CLIMATE CHANGE IMPACTS ON THE ISLAND FORESTS OF THE GREAT PLAINS AND THE IMPLICATIONS FOR NATURE CONSERVATION POLICY:

THE OUTLOOK FOR SWEET GRASS HILLS (MONTANA), CYPRESS HILLS (ALBERTA – SASKATCHEWAN), MOOSE MOUNTAIN (SASKATCHEWAN), SPRUCE WOODS (MANITOBA) AND TURTLE MOUNTAIN (MANITOBA – NORTH DAKOTA)

SUMMARY DOCUMENT

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INTRODUCTION

In the midst of the Great Plains, scattered from central Alberta to Texas, are island forests, refugia of trees and tree-dependent species isolated in a sea of grass. This study examines the impacts climate change will have on five of these unique and valuable forests and makes practical recommendations for the management of climate change impacts. The five study sites are numbered in Figures 1 and 2. Within these figures number 17 indicates Spruce Woods, 18 Turtle Mountain, 19 Moose Mountain, 20 Cypress Hills, and 21 Sweet Grass Hills. Many of this study's conclusions and recommendations may also be valid for the other isolated Plains forests shown in Figures 1 and 2. This study is the first attempt to consider the island forests collectively, rather than in isolation from each other, and to view the Plains island forests as related entities, rather than as isolated systems to be managed individually.

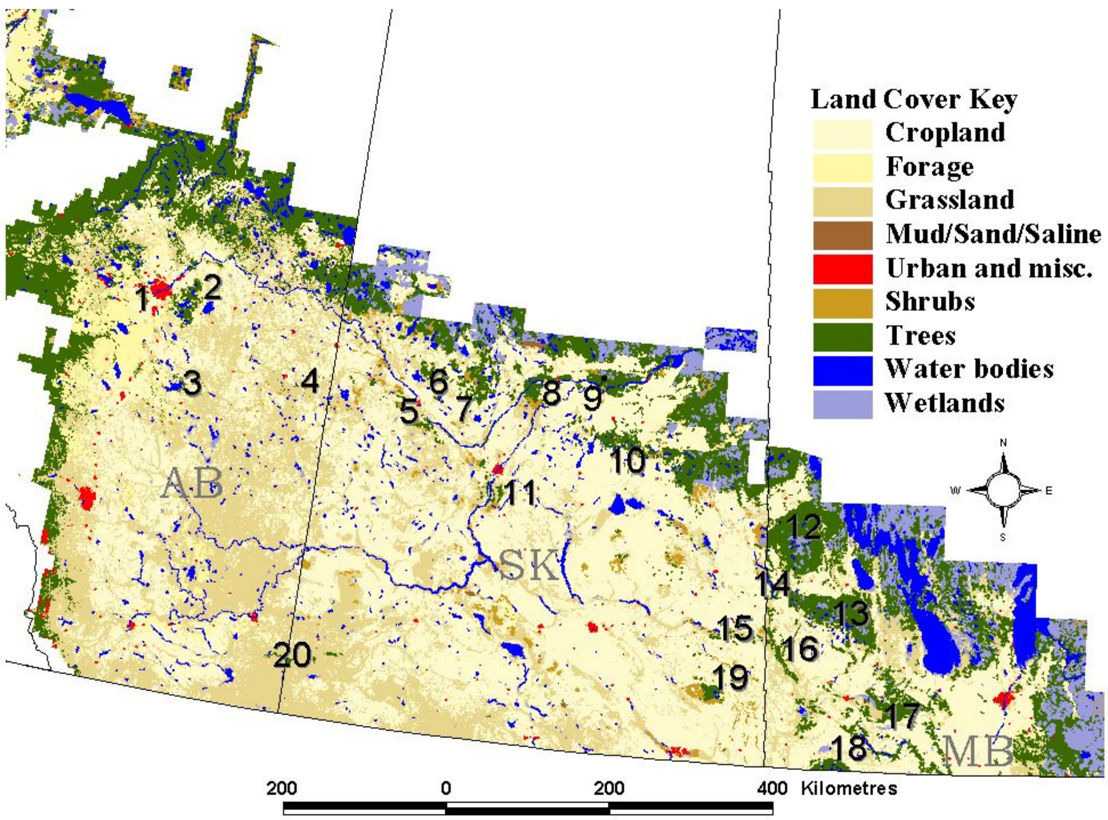

Figure 1: Island Forests of the Canadian Plains
(GIS data from: Ashton, J. PFRA's Generalised Landcover, Version 1. 2001).

