

Highlights for the Tree Species Adaptation Risk Management Project¹

Funded by the Climate Change Emission and Management (CCEMC) Corporation

Tree Improvement Alberta

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Background

Since the 19th century, foresters and plant biologists have understood that plant populations are genetically differentiated in a manner that matches the variation in the environment in which the species occurs naturally. Studies in forest trees were the first to reveal this phenomenon and identified variation in climate and day length (photoperiodism) as major factors of natural selection in wild plant populations (e.g., Linhart and Grant 1996; Wu and Ying 2004). In Alberta, tree populations are genetically differentiated in a pattern that is consistent with the variability in the Alberta climate (e.g., Rweyongeza et al. 2010; Rweyongeza 2011; Rweyongeza et al. 2007). This immense variability in climate is a product of a complex topography superimposed on a north-south change in temperature and day length.

Collection and use of seed and vegetative material for artificial forest regeneration has generally evolved along an attempt to match the climate or geography of the seed source with the climate or geography of the planting site. This assures that, at least from an evolutionally point of view, the planted trees have an environment that is suitable for their survival and reproduction. The concept of seed zoning, which involves dividing a country, state or province into regions to facilitate safer collection and use of seed, is aimed at safeguarding this adaptation of trees to their environment (e.g., [Alberta seed zones](#)). However, from the forestry viewpoint where growth and yield have to be maximized, artificial forest regeneration goes beyond survival and reproduction of a forest tree species. It has long been observed that forest trees exhibit greater environmental adaptation amplitudes than the discrete locations in which populations are currently found. When the basic requirements of survival and reproduction are met, trees may be planted further than their native locations to increase forest productivity (e.g., Namkoong 1969; Mangold and Libby 1978). Therefore, with good data and knowledge of the species natural range, and the pattern of population genetic differentiation in the species for adaptive traits, foresters have always planted tree populations beyond their native locations.

Replicated field experiments have been a major tool for mapping the population differentiation of forest tree species; relating tree characteristics such as growth and phenology (e.g., initiation and cessation of shoot elongation) to characteristics of the environment (e.g., climate, day length and soils); and subsequently, developing guidelines for use of seed in Alberta. One of the major findings from these

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experiments is that in the contemporary climate, cool season (winter) temperature and short growing seasons are the main drivers of population differentiation for growth potential (see Rweyongeza et al. 2010). By tracking seasonal changes in day length, photoperiodism becomes another major determinant of population differentiation for growth potential in places such as Alberta, which alongside climate explains the tendency for populations to differ along the north-south cline. Thus, in a static climate, we have a system of seed transfer guidelines that is designed to protect trees from winter conditions. A transfer of reproductive material outside the seed zones of origin is permissible if it poses no potential for winter damage and/or reduces productivity in the new environment.

The impending change in climate has changed the focus of future seed transfer guidelines from protecting the forest against winter temperatures to sustaining survival, growth, forest productivity and general forest health under drought. It is projected that in the near future, Alberta will be warmer and drier (e.g., Mbogga et al. 2010), thus calling for revision of seed transfer guidelines to address climatic limitations of the future.

Climate change poses both opportunities and challenges. On one hand, a warming climate in places that currently have sufficient precipitation but limited summer heat promises to boost forest productivity. Warming climate has also a potential to enable longer distance transfers of highly productive populations to places where local populations have intrinsically lower growth potential due to historical adaptive constraints of the past climate. On the other hand, in places where precipitation and heat are currently at an optimal level, warming will lead to drought causing decline in forest productivity and even replacement of forest ecosystems by woodlands and grasslands.

A typical constraint to evolution in forest trees species is the long generation interval. Because evolution and adaptation by natural selection proceed through reproduction, any rapid change in climate will certainly outpace the ability of trees to produce genotypes adapted to a changed climate. Therefore, human intervention will be needed to:

- i. Physically move germplasms to new locations where their suitable climate has shifted to (species and gene conservation goal) or replace populations with new ones if native populations have lagged behind climate change (restoration or sustenance of forest value such as productivity).
- ii. Identify and conserve in-situ and ex-situ, populations with unique genes such as those controlling tolerance to climatic stress (e.g. drought) and resistance to insects and diseases.
- iii. Assist clonally regenerated species, which except for accumulation of somatic mutations and rare seedling establishment in gaps have sustained their populations through replication of the same genotypes through coppicing for millennia. Such species have a greater change of lagging behind climate change unless effort is made to propagate them artificially either through seed or infusion of new clones suitable for the changed climate.

