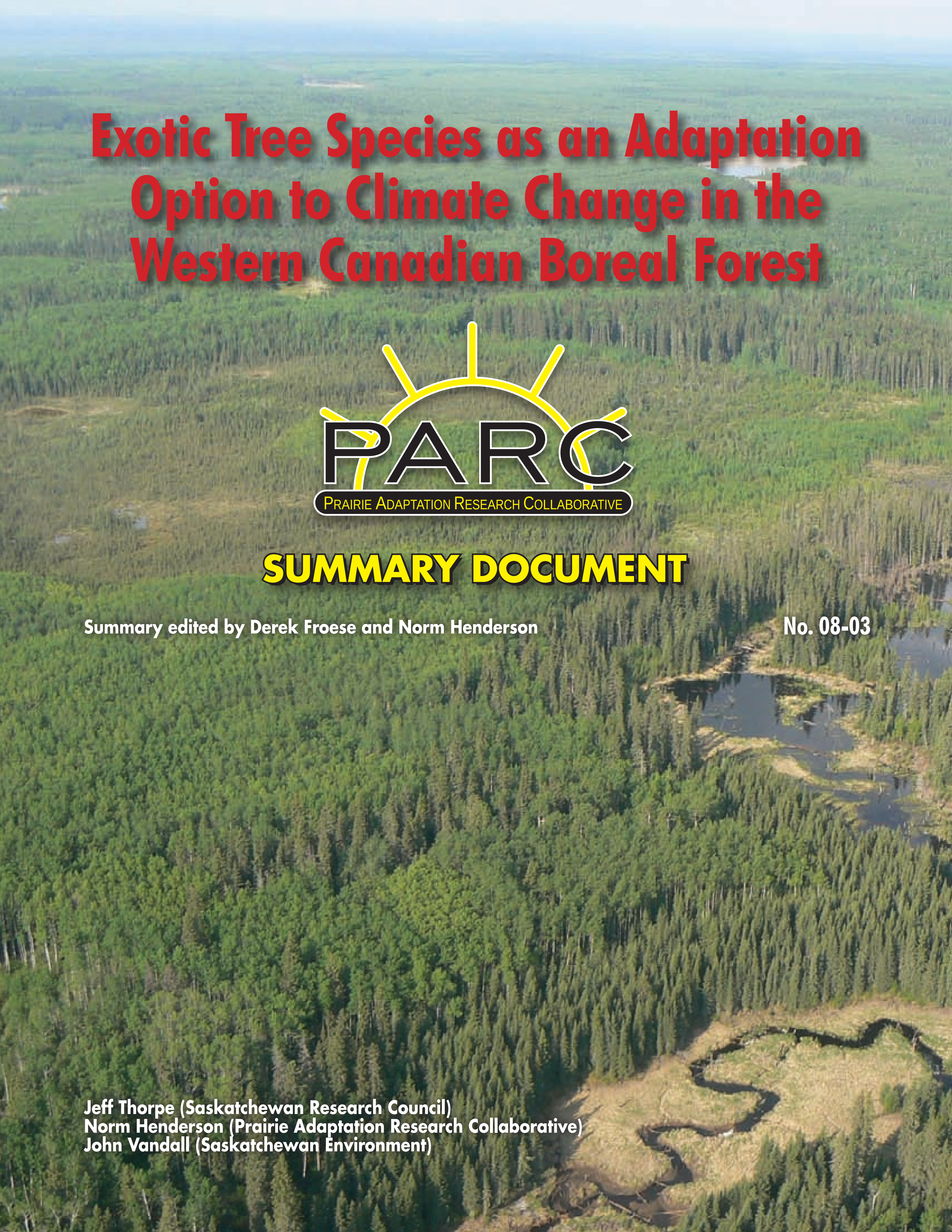

Exotic Tree Species as an Adaptation Option to Climate Change in the Western Canadian Boreal Forest

PARC
Prairie Adaptation Research Collaborative

SUMMARY DOCUMENT

Summary edited by Derek Froese and Norm Henderson

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Jeff Thorpe (Saskatchewan Research Council)
Norm Henderson (Prairie Adaptation Research Collaborative)
John Vandall (Saskatchewan Environment)

Aspen-white spruce mixedwood

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INTRODUCTION

Under conditions of climate change, maintaining species and ecosystem diversity in the western boreal forest may require increasingly intensive management policies. The purpose of this summary is to assess the possibility of introducing new tree species into the western boreal forest as an adaptation to climate change, and discuss government policies to address this issue. The regional focus is on the Boreal Plain Ecozone of Manitoba, Saskatchewan, and Alberta. This region encompasses the main areas of production forestry in these provinces, but also includes parks and other protected areas, as well as areas along the southern fringe of the region where forest has been cleared for agriculture.

The study looks beyond the Prairie region to gain a global perspective on the benefits of exotic tree species, the threats posed by these exotics, and methods for assessing their invasiveness. Next is an assessment of present and future climatic suitability for a number of native and non-native tree species to the region under study. Seven non-native species are examined in greater detail to determine their suitability for introduction. Finally, an examination of global, federal, and provincial policies on exotic tree species provides further context for the development of a new policy perspective on the issue and policy recommendations.

