Outline of Tree Improvement Alberta (TIA) and Climate Change and Emissions Management (CCEMC) Corporation Tree Adaptation Risk Management Project

1.1 Background

The Climate Change and Emissions Management (CCEMC) Corporation is an Alberta based not-for-profit Corporation with a mandate to reduce greenhouse gas emissions and assist Alberta in adapting to climate change through the discovery, development and deployment of clean technologies. The CCEMC is investing in projects that address adaptation to climate change, specifically focusing on natural resources management challenges. As a result of risk to tree populations arising from a changing future climate, the Climate Change and Emissions Management (CCEMC) Corporation has agreed to fund the project titled *Tree Adaptation Risk Management*. The following material describes the project, the project management schedule and the desired outcomes.

Forestry is an important part of the Alberta economy. In 2010, $4.0 billion was generated from sales of forest products[1] and the livelihood of many rural communities in Alberta depends directly or indirectly on forestry. Alberta's forests provide habitat for a diversity of wildlife and are a major tourist destination for urban communities. Our vast boreal and mountain forests are sinks for carbon dioxide (CO_2) thereby contributing to provincial and national efforts to reduce global warming and climate change.

It is predicted that, in a few decades, the Alberta climate will change significantly with much of the boreal forest region experiencing drought (e.g., Burrow and Yu 2005; Mbogga et al. 2010). These changes will expose both conifer and deciduous tree species to abiotic stress and may lead to regeneration failure for new forests, reduction in annual growth for existing forests, and potential shrinkage of the area currently occupied by native species and populations. At a finer scale, this stress could transform existing forest systems into woodlands or grasslands, change the ecosystem species composition, and result in the disappearance of unique populations of commercial and non-commercial species in highly stressed areas. Therefore, current projections of climate change are likely to have the following implications for Alberta forests.

(i) Reduced economic value due to a decline in fibre production from natural and planted forests,

[1] Source: http://albertacanada.com/documents/SP-EH_AlbertaEconomicQuickFacts.pdf

(ii) Loss of forest ecosystems and function thereby affecting other sectors such as tourism, recreation and water supply,

(iii) Loss of genetic diversity for commercial tree species on which climatic and environmental resilience of these species depends.

1.2 Project Description

This proposal seeks to exploit the genetics of Alberta's major forest tree species as a tool for, (i) sustaining fibre productivity; (ii) maintaining forest ecosystems and their function; and (iii) identifying and conserving distinct populations that may be threatened by climate change. Reforestation by artificial regeneration in Alberta is possible through two types of material as described below.

(i) Stream 1 materials are seeds and/or vegetative propagules such as cuttings (for eg: poplars) collected from wild stands and used directly to establish new stands. The province regulates both the collection and use of these materials through a system of seed zones and transfer guidelines outlined in the Alberta Forest Genetic Resource Management and Conservation Standards (FGRMS 2009[2]).

(ii) Stream 2 materials are seeds and vegetative propagules produced by tree improvement programs. Parents for these materials undergo phenotypic selection, genetic testing and domestication in government approved production facilities such as a seed orchard. The province regulates these materials through a system of regions known as controlled parentage program or CPP regions, which are associated with forest management agreement (FMA) areas. CPP regions have designated deployment and exclusion areas. Standards governing production and use of Stream 2 materials are also found in the FGRMS (2009).

Currently, Stream 1 and 2 provide 85% and 15% of the reforestation materials respectively. It is expected that as seed orchards mature and tree improvement becomes fully operational across the province, the share of Stream 2 material will increase substantially. The emerging biotic (e.g., pests and diseases) and abiotic stresses (e.g., drought) that require regeneration material that are genetically selected for increased tolerance to stress will also result in an increase in the share of Stream 2

[2] FGRMS (Alberta Forest Genetic Resource Management and Conservation Standards). 2009. Publication No. Ref. T/213. Edmonton, AB.

materials. In addition, as the forest land base shrinks due to climate change and alternative land uses, the province will have to sustain fibre production on a smaller land base by use of highly productive Stream 2 materials.

