Towards adaptation: an overview of climate change impacts and management tools

Dave Daust, April 6, 2011

Ecosystems in the Nadina face stress from climate change. Ecosystem services, particularly timber supply, have already been impacted. Management can serve to increase overall ecosystem stress or can enhance ecosystem resilience. Adaptation to climate change requires development of management strategies that decrease risks of climate change. This document begins by providing an overview of climate change impacts and then outlines management tools available for influencing the forested landscape, affecting resilience. The task for the workshop is to develop management strategies that reduce the potential negative impacts of climate change.

Impacts of climate change in the Nadina Forest District

This section provides a general summary of the expected impacts of climate change on ecological functions and ecosystem services in the Nadina Forest District. Expected impacts consider projected changes in climate for the area (Table 1) and are based largely on the results of three expert workshops, one for each focal management objective: biodiversity, hydrology/aquatic resources and timber[1]. This summary of impacts is intended to provide a common baseline for discussing potential management responses. Developing management responses will be complicated by additional demands likely to be placed on forest managers (e.g., for timber, bio-energy, carbon sequestration, carbon storage, fire protection, biodiversity conservation)

Table 1. Median and range (90% of outcomes) of climate variables projected for 2055 in the Bulkley-Nechako Regional District from multiple runs of different climate models using different emissions scenarios ("ensemble" runs). Source: http://plan2adapt.ca

Variable	Median Change	Range of Change
Mean temp (annual)	+1.8 °C	+1.3 °C to +2.7 °C
Mean temp (summer)	+1.6 °C	+1.2 °C to +2.8 °C
Mean temp (winter)	+1.8 °C	+0.6 °C to +2.8 °C
Precip (annual)	+9%	+2 to +16%
Precip (summer)*	+2%	-7 to +11%
Precip (winter)	+11%	-2 to +21%
Snowfall (winter)	+7%	-4 to + 16%
Snowfall (spring)	-52%	-68 to -10%
Growing degree days	+213 (deg x days)	+127 to 394
Frost free days	+18 days	+11 to +29

*Climate change, particularly summer precipitation, is likely to differ between the western mountains and eastern plateau portions of the Nadina.

[1] Available at http://bvcentre.ca/research/project/a_multi-scale_trans-disciplinary_vulnerability_assessment/

Biodiversity

Potential ecological changes

- Maladaptation: mismatches between specialist species and their environments
    - altered soil moisture and nutrient regimes
    - increased direct climate related stress (e.g., temperatures exceed tolerances)
    - decoupling of plant phenology and seasonal weather
    - rate of shift of environmental conditions northward and upward greatly exceeds migration rate of trees, many plants and soil biota.
- altered age-class and seral-stage distributions due to increased stand-replacing disturbance
    - increased evapotranspiration from hotter summers increases drought and fire risk
    - increased vigour of insects and disease due to warmer winters and summers
    - reduced resistance of trees to insects and disease due to stress
    - increased wind and heavy snow damage
- forest decline (reduced vigour and growth and increased in-stand mortality) due to maladaptation
- altered successional pathways due to competitive advantage of generalist species
- increased dominance of invasive alien and southern species
- increased ecosystem productivity due to longer, warmer growing seasons and increased atmospheric CO_2

Risk to ecosystem services

- extirpation of species from all taxa
- loss of characteristic plant communities and soil communities
- reduced area and connectivity of old forest ecosystems
- reduced ecosystem function and resilience

Hydrology and aquatic ecosystems

Potential ecological changes

- shorter, warmer, wetter winters and hotter summers
    - increased frequency of rain on snow events
    - continued glacial retreat and permafrost melt
    - shorter lake/river ice season
- increased number and strength of storm events
    - increased frequency and size of floods
    - increased frequency and size of landslides
    - decreased channel, slope and fan stability
        - increased sediment loads in streams
- increased loss of vegetation cover due to fires, windthrow, snowpress, insects and disease
- altered timing and volume of stream flow: increased flows in fall/winter; earlier spring peak flows; increased duration of summer low-flow period
- increased water temperature
- reduced water table

Risk to ecosystem services

- increased risk to fish populations—e.g., loss of salmon—due mainly to warmer water, but also due to potential changes in stream habitat from increased flooding and sediment loading.
- increased risk to infrastructure (e.g., roads, bridges, culverts) from storms, floods and landslides
- increased risk to soil productivity due to compaction from operating on melting ground in winter and on saturated soil (possible in western mountains) in summer.
- increased risk of isolated wetlands drying and of dry sites becoming even drier.

