
Total	**45**

3.1.1 Current use of climate change projections Twenty-seven respondents/groups (60%) used climate change information in their work; 18 (40%) did not (Table 2). Use of climate data depended on business area. All researchers except one included climate change in their work. All engineers, ecologists, and forest managers considered climate change in their work. Most people who were involved in water decisions, rural policy, land use planning, dam safety, wildfire restoration, and land authorizations had not yet considered climate change.

Of those who were not using projections, some would like to include climate change information in decision-making; others felt that it is either unnecessary (particularly for short-term licensing) or would add uncertainty, which would complicate the justification of decisions. For those who would like to use climate change information, typical reasons for not doing so fell into the following general categories:

- lack of policy and legislative direction
- lack of resources or capacity
- lack of knowledge
- lack of accessible information and data

TABLE 2 *Current use of climate change projections by business area. Business area is ordered roughly by the proportion of respondents who have used climate projections.*

	Climate projections	
Business area	**Use**	**Do not use**
Ecology	5	0
Engineering	5	0
Forest management	4	0
Climate change	1	0
Aquatic ecosystems	1	0
Hazard: geohazard	1	0
Hazard: river forecast	1	0
Mining reclamation	1 (starting)	0
Economics	1 (starting)	0
Fisheries	2	1
Land permitting	1	1
Hazard: wildfire	1	2
Wildlife	1 (starting)	2
Water stewardship	1	3
Land use planning	1	3
Aquaculture	0	1
Hazard: dam safety	0	1
Rural policy	0	1
Terrestrial ecosystems	0	3
Total	**27**	**18**

3.2 Information Needs

3.2.1 Overview Climate change information can be used to inform decisions (Table 3) and develop research programs. Projecting shifts in ecosystems and associated species vulnerability is critical to informing biodiversity conservation, forest management, and wildlife management. Refining estimates of natural disturbance (including drought, floods, wildfires, insect outbreaks, pathogens, and storms) will improve many decisions related to safety and forest management, and will inform research projects.

TABLE 3 *Climate impacts that will likely influence decision-making outcomes for key values (summarized from Climate Change Integration Workshops)*

Key value	Decision	Drought	Flood	Fire	Invasive species	Ecosystem shift
Biodiversity, wildlife, and fish	Allowable annual harvest	–	–	–	–	×
	Wildlife Habitat Area	–	–	×	–	×
	Old Growth Management Area	–	–	×	–	×
	Fisheries-sensitive watersheds	×	×	–	–	–
	Temperature-sensitive streams	×	–	–	–	–
Forest management	Allowable annual cut	×	–	×	–	×
	Forest Stewardship Plan	×	–	×	×	×
	Road permit	–	×	–	–	–
Range	Range use licence/permit	×	–	–	×	×
Water	Water licence	×	–	–	–	–
Land	Lands authorization	–	×	×	–	–
	Infrastructure design	–	×	–	–	–
	Public safety	–	×	×	–	–

Overall, survey respondents highlighted the importance of clearly indicating trends, describing statistical methods, and estimating uncertainty.

3.2.2 Ongoing work and general needs

Biodiversity and wildlife Projected spatial distributions of Biogeoclimatic Ecosystem Classification (BEC) climate envelopes (Wang, Campbell, et al. 2012) will facilitate conservation. Projected climate envelopes can be extended to estimate habitat factors:

- potential distribution of rare ecosystems
- changes to habitat suitability for individual species or communities (e.g., important understorey plants, wildlife, epiphytic lichens)
- location of potential climate refugia
- areas of high climate velocity (Hamann et al. 2015) or high vulnerability (e.g., high concentrations of at-risk species)
- suitability of current reserved areas

Several respondents noted that the AdaptWest website provides useful information (e.g., climate refugia for some wildlife at a sufficiently fine scale). Increased information on links between climate factors and wildlife populations is needed.

Climate information can also inform site reclamation; for example, a tool that integrates soil and site characteristics with projected moisture deficit is being developed to guide mine site reclamation.

