Saskatchewan's Natural Capital in a Changing Climate: An Assessment of Impacts and Adaptation

PARC
PRAIRIE ADAPTATION RESEARCH COLLABORATIVE

SUMMARY DOCUMENT

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INTRODUCTION

Climate change impacts in Saskatchewan are already evident, and will become increasing significant over time. This report draws on the expertise of top climate change researchers and a large body of previous work to create a state-of-knowledge synthesis of key biophysical impacts and adaptation options specific to Saskatchewan. The focus is Saskatchewan's ecosystems and water resources and the sectors of our economy, agriculture and forestry, which are most dependent on these natural resources. The purpose of this report is to 1) document the expected impacts of climate change on Saskatchewan's natural resources and dependent industries, and 2) outline options for adaptation of resource management practices, policies and infrastructure to minimize the risks associated with the impacts of climate change and to take advantage of opportunities provided by a warming climate.

PAST CLIMATE AND RECENT TRENDS

Saskatchewan has one of the world's most variable climates. There is a large difference in mean temperature and precipitation between the southwest and northeast corners of the province, as shown in Figure 1 for precipitation. The distinction between the southern grassland and northern forest regions is made throughout this report. There is also a high degree of variability between seasons, years and decades. Figure 2 shows the rise in mean annual temperature since 1895 for five locations across Saskatchewan. Recent temperature trends strongly suggest that Saskatchewan is not getting much hotter, but rather ''less cold''; there has been a larger increase in daily minimum (as opposed to maximum) temperatures and the largest warming has occurred during winter and early spring, resulting in a longer frost-free period and more growing degree days. With a warmer, longer summer the deficit between precipitation and potential water loss by evapotranspiration has been growing (1 to 4 mm/yr in southern Saskatchewan). The recent droughts of 2001-2002 were less prolonged and severe than the Prairie-wide droughts in the early part of the 20th century (1915 through the 1930s), but were among the 10 worst. 2001-2002 was the worst two-year drought since 1929-1930, while 2002 was one of the worst one-year droughts on record.

Natural archives, such as lake sediments, tree rings and sand dune deposits, preserve the response of ecosystems to climate fluctuations and thus provide a record of historical climate variability and analogues of future climate. Reconstructions of the climate of the past several millennia reveal multi-centennial shifts in moisture regimes and also droughts that are more severe and prolonged in the centuries before Saskatchewan was settled by EuroCanadians. This longer view of the climate suggests that the climate that we have experienced in Saskatchewan over the past half century, while variable, did not include the range of climate conditions of the recent (pre-instrumental) past or the range projected for the near future under global warming.

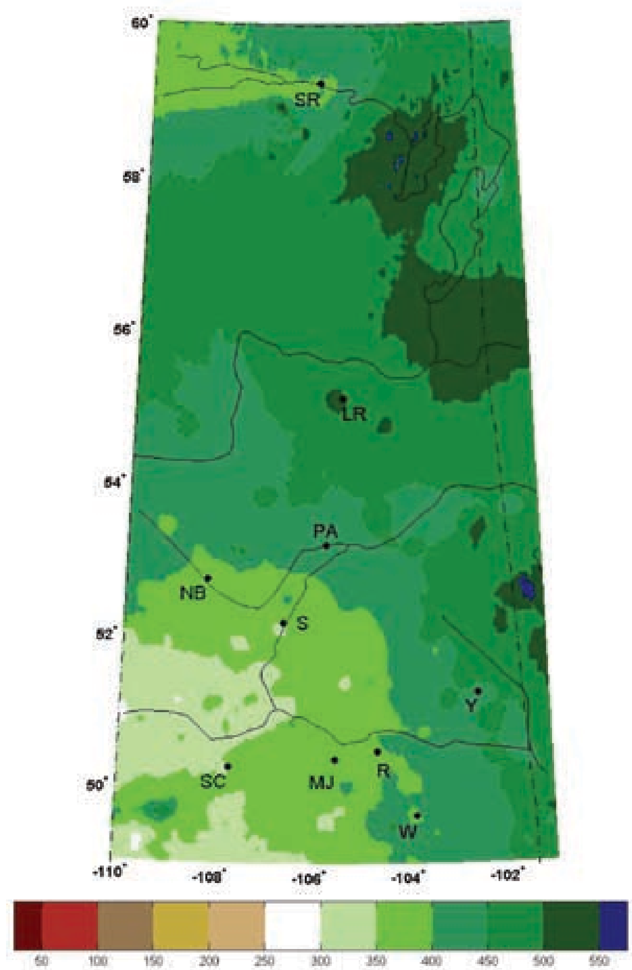

Figure 1: *1961-1990 averaged annual precipitation totals (mm) for Saskatchewan. SR – Stony Rapids; LR – La Ronge; PA – Prince Albert; NB – North Battleford; S – Saskatoon; Y – Yorkton; SC – Swift Current; MJ – Moose Jaw; R – Regina; W – Weyburn.*

SCENARIOS OF FUTURE CLIMATE

In the their most recent assessment report, the Intergovernmental Panel on Climate Change (IPCC 2007) concluded that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level". The Canadian Prairies have warmed at a faster rate than the global average and our future climate will be outside the range of natural variability.

Following recommendations outlined by the IPCC, Barrow (2009) produced new scenarios of climate change for Saskatchewan using the most recent results from global climate models. These scenarios were constructed by determining the changes in average climate for the 30-year periods centred on the 2020s (2010 2039), 2050s (2040 2069) and 2080s (2070 2099), relative to the 1961-1990 baseline period. Scenarios were selected based on the smallest, largest and median changes in an annual index of climate moisture.

Across a range of global climate models and greenhouse gas emission scenarios, there is a consistent increase in

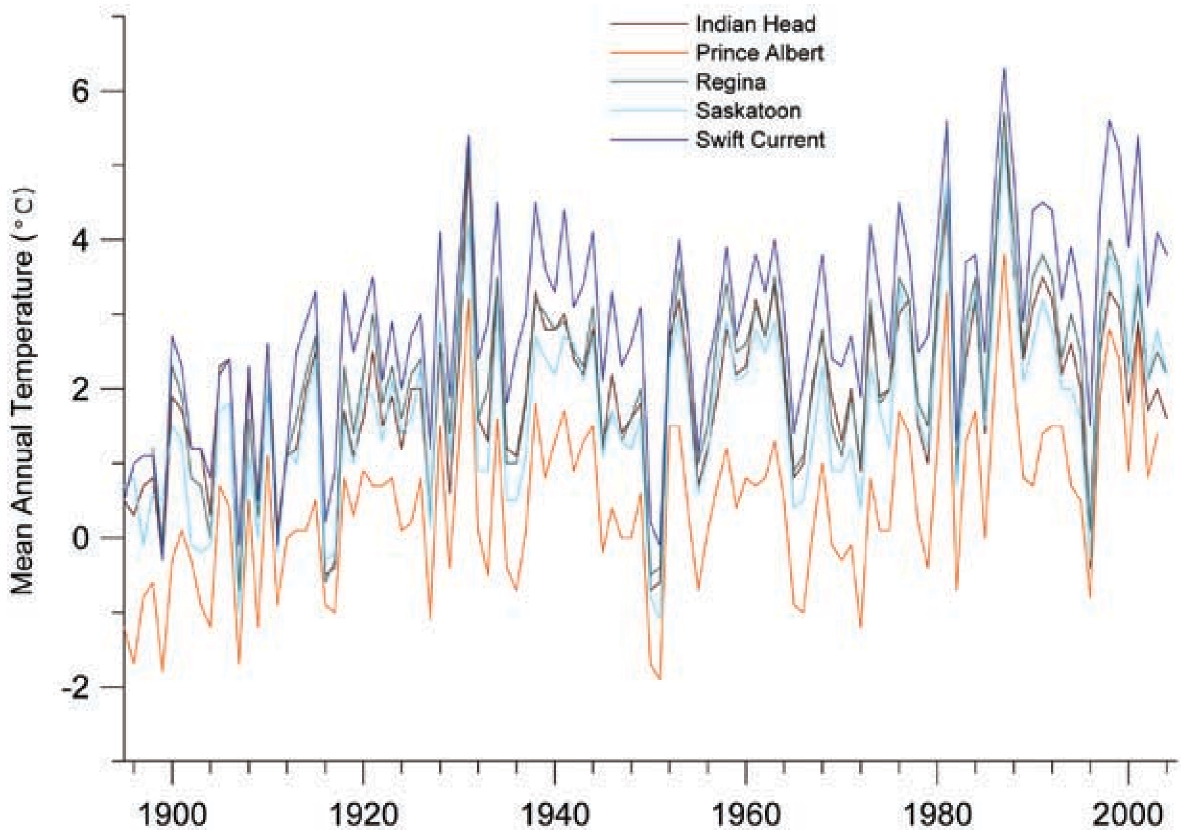

Figure 2. *Mean annual temperature records for five Saskatchewan communities.*

future annual temperature and precipitation throughout Saskatchewan, as shown in Figures 3 and 4, which are plots of seasonal temperature change and precipitation change by the 2050s for the grassland and forest regions. These climate changes impact many activities, especially agriculture. When within the year extra heat and water will be available is an important question. Most of the warming is occurring in winter. The frost-free growing season is getting longer, but we are also losing some of the advantages of a cold winter that enables transportation over ice and frozen ground in northern Saskatchewan, prevents many pests and diseases, and stores water as snow – our most abundant, reliable and predictable source of water. Most of the extra precipitation is expected in winter and spring and increasingly in the form of rain as the climate warms. Scenarios of summer precipitation are less consistent but many include decreased summer precipitation falling in fewer and more intense storms. Thus, on average, the mid to later stages of longer warmer summers will tend be drier, possibly much drier.