The production and/or regulation of Stream 1 and Stream 2 materials are supported by research on the genetics of tree populations. These designed genetics field experiments seek to (i) establish the relationship between trees and their environment to ensure maintenance of this relationship under artificial regeneration, and (ii) identify specific trees that will maximize the desired economic objectives (e.g., increased productivity). Maximum productivity can be assured only when trees are optimally adapted (e.g., survive, grow and reproduce) to their environment; maladapted trees cannot exhibit high productivity and may fail to survive. This proposal is seeking to maintain genetic adaptation, forest productivity and conserve genetic resources, which are raw material for both adaptation and productivity, through the following projects:

(i) Testing of wild tree populations for climatic tolerance with greater emphasis on drought,
(ii) Review Stream 2 programs for risk posed by climate change to aid in climate change adaptation preparedness,
(iii) Testing of populations from tree improvement programs for climatic tolerance with emphasis on drought,
(iv) Testing wild populations of alternative non-native species that may replace native species if the later fails due to climate change.

1.2.1 Testing wild populations for climatic tolerance

Beginning in the mid 1970s, the Government of Alberta has been testing wild populations of commercial coniferous species for adaptation to climate. These field experiments known as provenance trials are designed to determine how climate and other environmental conditions affect performance (survival, growth and reproduction) of trees when planted away from their site of origin. Likewise, beginning in the 1990s, the Alberta forest industry has been testing aspen provenances. In part, results from these trials have provided the foundation for the current Alberta seed transfer standards (FGRMS 2009). In addition, these trials have provided preliminary indicators of how recent changes in climate can affect survival, growth and forest productivity.

Despite their usefulness in informing the current provincial reforestation policy, existing provenance trials were designed assuming a static climate. These trials were primarily designed to test variation in the most productive environments of the green zone where industrial forestry activities are largely concentrated. Climate change is predicted to transform these regions to resemble the current climate in the Parkland. Therefore, to sustain forest productivity, populations that can survive and grow well in the typically drier Parkland type of climate must be identified. It is also predicted that, as the climate warms, highly productive populations from lower elevations could be used at higher elevations to increase productivity. Increasing productivity at higher elevations could provide an opportunity to compensate for the lost forest land base at lower elevations and in the boreal forest. Before this is possible, we need to know the limits with which materials from lower elevations can be transferred to higher elevations. These test sites do not currently exist, leaving Alberta vulnerable to being able to make sound policy decisions regarding reforestation and deployment of existing and future material.

Under this proposal, we plan to establish five new provenance trial sites to (a) bridge the climatic gap already identified in the existing trials, and (b) extend testing to drier parts of the province, which currently have climates that are similar to the future predicted climates for the boreal forest. The test material will include,

(i) All Alberta populations in the existing provenance trials,

(ii) New Alberta populations from dry environments that were not sampled or are underrepresented in the existing trials,

(iii) Deciduous sources of populations not currently in any existing provenance trials (balsam and aspen poplars),

(iv) Populations from selected areas in Saskatchewan, Manitoba, Ontario and Quebec. Existing provenance trials have shown that some of white spruce populations from central and eastern Canada can outgrow Alberta populations by more than 10% (SRD unpublished data). However, these out-of-province populations originate in areas with higher precipitation than Alberta and must be tested for drought tolerance to confirm their suitability for the future projected Alberta climate.

Once established, trees in these trials will be monitored and assessed for (a) climatic damage/tolerance (summer drought and winter frost) that affects forest regeneration; (b) rate of growth under drought stress; and (c) insects and diseases that may become prevalent due to drought stress. Results from these trials will enable the province to,

(i) Revise the existing transfer policy that governs the use of wild seed/clones (Stream 1) on crown land to include drought tolerance, which cannot be done based on existing trials.