Timber

Ecological changes

- tree growth may increase due to longer, warmer growing seasons and increased atmospheric CO2 where moisture is not limiting
- tree growth may decrease and in-stand mortality may increase where trees become maladapted to their changing environment
    - increased evapotranspiration due to warmer summers and possibly drier summers (eastern plateau) will increase drought-stress on some sites, reducing growth and increasing susceptibility to insects and disease.
    - tree phenological responses may decouple from seasonal weather patterns
- tree mortality from stand-replacing disturbance may increase
    - increased evapotranspiration increases fire risk
    - increased vigour of insects and disease due to warmer winters and summers
    - relaxation of climatic controls that limit insect outbreaks
    - reduced resistance of trees to insects and disease due to stress
    - increased wind and heavy snow damage
- regeneration success may decrease
    - disturbed sites are more directly affected by climate
    - seedlings are more sensitive than older, established trees
    - increased vigour of insects and disease
    - natural seed sources may be less reliable
- soil conditions and fire hazard may more frequently limit equipment use
    - warmer winters may reduce the period with frozen ground
    - possibly wetter summers in the western mountains may saturate soils.
    - hotter and possibly drier summers in the eastern plateau may increase the period of severe fire hazard

Risk to ecosystem services

- smaller timber harvesting land-base due to removal of sites with very low productivity and/or regeneration challenges
- reduced stocking and growth on some sites
- reduced area of mature green timber due to stand-replacing disturbance[2]

---

[2] we avoid the term "natural disturbance" because historical natural disturbance regimes no longer predict future disturbance; the term climate-induced disturbance may be more appropriate because it emphasizes the large influence of climate on disturbance processes.

- reduced timber supply because growth declines and mortality (i.e., from stand-replacing disturbance) likely exceed growth gains
- more frequent equipment shutdowns
- increased access costs to support salvage operations over a large area
- potential loss of soil productivity due to climate change, and repeated, frequent disturbances (including salvage)

Potential benefits to ecosystem services

- increased growth on some sites and potential for shorter rotations (based on minimum volume per ha)
- increased area of salvageable timber due to stand-replacing disturbance

Developing a management response

The condition of the forested landscape influences susceptibility to climate change. Forest managers have a limited set of methods (management tools) to directly affect the forest. Using management tools, managers can affect a number of key indicators of forest ecosystem structure and function that influence biodiversity, hydrology and timber supply.

Four basic types management strategies exist for addressing climate change (see also Appendix):

- reduce exposure to climate change (e.g., retain intact forest to buffer microclimate of dry site; some sites such as north-facing slopes have naturally-low exposure)
- reduce susceptibility/sensitivity to climate change (e.g., create fire breaks, plant southern species and genotypes); similar to increasing resilience
- control climate-induced impacts, particularly disturbance events (e.g., fires, floods) to limit damage
- mitigate climate-induced impacts (e.g., salvage dead merchantable timber)

Managers can try to reduce impacts of potential changes in driving ecological variables directly (e.g., Table 2) or can plan to adapt to changes in ecosystem services (e.g., Table 3). Potential responses include new management strategies, new monitoring and research and new planning initiatives. Management strategies can express desired activities (i.e., focussing on tools) or desired outcomes (i.e. focussing on indicators). At this exploratory stage of strategy development, expressing general targets (e.g., promote species diversity in planted stands) may be appropriate.

