Climate Change Impacts on Canada's Prairie Provinces: A Summary of our State of Knowledge

PRAIRIE ADAPTATION RESEARCH COLLABORATIVE

SUMMARY DOCUMENT

Summary edited by Norm Henderson and Dave Sauchyn

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Dave Sauchyn (Prairie Adaptation Research Collaborative)
Suren Kulshreshtha (University of Saskatchewan)
Elaine Barrow (University of Regina)
Danny Blair (University of Winnipeg)
Jim Byrne (University of Lethbridge)
Debra Davidson (University of Alberta)
Polo Diaz (University of Regina)
Norm Henderson (Prairie Adaptation Research Collaborative)
Dan Johnson (University of Lethbridge)
Mark Johnston (Saskatchewan Research Council)
Stefan Kienzle (University of Lethbridge)
Justine Klaver (University of Alberta)
Jeff Thorpe (Saskatchewan Research Council)
Elaine Wheaton (Saskatchewan Research Council)

Storm over southern Alberta

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PRAIRIE ADAPTATION RESEARCH COLLABORATIVE

Saskatchewan Ministry of Environment

Alberta Environment

UNIVERSITY OF REGINA

INTRODUCTION

Researchers have studied the impacts of climate change on the Prairie Provinces for several decades. While much remains to be researched, we now know a considerable amount about the impacts of climate change. We also have made advances in understanding our adaptation options. This document summarises our knowledge about climate change impacts and our adaptation options to manage these impacts. The challenges are very serious – the Prairies, already a dry region, are getting drier.

DESCRIPTION OF THE PRAIRIE PROVINCES

The Prairie Provinces span several major climatic, biogeographic and geological zones and watersheds (Figure 1). Because the region is located in mid latitudes and in the rain shadow of the Rocky Mountains, the climate is generally cold and subhumid. There are extreme differences in seasonal temperatures. During the period 1971–1990, mean temperatures in the coldest and warmest months were –7.8°C and 15.5°C, respectively, at Lethbridge and –17.8°C and 19.5°C, respectively, at Winnipeg.

Mean annual temperatures are highest in southern Alberta, elevated by winter chinooks, and decrease to the north and east towards Hudson Bay (Figure 2a). Annual precipitation varies considerably from year to year, ranging from less than 300 mm in the semiarid grassland to about 700 mm in central Manitoba and more than 1000 mm at high elevations in the Rocky Mountains (Figure 2b). Throughout the Prairie Provinces, snow is important for water storage and soil moisture recharge. The wettest months are April to June.

The temperature and precipitation patterns in Figure 2 result in annual moisture deficits in the southern and western plains, while there are moisture surpluses in the Rocky Mountains and foothills, and in the northern and eastern boreal forest. Most runoff is shed eastward via the Saskatchewan-Nelson-Churchill river system into Hudson Bay, and northward via the Athabasca, Peace and Hay rivers into the Mackenzie River and Arctic Ocean (Figure 1). Little local-origin runoff is generated across the southern Prairies. The few permanent streams in the south are thus important as local water sources.

The Terrestrial Land Classification of Canada includes seven ecozones that lie within the Prairie Provinces (Figure 3). The 25% of the Prairie Provinces occupied by the Prairie Ecozone is characterized by persistent, and sometimes severe, moisture deficits. It is the region's agricultural and industrial heartland and the most extensively modified region of the country — there remain only remnants of the original mixed- and tall-grass prairie, and less than half the pre-settlement wetland area.

PAST AND RECENT CLIMATE

Most weather records in the Prairie Provinces are less than 110 years in length. However, a longer perspective from geological and biological evidence has been assembled. In the Prairies, variations in climate are reflected in changes in vegetation, fluctuations in the level and salinity of lakes, patterns in tree rings, and in the age and history of sand dunes (Lemmen and Vance, 1999). Temperatures inferred from boreholes on the Canadian Plains (Majorowicz et al., 2002) and from tree rings at high elevations in the Rocky Mountains (Luckman and Wilson, 2005) show that the

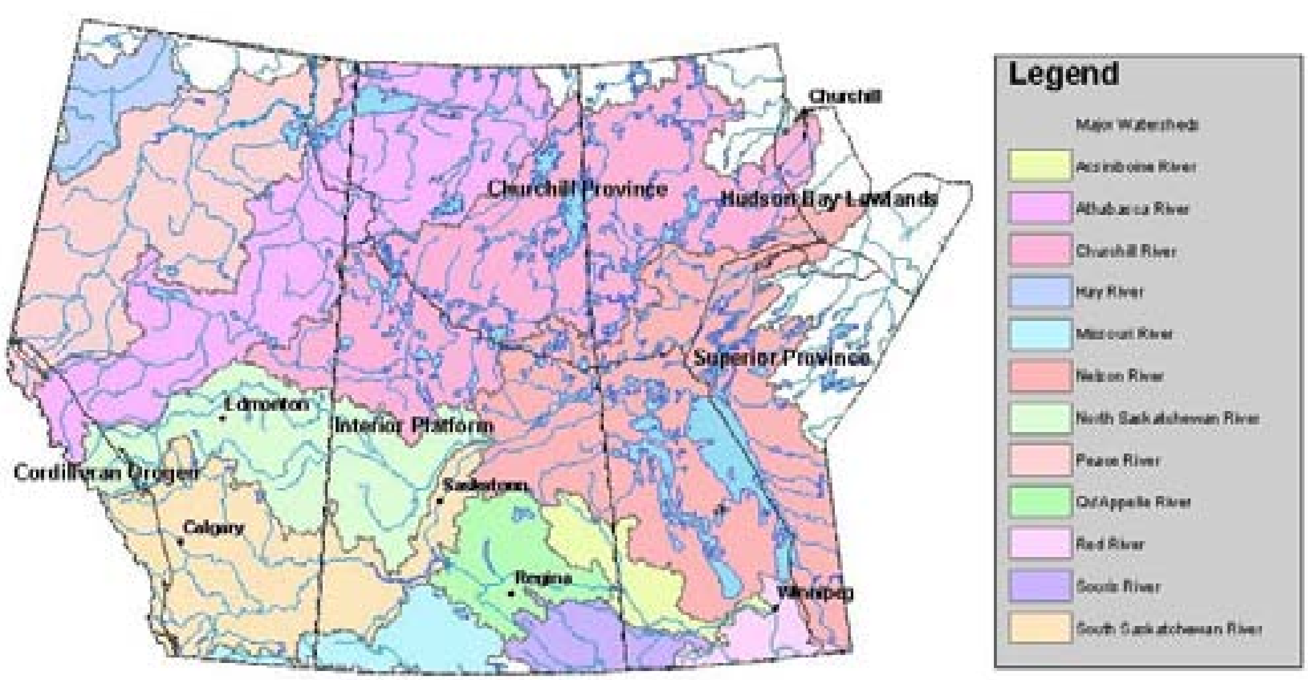

Figure 1*: Major watersheds and the geological provinces of the Prairie Provinces*