Plains island forests are at significant risk from climate change. They are marginal or ecotone systems, borderline between grassland and forest ecosystems, and therefore sensitive to relatively small changes in environmental conditions. As they are relatively small ecosystems, island forests may exhibit reduced genetic diversity and greater vulnerability to catastrophic disturbance, such as wildfire, pathogen attack or severe drought.

While vulnerable, island forests are also valuable landscapes. They typically contain important species and ecosystem outliers at the very edge of their natural range, making them of conservation importance. Highland island forests supply valuable water to the surrounding plains. Island forests sometimes contain small lakes and ponds that are valuable for a great variety of wildlife, especially waterfowl. They are often of cultural and spiritual importance to local Native North American peoples. Because they are ecotones, and in a more natural state than

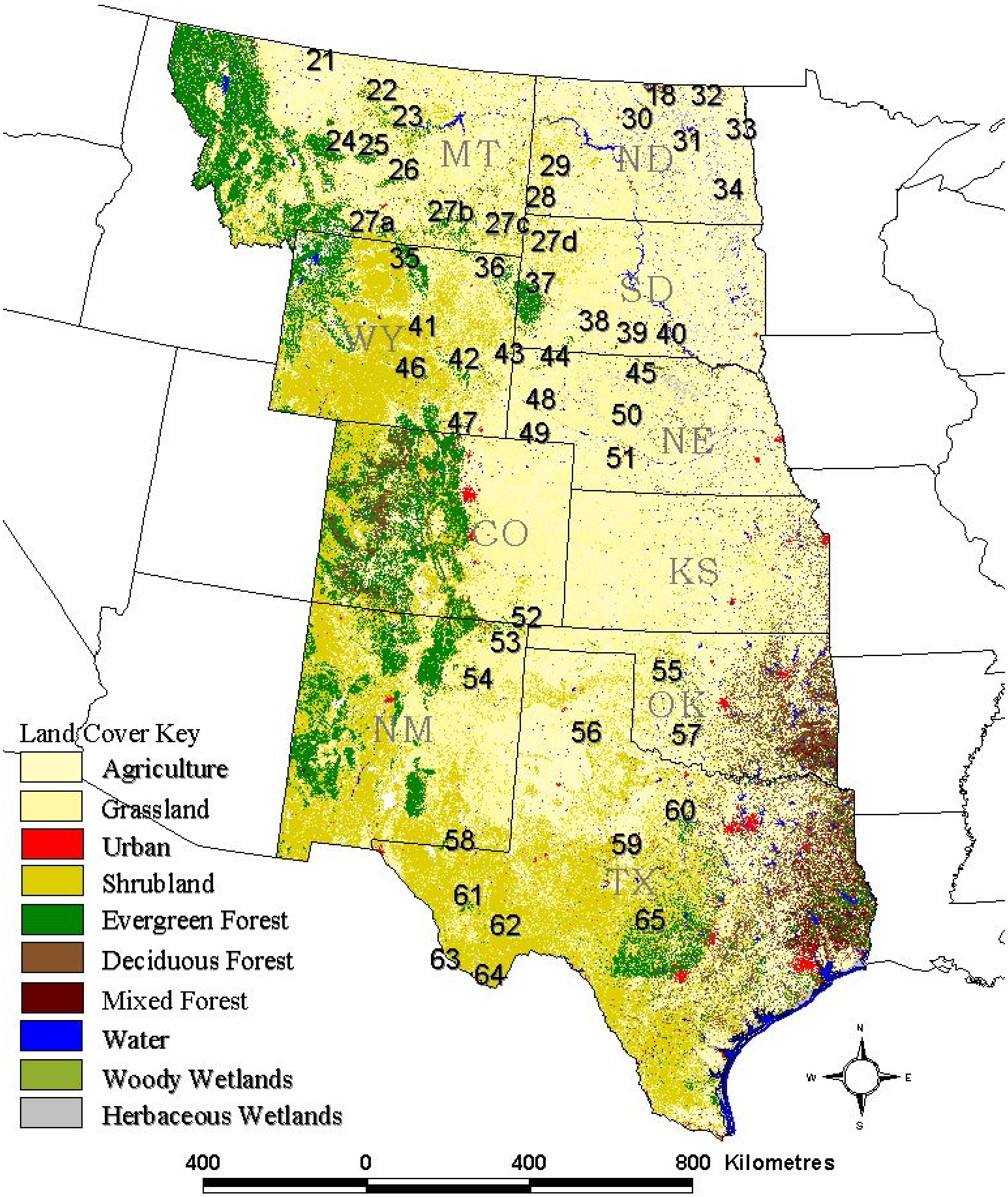

Figure 2: Island Forests of the American Plains
(GIS data from: USGS National Land Cover Data, 1992)

most of the Plains, island forests are also of great value for scientific research, not least because of their sensitivity to climate change. As trees are valued on the Plains, island forests are important centres of tourism and recreation.