Water, aquatic ecosystems, and fish Changes to streamflow and water temperature will inform stream and fisheries management (e.g., riparian buffer protection; water licensing in low-flow, sensitive, or heavily allocated systems; frequency of lethal thresholds for fish; habitat supply for bull trout and white sturgeon; designation of fisheries-sensitive watersheds; stocking decisions); hence, respondents requested information on trends in precipitation, streamflow, and water temperature (streams and lakes) by watershed and region. Stream temperature models can determine aquatic species and ecosystems that are at risk due to increased water temperature.

Changes to future seasonal water availability (due primarily to drought) and water balance will inform water allocation; hence, respondents requested improved scenario modelling of drought, glaciers, snow, runoff, and permafrost.

Assessing the risk of flooding requires forecasting tools that account for climate change, including regional vulnerability to larger snowpacks, freshets, and higher-intensity rainstorms. Dam safety and spillway design would benefit from a better understanding of extremes, including peak streamflow and precipitation.

Forest management Primary documented uses of climate change information within forest management included determining appropriate tree species, provenances, and stocking densities for planting (by site series and including uncertainty due to climate change), and refining growth-and-yield estimates for use in Timber Supply Reviews. Several ongoing research projects include climate change variables as predictive factors:

- development of a Climate Change Informed Species Selection (CCISS) tool that projects tree species suitability for BEC variants and site series over time; the tool incorporates some climate uncertainty by projecting a

different distribution of BEC ecosystem envelopes for 15 global climate models and two emissions scenarios (an algorithm combines different models based on a matrix of change probabilities)
- examination of tree growth and stress in historic drought and non-drought years and development of a stand-level drought risk assessment tool (Foord et al. 2017)
- correlation of retrospective climate and weather data with forest health agents to project future health and productivity impacts
- location and conservation of genetic refugia and rare/important provenances

Range management Information needs for incorporating climate change into range management decisions were similar to those for forest management but with a focus on grassland and dry forest ecosystems. Models of projected change in forage availability would be particularly useful. Improved projections of drought magnitude, including extremes, would allow seasonal water availability and variability to be estimated.

Hazards (wildfire, flooding, landslide) Preparation for, and response to, wildfire will benefit from knowing projected burn severity and probability. Addressing community interface wildfire involves overlaying projected days of extreme fire on maps of fuel cover, habitation, and high-value areas.

Flow projections, floodplain maps, and intensity, duration, and frequency (IDF) curves that include variability in scenario analysis will help in assessing flood risk to communities and infrastructure. Projected sea level rise will inform coastal development.

Landslide hazard assessment requires overlaying projected extreme precipitation on terrain hazard maps that show, for example, rock slopes and alluvial fans along populated lakes and fjords, communities, and transportation corridors.

Socio-economic impacts Examining the potential impacts of alternative futures—for example, with differing levels of mitigation and adaptation—on managed values, development challenges, and economic opportunities will help in assessing resilient strategies.

Engineering Engineers would like to integrate climate change into bridge, culvert, resource road, and dike design. They noted that consensus projections are critical in a field where professionals rely on codes and standards. Projected peak flow estimates will improve stream crossing design. Improved IDF curves, particularly for minor culverts and debris flows in small drainages, would be useful. Reliable estimates of high-intensity rainfall events would improve predictions of debris flows.

Estimates of long-term trends in wildfires would improve consideration of post-fire slope stability.

3.2.3 Specific variables requested Respondents asked for specific variables to aid projections:
- probability of extremes, including, for example, days with extreme drought, days with extreme rainfall, and maximum daily precipitation
- species- and ecosystem-specific climate envelopes for terrestrial and aquatic ecosystems

- hydrological consequences of climate means and extremes
- disturbance frequency and magnitude by disturbance type
- impacts of biophysical changes to ecological services and human settlements

In part, meeting these requests requires providing basic climate variables at spatial scales ranging from the landscape to the region, and temporal scales from months to hours. Many respondents already use variables that are available in ClimateBC (Wang, Hamman, et al. 2012, 2016), such as temperature, precipitation, rain versus snow, moisture deficit, evaporation, and snowpack. Time series information, historical and future, will be valuable to many.