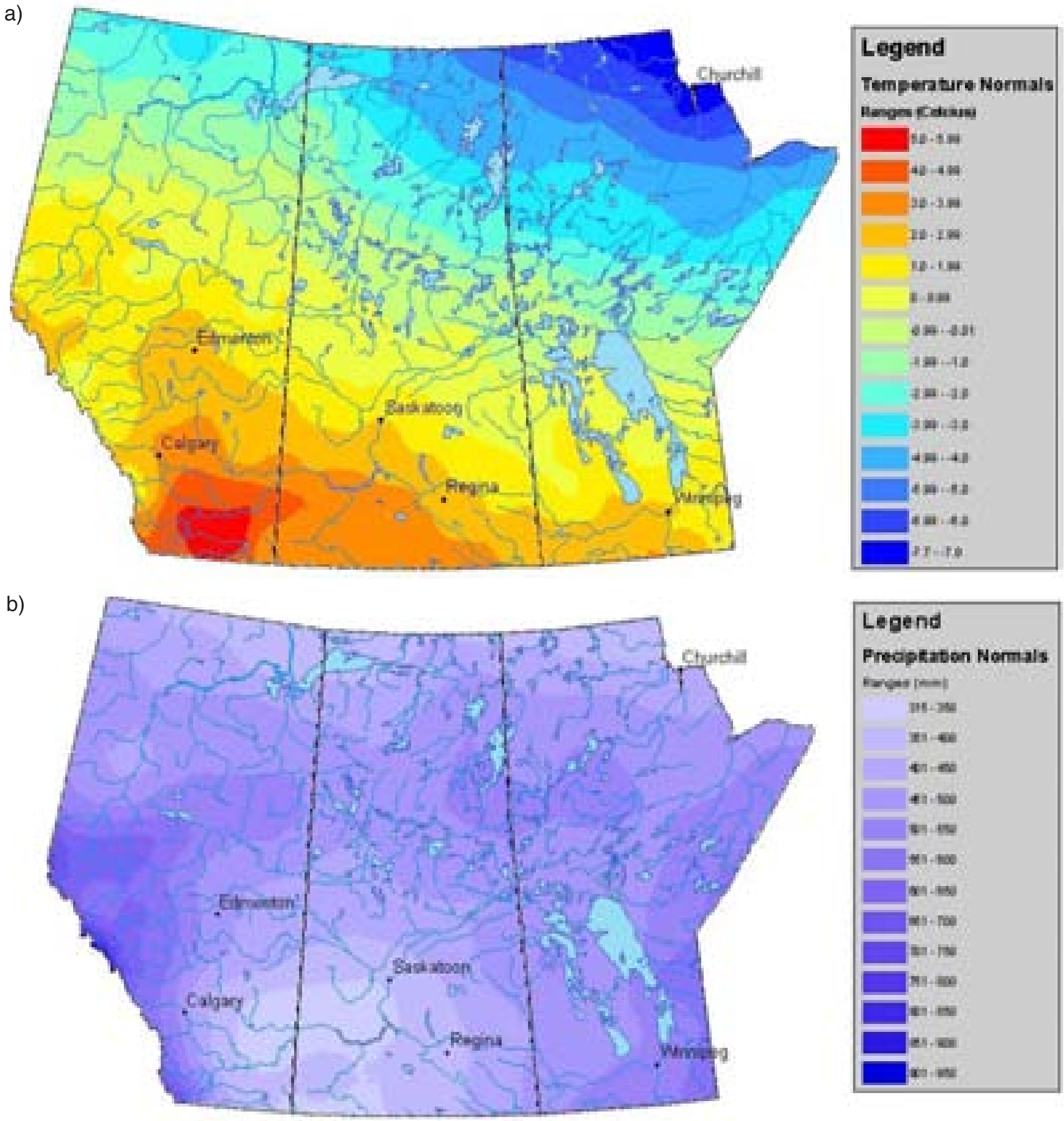

Figure 2: *Climate normals for the Prairie Provinces: a) temperature, and b) precipitation.*

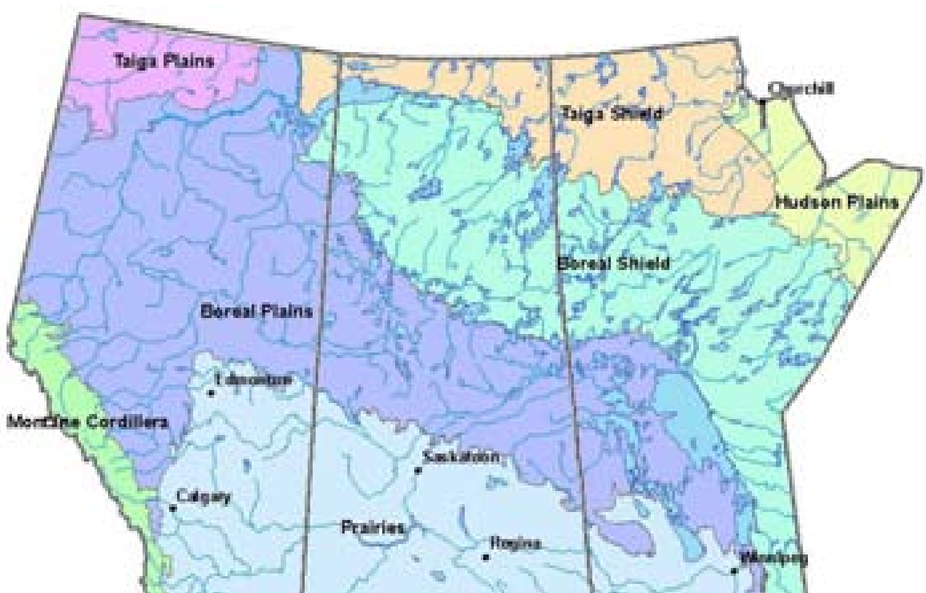

Figure 3: *Ecozones of the Prairie Provinces*

warmest climate of the past millennium was during the twentieth century.