Managers need advice on how to manage the island forests today. Emissions-driven climate change is already measurably under way, and today's sapling will likely have to cope, as a mature tree, with a significantly different climate. We also need workable management models to address such issues as the current and future risk of catastrophic landscape change. For example, should a major wildfire sweep one of the island forests, do we know what the prospects for natural regeneration are? Would we know what, if anything, to replant? To help address such challenges, we address the following questions in this study:

- What is the range of probable future climates for selected Plains island forests?
- What impacts would these climates likely have on the key tree species of these forests?
- What do these impacts imply for nature conservation management?
- What are the immediate and long-term management options available to us in response to probable climate change impacts?
- How should we choose amongst these options and which options seem most plausible?

Our climate scenarios indicate that the island forests will suffer serious challenges to ecosystem integrity. "Salvage ecology" will require relatively radical and intrusive management. For example, the experimental introduction of exotic species, or the undertaking of breeding programs to create tree varieties more adapted to a new climate, may be advisable.

STUDY REGION BOUNDARIES AND CURRENT CLIMATE

The island forests considered in this study are located in the southern Canadian and northern U.S. Great Plains within the region bounded by 47.5°N to 51.0°N and 95°W to 115°W (see Figure 3). This is a region of cold winters, hot summers, an annual temperature range exceeding 80°C, and large climate variability (Lemmen et al. 1997). Winters are generally dry, while summer (defined as June, July, August) is the wettest season. June is generally the wettest month. 20% to 30% of annual precipitation falls as snow, while 70% to 80% falls as rain. The western part of this region is in the rain shadow of the Rocky Mountains, which form an effective barrier to the maritime influence of the Pacific Ocean. The eastern part has greater exposure to southerly flows of warm, moist air from the central U.S. and the Gulf of Mexico. Precipitation amounts, therefore, tend to increase from west to east. Strong sunshine, low humidity and drying winds lead to large evaporative water losses in summer.

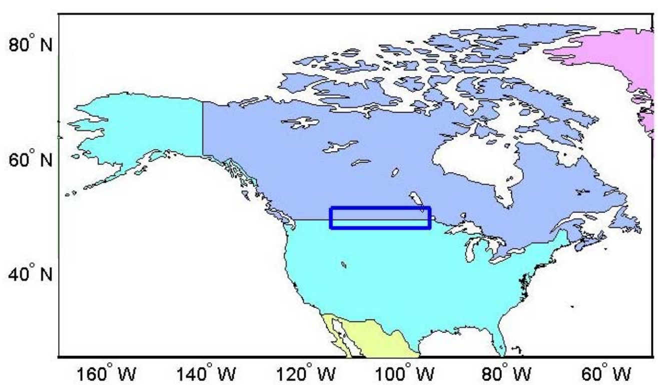

Figure 3: The boxed area indicates the region considered in this study

Joyce et al. (2001) note that annual precipitation has decreased by 10% in eastern Montana and western and central North Dakota over the past 100 years, while Bootsma (1994) notes there is no historical precipitation trend apparent for the Canadian prairie region. Statistically significant warming of 0.9°C from the late 1800s to the 1980s is evident over this region (Lemmen et al. 1998).

SELECTION, CONSTRUCTION AND INTERPRETATION OF CLIMATE SCENARIOS

For construction of the climate change scenarios used in this study we used recent output from three Global Climate Models (GCMs) incorporating four greenhouse gases and aerosols emissions scenarios representing different world futures with respect to population and economic growth, energy use, and technological development. By using different emissions scenarios we constructed a suite of climate change scenarios reflecting the range of probable future climate. The scenario results (valid for the study region shown in Figure 3) are shown by scatter plots of future temperature and precipitation (Figure 4). The scenarios agree that average temperatures will continue to rise. There may also be slightly more precipitation by the 2080s.