RATIONALE FOR INTRODUCING EXOTIC SPECIES

Many reasons exist for introducing exotic tree species throughout the world. Exotic species provide a number of benefits to forestry in particular. In many cases, exotic species grow faster than native species, have greater seed availability, are more easily managed, and are better understood by foresters. Introduction of exotic trees can also provide benefits to the land and ecosystems. Their introduction has frequently been justified by their value in reclamation of disturbed areas, such as eroded lands (Zobel et al. 1987). Fast-growing exotic plantations also tend to reduce the need for intensive management of the remaining natural forest (Zobel et al. 1987). It has even been argued that exotic species can have positive ecological value by contributing to the structure or function of a particular ecosystem (Williams 1997).

A new rationale for introduction of exotic trees is their possible role in adaptation to climate change. Recent climate change assessments in the Prairie Provinces have made the point that the climate may become less suitable for native trees in some areas, leading to reduced growth, regeneration failure, and gradual loss of forest cover. Retention of the economic and environmental values associated with forest may require introduction of exotic varieties or species that are adapted to the warmer and drier climate (Thorpe et al. 2001, Henderson et al. 2002). Williams (1997) argued that exotic plants now considered problematic may turn out to have ecological value in the future because of climate change, by filling the ecological roles played by native species that have been eliminated.

Figure 1: *Caragana bushes*

THREATS FROM INTRODUCING EXOTIC TREE SPECIES

Exotic species can pose a number of threats to regions and ecosystems. Threats of disease transmission, genetic cross-hybridization, site degradation, and biodiversity loss have been documented in various regions of the world. Globally the most important threat attached to the introduction of exotic plants is the potential for invasion of adjacent ecosystems. While most successful invasions do not alter large-scale ecosystem processes, some invasions do have major impacts (Vitousek 1990). This happens in situations in which invaders:

- Differ substantially from natives in resource acquisition or utilization
- Alter the trophic structure of the invaded area
- Alter disturbance frequency and/or intensity

Depending on the situation, certain exotics are deemed to be more invasive than others. In Canada, the following exotic shrubs and trees have been considered invasive in parks and other protected areas: European birch, Scots pine, common buckthorn, glossy buckthorn, white mulberry, and Scotch broom (Mosquin 1997). Trees and shrubs are less conspicuous as invasive species in the Prairie region, but three species intentionally introduced for horticultural purposes, Siberian elm, caragana, and common buckthorn (Archibold et al. 1997), are extremely invasive in local areas. Caragana is one of the most widely distributed species for shelterbelt plantings. In the aspen parkland and forest fringe, where agricultural settlement is in contact with boreal forest, there are many areas where caragana has aggressively spread into aspen stands, virtually eliminating the native understory plants. The observed invasive behaviour of some intentionally introduced species, even if they are only a small fraction of the total number of introductions, provides the main reason for concern about future introductions.

ASSESSING THE INVASION PROBLEM

Invasion of an exotic species depends on the biological characteristics of the species, the characteristics of the receiving habitat, and the interactions between species and habitat. Because the invasion process consists of a series of steps, each of which may have different barriers that must be overcome, the invasiveness of a species is difficult to predict (Heger and Trepl 2003). In spite of these limitations, a number of standardized systems have been developed for screening proposed introductions for potential invasive behaviour. These systems are of varying complexity, but typically ask a number of questions to determine whether the species should be accepted, rejected, or further tested and monitored. Reichard and Hamilton (1997) developed a system based on an analysis of woody species intentionally introduced into North America. It was found that conifers tend to be non-invasive in North America, and that species native to North America do not tend to be invasive when introduced to new North American habitats.

CLIMATE CHANGE IMPACTS

A new aspect of the invasibility question is the potential impact of climate change. As with any species, exotic plants are adapted to a given range of climates, and climate change could either expand or shrink the range that is suitable for a given exotic species. Climate change may discriminate against species that cannot quickly extend their ranges into new regions. The result may be poorly adapted communities that are susceptible to invasion, especially by fast-dispersing species that can shift ranges rapidly. Species that tolerate a wide range of climates in their native range are most likely to be successful invaders, and their climatic tolerance could give them an advantage as native species are stressed by climate change (Dukes and Mooney 1999).

CLIMATE SUITABILITY FOR INTRODUCED TREE SPECIES IN THE WESTERN BOREAL FOREST: METHODOLOGY

The study area was defined as including the Prairie, Boreal Plain, and Boreal Shield Ecozones between 49º and 57º north latitude, and 96º and 120º west longitude. Three bioclimatic variables were examined to determine present and future climatic suitability of native and non-native tree species in this region: growing-degree days, winter minimum temperatures, and a moisture index. Thompson et al. (2000a, 2000b) developed statistical distributions for these variables over North American tree and shrub species. For this study, the 10th and 90th percentiles from these distributions were used to represent the climatic envelope of each species. A similar methodology for assessing the climatic envelope of Siberian vegetation types from Tchebakova et al. (1994) was adopted for Scots pine and Siberian larch.

A number of coniferous and broad-leaved species occurring within the study area and in adjacent regions were considered, in addition to the two Eurasian species. These included native boreal species (white spruce, black spruce, balsam fir, jack pine, tamarack, trembling aspen, balsam poplar, and white birch); hardwood trees of the southern Prairie provinces (Manitoba maple, green ash, American elm, and bur oak); species associated with the Great Lakes region and further east (sugar maple, northern red oak, and basswood); and western montane conifers (Douglas-fir, ponderosa pine, Rocky Mountain juniper, and lodgepole pine).