Respondents highlighted the value of using maps for communication. Many requested spatial data and maps of primary and derived variables. For some respondents, the ClimateBC format worked well, others preferred spatial data, and several would like pdf (or similar format) maps. Expert users can extract spatial data from ClimateBC, but many lack the technical skill required. Forest managers would like to have climate linked to disturbance and growth-and-yield projections, as well as monitoring that documents plantation performance. In general, respondents reported that water data are harder to find than terrestrial data.

Requests for specific data included climate, terrestrial, and aquatic variables (Table 4).

TABLE 4 *Specific data requests*

Variable		Data request
Climate	Change maps	• spatial data and maps of primary and derived variables; for example, precipitation and moisture deficit tied to soil maps and/or surficial geology • gridded time series of air and ground temperature, snow depth, snow water equivalent, rain-on-snow events, soil moisture, permafrost temperature, and permafrost depth • heat maps indicating rate, direction, and magnitude of change for selected variables • climate velocity
	Extremes	• extreme events, including heat, drought, precipitation, and wind – several respondents noted that averages can be misleading; for example, early spring or late fall frosts control the distribution of Douglas-fir and western larch, and extreme precipitation, at daily and shorter timescales, is critical in assessing flood and debris flow risk – information on likelihood and variability in extremes will help in communicating risk to decision makers
	Links to non-climate layers	• spatial climate data linked to relevant non-climate strata; for example, precipitation and moisture deficit tied to soil maps and surficial geology
	Fine timescale	• daily and weekly climate variables – daily information could be provided as probabilities – combinations of moisture and temperature at small timescales affect pathogen agents (e.g., hard pine rust is related to temperature and moisture over a few hours)
	Moisture availability	• more accurate information on moisture deficits and surpluses
	Solar radiation	• effect of slope and aspect on climate parameters, including solar radiation, temperature, and climatic moisture deficit
	Oceanic variables	• oceanic variables, including sea level rise, change in sea temperature, salinity, acidity, and El Niño–Southern Oscillation; and ocean–atmosphere changes
Terrestrial	Biogeoclimatic Ecosystem Classification (BEC)	• updated BEC envelope projections by zone/subzone/variant and site series • BEC variant level projected for Alberta and the Pacific Northwest – for example, to facilitate assisted migration of seed populations
	Disturbance	• forest disturbance projections
	Growth and yield	• growth-and-yield projections – supported by monitoring of plantation performance

Variable		Data request
	Species shift	• projected tree species suitability
	Habitat envelopes	• species- and ecosystem-specific climate envelopes to enable modelling of habitat changes and to assess current and projected locations for Wildlife Habitat Areas, Ungulate Winter Ranges, and Old Growth Management Areas – sufficiently fine-scale spatial data for conservation planning • habitat migration envelopes for species at risk
	Biodiversity projection	• bio-climate velocity, climatic refugia, and strategic connectivity corridors in future climates • projected biodiversity hotspots
Aquatic	Streamflow	• historical streamflow • projected streamflow – low flows during drought; drought forecasting – extreme floods up to a probable maximum; projected Q100 flows for streams; a provincial map with estimated future Q200 for riverine floodplains and Q500 for coastal floodplains; flood forecasting, including changes in probability of debris flow – updated regression analysis to project streamflow for ungauged streams – streamflow input from modelled glacial recession – flow change by watershed or watershed group
	Intensity, duration, frequency (IDF) curves	• improved IDF curves
	Temperature	• projected water temperature (over space and time) – modelled stream water temperatures, including extremes – lake water temperature, particularly at the thermocline – temperature change by watershed or watershed group
	Ice	• lake ice thickness and ice-on and ice-off dates
	Snow	• projected snowpack
	Derived variables	• analyses of impacts of temperature and precipitation trends on lake and stream productivity and habitat suitability
	Cumulative effects	• cumulative effects analyses that consider impacts of climate change and land use practices on aquatic ecosystems
	Variety of timescales	• timescales that are appropriate to different fish species, ranging from 5 years for stocked fish and 10–30 years for native trout to 100+ years for white sturgeon

Decision makers need to know the confidence associated with projections to determine decision trigger points. For example, projected summer temperature increases of 2°C and precipitation decreases of 100 mm could trigger a reduction in water allocation or a request for an environmental flow needs study, if, and only if, confidence is sufficiently high. Several respondents suggested that ClimateBC variables have insufficient information on the accuracy of historical values to allow for assessment.