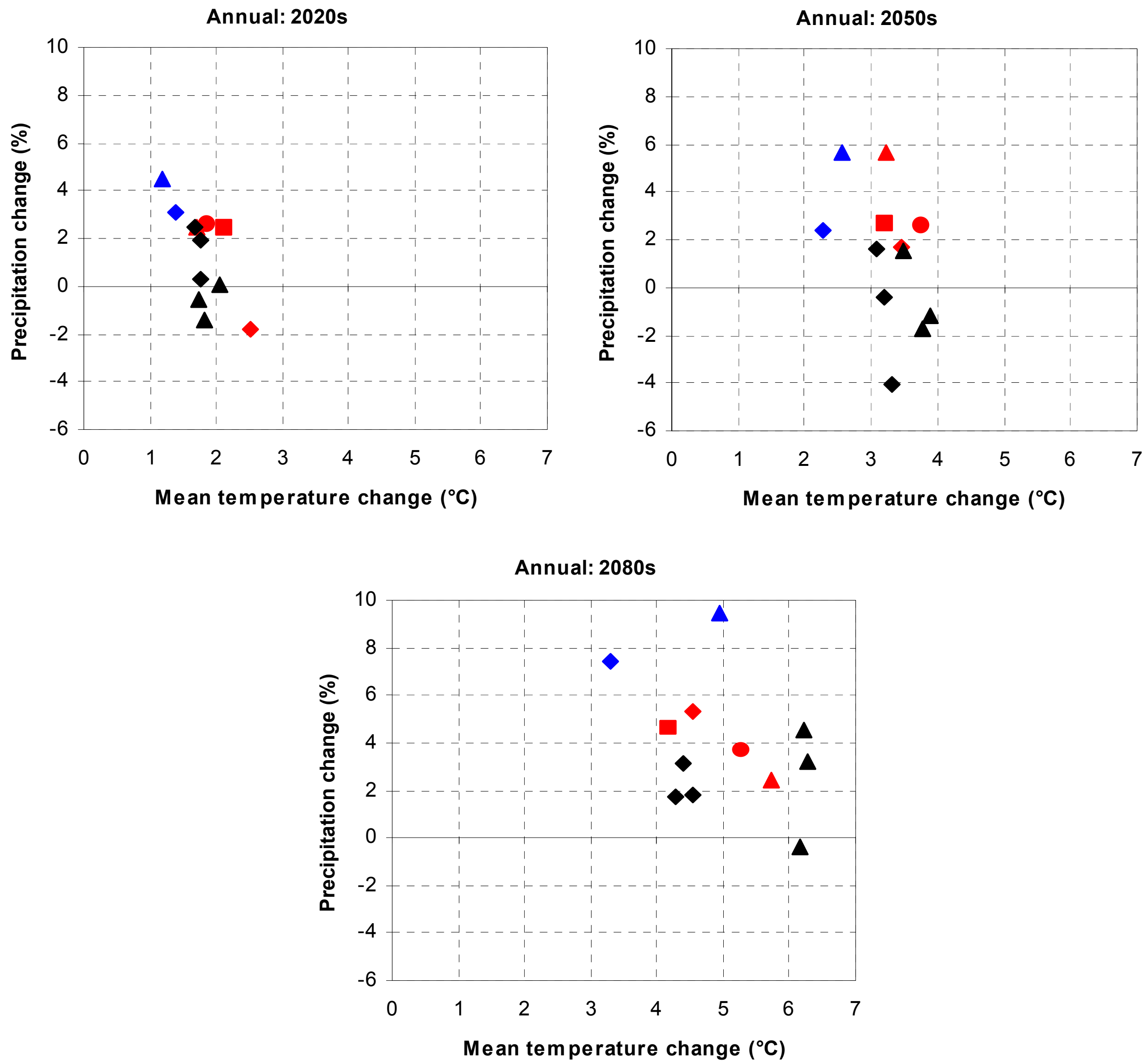

Figure 4: Scatter plots of annual mean temperature change and precipitation change over the study region for the 2020s, 2050s and 2080s. All changes are calculated with respect to the 1961-1990 climate. Different symbol colours indicate different global climate models; different symbol shapes indicate different emissions scenarios.

In the Plains, a region always on the edge of drought stress, soil moisture levels represent the single most important climate change parameter.. Both precipitation and temperature impact on moisture levels (warmer temperatures lead to lower moisture levels because of increased evaporation). The net effect on moisture levels of the foreseen changes in both temperature and precipitation is shown by a box-and-whisker plot (Figure 5).