Soil moisture inferred from tree rings, and lake salinity inferred from diatoms, indicate that the climate of the twentieth century was relatively favourable for the European settlement of the Prairies, as it lacked the sustained droughts of preceding centuries (Sauchyn et al., 2002, 2003). Tree rings suggest repeated multi-decadal wet and dry cycles (St. George and Sauchyn, 2006; Watson and Luckman, 2006) across the region. Tree-ring and archival records from Manitoba (Blair and Rannie, 1994; St. George and Nielsen, 2003; Rannie, 2006) have highlighted the recurrence of wet years and flooding, and point to a contrast in climate between the western and eastern Prairies.

During the period of instrumental record, there was an average increase in temperature of 1.6°C for 12 stations on the Prairies, most with data since 1895. The greatest upward trend is since the 1970s. Spring shows the greatest warming, a trend that extends from Manitoba to northern British Columbia (Zhang et al., 2000). Precipitation data indicate a generally declining trend during the months of November to February, with 30% of the monthly data from 37 stations showing a significant decrease during the period 1949–1989 (Gan, 1998).

A favourable consequence of general warming, and of higher spring temperatures in particular, is a warmer and longer growing season. There could be enhanced productivity of forests, crops and grassland - where there is adequate soil moisture. Unfortunately, summertime drying of the earth's midcontinental regions is projected, owing to greater water loss by evapotranspiration (Gregory et al., 1997; Cubasch et al., 2001). Projections vary from slight (Seneviratne et al., 2002) to severe (Wetherald and Manabe, 1999) increases in aridity. Declining water levels in closed-basin prairie lakes (Figure 4) are evidence that drying is already underway. Closed-basin lakes are sensitive indicators of hydrological and climatic change.

SCENARIOS OF FUTURE CLIMATE

Climate scenarios were derived from climate change experiments based on seven global climate models (GCMs) and the Intergovernmental Panel on Climate Change *Special Report on Emissions Scenarios* (Nakićenović and Swart, 2000). Maps and scatterplots for the Prairie Provinces illustrate the scenarios of projected climate change from the reference period 1961–1990 to the 2020s (2010-2039), 2050s (2040-69) and 2080s (2070-99) for the forest (northern) and grassland (southern) regions for mean annual temperature and precipitation (Figure 5). Temperature scenarios are similar for the forest and grassland regions, but increases in precipitation are larger for the northern forest. Much of the projected increase in temperature and precipitation is weighted to winter and spring in both forest and grassland regions.

The scenario maps present a geographic summary of the climate changes illustrated by the scatterplots. Temperature

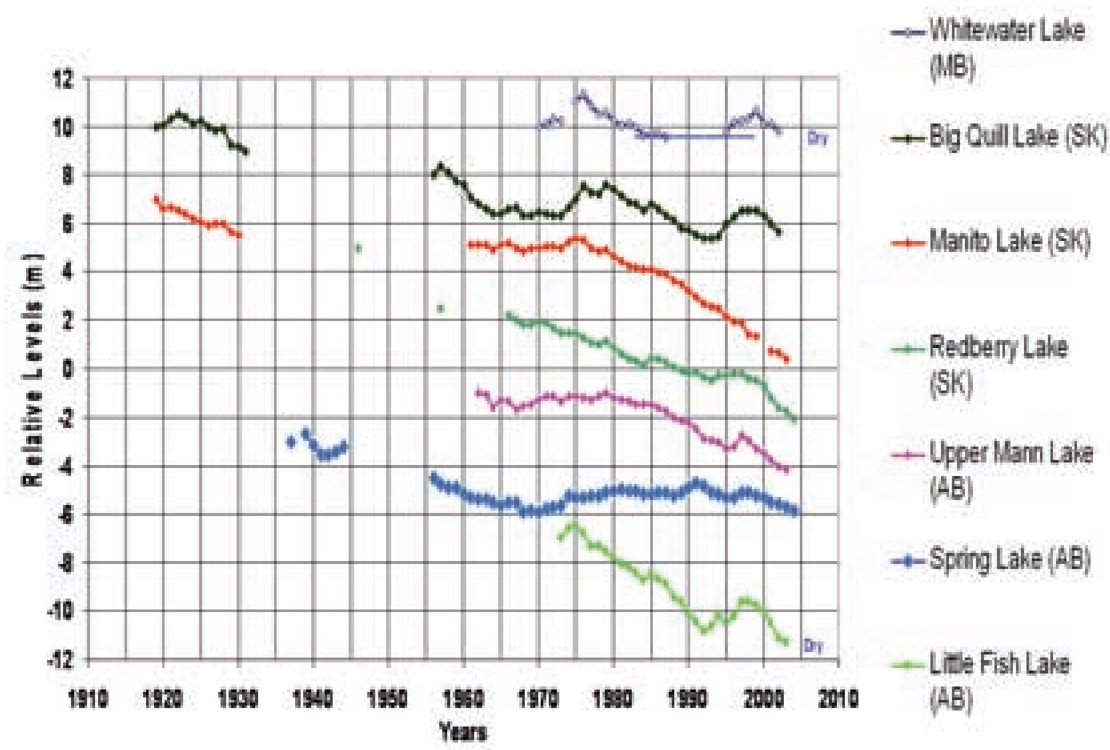

Figure 4: *Historical water levels for closed-basin prairie lakes (from van der Kamp and Keir, 2005; van der Kamp et al., 2006)*