The current climate was represented by 1961-90 normals for monthly temperature and precipitation, while future climates were represented by three scenarios of Global Climate Models (GCMs) for the 2041-2070 period (referred to as the 2050s). The approach was to compare the present and future climates in the Canadian Prairies with the climatic envelopes of these species to judge their climatic suitability. If all three bioclimatic variables fell within the 10%/90% range, the area was considered to be suitable. Results were mapped by comparing the present map with one of the future maps and determining the following categories for each species:

- Continued unsuitability – unsuitable in both 1961-90 and 2041-70
- Declining suitability – suitable in 1961-90, unsuitable in 2041-70
- Continued suitability – suitable in both 1961-90 and 2041-70
- Increasing suitability – unsuitable in 1961-90, suitable in 2041-70

CLIMATIC SUITABILITY OF NATIVE AND NON-NATIVE SPECIES

The bioclimatic variables were mapped for the current climate and one of the GCM scenarios (Figures 2 to 4). The growing degree-days variable shows a substantial change, with all parts of the study area predicted to have much warmer growing seasons. Mean temperature of the coldest month shows more moderate shifts towards milder winters in all regions. The moisture index shows slight shifts towards somewhat drier conditions in most regions.

Application of the bioclimatic model to the current and future climate for native and non-native tree species (Figures 5 to 8) resulted in the following conclusions:

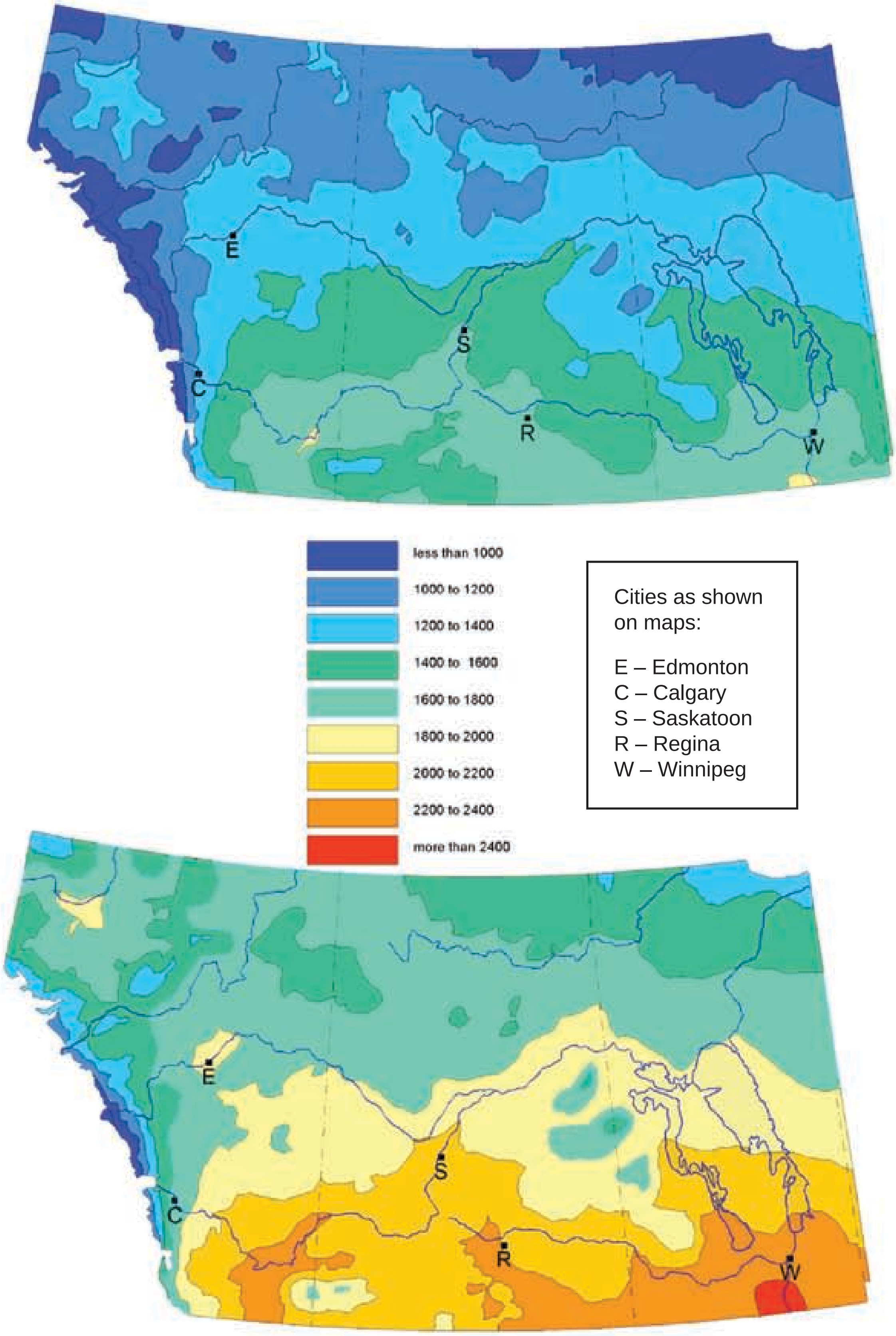

Figure 2: *Growing degree-days (5°C base) for the study area, in the current climate (top) and in the CSIROMk2b B11 scenario for the 2050s (bottom).*