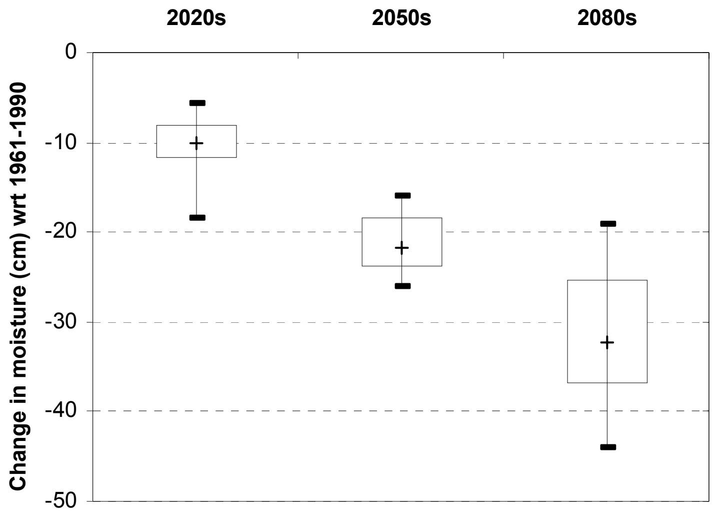

Figure 5: Summary of the projected changes in soil moisture levels (averaged over the five island forest study sites) for the 2020s, 2050s and 2080s. The thin vertical lines in the plot indicate the range of possible future moisture levels compared with the climate of 1961-1990. The boxes indicate the moisture level ranges within which 50% of the scenario projections fall. The horizontal dash within each box indicates the median moisture scenario.

Without exception, all scenarios project decreases in moisture levels with respect to the baseline climate of 1961-1990. Increased temperatures will have a powerful evaporation effect, such that soil moisture balances will decline substantially. To understand the net impact of precipitation and temperature changes one can simply imagine that the temperature regime of 1961-1990 is constant, but that annual precipitation declines by 10cm by the 2020s, 21cm by the 2050s, and 32cm by the 2080s across the study area shown in Figure 1.

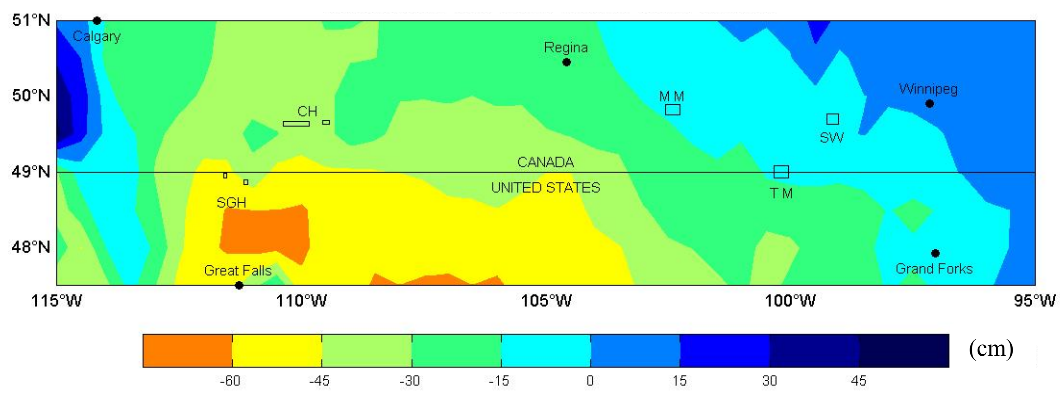

Figure 6: Average annual moisture levels for the 1961-1990 baseline climate period. Areas with moisture levels above zero are areas of moisture surplus and water run-off. Negative numbers indicate a soil moisture deficit; the greater the negative number, the greater the aridity. Conifer trees do not typically grow in moisture regimes below zero while aspen trees are not typically found in moisture regimes drier than –15. SGH – Sweet Grass Hills; CH – Cypress Hills; MM – Moose Mountain; TM – Turtle Mountain; SW – Spruce Woods.

Moisture levels are key in determining the regional distribution of vegetation on the Plains We can map future moisture scenarios. Figure 6 shows the moisture balance of 1961-1990. Figure 7 shows moisture scenarios calculated from the Australian Commonwealth Scientific and Industrial Research Organisation Global Climate Model. These are typical, average scenarios that fall within the “boxes” shown in Figure 5. The degree of drying foreseen by these scenarios is sobering, with implications well beyond the issue of island forest survival. It is beyond the focus of this study to examine the many impacts increasingly dry conditions will have in our study region – we concentrate here on island forests. However, it is obvious, for example, that the climate impacts on agriculture may be severe.

