Saskatchewan Research Council

Suitability and Adaptability of Current Protected Area Policies under Different Climate Change Scenarios: The Case of the Prairie Ecozone, Saskatchewan

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1. INTRODUCTION

Climate change is identified as one of the key threats to prairie biodiversity (James et al. 2001). Gratto-Trevor (1997) reviewed climate change effects on natural prairie vegetation and wildlife (species responses to drought). Herrington et al (1997) focused on climate impacts and adaptations for economic use of selected resources. Reviews of possible climate change effects on national parks found that the effects on the Great Plains of North America will be greater than other regions (e.g., WWF n.d.).

There have been two recent studies in Saskatchewan that examined the possible effects of climate change on prairie biodiversity (James et al. 2001) and island forests of northern Great Plains (Henderson et al. 2002). These studies suggest reduced or complete loss of integrity of existing ecological communities and protected areas in selected areas of the Prairie Ecozone. At the national level, Scott et al. (2002) predicted through modeling that 50% of Canada's National Parks will undergo significant vegetation changes with climate change and identified major policy challenges for Parks Canada. At the continental scale, a recent publication on North American grasslands provides a context for conservation of grassland in relation to a wide array of issues including climate change (Gauthier et al. 2003). All these studies suggest the need for major changes in protected area selection and management policies to respond to anticipated climatic changes. For example, establishing a network of protected areas to represent natural regions that includes vegetation type may be problematic. A key objective of protected area management is biodiversity conservation, yet some species may be eliminated from a given protected area as the climate becomes warmer. Other species better adapted to warmer climates may be prevented from immigrating to the protected area because of the absence of migration corridors.

Saskatchewan, through its Representative Areas Network (RAN) program, has established an extensive system of parks and protected areas across the province and is now nearing designating 9% of its land base. While lands will continue to be designated in under- or un-represented ecoregions, there is increased awareness and efforts among management agencies to ensure that ecological integrity of protected areas is sustained (SERM 2001). To address many of the threats to biodiversity (e.g. habitat change and fragmentation, exotic invasive species, overuse), policies and strategies (e.g. species at risk) have been developed. However, managing for climate change offers a greater challenge as "rapid climate change fundamentally changes the context of protected areas planning and of nature conservation policy making" and "… this is little understood amongst policy- makers, managers, or the wider public". (Henderson et al. 2002, p. 2). Henderson et al. also noted "a failure to incorporate climate change impacts within strategic planning is typical of conservation management throughout the northern Plains region" including Manitoba's "Protected Areas Initiative" and Alberta's "Special Places Program".

The purpose of this study is to assess the capacity, both barriers and opportunities, of the current protected areas policies (including the protected areas network) to represent and sustain ecological health in the Prairie Ecozone in Saskatchewan (Acton et al. 1998) under future climate conditions. A policy framework for Saskatchewan will be proposed. The policies are intended to support park and protected area planners and managers with responding to climate change now and in the near future.

1.1 Objectives

In consultation with protected area land managers and stakeholders:

1) Develop recommendations for policy and further research to support adaptation by protected areas to climate change.
2) Based on the case of the Prairie Ecozone, develop a protected area policy for Saskatchewan under climate change. This will specifically include adaptation strategies for the selection and management of parks and protected areas.
3) Develop a template to review protected area policy, under climate change, that could be used by other prairie provinces (Alberta and Manitoba).

1.2 Methodology

1.2.1 Assess Climate Change Impacts

- Building on the work of James et al (2001) and Henderson et al (2002), available climate change scenarios and associated vegetation models were reviewed and assessed for the prairies.
- Existing digital information about extant climate, landscapes and the protected areas network in the Prairie Ecozone in Saskatchewan were accessed to create digitized baseline maps for the prairie ecoregions. Significant land cover data and protected area databases already exist (Gauthier et al. 2002; Gauthier and Wiken 2003).
- Future climates and vegetation types were modeled at the ecoregional scale for the 2050s, expanding on the methodology used by Henderson et al (2002). Their work related the forest/grassland boundary to a climatic moisture index. A similar approach was used to define the climatic envelope of major vegetation types within the grassland region (e.g. dry mixed prairie, moist mixed prairie, fescue prairie, aspen parkland), which was then used to model the shifts in these types under future climates.

1.2.2 Identify Alternative Response Strategies

A variety of strategies to respond to climate change were developed and assessed in consultation with land managers and stakeholders. These included no response, maintenance of the status quo, and an adaptation response. Of primary interest are the adaptation responses. For future management of protected areas, adaptation responses can vary considerably in terms of level of intervention. Some of the adaptation responses that were considered include: expansion of the protected areas network with a focus to establishing connectivity among existing areas and selection of some protected areas based on current and future biological diversity. For protected area management, adaptation strategies may include: introduction of non-native species; revisions to wildfire management policy and adoption of a management planning process that incorporates climate change scenarios, potential adaptations and public consultation on the climate change issue.