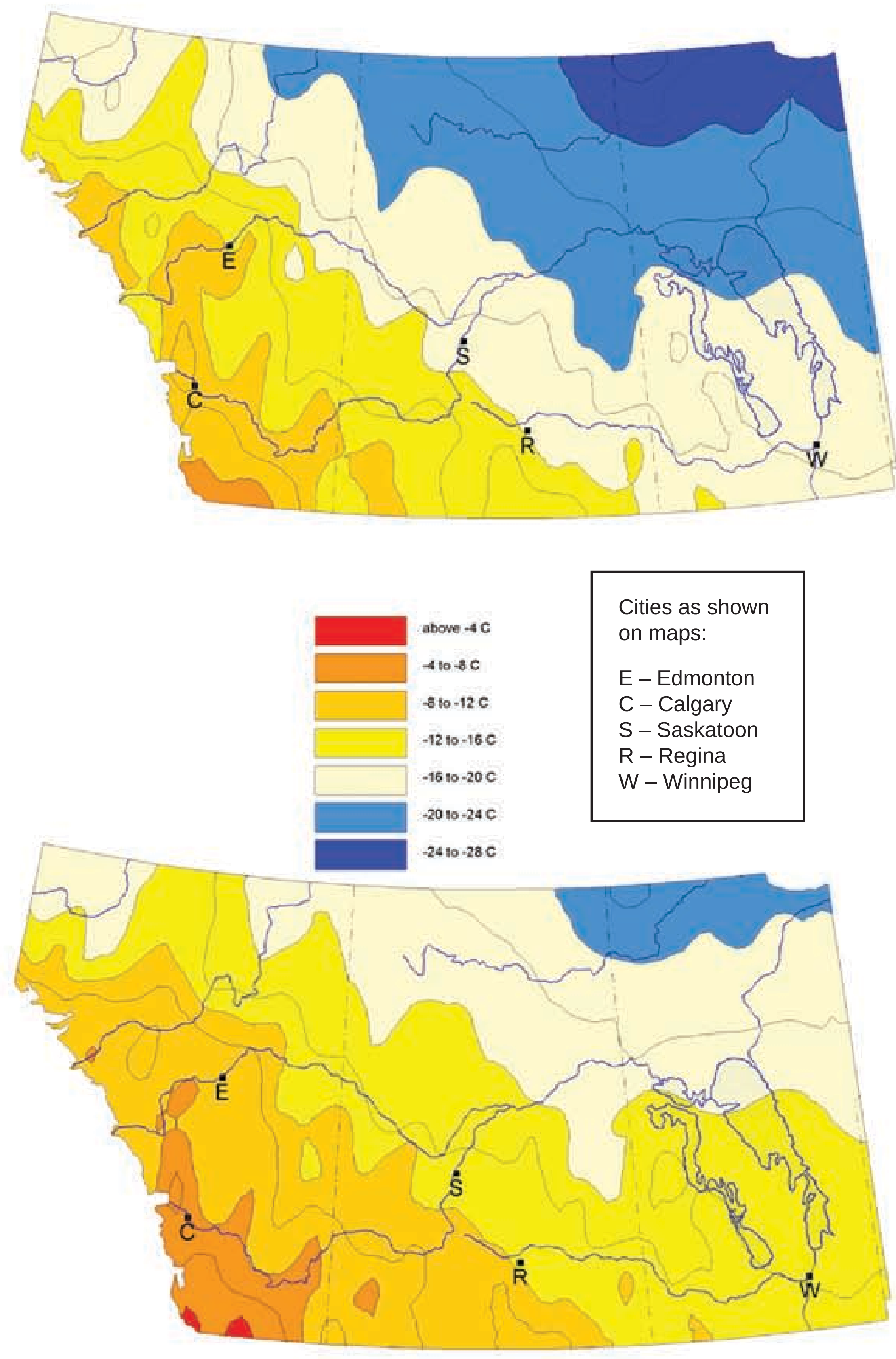

Figure 3: *Mean temperature of the coldest month (°C) for the study area, in the current climate (top) and in the CSIROMk2b B11 scenario for the 2050s.*