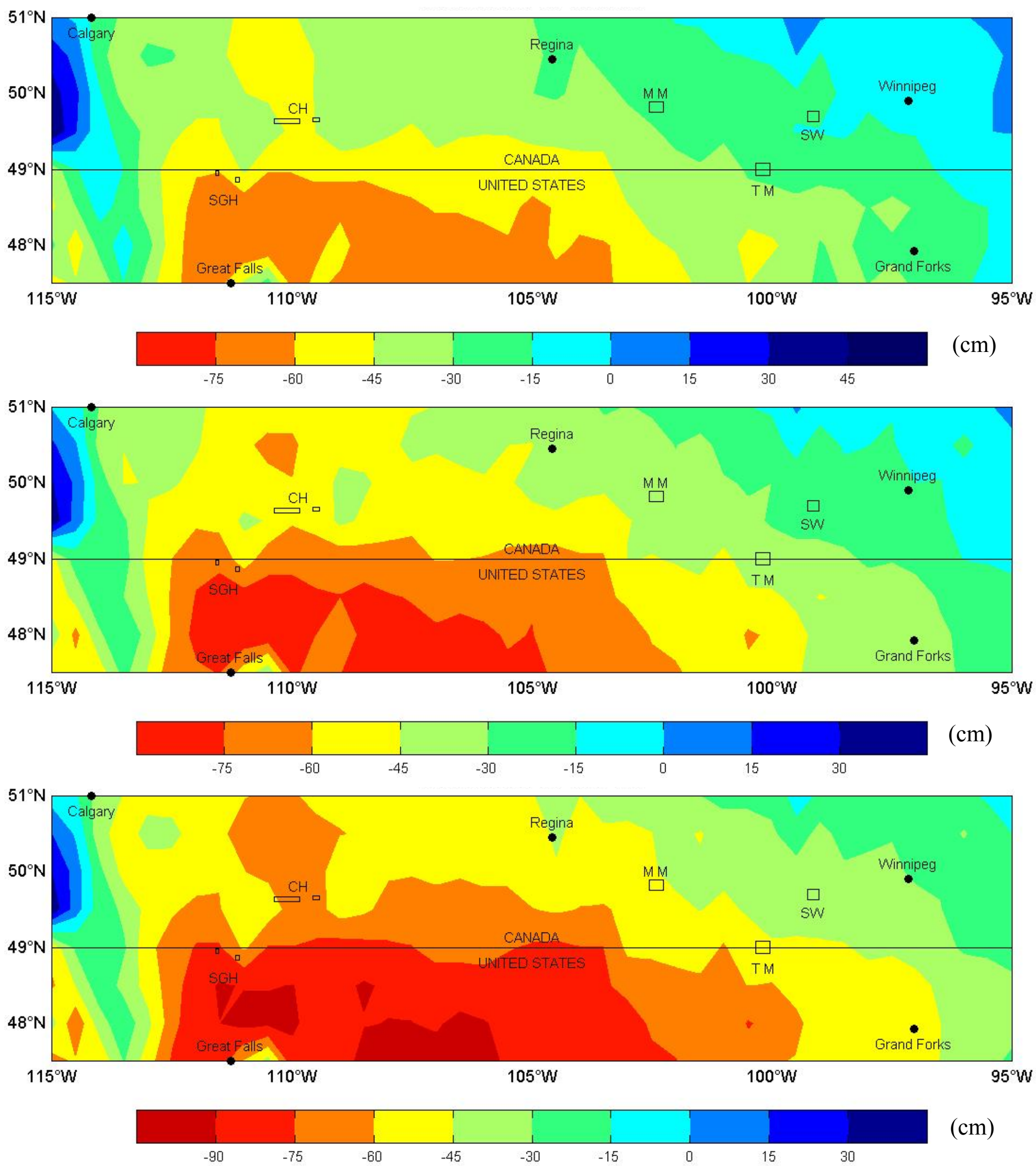

Figure 7: Projected soil moisture levels for the 2020s (top), 2050s (middle) and 2080s (bottom). Areas with moisture levels above zero are areas of moisture surplus and water run-off. Negative numbers indicate a soil moisture deficit; the greater the negative number, the greater the aridity. Conifer trees do not typically grow in moisture regimes below zero while aspen trees are not typically found in moisture regimes drier than –15. SGH – Sweet Grass Hills; CH – Cypress Hills; MM – Moose Mountain; TM – Turtle Mountain; SW – Spruce Woods.