1.2.3 Policy Review and Analysis

- A literature review was conducted on current knowledge of climate change impacts and policy adaptations on protected areas in the Great Plains of Canada, Unites States, and other international jurisdictions where similar climate changes are expected.
- A literature review was conducted on provincial protected area policies in Saskatchewan.
- Land managers and stakeholders were surveyed at the outset of the study to ascertain their perceptions of protected area policy issues under climate change.
- An evaluation method was developed to assess the capacity of protected areas policies (including the protected area network, management planning and habitat stewardship activities) to adapt to climate change. These criteria were used to identify barriers and opportunities to adaptive management. The approach addressed two key issues, the scope of policies to be reviewed and evaluation criteria. The scope of the review was intended to cover all policy, legislation and regulations that may impact on parks and protected areas and their ability to adapt to climate change. Specific criteria and supporting rationale were developed to allow for both objective and subjective evaluation of current policy.
- A policy review template, for use by other prairie jurisdictions, was developed in consultation with stakeholders.

1.2.4 Policy Development

- A policy framework for Saskatchewan to adapt to climate change was developed to guide both expansion of the protected areas network and management of parks and protected areas.
- A workshop was held with land managers and stakeholders to share findings of the climate-vegetation modeling and the alternative response strategies. The workshop was used to formulate options and recommendations for a protected area policy for Saskatchewan.

1.3 Report Outline

The report outlines the background and rationale for the project, and summarizes the findings of the protected area policy review, involving a literature survey and manager workshop. The expected biophysical impacts of climate change on a sample of Saskatchewan protected areas are analyzed. Lastly, policy recommendations and recommendations for further research on protected areas and adaptation to climate change are presented along with a policy review template.

2. BACKGROUND AND RATIONALE

2.1 Saskatchewan's Representative Areas Network (RAN)

Similar to other jurisdictions in Canada, Saskatchewan made a commitment in 1992 to "make every effort to complete Canada's network of protected areas representative of Canada's land based natural regions by the year 2000" (Federal Provincial Parks Council (FPPC) 2000, p.5). In Saskatchewan, the objective is to ensure that all of Saskatchewan's 11 Ecoregions are well represented within the Representative Areas Network (RAN). Further, within its biodiversity action plan, Saskatchewan committed to expand the RAN (from 9%) to include 12% of the land and water within the province by 2009 (Saskatchewan Environment 2004, p. 11). The framework for the RAN is based on "enduring features", that is the kind of features that do not really change over time (Saskatchewan environment 2005). The focus of the framework was landforms and soil types.

The RAN currently encompasses a variety of crown and private lands that are recognized for their protection or conservation values. Some of the lands, such as national and provincial parks and ecological reserves, were designated prior to 1992. Since then, additional lands have been recognized as protected areas and/or identified and designated pursuant to a consultation process involving a variety of government agencies, First Nations, stakeholders and general public. Lands that have been included within the RAN since 1996 include both federal and provincial community pastures, Wildlife Habitat Protection Act (WHPA) lands[1], and other provincial crown lands with a protection or conservation objective (game preserves, wildlife refuges, Fish and Wildlife Development Fund (FWDF) lands[2]).

As of 2005, a total of 10% of the Prairie Ecozone is encompassed within the RAN, with the vast majority (+85%) occurring on lands available for agricultural production (Tables 1 and 2, Figure 1). This includes Wildlife Habitat Protection Act lands that are available for grazing leases, and community pastures administered either provincially or federally (by PFRA). The remaining 15% is comprised of ecological reserves, national and provincial parks, and lands dedicated to wildlife protection.

Based on the IUCN Classification of Protected Areas, all the protected areas available for agriculture in the Prairie Ecozone are consistent with IUCN Class VI protected areas where the lands are designated and managed mainly for "sustainable use of natural ecosystems". The remaining protected lands in the ecozone are IUCN Class I to IV since they are managed primarily for their wilderness protection or ecosystem conservation values (Figure 2 and Appendix 1).[3]

[1] Wildlife Habitat Protection Act lands are provincial crown lands administered by Saskatchewan Agriculture and Food as grazing leases, but protected from clearing, breaking, or drainage under the Wildlife Habitat Protection Act.
[2] Fish and Wildlife Development Fund lands are lands purchased for the purpose of protecting habitat, using funds from a fee added to hunting and fishing licenses.
[3] Within the Prairie Ecozone the percentage of protected area falling within IUCN Classes I to IV is considerably less than for the province as a whole – 15% vs 45% respectively. The primary reason is that the Prairie Ecozone is dominated by agriculture and private land and the lands available and desirable for biodiversity conservation are part of the working landscape. Most of the remaining natural prairie in Saskatchewan is found on grazing lands, either community pastures or agricultural leased lands.