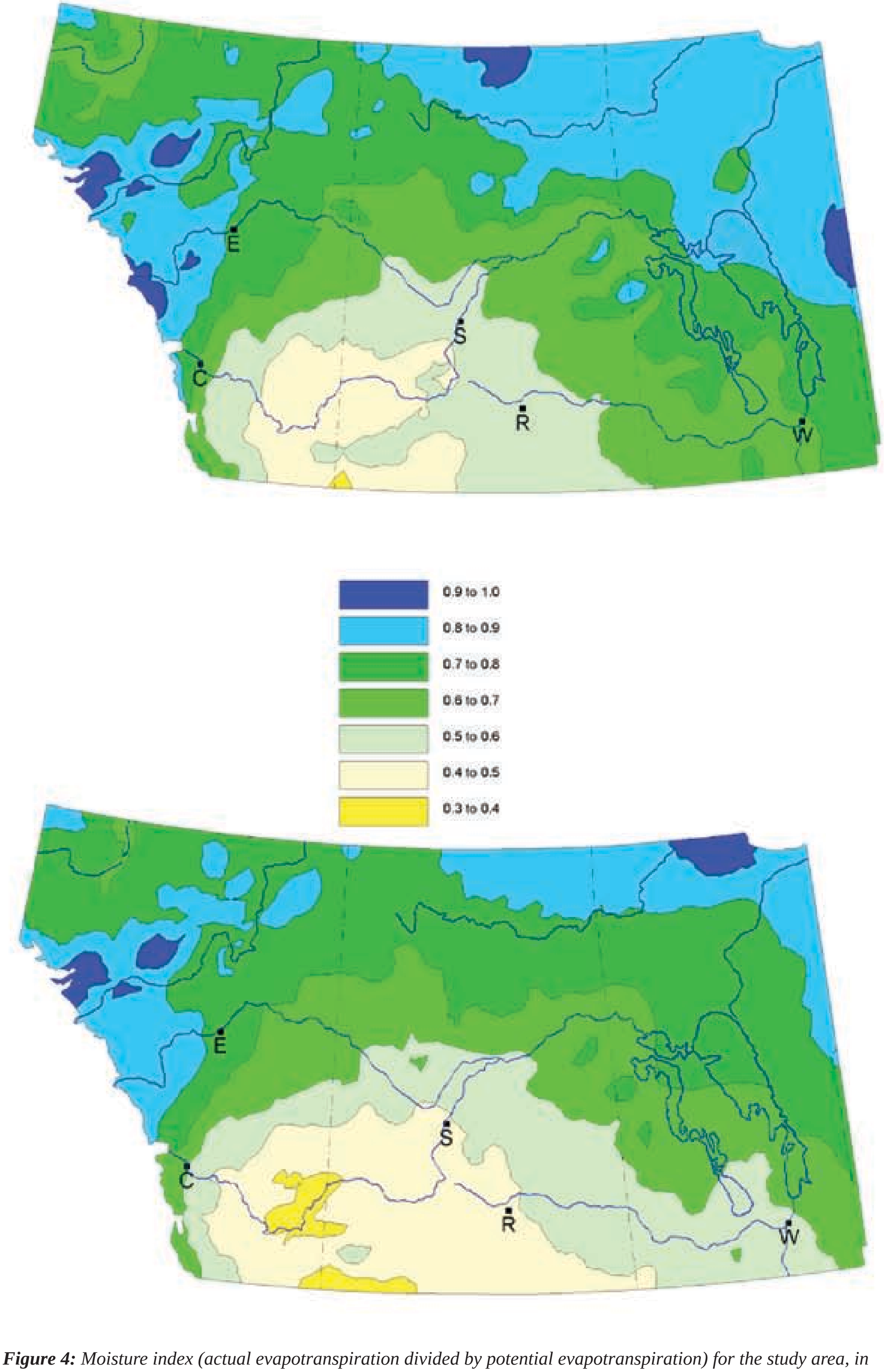

Figure 4: *Moisture index (actual evapotranspiration divided by potential evapotranspiration) for the study area, in the current climate (top) and in the CSIROMk2b B11 scenario for the 2050s (bottom)*

Cities as shown on maps:

E – Edmonton
C – Calgary
S – Saskatoon
R – Regina
W – Winnipeg

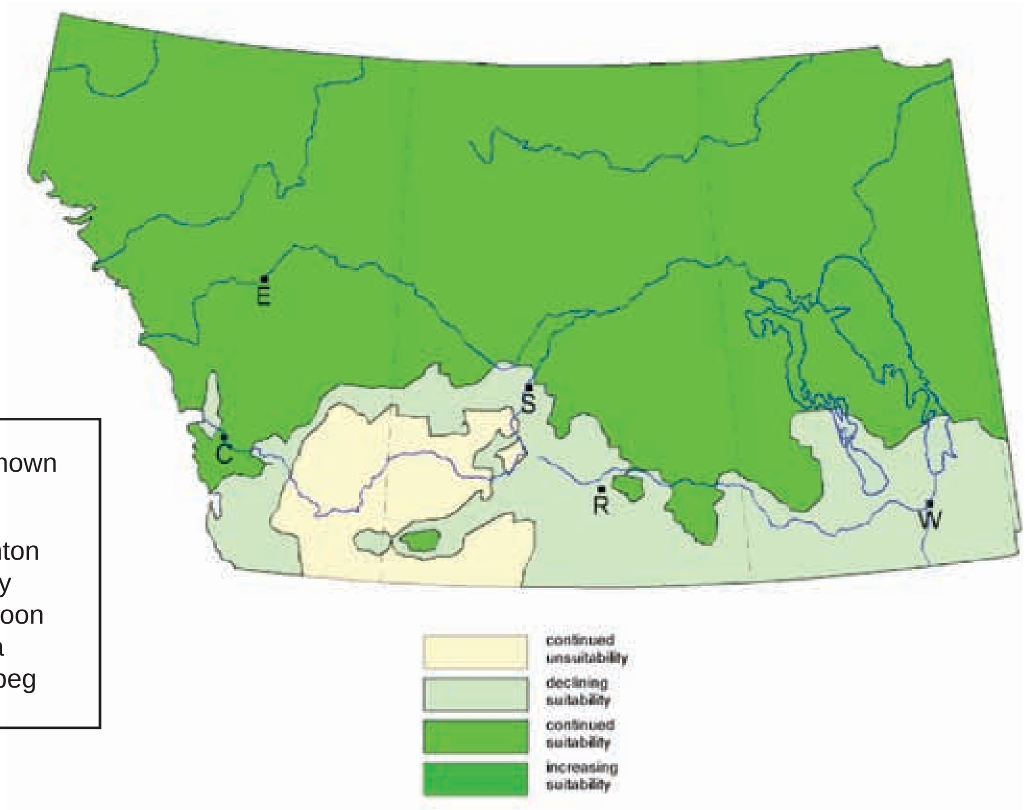

Figure 5: *Changes in climatic suitability for trembling aspen from the current climate (1961-90 normals) to the CSIROMk2b B11 scenario for the 2050s.*