Overall, on an annual basis, our climate will be drier, owing largely to increased evapotranspiration from warmer temperatures. This trend is mapped in Figure 5 for the grassland region for the baseline period and for three scenarios for the 2050s using the annual moisture index (defined as the ratio of total annual degree days above 5°C to annual precipitation). Projections for the forest region are similar. While a shift to warmer wetter winters and drier summers is almost certain, most of the risk from climate change will be an increase in the year-to-year variability, and from climate scenarios that project drought and unusually wet years with greater severity and frequency than in the past.

Annual mean temperatures are expected to rise at all sites (Figure 6). For the grassland region, annual temperature at seven selected sites increases such that by the 2020s, it is at least 1°C warmer than baseline conditions at all sites, and for Yorkton 3°C warmer. Precipitation is also projected to increase across all sites and all time periods (Figure 7).

The annual moisture index gives an indication of moisture availability for plant growth as a function of the ratio of temperature to precipitation. This index increases across all time periods for all sites (Figure 8). By the 2080s, the index values suggest more arid conditions overall and the potential for higher moisture stress. Effectively, what is happening is that increased evapotranspiration, driven by warmer overall temperatures, overwhelms the effect of increased precipitation, and leads to drier conditions.

WATER RESOURCES

Saskatchewan's environment, ecology and economy are water dependent and so are strongly impacted by hydrological cycling and water supply fluctuations. We have extensive periods of water shortage and excess, a strong seasonality in surface water supply and a general cool semi-arid to cold sub-humid climate. Many of our ecological and economic activities use close to or all available water and so we are particularly vulnerable to further variations in water resources due to climate change. For instance, our two major

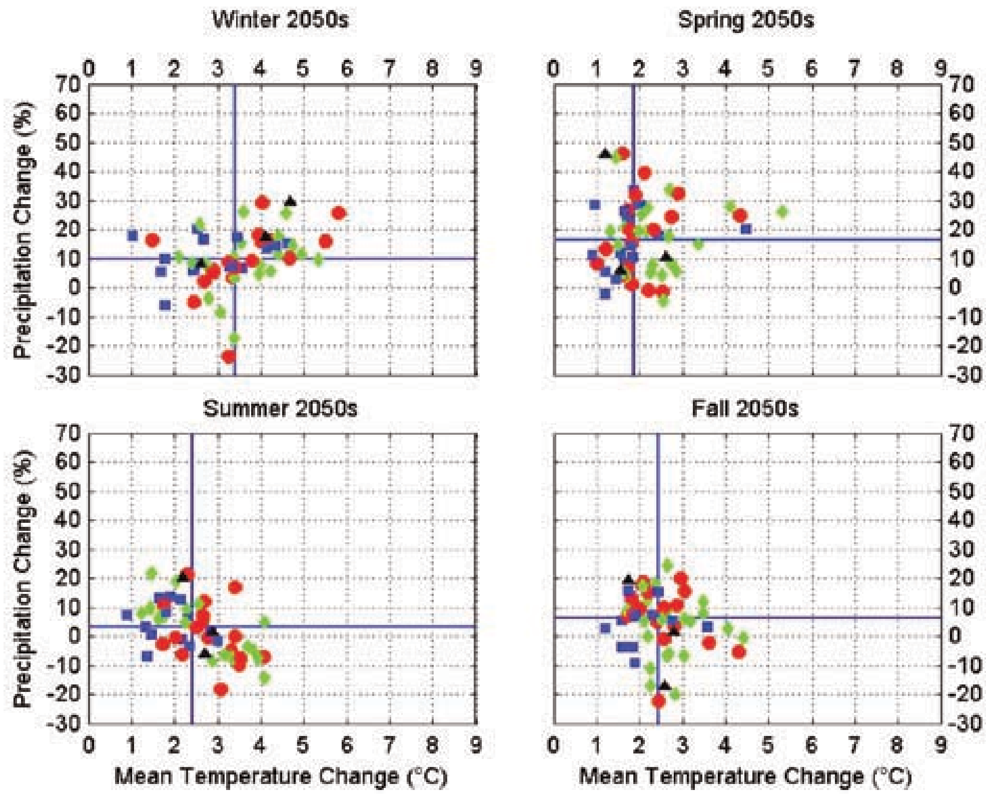

Figure 3: *Scatter plots indicating seasonal changes in mean temperature (°C) and precipitation (%) for the grassland region of Saskatchewan for the 2050s. The different coloured symbols represent different emissions forcings: green diamonds – A1B, blue squares – B1, red circles – A2. Black triangles indicate the three scenarios selected based on minimum, maximum and median change in annual moisture index. Blue lines indicate the median changes in mean temperature and precipitation for this suite of scenarios.*

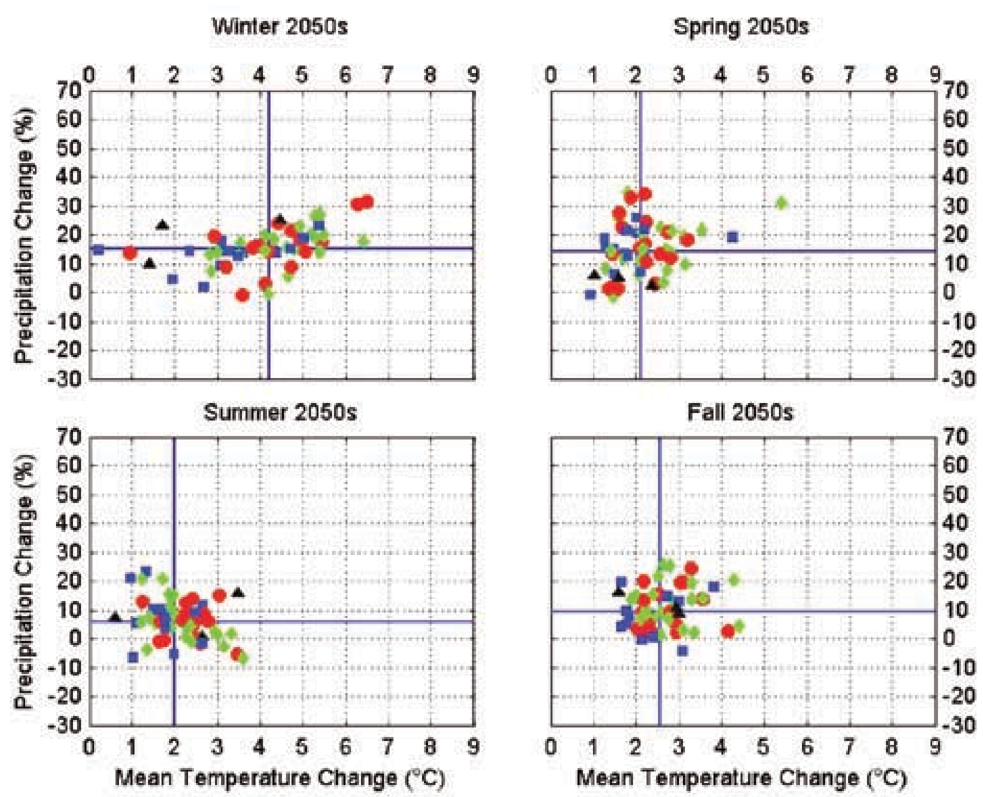

Figure 4: *Scatter plots indicating seasonal changes in mean temperature (°C) and precipitation (%) for the forest region of Saskatchewan for the 2050s. The different coloured symbols represent different emissions forcings: green diamonds – A1B, blue squares – B1, red circles – A2. Black triangles indicate the three scenarios selected based on minimum, maximum and median change in annual moisture index. Blue lines indicate the median changes in mean temperature and precipitation for this suite of scenarios.*