- iv. Where populations suitable in the new climate are not naturally available, plant breeding could be applied to produce adaptive germplasm at least for operational forests.

A more comprehensive discussion on options for adaptation to climate change in forestry is found in Aitken et al. (2008). Based on existing field experiments, interim measures have been made to adjust seed transfer guidelines in Alberta and other places such as British Columbia (e.g., O'Neil et al. 2008). Alternative measures for aspen and matching of seed zones based on projected future climatic similarities have also been suggested (Gray et al. 2011; Gray and Hamann 2011). However, these measures are aimed at allowing populations of better growth potential to be planted further than their current location to take advantage of their better yield given that the threat for lower winter temperatures is diminishing. They do not address the problem of drought tolerance and insect and fungal diseases, which will increase due to warming. Therefore, new initiatives are needed to deal with climate change inferences that the current field experiments are not designed to address.

The Tree Species Adaptation Risk Management Project

The Tree Species Adaptation Risk Management (TSARM) project is funded by the Climate Change and Emission Management (CCEMC) Corporation to address some of the climate change adaptation challenges outlined above. The partners in this project are the Alberta Government (Alberta Environment and Sustainable Resource Development or ESRD) and forest companies involved in tree improvement and tree breeding in Alberta. TSARM is being implemented through a consortium called Tree Improvement Alberta (TIA) where all project partners are members. Briefly, TSARM is implementing four major project components (some variations may exist in each component):

- i. **Expanded provenance trials:** Under TSARM, four field trial sites are being developed, which when completed, will house a number of provenance trials of different native and non-native species. The objectives of these sites is to provide field testing environments that will allow Alberta to screen wild tree populations for genetic tolerance to drought and other characteristics that are relevant to climate change. Some of these sites will be located in higher elevations where field testing has not previously occurred in Alberta to test the limit of cold tolerance of highly productive populations from lower elevations.
- ii. **Risk assessment of tree breeding programs:** ESRD and forest companies have tree breeding programs designed to produce genetically improved seed and vegetative material for reforestation and/or reclamation in specific parts of the province. Zoning of these programs was done under the assumption of the static climate. Each of these programs is supported by a network of field experiments and seed orchards all of which were designed to optimize forest productivity under the static current climate. Under TSARM, project partners will conduct a risk assessment of their programs to identify activities of the programs that may be negatively impacted by climate change and thus make the companies fail to meet their goals and/or reforestation obligations using genetically improved material. These risk assessments will

include things such as the size of the program, the number and climatic source of the genotypes included, the climatic similarities and genotypic overlaps among breeding regions, etc.

- iii. **Genetic analysis and climatic modeling:** Currently, the breeding programs associated with regions of the province operate independently under the assumption that each region has a different broader climate. In a changing climate, similarities may emerge among segments of the breeding regions making it possible to swap genotypes among programs and/or operate joint field testing and common seed orchards to attain efficiency. Under TSARM, a postdoctoral fellow has been hired at the University of Alberta to perform a comprehensive analysis of data from existing field experiments across breeding programs in light of the current and future climate. Under this item the following questions will be pursued, (a) how climatically different are the breeding regions in the current and projected future climate? (b) Which of the breeding regions can share seed in part or whole? (c) If climate change occurs as projected, how can the breeding regions be reorganized? If the breeding regions need to lower the risk level posed by the genotypic composition of their programs, where do they need to sample to capture genotypes that are better adapted to climatic limitations of the future (e.g., drought)?

- iv. **Mass vegetative propagation for aspen:** Aspen (*Populus tremuloides*) is a clonal species that propagates by sprouting from the root system. Currently, there is no reliable and cost efficient technique to produce large number of vegetative material for artificial regeneration of this species. Under climate change, if the local clones become less adapted to future climate, appropriate sources of new clones would have to be sought and artificially planted. Under TSARM, forest tree nurseries are developing more efficient ways to mass produce vegetative propagules for aspen, which will be needed to replant the species in the future.

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