ISLAND FOREST FUTURES

In addition to rising temperatures and changing precipitation regimes, there are many other ongoing climate changes that may impact on tree growth and survival in island forests. These include rising CO_2 levels, a lengthened growing season, increasing ground-level ozone, rising UV-b levels, changing diurnal temperature patterns, and changes in the timing and intensity of freeze-thaw events. Climate variability is important too. Many researchers are of the opinion that climate variability is increasing, even as "average" climate shifts. This would imply, for example, a greater future frequency of extreme drought and flood events. Thunderstorms and windstorms may also increase in frequency. If there is increasing variability it will likely further increase stress on trees.

Forests will change according to one of two patterns. One possible pathway is slow, cumulative decline, such as aspen break-up as aspen passes maturity, is subject to insect attack, and experiences conditions too dry for regrowth. Alternatively the change mechanisms may be spectacular and catastrophic, such as a major fire. Intense fires are increasingly likely as forest stands age and fuel loads increase at all five study sites. Under conditions of climate change, fire or pathogen attack could permanently remove forest cover if conditions have become too dry for new trees to regenerate.

The Outlook for Moose Mountain (Saskatchewan)

- The Moose Mountain forest is highly vulnerable. Even before climate change is considered, only a few hundred metres of elevation separate Moose Mountain from the surrounding prairie ecosystem. The forest lacks tree species diversity that could provide robustness. It also lacks major refugia such as steep coulees or major rivers with water input from more humid regions. Initially, aspen and balsam poplar will colonise contracting wetland sites, while trees on droughty sites will give way to grassland and bush. Over the long term, the forest will likely change to a very open parkland state, with trees restricted to low hollows and a few northern exposures. Regeneration of existing tree species will prove increasingly difficult. A catastrophic fire is increasingly possible.

- Ponds, lakes and wetlands will shrink in size. Where water remains, it will be warmer in summer, with lower dissolved oxygen and greater susceptibility to algal bloom. Maintaining any sport fishery will likely be impossible. Boating, swimming and the extraction of water for the golf course and waterslide complex will be negatively affected.

The Outlook for Turtle Mountain (Manitoba – North Dakota)

- The climate change impact outlook for Turtle Mountain is almost identical to that for Moose Mountain. The Turtle Mountain forest is also highly vulnerable. However, at Turtle Mountain the forest is slightly more diverse in tree species, which may make it somewhat more resilient – bur oak expansion may to a degree compensate for aspen dieback, for example. Bur oak will have the greatest chance of survival amongst the existing trees as moisture levels decline, and an oak savannah landscape may result.

The Outlook for Spruce Woods (Manitoba)

- Aspen is already under stress and short-lived on most sites within the sandhills and can be expected to suffer dieback as moisture levels decline. This could in turn negatively impact on spruce regeneration, since in the drier, more open, areas spruce may get its start under aspen canopy. As at Turtle Mountain, bur oak may prosper in some areas as aspen declines, forming an increasingly open savannah landscape. Mature white spruce in the sandhills will likely survive for some years as moisture levels decline, but regeneration will not occur. The long-term ability of trees to persist in the greater sandhills landscape outside the Assiniboine

Valley and its tributaries is very doubtful. Trees will, however, very likely persist in sheltered coulees and on valley slopes.

- Drier conditions may aid retention or expansion of grasslands within Spruce Woods Provincial Park.

The Outlook for Cypress Hills (Alberta – Saskatchewan)

- By the 2050s natural regeneration of aspen, lodgepole pine or white spruce is very unlikely to be possible outside of very localised sites within the Cypress Hills. The future landscape is likely to be one of small patches of stressed woodland persisting only in the most favourable sheltered sites. By the 2080s it is very possible that there will be no regeneration of spruce or lodgepole anywhere in the hills. Alternatively, a few sheltered coulee slopes may remain moist enough to prevent complete extirpation of extant tree species.

- Lodgepole stands will be increasingly vulnerable to mountain pine beetle attack. It is widely believed that periods of very cold winter weather act as an effective control on mountain pine beetle outbreaks. Periods of sanitizing cold are already less frequent. Spruce budworm attack is also possible.

- There is a great and increasing risk of catastrophic fire. It is possible that post-burn forest regeneration would be slow and patchy even under today's climate conditions, as conditions are already drier than those under which the existing forest developed. Regeneration will be ever more difficult in future.

