Adapting Forest Gene Resource Management to Climate Change

submitted by Sally Aitken

The importance of using appropriate populations as seed sources for reforestation has long been recognized, based on observed differences among populations within species for survival, growth, and resistance to biotic and abiotic stresses. Over 200 years ago, Linnaeus observed that yew trees from France were less cold hardy than those from Sweden, with obvious implications for reforestation.

Geographic patterns of genetic variation for traits related to adaptation to climate (e.g., timing of initiation and cessation of growth, cold and drought hardiness, and growth rates) are associated with climatic gradients in temperature and moisture. These observations have led to forest policies that legislate the use of relatively local seed sources for reforestation, particularly on publicly owned lands. However, the "local is best" approach assumes that offspring planted locally for reforestation will experience a similar climate to that experienced by their parents, grandparents, and more distant ancestors. We now know that this assumption is unlikely to be correct.

Substantive evidence that we are in a period of rapid global climate change is accumulating for both weather data and for biological responses to increased temperature over the past 30 years. Plant phenology, particularly the timing of growth onset in the spring, has advanced during this period of warming. Altitudinal ranges of some plant species are rising, and are predicted to climb an average of 400–600 m over the next century. This distance exceeds current allowable seed transfers for reforestation of almost all species in British Columbia.

If global climate change results in even a small decline in growth rates of these forests, the net effect on long-term wood and fibre production nationwide could be substantial. This could have a negative impact on Canada in two ways. First, it could reduce the total resource available to the forest industry. Second, it could reduce the net amount of carbon fixed in Canada's forests. Severe maladaptation could result in Canadian forests becoming a net source rather than a sink for carbon.

Conversely, if the existing genetic variation in major forest tree species is selected from and vigorous genotypes are redistributed across the landscape, matched to environments for traits relating to adaptation to climate, the result could be a substantial increase in carbon

Considerable uncertainty exists around future rates of climate change.

Strategies for reducing risk or mitigating effects of climate change need to take this uncertainty into account.

fixation and a positive impact on Canada's carbon budget.

If predominantly local populations are used for reforestation, and climate warms rapidly (as predicted), forest productivity will likely decline in the short term for at least some species due to maladaptation of local populations to new climatic conditions.

For example, the work of G.E. Rehfeldt at *www.forestry.ubc.ca/schaffer/rehfeldt/index.htm#3* predicts responses to climate change based on analyses of the extensive B.C. lodgepole pine provenance trials. However, if stands are planted with non-local populations and climate change predictions are wrong, similar problems will result.

By deploying intimate mixtures of seed from select genotypes from disparate regions (and environments), the effects of climate change over a wider range of potential future conditions could be mitigated. As many more trees are planted per hectare than are harvested, the system has room to increase the adaptive diversity of seedlots without necessarily reducing stand productivity. The use of higher than current initial planting densities may also provide more opportunity for selection of the best-adapted individuals through intraspecific competition.

Forested areas where management activities include tree planting hold opportunities to match genotypes with environments as climate changes. In areas where natural regeneration is used following harvest, or in *in situ* gene conservation reserves where trees are not cut, populations will have to adapt to new conditions. The ability to evolve sufficiently rapidly to adapt to a changing environment is a function of the rate of environmental change per generation, the amount of genetic diversity, and the strength of natural selection on traits conferring adaptation to changing environmental conditions.

Relatively little attention has been paid to the potential role of adaptation in response to climate change.

The CFGC is exploring:

- **genetic strategies to mitigate the effects of climate change**
- **the potential for natural populations of forest trees to adapt to new climates without human intervention.**

Differences in adaptation to climate among populations in a trial at Red Rock, B.C.:

(a) a well-adapted lodgepole pine provenance from ~1° latitude south of the test site

(b) a poorly adapted provenance from ~6° latitude north of the test site

The CFGC was recently awarded a grant funded jointly by the NSERC Strategic Grants Program and the BIOCAP Canada Foundation. This grant will be used to explore genetic strategies to mitigate the effects of climate change, and the potential for natural populations of forest trees to adapt to new climates without human mitigation. The research team for this 4-year project includes Sally Aitken, Alvin Yanchuk, Rob Guy, Tongli Wang, incoming PhD student Kirstin Campbell, and one additional graduate student.

The project has three primary components:

1. Evaluation of the potential for mixtures of improved and unimproved genotypes from different provenances to buffer some effects of climate change and future climatic uncertainty. The responses to temperature of lodgepole pine populations inferred by Rehfeldt in simulations run using the TASS computer model under varying future climatic scenarios will be used.
2. Investigation of the underlying physiological responses of genotypes from different populations to both temperature and carbon dioxide to better understand and predict population responses to climate change. A series of growth chamber experiments with lodgepole pine and possibly one additional species will be undertaken.
3. Prediction of the ability of naturally regenerated populations of forest trees, in conservation reserves or in operational forest areas, to adapt to a rapidly changing climate by combining information from existing provenance and new genecological trials, for species to be determined.