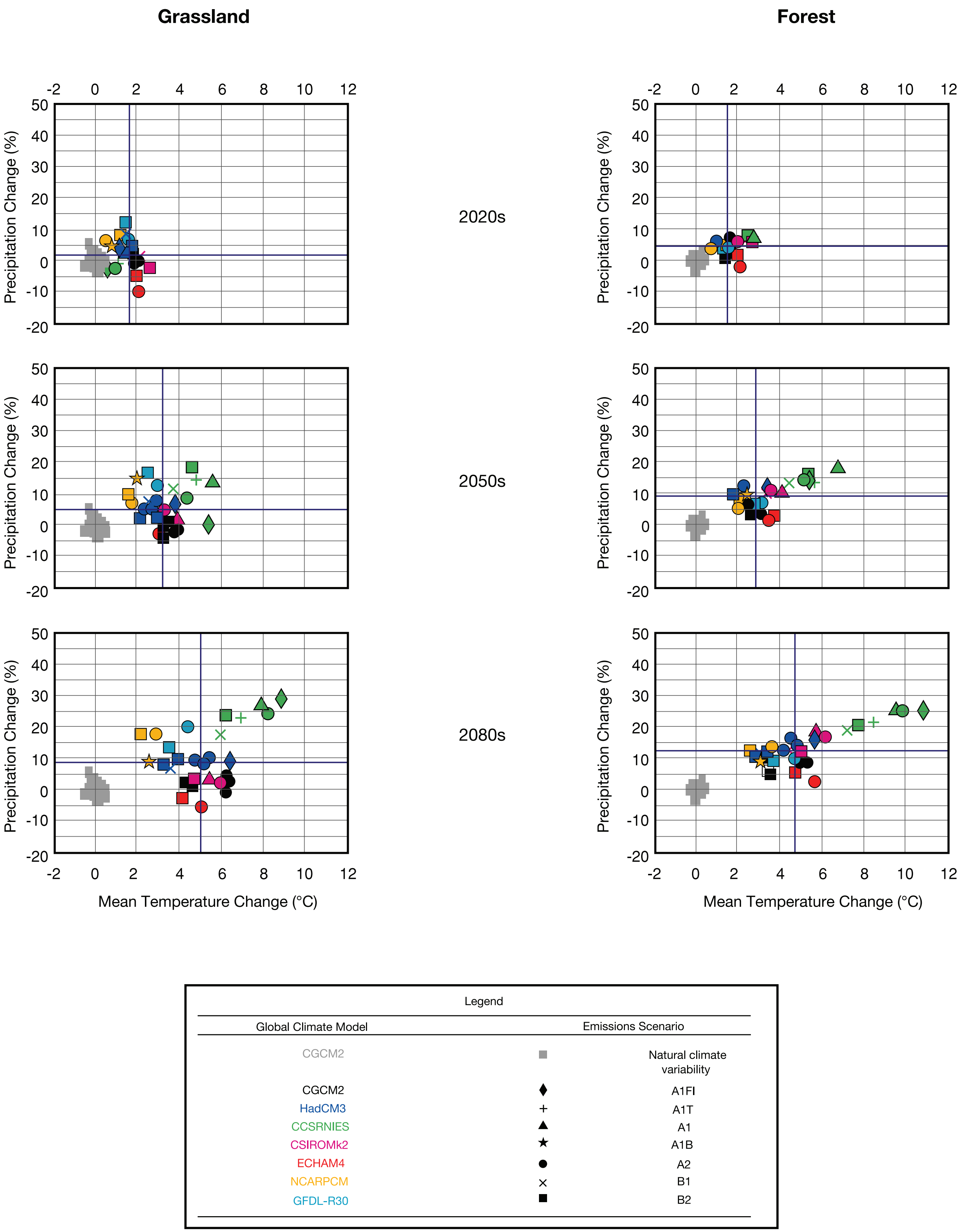

Figure 5: *Scatterplots of forecast changes in mean annual temperature and precipitation for the forest and grassland regions of the Prairie Provinces for the 2020s, 2050s and 2080s. The grey squares indicate the 'natural' climate variability. The crosshairs indicate the median forecast.*

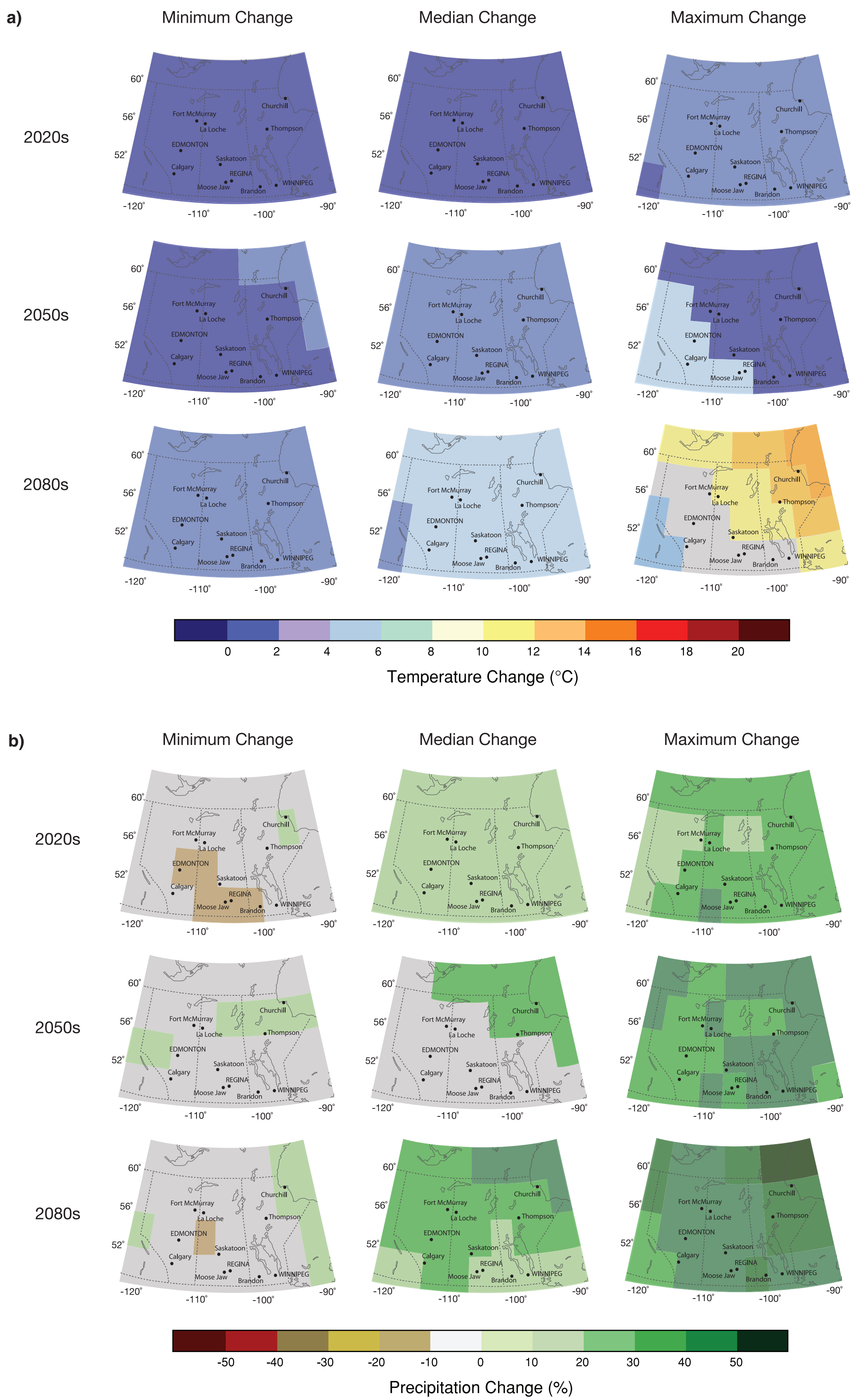

Figure 6: *Climate change scenario maps for the Prairie Provinces in the 2020s, 2050s and 2080s, showing minimum, median and maximum forecast changes in **a)** mean annual temperature, and **b)** mean annual precipitation*