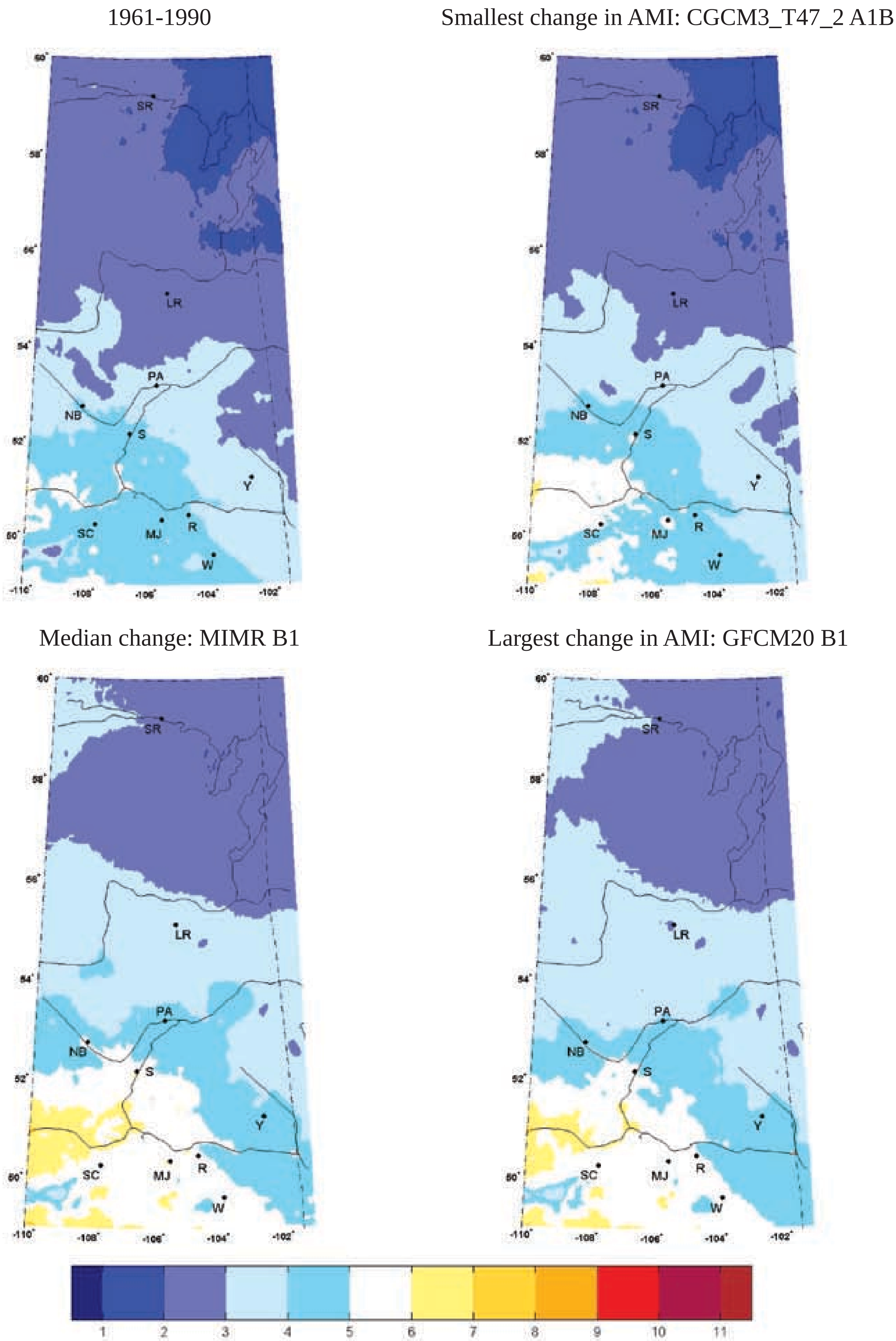

Figure 5: *Annual moisture index for the 2050s, selected based on AMI change over grassland region of Saskatchewan.*

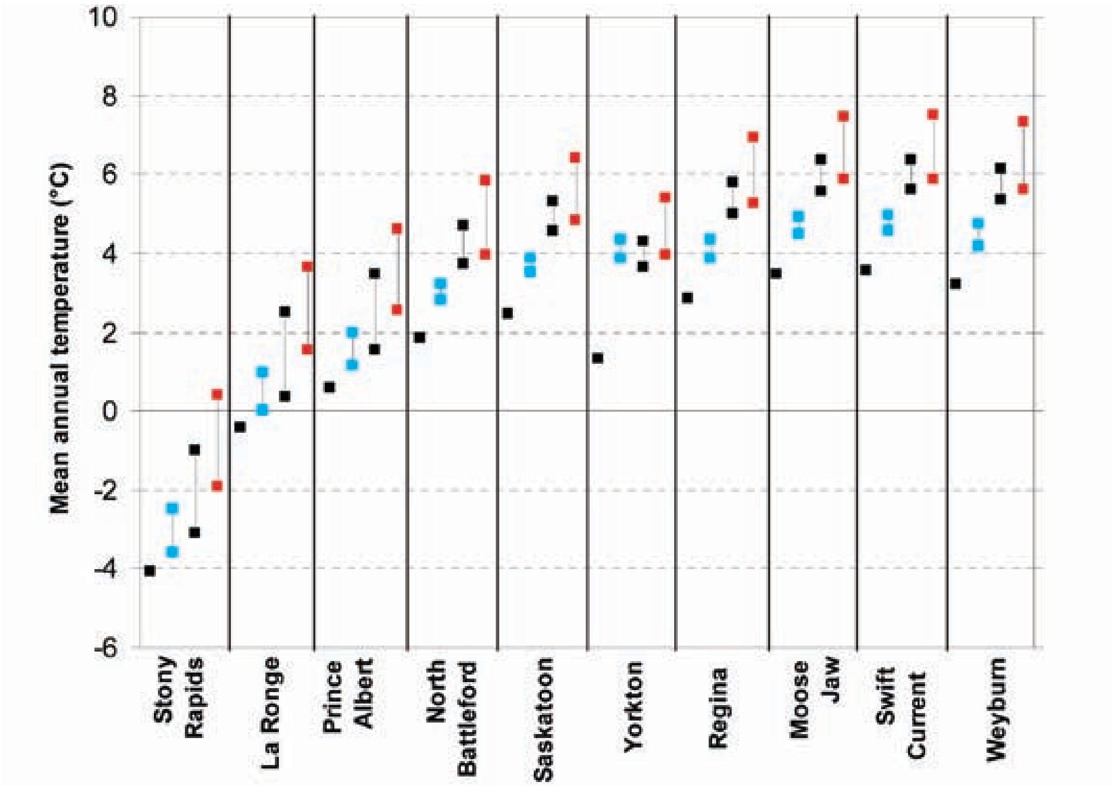

Figure 6: *Annual mean temperature (°C) for the forest and grassland sites in Saskatchewan. At each site there are four blocks of data: 1961-1990 baseline (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines). The scenario range has been calculated from the results of the three selected scenarios for each region.*

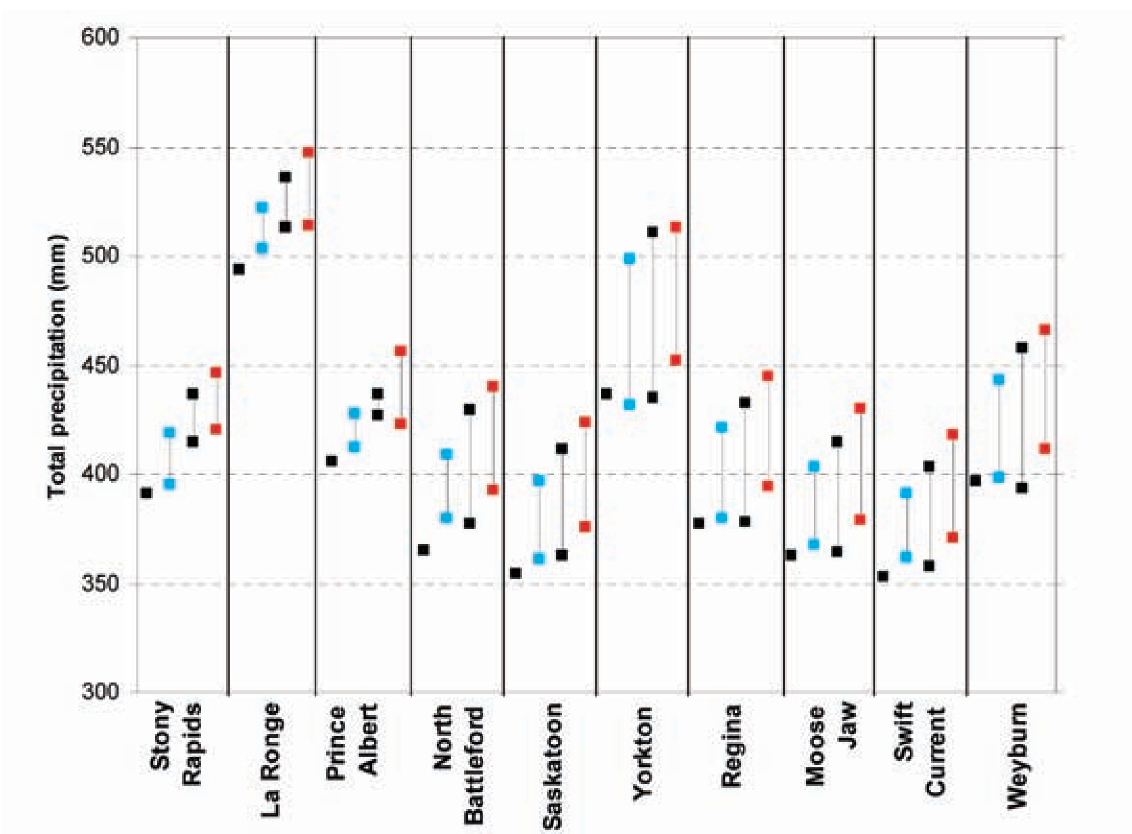

Figure 7: *Annual total precipitation (mm) for the forest and grassland sites in Saskatchewan. At each site there are four blocks of data: 1961-1990 baseline (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines). The scenario range has been calculated from the results of the three selected scenarios for each region.*