Researchers would like to know about improvements to PRISM surfaces, ClimateBC, and global climate models to enable updates of their work. Knowing whether climate model outputs converge as information improves would be helpful.

3.3 Information Delivery

3.3.1 Delivery mechanism Respondents would prefer a central consolidated information repository. User needs vary, which suggests that the design will include multiple levels: researchers prefer web-based tools and models, including application program interface (API)–enabled database tools and the capacity to use data via R code; technical advisors and decision makers would like summary maps and tabular data to be available on an easily accessible website; and people working with community members would like infographics and illustrations to assist with communications.

Several respondents highlighted a need for consensus data and models, which requires expert workshop processes and time. Others noted the importance of regional climate specialists. ClimateBC seems to be a well-known and used tool; rather than developing new tools, building on the existing website may be preferable.

Specific requests included the following:

- web-based tools for specialists, supported by documentation
  - capacity to use ClimateBC via R language (R Core Team 2016)
  - gridded data set that is accessible through an API
  - geodatabase with metadata
- standardized data for all, supported by easily accessed documentation that describes variables, interpretation, and assumptions
  - data that are available in the British Columbia government warehouse
  - data that are shareable with external consultants
  - format that integrates with a variety of projects, including correlation analyses for wildlife habitat
  - Oracle database tables/spatial data sets for use in all FLNRORD applications; for example, RESULTS/SPAR, CBST/CCISS, and map viewers
  - updates on improvements to data collection methods, additions of new variables, refined scenarios
- combination of summary maps and data inputs for GIS for non-specialists, supported by training workshops
  - user-friendly GIS data layers (including KML layers) and mapping interface
  - models that staff can manipulate
  - user-friendly watershed-based online tools
  - user-friendly models that project economic impacts
- layperson-friendly illustrations for communications
  - concise, using non-technical terms and infographics
- peer-reviewed publications for use in proposals
- website, plus presentations, webinars, and supporting web tutorial

3.3.2 Training and support Researchers generally found the support they needed through specialists, although they appreciated extra internal support. Other users noted a lack of internal capacity for support. Decision makers requested help in navigating complex information to enable them to assess where trends are clear and the extent of uncertainty where trends are less clear. Often, the challenge involved integrating climate information into existing technical/decision-making processes in a defensible manner. Non-scientific staff and community members needed knowledge translated into accessible formats.

Recommendations for support included the following:

- new staff
  - regional climatologists and climate data specialists
  - decision-support analysts to help navigate data and output from various models
  - GIS and statistical support
  - regional topic experts with knowledge of climate impacts
  - specialists who are able to relate to operational needs and to develop tools

- policy support
- training on information use
  - face-to-face workshops or seminars that describe websites, tools, and literature, and explain how to access data and climate projections
  - webinars and online tutorials as backup (respondents noted a preference for face-to-face training)
  - training tailored to specific audiences
- technical workshops that apply projections to specific case studies and describe uncertainty
  - for example, best practices for applying extremes to dam infrastructure
  - case studies from other regions, demonstrating tools and applications
  - technical workshop on interpreting atmospheric models

3.3.3 Existing websites Many respondents have used ClimateBC and found it to be extremely useful. Many others noted that the ClimateBC information that was available to them was good for a general overview and was useful for educational purposes but was limited in information on specifics, regional detail, and extremes. Respondents have used various other websites for information, including those developed by the Pacific Institute for Climate Solutions, Pacific Climate Impact Consortium (PCIC), Fraser Basin Council, Natural Resources Canada, Environment and Climate Change Canada, National Oceanographic and Atmospheric Administration, IPCC, and AdaptWest. Plan2Adapt on the PCIC website is invaluable as a baseline. AdaptWest has useful information, particularly for derived indices and landforms, for interpreting potential ecological changes but is challenging to download and interpret. The Canadian Institute of Planners Climate Change web portal provides practitioner resources and case studies. Respondents noted that accessibility of water data was particularly poor, with only general data available on websites, except for purchase.