The Outlook for Sweet Grass Hills (Montana)

- The smallness of the Sweet Grass forests increases their vulnerability. However, these forests are relatively diverse in conifer species and are therefore potentially more resilient than the forests at Cypress Hills. The presence of a forest elevation range of about 700 metres also provides resiliency. However, the speed of climate change may make colonisation of higher (i.e. moister) elevations impracticable for some tree species. Those species present both at the hill summits and far down the slopes do not need to migrate, but will see their natural range contract up-slope. Tree species presently found only towards the top of the hills, i.e. subalpine fir and whitebark pine, will very likely disappear entirely. Most other tree species will likely persist, either in small sites near the summits or in steep ravine refugia. However, the bulk of the current forest can be expected to disappear.

- In the absence of a major disturbance the current forest may persist for some time, declining slowly with ever-decreasing regeneration. However, the fire risk is increasing and high-impact pathogen disturbances are becoming more likely over time. This means that sudden forest loss is increasingly likely.

MANAGEMENT RECOMMENDATIONS

Climate is only one co-determinant of the island forests' future. Management choices will also co-determine vegetation outcomes. No management option can avoid change entirely, but active and intrusive management could retain significant areas of forest cover. Management that aims simply to retain existing vegetation, or to restore historical vegetation distributions and ecosystems, will fail as the climate moves farther away from recent and current norms. To retain some forest cover it may be necessary to introduce non-native tree species into the island forests. Climate change is not currently considered within the management plans of any of our five island forest study sites. As trees are rare and valued on the Plains, and likely to become rarer in future, the following recommendations centre on ways of retaining forest cover via active, anticipatory management:

1. Incorporate the probable range of climate change impacts and include an analysis of management options to deal with these impacts in all vegetation management strategies for the island forests.

2. Include estimates of the net CO_2 impacts of vegetation management alternatives in all vegetation management strategies for the island forests.

3. Implement systematic monitoring for climate change impacts on Plains island forests. The monitoring should be binational and linked across sites and jurisdictions.

4. Adopt the following measures to retain forest cover and support existing species and ecosystem diversity:
   - maintain a diversity of age stands in the forest;
   - manage fuel loads to avoid excessive fuel build-up;
   - create and maintain fire breaks;
   - apply prescribed fire where appropriate;
   - undertake forest harvest where appropriate;
   - target savannah-like landscapes less vulnerable to catastrophic disturbances, where appropriate;
   - replant to aid regeneration where necessary;
   - counter potentially catastrophic insect or vegetation disturbances by biological, chemical or physical controls, if necessary; and,
   - determine the likely critical constraints on tree species' survival and determine and implement management to extend the survivability of extant species beyond their normal moisture range.

5. Undertake a discovery, provenance and breeding program, encompassing both extant tree species within the island forests and possible new species introductions, with the objective of establishing which varieties and species are best adapted to the range of probable future climates in the island forests. Such a program could include:
   - collection of seed from dry microsites within and outside the island forests;
   - determination of related tree species to those now extant which might add resiliency to the island forests;
   - the use of plantation trial sites within or adjacent to the island forests; and,
   - the use of plantation trials in dry sites outside the island forests where such sites might serve as analogues for future moisture conditions at the island forest sites.

6. Consider the management options available to preserve fauna and non-tree flora which may be threatened as climate change progresses. Consider the introduction of new species whose habitats are under threat elsewhere or which could partially substitute for disappearing species in the island forests.

7. Integrate adaptation to climate change within protected area zoning plans and establish differentiated responses to climate change impacts in appropriate zones.

8. Institute a climate change impacts assessment and management study of the entire Plains island forest archipelago in order to:
   - establish the bounds of probable climate change at each island forest site;
   - determine the vulnerability of all Plains island forests to probable climate change impacts;
   - establish whether climate change risk management and adaptation strategies are in place;
   - examine whether there is evidence of climate-change-related vegetation shifts;
   - compare current climate change monitoring approaches and foster knowledge transfer of best practice across all Plains island forests;
   - determine the utility of a trans-Plains island forest climate change monitoring system;
   - establish whether particular species assemblages or ecosystems in a given island forest will likely become viable in another;
   - identify potential seed and species stock for potential inter-island transfer;

- compare current management approaches and foster knowledge transfer of best-practice management across all Plains island forests;
- compare current climate change consultations and communications practice and foster knowledge transfer of best practice across the island forests; and,
- determine the utility of a formalised trans-jurisdictional information network for the island forests.

9. Design and implement a climate change communications and consultations strategy that is integrated across the island forests. Existing island forest interpretation centres should interpret site-specific climate change scenarios and impacts and also survey visitor preferences for management responses. The Turtle Mountain International Peace Garden should be investigated as a potential binational Plains "flagship" climate change interpretation centre.

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