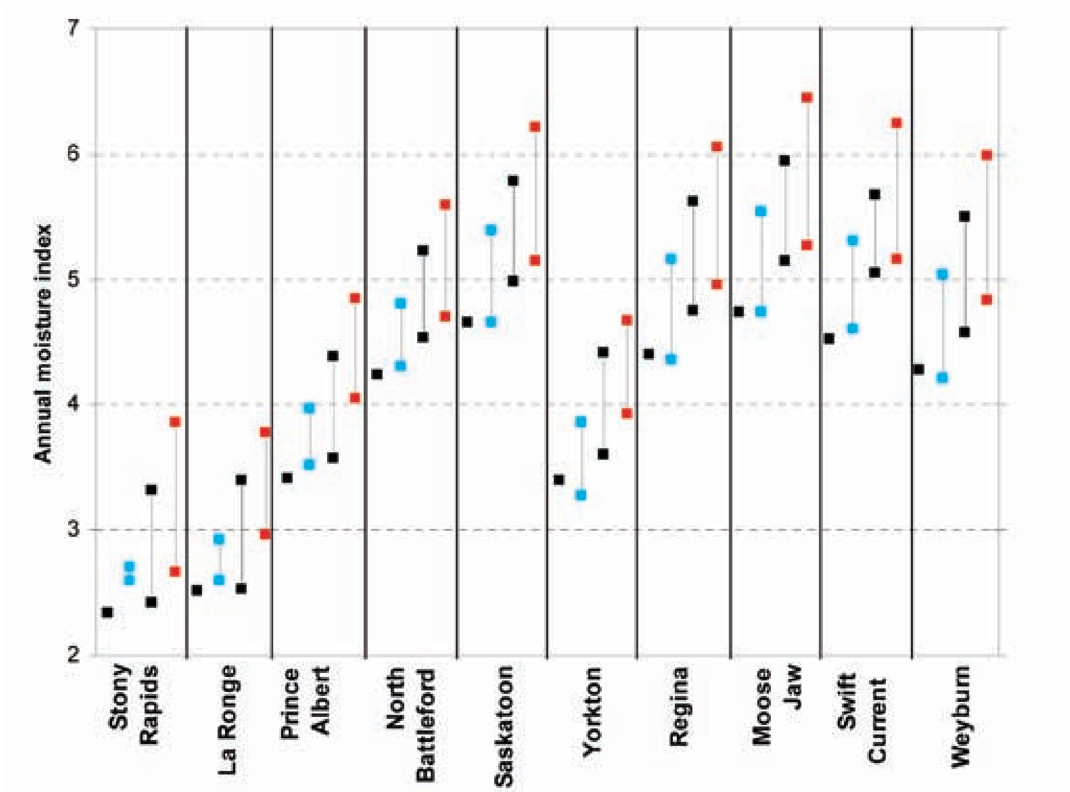

Figure 8: *Annual moisture index for the forest and grassland sites in Saskatchewan. At each site there are four blocks of data: 1961-1990 baseline (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines). The scenario range has been calculated from the results of the three selected scenarios for each region.*

economic disasters in the province have been due to lack of available water in the drought of the 1930s and the recent drought of 1999-2004. In 2001-2002, the national loss of $6 billion in GDP and the disappearance of 41,000 jobs due to lack of water largely occurred in Saskatchewan. It is therefore prudent to examine what features of our climate, hydrology and water resources make our response to changes in water supply potentially unique, what are the anticipated impacts of climate change on our water resources, and what water management options are available or should be considered to minimize the risk caused by climate change.

Saskatchewan's water

Saskatchewan's hydrology is characterized by low precipitation which mostly evaporates leaving little for runoff. This means that local-scale water resources are quite limited and very sensitive to changes in climate and land cover. The perception of plenty caused by seeing stored water in lakes, snow covers, and wetlands does not match the reality of low flow rates in the hydrological cycle. Prairie province hydrology is dominated by cold region processes so that snowmelt is the primary hydrological event of the year for both the major rivers that derive from the Rocky Mountains and small streams and rivers that arise in Saskatchewan. Climate change impacts on water resources are therefore focused on changes to snow accumulation, snowmelt, and infiltration to frozen soils. Large-scale hydrological models that take into account the warmer and wetter winters projected for Saskatchewan suggest changes in the annual streamflow of the South Saskatchewan River ranging from an 8% increase to a 22% decrease, with an 8.5% decrease being an average prediction. Small-scale hydrological models for prairie streams suggest a 24% increase in spring runoff by 2050 followed by a 37% decrease by 2080 as the winter snowcover becomes discontinuous. Both model results suggest that there is not a dramatic drying of the prairies to be anticipated in the short term under climate change and that in some cases streamflow will increase for certain scenarios and under moderate degrees of climate change. While prairie runoff should increase in the near term, as climate change progresses later in the 21st C there will be dramatic drops in runoff and in the flow of small streams to wetlands and depressions and to small prairie rivers. What these studies do not address is the longer summers and longer periods of evapotranspiration that will result in drier soils for more d ays in summer. So while river and streamflows might be reduced by small amounts or even increase, water needs for agriculture will likely increase and so pressure for irrigation of farmland using river water will increase. These studies also do not address the potentially increasing year-to-year variability, for example, drought years, where pressure on water resources from increased demand and diminished supply will likely cause a crisis in future years.

Most of Saskatchewan's water use is in the south, while most of the water is in the north. Much of the provincial population is now located in several large centres which require secure, high quality and steadily increasing municipal supplies; these centres also produce waste water that must be treated. Drought in the south has shown that many local surface water supplies are unreliable and alternatives are being increasingly explored. The major water resource of the south is the South Saskatchewan River which has been substantially developed as a water resource. The share of extracted surface water used in the South Saskatchewan River Basin (SSRB) for agriculture is 86.5%, with only 8.7% going to municipal use, 3% for thermal and 1.8% for industrial use Martz *et al*. (2007). More efficient water use for irrigation or a reduction in irrigated acreage in Alberta could compensate for the reduced water availability, which is due mainly to reduced mountain snowmelt.

Saskatchewan should evaluate its plans for increased irrigation very carefully in light of reduced water availability from Alberta due to consumption and climate change. It

Case Study: Flow Rates of a Typical Prairie Stream: Management Challenges

An example of a prairie streamflow regime is that of Smith Creek in the eastern part of the province. The creek drains up to about 400 km^2 and normally peaks during and just after snowmelt, becoming dry by midsummer, and remaining so until the subsequent spring (Figure 9). It is highly variable from year to year with daily peak flows of almost 24 m^3/s during flood to minimal yearly flow in times of drought. Streams with such intermittent and variable flow regimes are not normally usable for water supply without impoundment as reservoirs. However, reservoir management of such variable streamflow is challenging in periods of extreme drought or water excess. Hence few prairie streams are managed for substantial water consumption or irrigation; the most reliable water supply comes from groundwater and rivers that originate in the Rocky Mountains in Alberta.

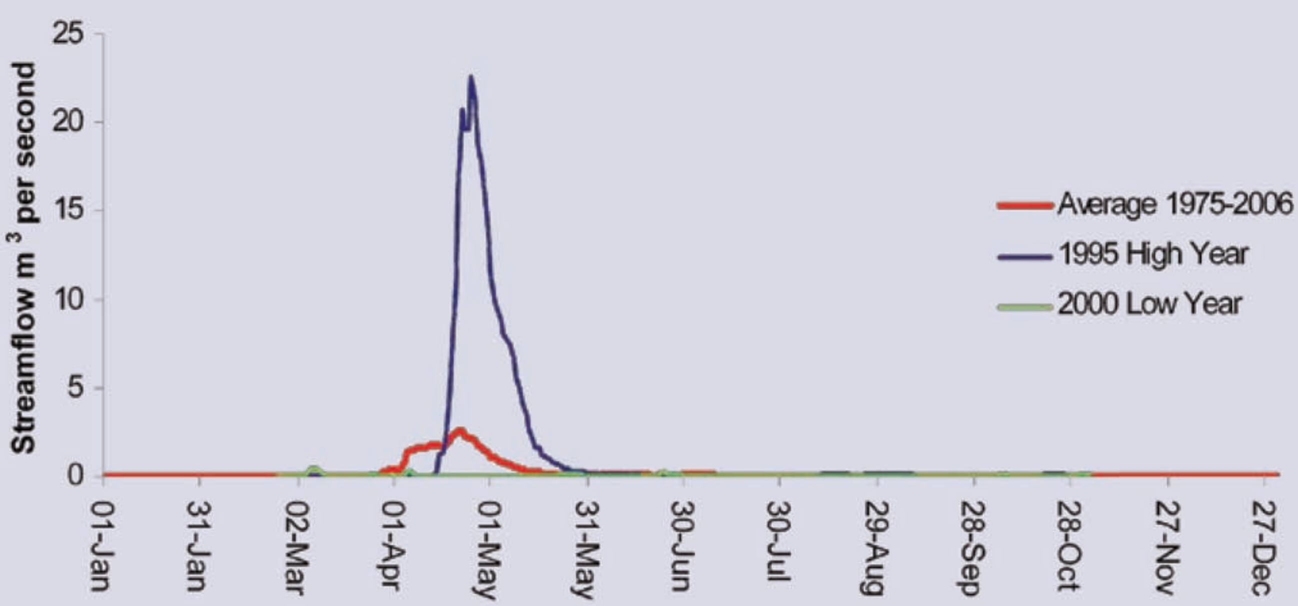

Figure 9. *Annual hydrograph of a small prairie stream, Smith Creek, near Langenberg, SK.*

is possible in drought years that unless Alberta acted to reduce irrigation demand, streamflows downstream of Lake Diefenbaker could be negatively affected to a degree not experienced since the dam was constructed. This would have direct impact on ecological instream flow needs and water supplies for Saskatoon, Regina and Moose Jaw in addition to smaller centres. Infrastructure will have difficulty keeping up with the impact of change on water resources unless agricultural land management is used to compensate for changes in hydrology. New crop varieties and tillage methods which are able to leave some water for runoff to natural ecosystems will need to be devised. Drainage of wetlands may have to be reversed to limit high spring streamflows and wetland/lake levels.

Climate change can make current water practices unsustainable from an ecological perspective. The current data and projections however, do not predict ecological collapse, nor do they say that current projections in economic and population growth are unstable. If, on the other hand, current human consumption is close to ecological limits, then climate change can make current consumption unsustainable. With this in mind, if consumption does not change to accommodate the potential fall in water supplies, then extreme water stresses may transpire along with a potential ecological collapse within the SSRB. Integrated basin management of the South Saskatchewan River across both Alberta and Saskatchewan and for smaller watersheds in Saskatchewan is the preferred adaptation method for dealing with these uncertainties. Integrated basin management plans with apportionment powers, enforceable land use controls and agricultural management incentives will need to be implemented to deal with rapid changes and increased uncertainties in water management designs.