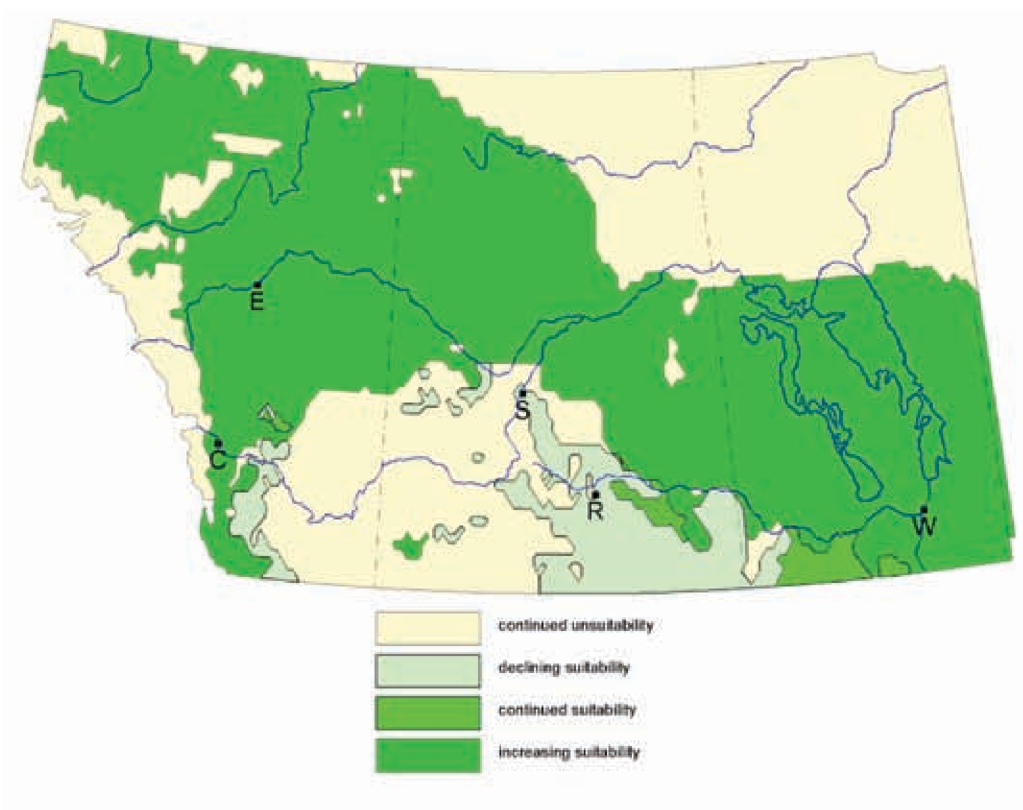

Figure 6: *Changes in climatic suitability for Manitoba maple from the current climate (1961-90 normals) to the CSIROMk2b B11 scenario for the 2050s.*

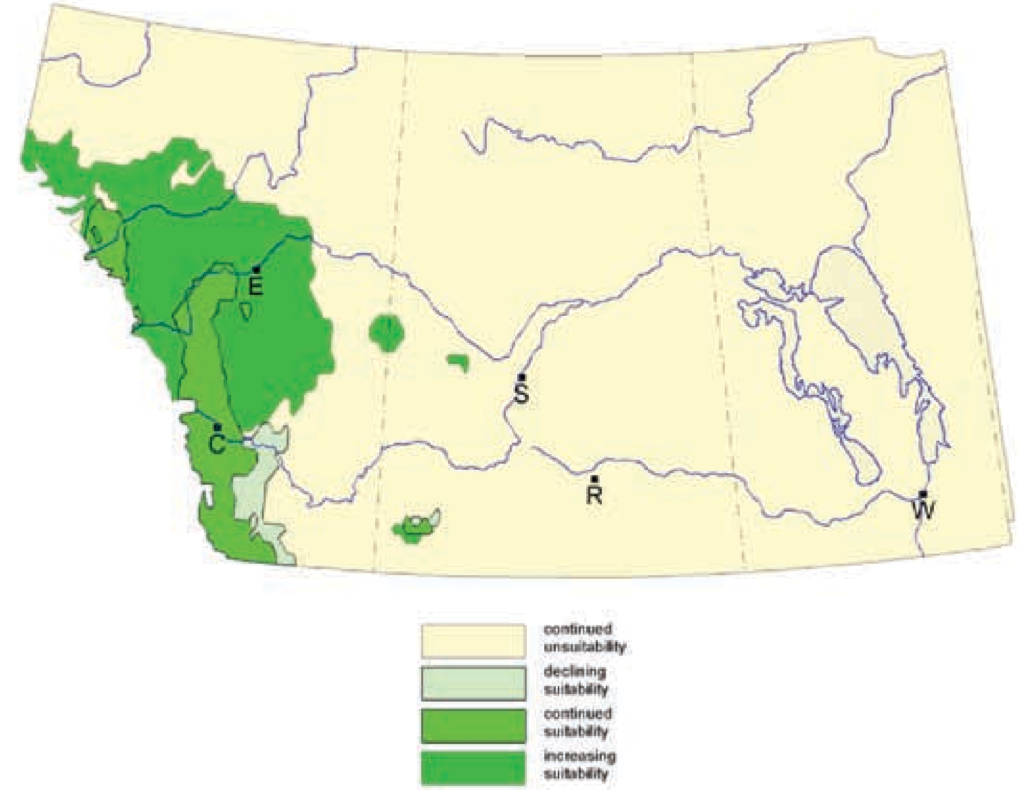

Figure 7: *Changes in climatic suitability for Douglas-fir from the current climate (1961-90 normals) to the CSIROMk2b B11 scenario for the 2050s.*