(ii) Determine if CPP regions can be expanded or material shared because the sampled populations and test sites transcend boundaries of individual CPP regions. Results from these trials will show if and how tree improvement programs can use the same breeding populations or share Stream 2 materials if climate change demands it. The policy governing use of Stream 2 materials within individual CPP plans may also be changed.

(iii) Identify areas of genetically distinct populations, especially for climate change related attributes such as drought tolerance that may be in danger of being lost. These populations may be conserved on site (*in-situ*), in conservation stands (*ex-situ*) or moved to safer areas for future use (assisted migration).

Under this plan, the deliverables will be:

(i) Data and information to aid policy revision on use of both Stream 1 and Stream 2 materials.

(ii) Recommendations for possible use in Alberta of conifer populations from outside Alberta.

(iii) Recommendations on conservation of distinct populations in areas highly threatened by climate change.

1.2.2 Climate change adaptation needs for tree improvement programs

While Stream 1 materials can be collected and used anywhere within their deployment seed zone and if applicable outside the seed zone of origin, Stream 2 materials can be developed only from and used within a designated CPP region. While Stream 1 materials can be collected anywhere in wild stands in any year, each Stream 2 program has a specific production facility (e.g., seed orchard) and a network of research trials to support it. This specificity in the source and deployment area, fixed location for both the production facility and supportive research trials pose a significant climate change risk. Therefore, the risk posed by climate change to tree improvement programs is of two categories.

(i) Risk to the fixed infrastructure that produce (e.g., seed orchard) or support (research trials) production of Stream 2 materials.

(ii) Risk arising from the potential maladaptation of tree populations and parents currently being used in specific CPP regions.

Economically important conifers in Alberta are propagated through seed, whereas aspen and poplars can also be vegetatively propagated. The reproductive biology of the two groups of species is also very different. In addition, conifers and deciduous species are at different levels of development and production of Stream 2 materials. Therefore, climate change adaptation for tree improvement programs may have to be approached differently between conifers and deciduous programs.

1.2.2.1 Review of Stream 2 programs

Review all conifer programs managed by industry to identify key areas of risk associated with climate change and stress tolerance planning. These reviews will provide direction on redesigning these programs and enhancing current strategies.

Review two trembling aspen CPP plans and one balsam poplar CPP plan managed by industry to identify key areas of risk associated with climate change and stress tolerance planning. These reviews will provide direction on redesigning these programs, enhancing current strategies or simply confirming that the programs have a risk management strategy in place.

1.2.2.2 Analyzing Stream 2 populations for climatic tolerance

The objective of tree improvement programs in Alberta is to increase productivity by breeding for rapid growth or replicating superior clones while maintaining adaptation of populations to the environment. Adaptation to the environment is attained through climatic tolerance and resistance to insects and diseases. Progeny trials associated with each CPP region are designed to provide data for assessing the genetic merit of selected trees for their productivity; wood quality; and adaptation to climate, insects and diseases. Assuming a static climate, existing progeny trials have allowed us to predict genetic merits of selected parents and associated genetic gain for productivity variables. Within the limits of individual CPP regions, existing progeny trials supplemented by data from province-wise provenance trials have also allowed us to determine climatically safer deployment areas for each CPP regions. Assessment of resistance to insects and diseases is ongoing and subject to natural cycles of insect and disease outbreaks.

The growing awareness of a changing climate has hastened the need to re-examine the relationship between selected parents of Stream 2 and climatic variables that are relevant to future climatic stresses such as drought. In this proposal, we will measure field trials for all CPPs and analyse existing and new data for adaptation to climate. The following activities will be undertaken:

Conifer programs

(i) Measure all existing field trials to obtain the latest data on survival, growth, climatic damages, and insect and disease incidences.

(ii) Analyse existing and new data to establish a relationship of survival, growth, and resistance to insects and diseases with climate. Emphasis will be given to specific temperature and precipitation variables that are drivers of future environmental stresses.