ECOSYSTEMS

In a global analysis, climate change is rated as second only to land use in importance as a factor that is expected to determine changes in biodiversity over the current century (Sala *et al.* 2000). In Saskatchewan's case, given relatively low population density and relatively stable land use, climate change may in fact exceed land use change as the dominant factor causing change to biodiversity and ecosystems. This will be particularly so in northern Saskatchewan, the part of the province least actively managed and with the lowest population density.

Saskatchewan faces major climate change impacts on ecosystems and landscapes that will combine and interact with impacts of land use activities. Increasing growing season aridity is the single most important ecosystem impact and also represents a major biodiversity management challenge. Changes in climate will alter environmental conditions to the benefit of some species, and detriment of others, often with economic consequences. As vegetation and animals shift in response to changing climate, tourism and recreation activities and agricultural, forestry and urban pest management practices will have to adjust.

Some research suggests that climate variability is increasing (Kharin and Zwiers 2000). This means that not only is "average" climate changing, but that incidence of extreme climate events, i.e. deviations from average climate, may increase in frequency and duration. Such events can have major ecosystems impacts. For example, the Prairies drought of 2001-02 reduced the net production of aspen stands to near zero owing to reduced growth and increased mortality (Hogg *et al.* 2008). The prolonged Prairies droughts of the 1930s caused major changes in grassland composition – taller and more moisture-demanding species such as western porcupine grass and wheatgrasses decreased in relative abundance while shorter and more drought-tolerant species such as blue grama increased (Coupland 1959). If droughts become more frequent, or intense, resultant vegetation composition and range shifts are certainly possible.

The boreal forest is expected to be significantly affected by climate change, especially at its southern boundary (Scholze *et al.* 2006, Carr *et al.* 2004, Henderson *et al.* 2002), where tree growth is typically moisture limited. In the northern boreal region, however, where the growth limitation is heat, productivity may well increase. The key climate change impacts on forest ecosystems are an increased rate and

A healthy eco-system

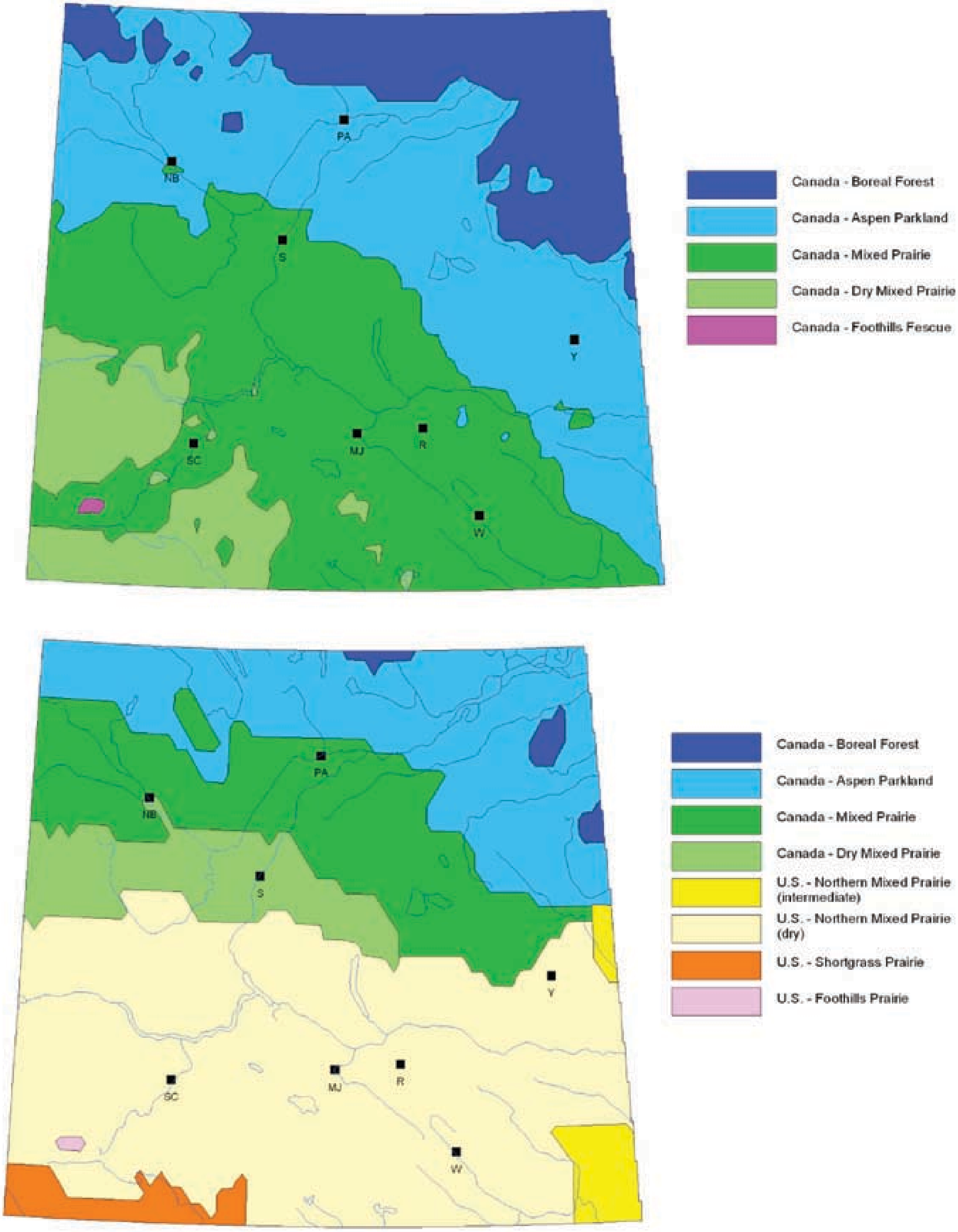

Figure 10: *Vegetation zonation in southern Saskatchewan as predicted by ecoclimatic models (Vandall et al. 2006). The upper map shows the zonation resulting from 1961-90 climatic normals. The lower map shows the predicted zonation resulting from the HadCM3 B21 scenario for the 2050s.*

intensity of forest disturbances, such as fire and pathogens, and the possible loss of forest cover in grassland-forest ecotone regions, that is, the southern boreal forest and the island forests of the Prairie Ecozone (Hogg and Bernier 2005).

Thorpe and Godwin (2009) modelled native and non-native tree species ranges under a suite of climate change scenarios. Native conifers will be significantly impacted by increasing aridity and decline in the southern parts of their current range, while the boreal hardwoods, in particular aspen, may prove more robust and more able to persist in their traditional ranges. As they are relatively small ecosystems, island forests may exhibit lower genetic diversity and greater vulnerability to catastrophic disturbance, such as wildfire, pathogen attack or severe drought.

A potential increase in plant productivity with a longer and warmer growing season, and increasing atmospheric CO_2, may be limited or overwhelmed at many sites by moisture limitations or other constraints. New landscape ecosystems might evolve; for example, a drier climate in southern Saskatchewan could potentially support shortgrass prairie currently found farther south. Vandall *et al.* (2006) modelled the shifts in Saskatchewan vegetation zones resulting from three climate change scenarios for the 2050s. Vegetation zones in the Great Plains of the United States were used as analogues for the warmer future climates projected for Canada. Results for one of these scenarios are shown in Figure 10 (all scenarios gave similar results). Most of the boreal forest up to 54° latitude is replaced by aspen parkland. Most of the aspen parkland is replaced by mixed prairie. Most of the Canadian mixed prairie is replaced by U.S. mixed prairie *(i.e.* the kind of mixed prairie found in Montana, Wyoming and the Dakotas). The driest area, in southwestern Saskatchewan, shifts to shortgrass prairie, currently found from Colorado southward.

In Saskatchewan, grassland production is chiefly limited by moisture supply. While the warmer and drier climate projected for Saskatchewan 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, Thorpe 2007).

The increased stress on aquatic ecosystems from warmer and drier conditions, and loss of wetlands, could place prairie aquatic species at risk of extirpation and cause declines in migratory waterfowl populations. The prairie pothole region of central North America is the single most productive habitat for waterfowl in the world, with the Canadian Prairies producing 50% to 80% of the Canadian duck population (Clair *et al.* 1998). As a long-run trend, increasing aridity in the prairie grasslands is likely to negatively impact migratory waterfowl populations as waterfowl numbers decrease in response to drought and habitat loss.

We have many adaptation options, and some alternative choices about future ecosystems, but it will not be possible to maintain Saskatchewan's ecosystems as they were or as we know them now. The new climate-driven reality is that biodiversity managers need to think of themselves not as practitioners of preservation, but as "creation ecologists", since antecedent landscapes can no longer be effectively targeted. We have options, but the past is not one of them. Passivity in the face of impacts may shrink our ecosystem options, particularly in Prairie forests. However, active management entails some risk and expense. Whatever options we choose, the future ecosystems that result from climate change in Saskatchewan will be unprecedented.

SOIL RESOURCES

Soil is a major element of Saskatchewan's natural capital and historically the basis for the regional agricultural economy. Among the most active landscapes on earth are semiarid valleys and dune fields, such as those in the driest parts of Saskatchewan (Lemmen *et al.* 1998). Prolonged dry and wet spells have a strong influence on the resistance of soil and vegetation to hydroclimatic events (strong winds,

Slope and aridity make these soils prone to erosion intense rain, rapid snow melt). Widespread reactivation of sand dunes about 200 years ago is correlated with tree-ring evidence of prolonged droughts of the mid to late 18th century (Wolfe *et al.* 2001).