Management tools

- harvest rate, location and pattern (i.e., including landscape reserves)
- harvest intensity/type (e.g., stand-scale reserves, decay-waste-breakage, partial cuts)
- slash burning and broadcast burning
- road density and location
- road construction, maintenance and deactivation standard[3]
- number and location of stream crossings
- stream crossing construction, maintenance and deactivation standard

[3] The term "standard" refers to level typically achieved rather than regulatory standard.

- trail and landing density, location and standard (e.g., size)
- scalping and compaction of soils (governed by in-block soil disturbance limits)
- planting (delay, species composition, provenance and stocking density)
- brushing and weeding
- thinning
- fertilization
- fire control

Key indicators (examples)

Biodiversity

- seral stage distribution and representation of ecosystems
- landscape-scale species composition
- connectivity
- interior forest
- amount of stand-scale retention
- location/type/pattern of stand-scale retention (e.g., riparian cover versus upland wildlife tree patches, deciduous versus coniferous, large live trees versus snags versus down wood, large patches versus dispersed retention)
- protected proportion of focal species' habitat and rare ecosystems

Hydrology

- forest cleared in a watershed (e.g., as measured by equivalent clearcut area)
- road length in unstable terrain
- riparian cover on fans and floodplains
- riparian cover along different stream types (e.g., source, transportation, deposition zones)
- riparian cover around lakes, wetlands, forested swamps, etc.
- riparian cover around high value-fish habitat
- riparian cover around temperature-sensitive stream systems
- area of denuded sites with low water tables (pooled water and saturated soil heats and can increase stream water temperature)
- ditch maintenance and deactivated road standards for sites that feed streams (pooled water heats and can increase stream water temperature)

Timber

- average, over the timber harvesting land base, of mean annual increment.
- percent of stand's maximum mean annual increment at harvest
- growing stock (m^3/ha x THLB ha)
- unsalvaged volume
- regeneration delay and free-growing delay
- percent of planted stands with genetically-improved stock
- road cost per m^3

Table 2. Example adaptive responses to changes in ecological drivers.

Ecological Change*	**Sensitivity by Site/region****	**Management Response**	**Management influence*****	**Monitoring response**	**Planning response**
Tree growth ↑	• **Low-Mod** on sites without moisture stress • **Low** on sites with moisture limitations				
Fire mortality ↑	• **High** in dry eastern plateau • **Low** in wet western mountains				
Bark beetle mortality ↑	• **High** for pine component • **Mod-High** for spruce component • **Mod-High** for balsam component	e.g., salvage	High → Mod Mod-High → Mod	Beetle research	Salvage guidelines
Diseases of young stands ↑	• **Mod-High** in pine leading plantations in SBS mc2 (Dothistroma)				
Maladaptation due to climate-stress ↑	• **High** on dry sites • **Low** on moist and wet sites				
Forest-scale resilience ↓	• **Mod** everywhere • specific BEC zones?				

*Columns 1 and 2 are based on expert workshops, but are open to modification.
**Sensitivity (most likely magnitude of change) ranges from low to moderate to high and includes intermediate categories (e.g., mod-high).
***Shift in sensitivity due to management (e.g., High → Mod).

Table 3. Example responses to changes in ecosystem services. Some changes may be forced upon managers (e.g., costly reforestation) but advance warning can increase ability to plan and cope with change.

Ecosystem Service Δ	**Sensitivity***	**Management Response**	**Management Influence**	**Monitoring Response**	**Planning Response**
Timber supply ↓	• Mod-High	• Reduce milling capacity			
Percent salvage ↑	• High	• Less lumber, more bioenergy			
Plantation failures ↑	• Mod	• More costly reforestation			
Road access per m^3 ↑	• Low	• More costly harvesting			
Shutdown periods ↑	• Low	• Low ground-pressure tires • Larger, seasonal work force			

*Impact (most likely magnitude of change) ranges from low to moderate to high and includes intermediate categories (e.g., mod-high).