(iii) Based on the analysis, identify sampling gaps in seed source and test site climates within individual CPP regions; compare trends and gaps across CPP regions to facilitate extensive joint testing among CPP regions.

Deciduous programs

(i) The deciduous programs have aspen and/or balsam poplar provenance and progeny trials similar to the conifer trials. These trials will be measured to obtain the latest data on survival, growth, climatic damages, and insect and disease incidences.

(ii) Analyse existing and new data to establish a relationship of survival, growth, and resistance to insects and diseases with climate. Emphasis will be given to specific temperature and precipitation variables that are drivers of future environmental. Interpretation of results for these clonal species where genotypes (clones) have persisted in place for thousands of years may differ from that of conifers.

(iii) Based on the analysis, we will identify sampling gaps in population and test site climates within individual CPP regions; compare trends and gaps across CPP regions to facilitate extensive joint testing among CPP regions. Again unique characteristics of clonal species will be taken into consideration.

By showing how productivity and climatic adaptation are related, and revealing climatic sampling gaps in the current Stream 2 testing programs, the measurement and data analysis component of the proposal is preparing the ground work for new field testing and redesigning of production facility populations in light of climate change. The maximum contribution to the provincial policy from these measurements and analyses would come from field testing that this stage of the project will enable. Nevertheless, there are interim policy benefits as outlined here.

Summary adapted from the CCEMC Grant Agreement proposal

(i) Results of climatic trends may lead to revision of provincial guidelines on deployment of Stream 2 materials within CPP regions including the exclusion zones.

(ii) Assembly of the breeding and production populations may be revised to give greater emphasis to part of the CPP region where climatically tolerant genotypes are likely to come from.

1.2.2.3 Testing tree improvement populations for climatic tolerance

Each CPP plan has developed a ‘population’ that is larger than the population mentioned in 1.2.1, which is a collection of families or clones selected primarily for higher productivity. Currently, material from each of these populations can be used only in a CPP region where parent trees or clones were selected and tested. If the climate were to change such that these populations become maladapted for their specific regions, both industry and government could (a) lose their investment and (b) return to using Stream 1 material in areas that would otherwise have been planted with more productive trees. Therefore, we need to test the climatic resilience of tree improvement populations (Stream 2) and redevelop them for suitability to future climate.

To redesign Stream 2 populations for climate change purposes, we must first determine the climatic plasticity of populations developed to maximize productivity in specific CPP regions. Specifically, we would like to know, (a) if and by how much can Stream 2 materials be shared among CPP regions, and (b) the association between growth potential and climatic tolerance on ‘real’ stressful (droughty or cold) environments.

While the current progeny trials allow us to identify the best families and genotypes, and predict genetic gain within the CPP, they are too few to allow assessment of climatic plasticity of Stream 2 populations beyond the boundaries of individual CPP regions. Transferability of Stream 2 materials across CPP regions is possible only when these materials are tested across the province in a manner described for wild populations in 1.2.1. Therefore, results obtained in 1.2.2.2 and considering the risk level identified in 1.2.2.1, we will design and test Stream 2 populations across the CPP regions. Again the approach may differ between conifers and deciduous species.

Conifer programs

(i) Identify families to be tested from each CPP region; select sites that provide desired levels of climatic stress; design a testing layout that maximizes the chance of identifying climatically hardy genotypes; and decide on characteristics to be assessed.

(ii) Where desired, perform controlled crosses among selected parents with desired traits for testing. Where individual crosses are not performed, bulk orchard seedlots will be used for testing.

(iii) Collect seed on an individual family basis for potential regrouping by parent and region to fit a desired testing and deployment population design.

Deciduous programs

(i) While taking into consideration the unique characteristics of clonal species, identify families to be tested from each CPP region; select sites that provide desired levels of climatic stress; design a testing layout that maximizes the chance of identifying climatically hardy genotypes; and decide on characteristics to be assessed.