The climate scenarios outlined above, with longer drier summers occurring more often, could cause Saskatchewan's soil landscapes to respond with local instability and erosion. This could include erosion and shallow slope failure caused by less frequent but more intense rainfall, and more widespread wind erosion, sand dune activity and dust storms, with impacts on health, tourism, transportation and agriculture. There could be a risk of desertification over a larger area as the extent of semiarid to subhumid climate expands beyond southwestern Saskatchewan at soil moisture thresholds below which landscapes are more vulnerable to disturbance and potentially desertified.

With the modification of about 90% of the Prairie Ecozone for agriculture, tens of millions of hectares were exposed to soil erosion. Saskatchewan has the largest share of Canada's agricultural land. Scenarios of future climate and soil moisture conditions demand serious thought about the adaptation required to adjust soil and water management to limit the risk of desertification. Despite the vast area and relatively sparse population of prairie rural Saskatchewan, most of the landscape is managed. Because management practices have more immediate influences on rates of erosion than climate change (Jones 1993), they have the potential to significantly mitigate or exacerbate the influence of climate. An increase in growing degree days could support a northward expansion of agriculture in Saskatchewan, but this would necessitate an assessment of the sensitivity of these soil landscapes to both climate change and a changed surface cover. Conversely, as the semiarid southwest becomes more arid, the soil landscapes may be at greater risk of desertification. Adaptation to minimize the impacts of climate on soil includes protecting soil landscapes from degradation during extreme hydroclimatic events, that is, storms and drought. Soil conservation has been an integral part of the adaptation of farming practices to the dry and variable climate of the interior plains (Sauchyn 2007). Land degradation is preventable throughout the subhumid Prairie Ecozone under current climatic conditions, policy framework and crop and soil management regimes. With better soil, water and crop management, the production of cereal crops has become less vulnerable to climate variability, although not to sustained drought. Within the last 20 years, different cropping systems and the adoption of soil conservation practices, specifically reduced tillage and zero-till, have begun to reverse the decline in soil productivity across the prairies crop land. Soil conservation practices can be defeated, however, by extreme climatic events and especially by consecutive years with droughts. Institutional adaptive responses to the soil degradation crisis of the 1980s-90s have reduced sensitivity of soil landscapes to climate over a large area. Other institutional mechanisms are required to provide rewards and incentives for adaptive soil and crop management practices that reduce vulnerability to climate change.

AGRICULTURE

Agriculture is a vital sector for food security and both rural and urban development. Agriculture in Saskatchewan is exposed to among the most extreme climate conditions in Canada. Most of the largest year-to-year differences in production of both crops and livestock are related to weather and climate. Many of the important on-farm and other agri-business decisions are made considering the threats and opportunities of weather and climate. This combination of exposure, sensitivity, and variable adaptive capacity makes agriculture relatively vulnerable. Current and future climate change is adding further stresses and opportunities for agriculture. This means that much better, more proactive, planned and effective adaptation and an enhanced understanding of potential impacts are required.

Climate impacts on the agricultural sector and adaptive responses are already occurring and these are likely to accelerate in the future. Changes in many agro-climatic variables, including growing season length, accumulated

After the harvest

heat units, and precipitation are fairly well documented and recognized. Climate variability is a main determinant of crop yield. Future climate change impacts on crop production are still uncertain, but they are consistent with recent changes and tending to converge towards increasing productivity in the near term until certain thresholds of climate change are reached. This upward trend is then followed by average decreases and interrupted by large losses accompanying severe climatic events, such as droughts and excessive moisture. The complex interactions of the effects of insects, diseases, and weeds on agricultural production are still not understood well enough to offer substantial findings for projected impacts. The loss of cold winters is contributing to the increasing risk of some pests, reduced water (snow) storage, and other problems. Conflicts over increasingly scarce water supplies are one of the most serious risks for agriculture and society. Projections of temperature increases are more certain than the slight annual precipitation increases, and the resulting higher evaporative demand is a strong driver of summer surface water deficits. Although warming winters are generally favourable for livestock production and management, increasing threats of stresses related to heat, water, insects and diseases, and other climate hazards tend to offset gains.

Extreme weather and climate are “wild cards”. A trend of increasing frequency and severity of extreme events is fairly certain, but the detrimental effects are not considered well or at all in future estimates of agricultural production. Prairie drought is Canada’s most costly natural hazard (Wheaton *et al.* 2005, 2008). Observed changes in drought show that some of the projected changes are already occurring. Droughts have shown an increase in intensity and duration globally since the 1970s (Dai *et al.* 2004).

Adaptation needs to be proactive, effective, innovative, and strategic and in some cases, places, and times, substantive, including changes to management and policy regimes. Enhanced adaptation would be beneficial now. Policies and institutions are currently constrained in their adaptive capacities to deal with climate change by weak networks with science and ability to use climate information. Agriculture is also expected to play a role in mitigating greenhouse gas emissions and storing carbon, amid many other challenges, including markets, and energy and food security issues. Appropriate integration of both adaptation and mitigation in agriculture is needed to ensure that they are coordinated and mutually supportive. Climate change information must be mainstreamed into strategic, operational, and policy considerations. Beneficial farm management practices, with adaptive components, may be useful in dealing with adaptation deficits. Best management practices that enable coping with droughts and climate change include water well management, land management for soils at risk, cover crops, nutrient recovery from waste water, irrigation, enhancing biodiversity, grazing plans, and integrated pest management planning.

FORESTRY

The Provincial Forest (*i.e.* the managed forest) in Saskatchewan makes up 54.5% of the total provincial land area. Most timber of commercial value in Saskatchewan is in the southern boreal forest, where the relatively warm climate and deep soils support a diverse and productive mix of pure conifer forests and extensive mixedwood forests consisting of white spruce, jack pine or black spruce mixed with trembling aspen, balsam poplar or white birch. Wetlands dominate almost half of the land base. Forests give way to grasslands where potential evapotranspiration exceeds precipitation. Many forests in this latter area grow on poor sites and are frequently subject to drought, insect attack, mistletoe and fires (Hogg and Bernier 2005).

Forests in Saskatchewan are already vulnerable to a range of climate and natural disturbance factors, and may be more vulnerable to climate change than other forest regions in Canada. Along with northern Manitoba and northwestern Ontario, northern Saskatchewan experiences the highest rate of fire disturbance in Canada (Balshi *et al.* 2009). Fires, insects and drought have had major impacts on the forest and will continue to do so regardless of climate change.

Case Study: Pulse Crop Futures

The area sown to pulse crops in the northern plains has accelerated in the last twenty years, with warmer longer growing seasons, especially in the semiarid regions where dry pea, chickpea, and lentil are used to extend the traditional wheat-fallow crop rotations (Cutforth *et al.* 2007). This rapid increase of pulse crop adoption appears to be a useful adaptation to warming climates and provides other benefits, *e.g.* diversification (Cutforth *et al.* 2007). Adaptation strategies discussed by Miller *et al.* (2002) include earlier seeding, use of winter pulses, crop sequencing in rotations, and altering the microclimate. Cutforth *et al.* (2007) examined the resilience of pulse crops to current weather extremes such as drought, excess water, heat, cool weather during grain filling, and early frost in order to explore effects of future climates. Adaptation strategies to cope with accelerated crop growth and crop failures include: earlier seeding, use of winter crops, crop rotations, and adjustments of microclimates (*e.g.* direct seeding), and technologies that increase the WUE of crops and cropping systems. Early spring seeding will improve dry pea productivity in the Canadian semiarid prairies. Management practices can enhance early seedling emergence, prolonged reproductive period, and increased pod fertility. No-till management and the resulting standing stubble are important for improving available water for crops by snow trapping, reducing wind speeds and evaporative demand for water and protection against soil erosion (Cutforth *et al.* 2007). Pulse crops appear to be a suitable strategy for dealing with climate change because of their drought and heat tolerance, efficient water use, and moisture-conserving growth habits.

Sawmill logs

suitability of habitat (McKenney *et al.* 2007). However, this general large scale trend will be affected by the small-scale pattern of landscapes and availability of resources. For example, trees will likely be lost from the southern margin of the boreal forest due to lack of available moisture but will preferentially survive in more northerly locations where rainfall is higher. However, the small-scale pattern of topography will likely result in moisture being sufficient for tree growth in some southerly locations. Therefore, species may persist in some isolated locations, resulting in a fragmented mosaic of forest and grassland rather than a wholesale movement of all tree species to the north.

In addition to ecosystem effects described above, climate change will likely bring change to the physical environment that will affect forest operations. Climate models suggest that winters will warm more than other seasons and that precipitation will increase, with a greater proportion falling as rain (Barrow 2009, Lemmen *et al.* 2008). A major implication for forest operations is the impact on the winter harvest season. In many boreal landscapes, conditions are too wet during the summer, so harvesting and hauling are done in the winter when soils are frozen. In addition, warmer and wetter springs will likely restrict the period of spring hauling, thereby increasing costs and affecting timely delivery to the mill site, with more frequent road closures and impacts to infrastructure *(e.g.* culverts, bridges, stream crossings).

The adaptive capacity of the forest management community in Saskatchewan is high in terms of the ability to implement sustainable forest management (Johnston *et al.* 2008b). However, there is less capacity in terms of the scientific details of climate change impacts; increasing interactions between scientists and managers should be a priority. The concept of "embedded science" can be an effective approach to educating both managers and scientists about implementing adaptation. Considering climate change in forest management will require further information on impacts at a scale consistent with decision-making. Forest management institutions need to be examined for the extent to which they support or hinder the development and implementation of adaptation options. Consideration of new species, assisted migration of existing species and populations, and revised ten ure agreements are examples of policy changes that could assist in more effective adaptation. Local autonomy and flexibility in decision-making will become increasingly important in an environment in which conditions are changing rapidly and where the past is no longer a guide to the future.