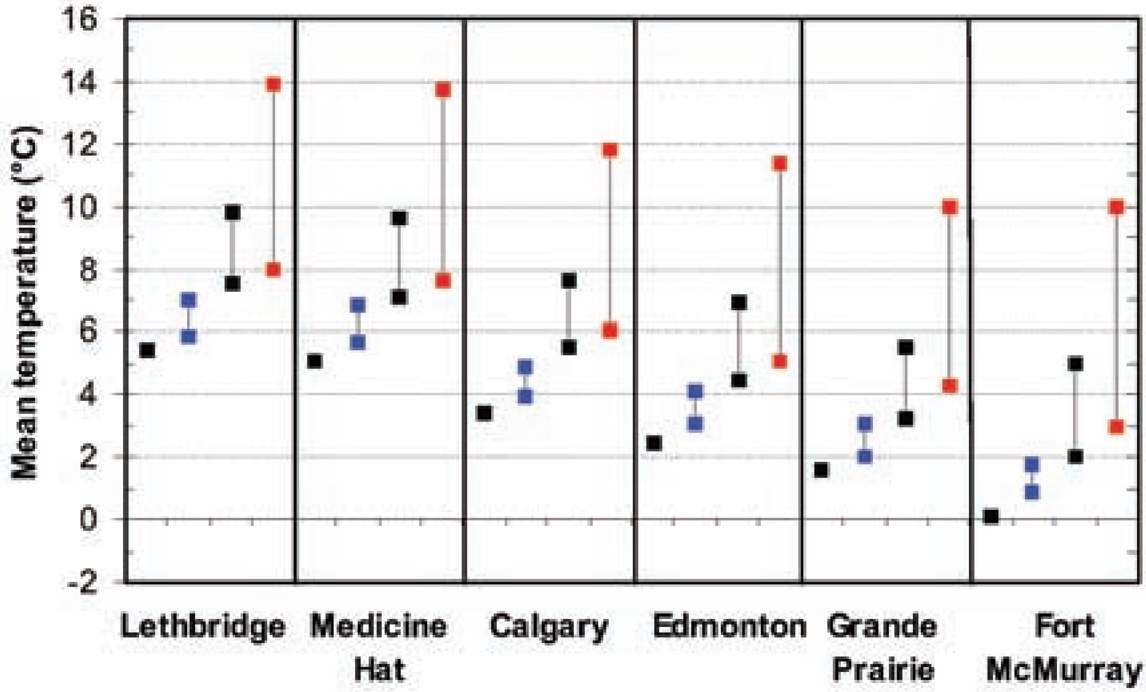

Figure 7: Annual mean temperature for six Alberta cities. The single black square indicates the baseline recorded mean temperature over the period 1961-1990. Blue squares indicate the bounds of the scenario range for the 2020s; black squares the range for the 2050s; red squares the range for the 2080s (from Barrow and Yu, 2005).

and precipitation scenarios are mapped for the 2020s, 2050s and 2080s in Figure 6. The maps show that greatest warming is projected to occur in the north and east. These regions are also forecast to have the largest increases in precipitation.

The few studies that have examined GCM outputs for extremes of future climate (e.g. Kharin and Zwiers, 2000) suggest increased climate variability and more frequent extreme events, including a greater frequency of flooding and severe drought. Warmer temperatures increase the likelihood of extreme rainfall events (Groisman et al., 2005).

Changes in mean temperature have been specifically projected for six Alberta cities (Figure 7). A mid-range forecast is that by the 2080s Fort McMurray will be warmer than Lethbridge's recent (1961-1990) climate. Of course, in the meantime all of Alberta, including Lethbridge, will be warming as well.

WATER AND SOIL RESOURCES

The sustainability and wealth of the Prairie Provinces are intimately linked to the quality and quantity of available water. Water impacts our health and well-being, food production, infrastructure, energy production, forestry, recreation, and communities large and small. Some of the greatest stresses endured in the Prairies have been directly related to hydrologic extremes of drought and flood.

Reduced winter snowfall in the latter half of the twentieth century (Akinremi et al., 1999) contributed to the observed trend of declining streamflows. This is already a critical issue for many rivers in the southern Prairies, such as the Bow, Oldman and Milk, particularly in dry years. Winter warming will reduce snow accumulations in alpine areas (Leung and Ghan, 1999; Lapp et al., 2005) and across the Prairies. This will cause declines in annual streamflow and a shift in streamflow timing to earlier in the year, resulting in lower summer water supplies – unfortunately summer is the season of greatest demand for water.

Continued glacier retreat (Demuth and Pietroniro, 2003) will exacerbate water shortages already apparent in many areas of Alberta and Saskatchewan during drought years. Drier soils result in decreased subsurface recharge, which will lead to a decline in the water table in many regions. Increases in the demand for water will compound issues of declining water supply and quality.

In the Alberta Rockies an increased frequency of landslides, debris flows, rock avalanches and outburst floods is probable, given current and projected future trends that include increased rainfall (especially in winter), rapid snowmelt and shrinking glaciers (Evans and Clague, 1994, 1997). The decay of permafrost could accelerate slope failures at high elevations for many decades (Evans and Clague, 1997).

In the taiga and boreal forest regions, increased drought frequency, including persistent multi-year droughts (Sauchyn et al., 2003), will result in declining soil moisture and increased forest fire extent. During recent extreme droughts, organic soils have dried and burned together with forests, resulting in an almost total loss of vegetation and soil cover. Thereafter runoff becomes instantaneous, resulting in flash floods.

Figure 8: *An Alberta glacier in retreat*

emit greenhouse gases (St. Louis et al., 2000), and dams and diversions have well-documented negative environmental impacts (Environment Canada, 2001; Mailman et al., 2006).