4 DISCUSSION

Two distinct user-groups—researchers and decision makers/technical advisors—differ in their data needs and preferred delivery mechanism:

- Researchers prefer easy access to raw information for manipulation, and close communication with other specialists, including climatologists. They have specific requests and would like the most recent data available.
- Decision makers and technical advisors prefer interpreted data that clearly show trends and uncertainty. They need to assess the accuracy of climate projections and would like to work with consensus projections and tools.

Information for all, but particularly for decision makers and technical advisors, includes:

- agreed-upon downscaled climate projections with approved ensembles and models
- agreed-upon tools that apply climate projections to different ecosystem functions and services

Challenges include the considerable time and effort required to review policy and science prior to approving models and tools. Many existing tools are not yet housed on government platforms, and hence, are unavailable for use by technical staff and managers. Some data require substantial expertise to apply appropriately (e.g., climate velocity metrics); interpretation of trends and uncertainty by topic experts—including collaborative processes that bring experts together to discuss areas of disagreement—will be critical. Because the approval of tools and development of expertise will take time, an interim set of recommendations must fill the gap. Interim measures include designating contact people who can recommend current versions of tools and can direct staff to websites and current, relevant sources of information.

Ensuring consistency among, and within, ministries poses an additional challenge. Groups work independently to address user needs that are specific to their area of interest (e.g., BC Agriculture and Food's Climate Action Initiative). Awareness and collaboration will allow groups to identify synergies, reduce duplication, and ensure consistency in baseline climate information.

Options for dealing with extreme events include general approaches that estimate the probability or frequency of days beyond a specified threshold for a particular variable, and specific approaches in which topic experts create combinations of variables and thresholds related to specific disturbance events such as beetle outbreaks, fires, and floods. In the latter case, users could select events and regions and query the percent increase or decrease in frequency of occurrence.

The 45 respondents provided considerable information related to their specific needs. Achieving FLNRORD's goal of integrating climate change into decision-making will require feedback and direction from additional decision makers.

5 RECOMMENDATIONS

1. Develop agreed-upon climate projections, models, and tools
   - because approval takes time, provide interim recommended projections, models, and tools
   - designate contact people to recommend versions and direct people to websites and other sources for information
2. Improve ClimateBC's flexibility
   - add the ability for users to delineate area for analysis
   - provide finer-scaled data (spatial and temporal as appropriate to the need and uncertainty)
   - improve accessibility of spatial layers
3. Provide access to requested elements
   - describe extremes such as storms, heatwaves, and fire hazard
     - provide qualitative trends if quantitative data are unavailable
   - project water flow and temperature
     - include information on streamflow (e.g., broad-scale water-balance model)
     - project water temperature in streams and lakes
     - describe oceanic variables
   - increase accessibility of tree species selection tools

4. Build a single web-based framework with multiple layers linked to interpreted data (Table 5)
   - entry interface level:
     - provide clear indication of trends with estimates of uncertainty
     - include pdf maps and tables with a single set of numbers
     - ensure ease of access for all users
     - provide links to other layers for experienced users
   - core level:
     - link to tools for specific users, each with interpreted data that are accessible to all, and ensure the ability to manipulate for increased flexibility
     - provide user-friendly GIS layers
   - depths for researchers:
     - provide raw gridded data, including all inputs, and an API
     - enable capacity to use data with R, include R scripts
5. Support use of climate change data at regional and provincial levels
   - ensure access to climate experts
   - ensure that some topic experts have climate change knowledge
6. Tailor training to users
   - provide hands-on, face-to-face workshops backed up by webinars, online tutorials, extension notes, and literature
   - work through examples that are relevant to the user group
   - provide more detailed technical workshops in response to requests