Warmer, drier conditions in the future, and interaction of factors, will likely magnify the impacts. Increases in forest fire frequency, more severe fire behaviour and increased area burned are expected (Parisien *et al.* 2004). Mountain Pine Beetle is limited by the occurrence of −40°C temperatures in early winter. With warming, this limiting temperature is likely to occur further to the north and east, allowing the beetle to spread into jack pine in the boreal forest. Recent research suggests increased tree mortality resulting from the interaction of insects, drought and fire in the southern margin of the boreal forest in the Prairie Provinces (Hogg and Bernier 2005, Volney and Hirsch 2005). The southern margin of the boreal forest will become increasingly vulnerable to a range of climate change impacts and may eventually lose forest cover altogether.

On the positive side, there may be some locations where other conditions are not limiting and CO_2 fertilization may result in increased productivity. Forest growth may either increase or decrease under future climate conditions, since the potential effects of CO_2 may be reduced due to limitations in other environmental resources (nutrients, water) or enhanced when other resources are not limiting (Oren *et al.* 2001). Johnston and Williamson (2005) used a forest ecosystem model to explore responses of white spruce productivity under a range of future climate conditions in Saskatchewan. They found that even under severe drought conditions, increased water use efficiency under increased CO_2 concentrations resulted in an increase in productivity relative to current conditions. However, productivity declined by about 20% when this effect was not included in the model.

Research has shown that species will migrate northward, at rates determined by their dispersal abilities and the

Case Study: Island Forests in Central Saskatchewan

The southernmost boreal forest in central Saskatchewan (Figure 11) is characterised by patches of isolated forest cover on sand dune deposits that are somewhat higher in elevation that the surrounding agricultural land (Johnston et al. 2008a). Because of low agricultural suitability these "Island Forests" have remained forested while the surrounding lands have been cleared and farmed. Most of the stands in the island forests are dominated by either jack pine (*Pinus banksiana*) or trembling aspen (*Populus tremuloides*). The island forests are close to the threshold at which moisture becomes insufficient to support continuous forest vegetation. The predominantly sandy soils allow rapid infiltration of rainwater, favoring deeper-rooted trees over shallow-rooted grasses, and allowing forest to develop in this forest-marginal climate.

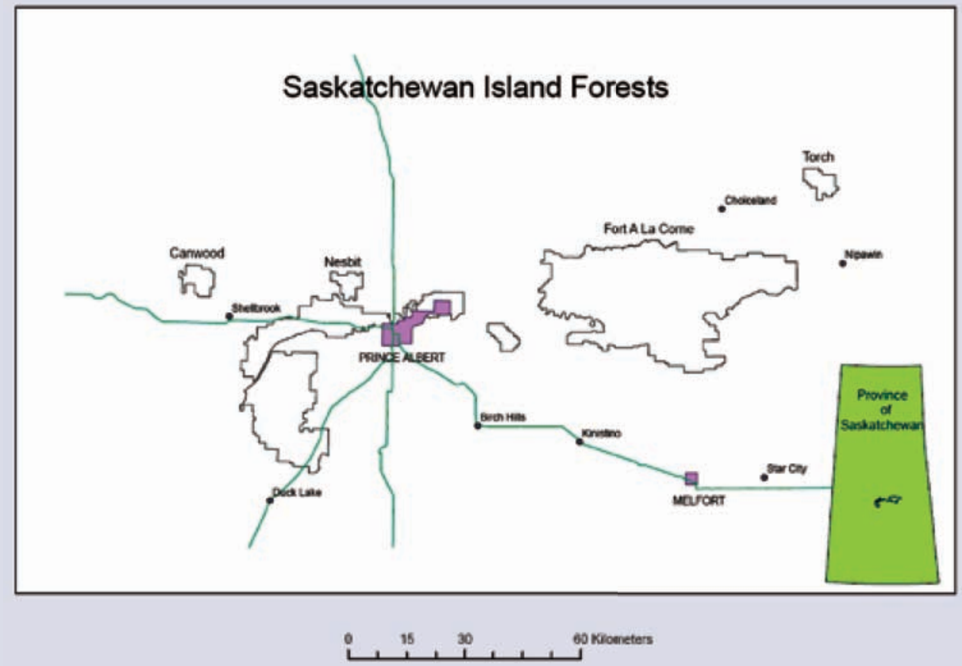

Figure 11: *Location of the Island Forests in central Saskatchewan.*

The Island Forests may already be showing signs of climate change impacts, and are likely to be severely affected in the future (Johnston et al. 2008a). The number of days with minimum temperatures below -40°C has declined in the past three decades, and is expected to decline further with a warming climate. This temperature threshold limits the reproduction of mountain pine beetle and the parasitic plant dwarf mistletoe, both pests of jack pine. Nearly 60% of the forest is more than 70 years old. This age class is the most susceptible to pests. A projected increase in aridity and drought make this area highly vulnerable. Modelling analysis for the Island Forests has indicated that future moisture availability may become similar to that currently in southern Saskatchewan (e.g. Swift Current), and that tree growth could decline by up to 30% (Johnston et al. 2008a). Pests and the older forest age classes add to the high fire hazard in the Island Forests.

For these reasons, the Island Forests are an excellent example of the "canary in the mine shaft", where the impacts of climate change are likely to occur earlier than in the contiguous boreal forest to the north. This area could form part of a national "early warning" network of intensively monitored sites in which the signs of climate change will emerge first. Demand for recreation activities from growing urban populations, exploration and likely extraction of diamonds, other mining potential and continued forest harvesting will all have impacts on the Island Forest ecosystems, interacting with the effects of climate change. This area is important to the local forest industry, particularly to the First Nations involved in the First Nations Island Forests Management Inc. An integrated land management approach in which all resource development actors cooperate on minimizing their footprint is essential for managing the impacts of development in this area, particularly in light of some of the ecological vulnerabilities identified above.

Forest management, including immediate and aggressive regeneration of harvested (and possibly burned) stands, will help ensure that forest cover is maintained. Selection of seed from drought-resistant individuals could also assist with maintaining future forest cover. Experimental planting and monitoring of exotic species (e.g. red pine, ponderosa pine) may help identify species that will grow better under future conditions (Carr et al. 2004, Thorpe et al. 2006). In spite of these opportunities for reducing risk, the Island Forests may permanently lose forest cover in the future. Regeneration failure following fire or harvest is likely on some sites. This suggests that management planning needs to include the potential for change to grasslands in some locations.

KEY FINDINGS

This report provides an overview of the scientific understanding of the impacts of climate change on Saskatchewan's water resources, soil landscapes and ecosystems, and the key sectors of the provincial economy, agriculture and forestry, that depend directly on this natural capital. The other major component of this biophysical assessment of climate change is the identification and discussion of adaptation options and strategies that could limit exposure to future climate risks and provide new opportunities from more favourable conditions. The general approach is a vulnerability assessment framework of exposure to climate risk, sensitivity to climate change and variability, and an assessment of adaptive capacity. This concluding section provides a summary of key findings that emerge from a synthesis of the content of this report and a brief overview of options for managing the impacts of climate change through adjustments in policy, management practices and decision-making processes.

- The major biophysical impacts of climate change in Saskatchewan are seasonal, annual and geographic shifts in the distribution of water resources and plant and animal species.

- One of the most certain projections is that extra water will be available in winter and spring and summers generally will be drier as the result of earlier spring runoff, and a longer warmer summer season of water loss by evapotranspiration.
  Much of the observed and projected warming in Saskatchewan is during winter and spring, such that the frost-free growing season is getting longer and expected to get significantly longer as the climate warms.

- A longer warmer growing season will favour diversification of prairie agriculture and higher crop, pasture and forest productivity. However, higher productivity will be limited by available soil moisture.

- The impacts of climate change tends to be adverse because our communities and resource economies are sensitive to fluctuations in the quantity and quality of natural capital and they are not adapted to the projected larger range of climate conditions.

- The net impacts of climate change depend heavily on rates of climate change and the effectiveness of adaptation measures. South of the Churchill River, nearly all of Saskatchewan's ecosystems and water resources are managed. Most impact assessment has assumed no adaptation or made simple assumptions. This reflects a lack of understanding of adaptation processes and the difficulty of predicting changes in public policy and socio-economic factors.

- Planned adaptation is a component of adaptive resource management and sustainable economic development. There is a gap in our understanding of the extent to which existing management practices and public policies either encourage or discourage the implementation of adaptive strategies. There is also a need to determine the relative importance of adaptive responses versus other priorities, and to develop approaches that incorporate climate change considerations into existing policy instruments.

- The major threats are understood with the least certainty. The recurring impacts of drought in Saskatchewan suggest that the severity and duration of future droughts will determine much of the impact of climate change. Droughts, and to a lesser extent flooding, could limit opportunities provided by a warmer climate and will challenge our capacity to adapt to changing conditions. Nearly all climate change assessments are based on climate change scenarios that give shifts in mean conditions between decades.

- A key finding of this impact assessment, therefore, is that the gap in our knowledge of climate variability is problematic for evaluating impacts and developing appropriate adaptation strategies.

The people of Saskatchewan have historically managed their water resources while maintaining a healthy aquatic environment because there has been a relatively abundant supply of high quality water to meet the needs of communities and the economy. However, fluctuating water supplies in recent years have stressed the need to make some major shifts in our approach to managing this renewable, but finite, resource. Uncertain water supplies could require major innovations in planning and managing how water is allocated, stored, used and distributed. Integrated basin management of the South Saskatchewan River across both Alberta and Saskatchewan and for smaller watersheds in Saskatchewan is the preferred adaptation method for dealing with these uncertainties. Integrated basin management plans with apportionment powers, enforceable land use controls and agricultural management incentives may need to be implemented to deal with rapid changes and increased uncertainties in water management designs.