(ii) Clonal forestry is another option available for deciduous deployment of superior materials and provides significant advantages from a gain perspective (Gylander 2011[3]). A major challenge faced by industry is the economic mass propagation of this material. Since aspen cannot be propagated from stem cuttings as with balsam poplar, alternative propagation technology needs to be developed. In order to maximize productivity on a reduce landbase, clonal deployment provides the best opportunity from both an adaptation and yield perspective. Under this project, we will develop an economically viable system for mass propagation of selected best adapted clonal material.

With this proposed action plan, ASRD and industry will work together and develop joint test complexes for testing provenances, families and species for stress tolerance. Industry and ASRD will share data, outcomes and knowledge to assist with sound, science based policy change. This may include scientific advice to forest genetic resource management policy makers on options for revising forest management policy to accommodate revised and expanded CPP plans. Specifically results from the proposed conifer testing program could have the following policy implications:

(i) If it is found that seeds from current seed orchards can be safely used outside the current permitted CPP region, policy governing parental

[3] Gylander, T. 2011. The potential aspen clones and hybrids for enhanced forest management in Alberta. MSc. Thesis. University of Alberta. Edmonton. 112pp.

composition of the seed orchard (e.g. use of parents from outside the CPP region) would be changed; CPPs may be allowed to sell seed among regions or otherwise operate joint facilities; and sections of the CPP regions currently excluded from deployment would also be reviewed.

(ii) If it is found that drought tolerance and productivity are negatively correlated, policy would be needed on how to reconstitute the seed orchards to balance productivity and adaptation. One option would be to mix parents of higher productivity but low drought tolerance with parents of low productivity with high drought tolerance to introduce drought tolerant genes into families of higher productivity.

(iii) Because policy implication (ii) would reduce genetic gain which is a primary objective for most of the tree improvement programs, a 'consequential' policy implication would arise on how to offer ACE (allowable cut effect) when the industry gives up some of their genetic gain to accommodate adaptation to climate change in their FMA areas.

1.2.3 Testing wild populations of non-native species

The threat posed by climate change on Alberta's commercial forest tree species is of two types, (a) loss of adaptation and subsequently, productivity due to changes in the physical environment such as drought, and (b) loss of species and/or productivity due to pests and diseases that are increased by climate change. The ongoing mountain pine beetle outbreak on lodgepole pine is an example of the latter. Where it is desirable to maintain a forest ecosystem and /or forest industry, and a native species is unsuitable for that purpose, introducing a non-native species with potential for natural migration into the province would be appropriate.

Under this proposal, selected wild populations of non-native species such as ponderosa pine and interior Douglas-fir would be tested in some of the sites described in 1.2.1. Ponderosa pine is not native in Alberta, but is native just across the border in British Columbia and the USA. Douglas-fir, although native, is only to the Rocky Mountains. The two species would be tested at lower elevations and in southern Alberta as substitutes for lodgepole pine, which is currently threatened by the mountain pine beetle and projected future drought.

Deliberate testing of non-native species as a potential climate change adaptation option would enhance the discussion on the role of non-native species in Alberta, and managed forests in which non-native species would most appropriately be grown. Both issues are still controversial in Alberta and not currently allowed by policy but might be inevitably employed as an adaptation strategy should the climate changes and the forest land base shrink and public opinion change.

2.0 Fit with Relevant Provincial Policies

Policy implications arising from this project have been separately stated for each component of the proposal. Collectively, the project will provide the data needed for considering revision of existing policy and/or creating a new policy governing use of seed and vegetative material for reforestation and reclamation on crown land in a way that reduces negative impacts of climate change. The new test sites to be established and information extracted from the existing and new measurements will allow Alberta to refocus its reforestation programs with better adapted trees that will also contribute to a significant CO_2 sink.

References

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