TABLE 5 *Potential structure of climate information website, with example information types*

Information type	Primary climate data	Applied climate data
Example data	• Temperature • Precipitation	• Ecosystems • Tree species • Insects and disease • Drought • Fire • Hydrology
Summaries for decision makers (descriptions, maps, and data)	• Regional climate summaries	• Regional climate impact summaries • Climate-informed stocking standards
Interactive tools for technical support staff	• Plan2Adapt • ClimateBC	• Tree species selection tools (CBST, CCISS)[a] • Hydrology tools • Tree mortality projections • Drought tools/indices • Fire tools
Spatial data for analysts and researchers	• ClimateBC • PCIC[b] • Climatedata.ca	• Projected BEC[c] • Tree species distribution maps
Guidelines	Recommended climate scenarios and references	

a CBST: Climate Based Seed Transfer; CCISS: Climate Change Informed Species Selection.
b PCIC: Pacific Climate Impact Consortium.
c BEC: Biogeoclimatic Ecosystem Classification.

Foord, V., C. Delong, and B. Rogers. 2017. A stand-level drought risk assessment tool for considering climate change in forest management. B.C. Min. For., Lands, Nat. Resource Ops., Victoria, B.C. Exten. Note 119. www.for.gov.bc.ca/hfd/pubs/Docs/En/En119.htm

Hamann, A., D.R. Roberts, Q.E. Barber, C. Carroll, and S.E. Nielson. 2015. Velocity of climate change algorithms for guiding conservation and management. Global Change Biol. 21:997–1004. DOI: 10.1111/gcb.12736.

Intergovernmental Panel on Climate Change (IPCC). 2007. Fourth assessment report. www.ipcc.ch/assessment-report/ar4/

______. 2014. Fifth assessment report. www.ipcc.ch/assessment-report/ar5/

Murdock, T.Q. and D.L. Spittlehouse. 2011. Selecting and using climate change scenarios for British Columbia. Pac. Clim. Impacts Consortium, Univ. Victoria, Victoria, B.C. www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

R Core Team. 2016. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Wang, T., E.M. Campbell, G.A. O'Neill, and S.N. Aitken. 2012. Projecting future distributions of ecosystem climate niches: uncertainties and management applications. For. Ecol. Manag. 279:128–140. DOI:10.1016/j.foreco.2012.05.034.

Wang, T., A. Hamann, D. Spittlehouse, and C. Carroll. 2016. Locally downscaled and spatially customizable climate data for historical and future periods for North America. PLOS ONE. doi:10.1371/journal.pone.0156720.

Wang, T., A. Hamman, D.L. Spittlehouse, and T.Q. Murdock. 2012. ClimateWNA—high-resolution spatial climate data for western North America. J. Appl. Meteorol. Climatol. 51:16–29. DOI:10.1175/JAMC-D-11-043.1.

APPENDIX 1 Questionnaire: applying climate change information in resource management

Context: your business area

1. What is your business area?

2. What decisions do you make or inform?

Your interest in using climate projections

3. Have you used climate projections in your analyses and/or decision-making?
   a. If yes, how?
   b. If no, why not?

4. If no, would you like to use climate projections in your analyses and/or decision-making?

Specific information needs

5. How would you apply climate projection information to your work?
   – what particular analyses and/or decisions and/or communications

6. What specific variables would you like to use?
   – a wish list is fine; not all requests will be deliverable immediately
   – please specify relevant scale(s) and data type (e.g., time series, spatial data)
   – consider direct variables (e.g., temperature, precipitation) and derived variables (e.g., moisture deficit, surplus precipitation)

Delivery mechanism, training, and support

7. How would you like the information delivered?

8. Do you have sufficient capacity in your group to apply projections currently?
   a. If not, what training or support services would you find helpful?

9. Have you used existing climate change websites?
   a. If yes, how useful were they?

Follow-up

10. Would you be interested in working through a scenario to test needs further?
    a. If yes, in your work for the next week, please think about where information would help you, and let us know.
    b. If you would like to follow-up by phone, please provide a contact number.