Examples of policy and decision-making processes that are suitable for the planning of adaptation to climate change include environmental farm plans, watershed basin councils, and principles of adaptive forest management and integrated water resource management. Policies must be evaluated in terms of how they support adaptation or, conversely, foster maladaptation by providing the wrong incentives or creating barriers to adaptation. Similarly, management practices and processes must be considered from the perspective of adaptation to embed decision making about climate change in the planning and management process.

Adaptation on the farm, in the forest, and in local communities is largely achieved by municipalities and individuals working collectively in social networks and as informal institutions (*e.g.* producer co-ops). The provincial government plays a critical role in terms of facilitation and a policy framework that enables proactive and effective adaptation. In Saskatchewan, adaptive capacity varies among communities, but it is generally high given our financial resources, natural capital, stable governance institutions and social capital. Adaptive capacity is low in some rural and northern communities in Saskatchewan, and in some First Nations. Capacity is only the potential to respond; however, and it must be mobilized by government and other actors.

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REFERENCES

Balshi, M., A.D. Mcguire, P. Duffy, M. Flannigan, J. Walsh and J. Melillo. 2009. Assessing the response of area burned to changing climate in western boreal North America using a Multivariate Adaptive Regression Splines (MARS) approach. Global Change Biology 15: 578-600.

Barrow, E. 2009. Climate Scenarios for Saskatchewan. A Report Prepared for the Prairie Adaptation Research Collaborative (PARC).

Carr, A., P. Weedon and E. Cloutis. 2004. Climate Change Implications in Saskatchewan's Boreal Forest Fringe and Surrounding Agricultural Areas. Final Report submitted to Natural Resources Canada, Climate Change Action Fund. Natural Resources Canada, Climate Change Action Fund, Ottawa ON. Available on-line at: http://adaptation.nrcan.gc.ca/projdb/pdf/125_e.pdf

Clair, T., B. Warner, R. Robarts, H. Murkin, J. Lilley, L. Mortsch, and C. Rubec (1998). "Canadian inland wetlands and climate change" (chapter 3) in Koshida, G and Avis, A. (editors), The Canada Country Study: Climate Impacts and Adaptation (Volume 7: National Sectoral Volume), Environment Canada.

Coupland, R. 1959. Effects of changes in weather conditions upon grasslands in the Northern Great Plains, in *Grasslands* (Pub 53), Amer. Soc. Adv. Sci., Washinton DC, pp. 291-306.

Cutforth, H. W., S. M. McGinn, K.E. McPhee, P.R. Miller. 2007. "Adaptation of Pulse Crops to the Changing Climate of the Northern Great Plains." *Agronomy Journal*, **99**(6): 1684-1700.

Dai, A., K. E. Trenberth, and T. Qian. 2004. "A Global Dataset of Palmer Drought Severity Index for 1870-2002: Relationship with Soil Moisture and Effects of Surface Warming." *Journal of Hydrometeorology*, **5**: 1117-1131.

Henderson, N., T. Hogg, E. Barrow and B. Dolter. 2002. Climate Change Impacts on the Island Forests of the Great Plains and the Implications for Nature Conservation Policy. Prairie Adaptation Research Collaborative, Regina.

Hogg, E., J. Brandt, and M. Michaelian. 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. *Canadian Journal of Forest Research*, vol. 38, 1373-1384.

Hogg, E.H. and P.Y. Bernier. 2005. Climate change impacts on drought-prone forests in western Canada. The Forestry Chronicle 81: 675-682.

IPCC (2007): Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Johnston, M. and T. Williamson. 2005. Climate change implications for stand yields and soil expectation values: A northern Saskatchewan case study. The Forestry Chronicle 81: 683-690.

Johnston, M., R. Godwin and J. Thorpe. 2008a. The Impacts of Climate Change on the Island Forests of Saskatchewan. Final report submitted to the Prince Albert Model Forest by the Saskatchewan Research Council. SRC Publication No. 12168-1E08, Saskatchewan Research Council, Saskatoon, SK.

Johnston, M., T. Williamson, E. Wheaton, V. Wittrock, H. Nelson, H. Hesseln, L. Vandamme, J. Pittman and M. Lebel. 2008b. Climate Change Adaptive Capacity of Forestry Stakeholders in the Boreal Plains Ecozone. Final Report Prepared for Government of Canada's Climate Change Impacts and Adaptation Program, Project A1383. SRC Publication No. 12306-3E08, Saskatchewan Research Council, Saskatoon, SK, 182 pp.

Jones, D.K.C. 1993. Global warming and geomorphology. The Geographical Journal, 159(2): 124-130.

Kharin, V.V. and F.W. Zwiers. 2000. Changes in the Extremes in an Ensemble of Transient Climate Simulations with a Coupled Atmosphere-Ocean GCM. Journal of Climate, 13:3760-3788.

Lemmen, D.S., F.J. Warren, J. Lacroix and E. Bush. 2008. From Impacts to Adaptation: Canada in a Changing Climate 2007. Government of Canada, Ottawa, ON. 448 p.

Lemmen, D.S., Vance, R.E., Campbell, I.A., David, P.P., Pennock, Sauchyn, D.J., & Wolfe, S.A. 1998. Geomorphic Systems of the Palliser Triangle: Description and Response to Changing Climate; Geological Survey of Canada Bulletin 521.

Martz, L., J. Bruneau and J. Rolfe (editors). 2007. Climate Change and Water: South Saskatchewan River Basin Final Technical Report, 252pp.

McKenney D., J. Pedlar, K. Lawrence, K. Campbell and M. Hutchinson. 2007. Potential impacts of climate change on the distribution of North American trees. BioScience 57: 939-948.

Miller, P. R., B. G. McConkey, G. W. Clayton, S.A. Brandt, J.A. Staricka, A.M. Johnston, G.P. Lafond, B.G. Shatz, D.D. Baltensperger, and K.E. Neill. 2002. "Pulse Crop Adaptation in the Northern Great Plains." *Agronomy Journal*, **94**(2): 261-273.

Oren, R., Ellsworth, D., Johnsen, K., Phillips, N., Ewers, B., Maier, C., Schafer, K., McCarthy, H., Hendrey, G., McNulty S. and Katul, G. 2001. Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. Nature 411: 469-472.

Parisien, M.A., K.G. Hirsch, S.G. Lavoie, J.B. Todd and V.G. Kafka. 2004. Saskatchewan Fire Regime Analysis. Information Report NOR-X-394, Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada. Edmonton, AB. 61 p.

Sala, O.E., Chapin, F.S. 3rd, Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., and Wall, D.H. (2000): Global biodiversity scenarios for the year 2100; Science, v. 287, no. 5459, p. 1770–1774.

Sauchyn, D. 2007. Climate Change Impacts on Agriculture in the Prairies. In: Wall, E., B. Smit, and J. Wandel (Editors). *Farming in a Changing Climate: Agricultural Adaptation in Canada*. UBC Press, Vancouver, British Columbia.

Scholze, M., W. Knorr, N. Arnell and I. Prentice. (2006). A climate-change risk analysis for world ecosystems, *Proceedings of the National Academy of Sciences*, vol. 103, pp. 13116-13120.

Thorpe, J. 2007. Impacts of climate change on range site classification in the Canadian Prairies. Saskatchewan Research Council Publication No. 11929-1E07.

Thorpe, J. and B. Godwin. (2009). *Ecological Assessment of Potential Tree Species for Adaptation to Climate Change in the Prairie Provinces*. Saskatchewan Research Council, Saskatoon.

Thorpe, J., B. Houston, and S. Wolfe. 2004. Impacts of climate change on grazing capacity of native grasslands in the Canadian prairies. Saskatchewan Research Council Publication No. 11562-1E04.

Thorpe, J., N. Henderson and J. Vandall. 2006. Ecological and Policy Implications of Introducing Exotic Trees for Adaptation to Climate Change in the Western Boreal Forest. Final Report submitted to the Prairie Adaptation Research Collaborative. Saskatchewan Research Council Publication No. 11776-1E06. Saskatchewan Research Council, Saskatoon, SK.

Vandall, J.P., N. Henderson, and J. Thorpe. 2006. Suitability and adaptability of current protected area policies under different climate change scenarios: the case of the Prairie Ecozone, Saskatchewan. Saskatchewan Research Council Publication No. 11755-1E06.

Volney, W.J.A. and K.G. Hirsch. 2005. Disturbing forest disturbances. The Forestry Chronicle 81: 662-668.

Wheaton E., H. Auld, G. Koshida, D. MacIver. 2005. *Agricultural Water Conservation in Canada: Scoping Pressures, Trends and Vulnerabilities.* Prepared for the Adaptation and Impacts Research Division, Environment Canada. SRC Publication No. 11926-1E05. Saskatchewan Research Council, Saskatoon, Saskatchewan.

Wheaton, E., S. Kulshreshtha, V. Wittrock, and G. Koshida. 2008. “Dry Times: Lessons from the Canadian Drought of 2001 and 2002.” *The Canadian Geographer*, **52**(2):241-262. SRC Publication No. 11927-6A06. Saskatchewan Research Council, Saskatoon, Saskatchewan.

Wolfe, S.A., Huntley, D.J., David, P.P., Ollerhead, J., Sauchyn, D.J. and Macdonald, G.M. (2001). Late 18th century drought-induced sand dune activity, Great Sand Hills, southwestern Saskatchewan. Canadian Journal of Earth Sciences, 38: 105-117.

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Killdeer Badlands *Photo Credit: Dave Sauchyn*

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