ECOSYSTEMS

Models of vegetation zonation have shown a northward shift of the forest-grassland boundary in the Prairie Provinces with climate change (Hogg and Hurdle, 1995; Vandall et al., 2006). In water-stressed forest regions there will be a general reduction in tree growth, regeneration failure in dry years, a gradual reduction in tree cover, and expansion of grassland patches. Major changes in species representation are projected for the boreal forest, especially at its southern boundary (Herrington et al., 1997; Henderson et al., 2002; Carr et al., 2004). Increased average winter temperatures will lead to greater overwinter survival of pathogens and increased disease severity (Harvell et al., 2002). Drought conditions weaken trees' defences to more virulent pathogens (Saporta et al., 1998). Henderson et al. (2002) noted two pathways of forest change: 1) slow and cumulative decline; or 2) catastrophic loss, such as a major fire.

In the aspen parkland there will be shrinking of aspen groves and decreasing shrub cover. Aspen parkland and fescue prairie of the present northern grassland fringe will

In agricultural regions, droughts could result in enhanced soil erosion and increased sand dune activity (Wolfe and Nickling, 1997). Slopes and stream channels exposed to less frequent but more intense rainfall will also be vulnerable to increased erosion and shallow slope failures (Sauchyn, 1998; Ashmore and Church, 2001). Erosion will increase stream sediment and nutrient loads in local water systems, leading to eutrophication of water bodies and increased pathogen loading in streams during the summer (Hyland et al., 2003; Johnson et al., 2003; Little et al., 2003). The Millennium Ecosystem Assessment (2005) identified the joint effects of climate change and nutrient overenrichment as the major threat to drylands agro-ecosystems.

Changing the timing of irrigation to after sunset and using more efficient irrigation methods can help offset increasing water demands (Bjornlund et al., 2001). Increasing water recycling or issuing licenses to industries that are based on best water management practices and water recycling standards are other adaptation opportunities (Johnson and Caster, 1999).

Future water scarcity could lead to abandonment or underutilization of major infrastructure (canals, pipelines, dams and reservoirs) worth billions of dollars. Equally, rising water demand combined with a decline in summer runoff in some years will lead to calls for new infrastructure for increased storage and diversion of water. However, reservoirs

Figure 9: *Drifting soil near Oyen, Alberta*

Figure 10: *Waterfowl sanctuary, Ministik Lake, Alberta*

give way to variants of mixed prairie. The most significant impacts will occur at ecozone boundaries, for example, where grassland meets parkland or forest, or where drier lower-elevation grassland meets moister foothills grassland (Vandall et al., 2006).

Prairie-parkland national parks can expect increases in forest fire frequency and intensity, increased forest disease outbreaks and insect infestations, and loss of boreal forest to grassland and temperate forest (Scott and Suffling, 2000; de Groot et al., 2002). In Alberta's mountain parks, climate change has already caused vegetation and associated species to migrate to higher elevations (Scott et al., in press), a trend that will accelerate. Isolated island forests will suffer serious challenges to ecosystem integrity. Highly intensive management will likely be necessary to preserve some type of forest cover at these sites (Henderson et al., 2002).

Possible adaptation actions to protect forest systems range from maintaining a diversity of age stands and responding aggressively to pathogen disturbances, to regenerating the forest with alien tree species that are better adapted to new climate parameters. Current policies disfavour alien introductions (e.g., Alberta Reforestation Standards Science Council, 2001; Alberta Sustainable Resource Development, 2005; Manitoba Conservation, 2005). However, western conifers, such as Douglas fir and ponderosa pine, and hardwoods of the southern Prairies, such as Manitoba maple and green ash, may be suited to future climates of the western boreal ecozone (Thorpe et al., 2006).

The prairie pothole region of central North America is the most productive habitat for waterfowl in the world (Clair et al., 1998). Increasing aridity and habitat loss in the prairie grasslands is likely to negatively impact migratory waterfowl populations (Poiani and Johnson, 1993; Bethke and Nudds, 1995).

Aquatic ecosystems will be stressed by warmer and drier conditions. A large number of prairie aquatic species are at risk of extirpation (James et al., 2001). Many fish species and amphibians are sensitive to small changes in temperature, turbidity, salinity or oxygen regimes. The size of the massive algae blooms in Lake Winnipeg correlates with higher summer temperatures (McCullough et al., 2006). Larger algal blooms, accelerated eutrophication, and serious impacts on fish species are expected, due to a combination of climate change, increasing nutrient runoff, and increasing human use pressures on natural water systems (Schindler and Donahue, 2006; Xenopoulos et al., 2005).

Increasing connectivity between protected areas to facilitate migration of species populations is commonly proposed as one method of coping with climate change (Malcolm and Markham, 2000; James et al., 2001; Joyce et al., 2001). Although some species may able to migrate, others will be threatened by the arrival of new competitors or by the pathogens that increased connectivity supports. Thus, increased connectivity may also hasten the decline of some ecosystems by favouring alien invasions.

Conservation management that aims simply to retain existing flora and fauna, or to restore historical vegetation

Figure 11: *Summer algae bloom on Lake Katepwa, Qu'Appelle Valley, Saskatchewan*

***Figure 12:** Irrigation on the Prairies (Frenchman River Valley, southwestern Saskatchewan)*

distributions, will fail as the climate moves farther away from recent and current norms. Biodiversity protection planning may need to build resilience into ecosystems, rather than seeking stability (Halpin, 1997). Selection of protected areas may need to focus on site heterogeneity and habitat diversity (as these provide some buffer against climate change) rather than on representativeness (Henderson et al., 2002).

Climate change means ecosystem change is inevitable. Therefore, biodiversity managers must become less practitioners of preservation than stewards of new and unprecedented ecosystems and landscapes.

AGRICULTURE

Higher levels of atmospheric CO_2 improve water-use efficiency, and may increase some crop yields (particularly for plants using the C3 carbon-fixation pathway, like wheat or canola). However, the picture is complex, since weeds may also be more vigorous under a carbon-enriched atmosphere. Warmer and longer growing seasons could be positive for crop growth and yield. Shorter and milder winters may put less stress on livestock. Potential negative impacts include changes in the timing of precipitation, more intense precipitation events, the emergence of new pests, and, especially, the increased frequency and intensity of droughts.

Manitoba, the least water-deficient province, has been projected to benefit from warming as producers shift to higher value crops (Mooney and Arthur, 1990). By contrast, the more arid mixed grassland ecoregion of southern Alberta and Saskatchewan, an area of approximately 200,000 km^2, is at risk of desertification.