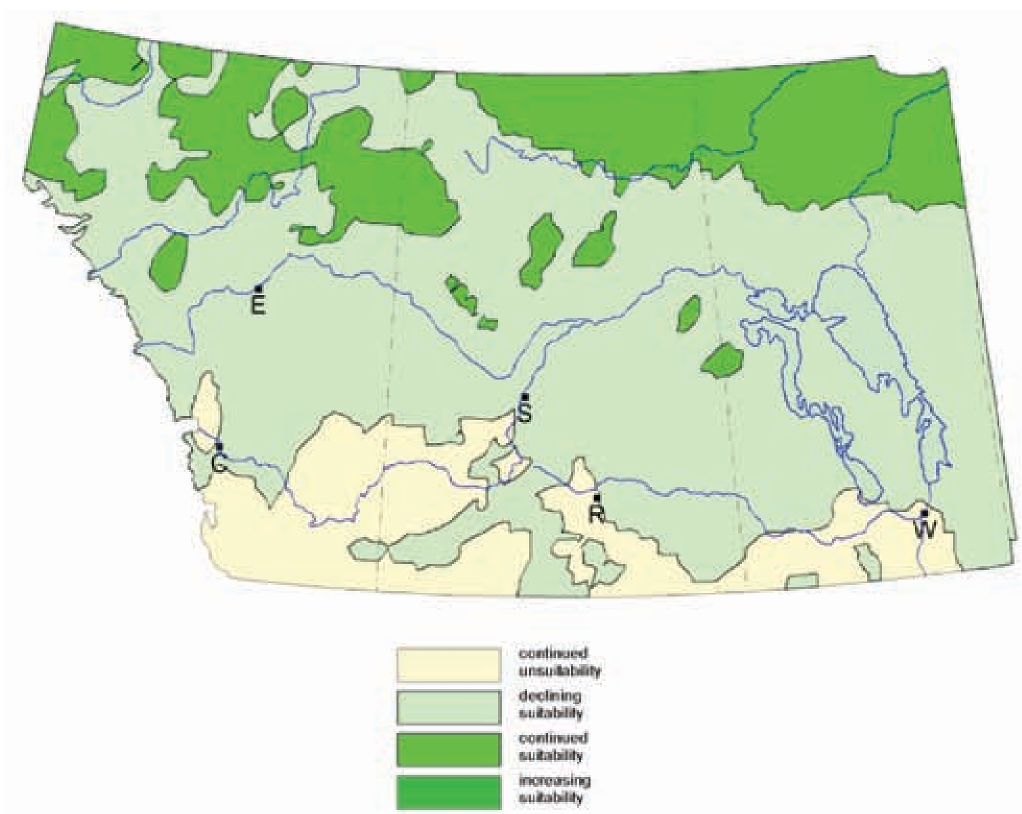

Figure 8: *Changes in climatic suitability for Siberian larch from the current climate (1961-90 normals) to the CSIROMk2b B11 scenario for the 2050s.*

- Native boreal species are expected to shift northward in distribution, probably declining in viability in the southern parts of their current range.
- Hardwoods of the southern Prairies may be suitable for a larger and more northerly range in the future.
- Species of the Great Lakes region may be limited in suitability for our region by climatic dryness, which is expected to increase.
- Western conifers such as Douglas-fir and ponderosa pine may be more suitable for the milder western parts of the study area, provided that moisture is adequate. The area currently suitable for lodgepole pine in northwestern Alberta is predicted to decrease almost to the point of elimination, driven by the rise in growing degree-days beyond its modeled threshold.
- Eurasian boreal species such as Scots pine and Siberian larch may be more tolerant of climatic dryness than the native boreal species, but may not be suited to the increased warmth in southern regions.

Figure 9: *Red pine*

CASE STUDIES OF SELECTED SPECIES

To look more closely at the issues related to tree introductions, information was gathered on several species that might be considered for planting for forestry purposes in our region. These included three western North American conifers (lodgepole pine, ponderosa pine, and Douglas-fir), one eastern North American conifer (red pine), two Eurasian conifers (Scots pine and Siberian larch), and hybrid poplar, which is currently being widely planted in the region. Information gathered on the species included future climatic suitability (as already discussed) and factors such as native habitat and biological characteristics to assess invasiveness. Most of the species were assessed for potential invasiveness using the American model developed by Reichard and Hamilton (1997).

Analysis of these species produced the following conclusions:

- Relative invasiveness based on biological characteristics and behaviour elsewhere, ranks the species as follows (from greatest to least invasive): lodgepole pine, Scots pine, Douglas-fir, ponderosa pine, red pine. There is insufficient information to place Siberian larch in this list.
- Application of the Reichard and Hamilton (1997) decision tree for predicting invasions in North America suggested that further analysis/monitoring is required for lodgepole pine, ponderosa pine, and

Douglas-fir; that red pine should be accepted; and that Scots pine should be rejected.

- Most of the species are unlikely to invade intact forests as they are predominantly shade-intolerant, early-seral species. However, all species could invade open habitats adjacent to plantations and could regenerate following disturbance in adjacent forests.
- Invasion is likely to be a slow process for these species, as most seedfall occurs in close proximity to parent trees, and long-distance spread is possible but less likely.
- Gene transfer could pose risk in the case of hybrid poplars which could cross with native cottonwoods, but it is not clear whether the risk is significant.

Figure 10: *Lodgepole pine*

POLICY ON INTRODUCTION OF EXOTIC TREE SPECIES

The International Union for Conservation of Nature and Natural Resources (IUCN 1987) recommends that exotic species should never be introduced into any natural habitat, and only when there are exceptional reasons for doing so should an exotic species be introduced into a semi-natural habitat. Even if these criteria are met, an extensive assessment of benefits and risks and monitored field trials are called for before the species can be introduced more extensively. Furthermore, the organization introducing the species should bear the cost of control.

Exotic species policy in the United States and European Union varies from jurisdiction to jurisdiction, but is generally much less stringent than IUCN policy. The most relevant federal legislation in the United States is the *Noxious Weed Act 1974*, which prohibits the import of 94 listed plants, but does not prohibit the entry of exotics. While European Union legislation contains provisions to ensure that exotic introductions do not prejudice local flora and fauna, European nations have a long history of importing and domesticating many new plant species, including exotic conifers.

In Canada there is no known example of an exotic tree whose transport and planting is forbidden by law. The federal *Plant Protection Act 1995* proscribes the import to Canada or transport within Canada of various species, but in the interests of phytosanitation, not invasiveness. The "New Substances Notifications Regulations: under the *Canadian Environmental Protection Act 1999* could also require an extensive risk assessment of a new non-Canadian tree species imported into Canada, but the regulations seem largely directed at inorganics, micro-organisms and potential impacts on human health, though invasiveness is also a concern.

All three Prairie Provinces have similar Acts to control the spread of undesired species, particularly weeds, but none are directed at trees. In the western boreal, there are no legal prohibitions against the introduction of exotic tree species. Exotics can be and are frequently planted on freehold land. In general, stocking policies on Crown land in these provinces precludes the introduction of exotic species, although some test plantations of exotics are underway.

A DIFFERENT PERSPECTIVE: EXOTIC SPECIES AND ADAPTATION TO CLIMATE CHANGE

In many well-documented cases around the world, introduced exotic plants have been identified as serious threats to biodiversity and other values, usually because of invasive behaviour leading to alteration of neighbouring ecosystems. Recent developments in policy have focused on reducing these threats in order to protect existing ecosystems. In addition, conservation strategies throughout North America have focused on protecting representative areas from human impact without incorporating the impacts of climate change. The increasing evidence for global climate change suggests that a different perspective may be needed on the issue of exotic species and conservation management.

Under conditions of climate change, if we wish to maintain species and ecosystem diversity, we may have to abandon a laissez-faire wilderness preservation model and adopt increasingly intensive management policies. These could include deliberately assisting the movement of species to newly suitable habitats. This issue is particularly acute for forest systems, where natural migration (for example, of new tree species or of climatically more suitable genetic varieties of locally extant tree species) may not be possible without human intervention.

With the correct policies in place, exotic tree species could play a significant role in adaptation. As the range and density of existing species changes with climate, new species could be sought to replicate as closely as possible the ecological function of native species. Management of the area should focus not only on the potential invasiveness of the exotic species, but on whether the species contributes to large-scale biodiversity preservation within the ecosystem. The introduction of new species might contribute to the resilience of the western boreal in the face of oncoming changes.

Figure 11: *Exotic tree plantation in southern Alberta*

POLICY RECOMMENDATIONS

A number of policy recommendations have been developed as a result of the scientific literature review, the policy review, and input from a stakeholders workshop held after the study's completion. The recommendations are as follows:

1. The western boreal forest should be monitored carefully for signs of systematic decline of native tree species arising from climate change or other factors, as this information is crucial to evaluating the need for introduction of exotics.
2. Replanting of harvested sites with seed stock of natives trees from sources distant from the planting site should be allowed, if distant seed sources are better adapted than local sources to the changing climate.
3. Policies for introduction of exotic trees should vary according to land ownership and land use/ecological objectives. In protected areas that serve as ecological benchmarks, for example, exotic plantations should not be approved, while on provincial forest land, exotics may be acceptable in some situations.
4. Individual exotic tree species should be subject to a standardized assessment process to determine potential invasiveness, based on the recommendations made by the International Union for the Conservation of Nature (IUCN 1987). Some examples include:
    - an estimation of the probability the species will so increase in numbers as to cause environmental damage
    - an estimation of the risk of interbreeding with native species
    - a study of the risk of introduction of diseases and parasites the exotic may host
    - a study of all phases of the relevant biological and climatic cycle
    - a summary of benefits and risks
5. In addition, the assessment should include analysis of such factors as the net effects on timber supply, the net effects on carbon sequestration, the effect on the fire regime, and the potential contribution of the introduction to ecosystem diversity and resiliency in the face of climate change.
6. Controlled planting trials, with appropriate monitoring and evaluation, should precede widespread planting.
7. Assessment of previous introductions should take place; priority should be given to suspected problem species (such as caragana in the forest fringe) and to trial plantings of exotics from past decades (to examine survivability and invasiveness).
8. Using the results of the above assessments, governments should regulate which exotic tree species are acceptable for widespread planting, and the conditions or guidelines under which such planting could occur.
9. Government should develop guidelines for the location and design of exotic plantations, aimed at minimizing invasion risks.
10. As with other developments, widespread planting of an exotic tree species should be preceded by and subject to an environmental assessment, including public and stakeholder consultation.
11. Federal and provincial governments should jointly review their current policies related to introduction of exotic tree species, to determine whether new legislation or regulations are needed, and to avoid duplication.
12. There should be communication to stakeholders and the public about the challenges of a changing climate to the western boreal ecosystem, and options for adaptation.
13. Governments should articulate their current policies regarding introduction of exotic species.

Figure 12: *Siberian larch*

PHOTO CREDITS

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***Figure 13:** Scots pine*

Aspen-white spruce mixedwood

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