Historically, federal and provincial governments have responded to drought with safety net programs to offset negative socioeconomic impacts (Wittrock and Koshida, 2005) and, more recently, through development of drought management plans. More intense and longer droughts will be expensive challenges to safety net programs.

Grassland production is limited by moisture supply. Although a drier climate would suggest declining production and grazing capacity, actual changes in grassland production are likely to be modest, given a longer growing season, reduced competition from shrubs and trees, and increases in warm-season grasses that have higher water-use efficiency (Thorpe et al., 2004).

Soil conservation and irrigation are major agricultural adaptations to annual soil water deficits. Soil conservation is a prime example of a ‘no regrets' strategy, since preventing soil loss is beneficial whether or not impacts of climate change occur exactly as projected. The Permanent Cover Program (Vaisy et al., 1996) has reduced sensitivity to climate over a large area. The move in recent decades to more efficient irrigation techniques has dramatically increased on-farm irrigation efficiencies. However, the continued loss of water from irrigation reservoirs and open-channel delivery systems due to evaporation, leakage and other factors indicates the need for further improvement in the management of limited water resources.

FORESTRY

Generally, net primary forest productivity is expected to increase under warmer temperatures and longer growing seasons, if water and nutrients are not limiting (Norby et al., 2005). Increased photosynthetic activity for much of Canada during the period 1981–1991 has been attributed to a longer growing season (Myneni et al., 1997).

Free-air CO_2 enrichment experiments found trees respond to increased CO_2 concentrations more than other vegetation, with biomass production increasing an average of about 20 to 25% (Long et al., 2004; Norby et al., 2005). Higher levels of atmospheric CO_2 improve water-use efficiency (WUE); that is, less water is lost for a given unit of CO_2 uptake (Long et al., 2004) – particularly important for water-limited sites. Johnston and Williamson (2005) found that, even under severe drought conditions, increased WUE under a high CO_2 future would result in an increase in productivity relative to current conditions. Simulated future drought reduced productivity of white spruce in Saskatchewan by about 20% on sites with low available water-holding capacity (Johnston and Williamson, 2005).

Insect outbreaks are expected to be more frequent and severe (Volney and Fleming, 2000). Of particular concern is the mountain pine beetle, currently in a major outbreak phase

Figure 13: *Fire in the boreal forest*

in the interior of British Columbia. It is now beginning to spread east, with approximately 2.8 million trees affected in Alberta as of spring 2007 (Alberta Sustainable Resource Development, 2007). The beetle is limited by the occurrence of −40°C winter temperatures; with warming, this limiting temperature is likely to occur farther to the north and east, allowing the beetle to spread into jack pine in the Prairie Provinces.

Forest fires are expected to be more frequent (Bergeron et al., 2004), of higher intensity (Parisien et al., 2004), and to burn over larger areas (Flannigan et al., 2005). Increased forest fire activity will likely favour hardwood species (e.g. aspen) over some conifers (e.g. white spruce). Increased tree mortality in the southern margin of the boreal forest is projected as a result of the interaction of insects, drought and fire (Hogg and Bernier, 2005; Volney and Hirsch, 2005).

In areas where winter operations are important, a shorter period of frozen ground conditions will limit operations and affect scheduling of harvesting equipment. Potential adaptation measures for dealing with climate change impacts include managing forests to reduce fuel loads and fire loss potential; assisting the migration of commercial tree species; thinning forests to enhance growth and insect / disease resistance; and maintaining connectivity (Spittlehouse and Stewart, 2003). Forest loss could be irreversible if adaptation is slow or only reactive.

TRANSPORTATION

Increased frequencies of extreme precipitation events (Kharin and Zwiers, 2000) and increased inter-annual climate variability are likely to result in increased damage to roads, railways and other structures as a result of flooding, erosion and landslides. Asphalt surfaces, particularly those with significant heavy truck traffic, are especially susceptible to damage during heat waves, which are expected to increase in frequency.

Winter roads have experienced significant negative impacts. Manitoba Transportation and Government Services has reported decreased ice thickness, poor ice texture and density, delayed winter road seasons, problematic muskeg areas and decreased load limits. The average length of the winter road season in Manitoba is expected to decrease by 8 days in the 2020s, 15 days in the 2050s and 21 days in the 2080s (Prentice and Thomson, 2003).

The longer ice-free season in Hudson Bay and northern channels resulting from continued climate warming (Arctic Climate Impact Assessment, 2005) will increase opportunities for ocean-going vessels to use the Port of Churchill terminus for grain and other bulk commodities. But northern railways passing through areas of permafrost, as does the rail line serving Churchill, will require frequent repair, if not replacement, as a result of continued permafrost degradation (Nelson et al., 2002). Additionally, some paved roads in northern areas are stabilized by frozen substrates during winter and may be compromised by warmer winter temperatures.

Figure 14: *Freight Train*

Figure 15: Port of Churchill

COMMUNITIES

Prairie cities may find existing water storage and drainage systems inadequate to handle projected changes in precipitation intensity and snowmelt. Increasing drought frequency and severity will require water efficiency initiatives. The City of Regina has developed drought contingency plans, including water conservation programs and expansion of water treatment and delivery capacity (Cecil et al., 2005). Other Prairie cities do not have such contingency plans in place (Wittrock et al., 2001). More frequent heat and drought events can place urban vegetation and wildlife under extreme stress. For example, the City of Edmonton (2007) estimated the loss of approximately 23,000 trees to drought since 2002.

In general, rural communities are more sensitive to climate change impacts than cities, due to their more direct natural-resource dependency and lack of economic diversification. Drought is of particular concern, as small communities are largely dependent on well water or smaller reservoirs. Of greatest concern for agricultural communities are extreme weather events, droughts and ecosystem shifts. Rural residents may be more sceptical than urbanites about climate change (Neudoerffer, 2005), which may hinder adaptation initiatives.

Many Aboriginal communities are partly dependent on subsistence for their livelihood. Declines or uncertainties in the availability of moose, caribou, deer, fish and wild rice will increase dependence on imported foods. Unsuitable snow and ground conditions greatly hamper travel to trap lines, hunting grounds and fishing areas. At the February 2004 Prince Albert Grand Council Elders' Forum, elders reported more frequent extreme weather events, deterioration in water quantity and quality, changes in species distributions, changes in plant life, and decreasing quality of animal pelts. Traditional knowledge and land management systems served as a source of resiliency in the past, and could play an important role in strengthening adaptive capacity in the future.

HEALTH

Prairies residents may experience increasing negative health burdens from air pollution, food-borne pathogens, heat-related illnesses, particulate matter, water-borne pathogens and vector-borne diseases (Seguin, in press). Subpopulations most at risk are children, the elderly, Aboriginal peoples, the poor, the homeless, and people with underlying health conditions.

An increased frequency of wildfires may result in increases in respiratory conditions, hospital visits and mortality (Bowman and Johnston, 2005). Warmer temperatures decrease the number of cold-related deaths, but also enhance the production of secondary pollutants, including ground level ozone (Last et al., 1998; Bernard et al., 2001). Drought may increase concentrations of pathogens and toxins in domestic water supplies (Charron et al., 2003; World Health Organization, 2003). Outbreaks of water-borne disease have been linked to intense precipitation, flooding and runoff from agricultural livestock areas (Millson et al., 1991; Bridgeman et al., 1995; Charron et al., 2003, 2004; Schuster et al., 2005). Hantaviruses may increase, as well as West

Figure 16: Dene settlement, northern Saskatchewan

Figure 17: *The Alberta-Saskatchewan Cypress Hills, a threatened island forest landscape*

Nile virus. Other potential health threats are western equine encephalitis, rabies, influenza, brucellosis, tuberculosis and plague (Charron et al., 2003).

ENERGY

Increasing water scarcity and water supply variability are the major climate change risks to energy industries. Production of oil, and even some natural gas, relies on significant quantities of water (Bruce, 2006). Tar sands production is already putting pressure on Athabasca River water; climate change and expanding production will worsen this problem (Bruce, 2006). Drought periods will reduce the supply of cooling water to power plants.

Approximately 95% of the electricity generated in Manitoba comes from renewable water energy (Manitoba Science, Technology, Energy and Mines, 2007). Future hydro generation will be impacted by decreasing water flows from the western portion of the Prairies due to glacial ice decline (Demuth and Pietroniro, 2003) and lower snow accumulations (Leung and Ghan, 1999; Lapp et al., 2005).

Warming is already causing substantial permafrost degradation in many parts of the north (Majorowicz et al., 2005; Pearce, 2005), which will lead to land instability, soil collapse and slope failures. Together with an increased frequency of extreme climate events, this will create problems for foundations and roads. There will be pipeline ruptures and costs to reroute existing pipelines to more stable locales (Huang et al., 2005).

TOURISM AND RECREATION

Lower lake and stream levels, particularly in mid- to late summer, may reduce opportunities for water-based recreation: swimming, fishing, boating, canoe-tripping and whitewater activities. Hunting and fishing could decline with falling waterfowl and game fish populations. The island forest parks (Henderson et al., 2002) and small recreation areas of the southern Prairies, where water and trees draw visitors, are particularly sensitive to changing climate. Banff's ski industry may be negatively affected by less snowfall (Scott and Jones, 2005). Less snow cover and a shorter season will also impact cross-country skiing, snowshoeing and snowmobiling (Nicholls and Scott, in press).

ADAPTATION – EVERYONE'S RESPONSIBILITY

Addressing climate change requires cutting across traditional sectors, issues and political boundaries. Adaptation will generally be slow to be implemented, and adaptive capacity slow to develop, without involvement of all levels of government and other decision-makers. Coping with the impacts of climate change ideally involves a planned response that allows for the identification, prevention and resolution of problems. Appropriate government policy frameworks may help achieve a systematic and efficient response. Of the Prairie Provinces, planning is most advanced in Alberta, where the provincial government has initiated province-wide and multi-sectoral vulnerability assessments and adaptation strategies (Barrow and Yu, 2005; Davidson, 2006; Sauchyn et al., 2008). The private sector, social institutions and individuals must also adapt to the climate change impacts most relevant to their situation.

ADAPTATION – THE LINK TO GREENHOUSE GAS EMISSIONS

Some adaptation measures also have an impact on greenhouse gas emissions (the emissions driving much current climate change). For example, improving building insulation to reduce heating and cooling costs has the co-benefit of reducing energy consumption and greenhouse gas emissions. Natural grasslands and low-till agricultural systems are good adaptations to drought conditions, but also retain and absorb CO_2. Protecting forests from fire or decay also helps prevent the release of greenhouse gases. Promoting climate adaptations that have such emissions-reducing co-benefits is especially important.

KEY CONCLUSIONS

- There will be lower summer streamflows, falling lake levels, retreating glaciers and declining soil moisture. Less water will be stored as winter snow and ice – historically a reliable and important source of water. Water scarcity may constrain economic and population growth in Alberta.
- Within the framework of an environment that is tracking warmer and drier, there will be more flood events, severe storms and climatic extremes. The climate is becoming increasingly variable season to season and year to year.
- Droughts of extreme severity or long duration are an increasing threat to communities and industries, particularly agriculture.
- Generally summers will be especially dry.
- Much of the projected temperature increase will occur in winter and spring. There will be reduced energy demand for heating and higher demand for cooling.
- A shorter, warmer, winter season will make winter ice roads less viable and will hinder some forestry and energy industry operations. Some agricultural and forest pests will survive warmer winters more easily – mountain pine beetle is a serious threat. Ice-fishing, snowmobiling and skiing may decline.
- Higher potential forest, grassland and crop productivity from increased heat and atmospheric CO_2 will be limited by available soil moisture.
- There will be major ecosystem changes. Aquatic habitats will be stressed and some fish and waterfowl populations will decline. Non-native plants and animals will appear on the landscape, while some native species will decline or disappear entirely. The southern boreal forest is at serious risk.
- Some vector-borne diseases, such as West Nile virus and hantavirus pulmonary syndrome, could become more common.
- The most vulnerable people to climate change impacts include the elderly, children, the poor, those with underlying health problems, farmers, and Aboriginal peoples.
- Adaptation to climate change is necessary. Minimum tillage practices and crop diversification in the agricultural sector, infrastructure and water conservation programs across the Prairies, new water policy in Alberta, and re-engineering of the Red River floodway in Manitoba, have enhanced resilience and increased adaptive capacity.
- Climate change impacts are on-going, and the acceleration of impacts is now inevitable. To avoid the most damaging worst-case climate change impacts scenarios, significant reductions in greenhouse gas emissions are urgently required.

Figure 18: *Rainfall over the Hand Hills, Alberta*

PHOTO CREDITS

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