Figure 3 illustrates the distribution of protected areas within the Prairie Ecozone. Typically the distribution is fragmented, but there are areas of contiguous lands that are protected such as the Great Sand Hills, and the lands south of Cypress Hills and along the South Saskatchewan River.

Table 1: Representative Areas Network Within the Prairie Ecozone

Representative Area	Number	Area (ha)	IUCN Class	Total %
Provincial Administration				
Saskatchewan Agriculture and Food (SAF)				
Provincial Community Pasture	28	239,246.54	VI	10%
Wildlife Habitat Protection Act (WHPA) Land	227,77	1,102,090.79	VI	45%
Saskatchewan Environment (SE)				
Ecological Reserve	4	850.8	Ia	less then 1%
Fish and Wildlife Development (FWD) Fund Land	1070	45,121.99	IV	2%
Game Preserve	43	26,793.82	IV	1%
Park Land*				
• Provincial Parks			Ib	
• Protected Areas			II	
• Recreation Sites			III	
			VI	
*(Historic Sites and Historic Parks not included)	62	83,668.47		3%
Representative Area (RA) Ecological Reserve	1	37,343.45	Ia	2%
Special Management Area	0	0	VI	0%
Wildlife Refuge	24	2,937.2	VI	less then 1%
Saskatchewan Watershed Authority (SWA)				
Saskatchewan Watershed Authority (SWA) Land	699	34,405.04	VI	1%
Federal Administration				
Canadian Forces Base (CFB) Dundurn	1	21,537.69	VI	1%
Migratory Bird Sanctuary	14	56,432.05	IV	2%
National Park	1	48,822.11	II	1%
National Wildlife Area	38	36,470.98	IV	2%
Prairie Farm Rehabilitation Act (PFRA) Community Pasture	169	707,003.67	VI	29%
Corporate				
PCS Rocanville	1	1,495.8	VI	less then 1%
NON-Gov Organizations				
Ducks Unlimited Land	1080	N/A	V	
Private Land				
Conservation Easement	207	N/A	VI	
TOTAL RAN Land within PE	26219	2444220.4		

Table 2: Types of Protected Areas in Saskatchewan

Protected Area Type	Purpose
Saskatchewan Environment Administered Legislation	
Park Lands under *The Parks Act* • Provincial parks o Natural environment o Recreation o Wilderness o Historic • Historic Sites • Recreation Sites • Protected Areas • Park Land Reserves	***Protection of natural and cultural resources, landscapes or features for future generations for their recreation education*** (arising out of achieving these there is a tourism role) Protected areas are more for protection and not recreation and education. Park Land Reserves are designations which are designed to set lands aside for a five year period while discussions are undertaken regarding a permanent designation
Ecological Reserves under *The Ecological Reserves Act*	Land is protected for biodiversity and natural resource protection. Public use is not encouraged and only those activities identified in regulations creating them are permitted – usually pre-existing non-development activities
Fish and Wildlife Development Fund Lands under *The Natural Resource Act*	Protection of wildlife and aquatic habitat through land acquisition funded by hunters and fisher-persons
Wildlife Refuges under *The Wildlife Act*	Areas for protecting, propagation, perpetuating, managing, controlling, regulating or enhancing wildlife or its habitat
Game Preserves under *The Wildlife Act*	Areas for protecting, propagation, managing, controlling, regulating or enhancing wildlife or its habitat
Special zones under *The Lands Act* Special Management Areas are an example of this classification which were set aside by formal agreement with Prince Albert Grand Council	To protect areas of Crown Resource Lands without a legal designation, land use plans may identify specific zones for conservation under this Act
Other Provincially Designated Land	
Provincial Community Pastures under SAF	Primarily to protect grazing land but also protect native prairie ecosystems
Wildlife Habitat Protection Land under SAF	Primarily to protect habitat for ungulates and licensed hunting and angling opportunities
Saskatchewan Watershed Authority	Protection of waterfowl habitat
Government of Canada/Federal Administrations	
Parks Canada • National Parks • National Historic Sites	Protect and present nationally significant examples of Canada's natural and cultural heritage and foster public understanding, appreciation and enjoyment in ways that ensure their ecological and commemorative integrity for present and future generations
Migratory Bird Sanctuaries	Protect staging waterfowl areas/colonial nesting birds
National Wildlife Area	Protection of wildlife habitat
CFB Dundurn	
PFRA Community Pastures	Primarily to protect grazing land and also native prairie ecosystems
Non Government Agencies	
Ducks Unlimited	Primary purpose is habitat for ducks and other waterfowl
Nature Conservancy of Canada	Protection of native habitat
Corporate	
Potash Corporation of Saskatchewan (PCS) Rocanville	Protection of native habitat
Others	
Conservation Easements on private land	Protection of native habitat

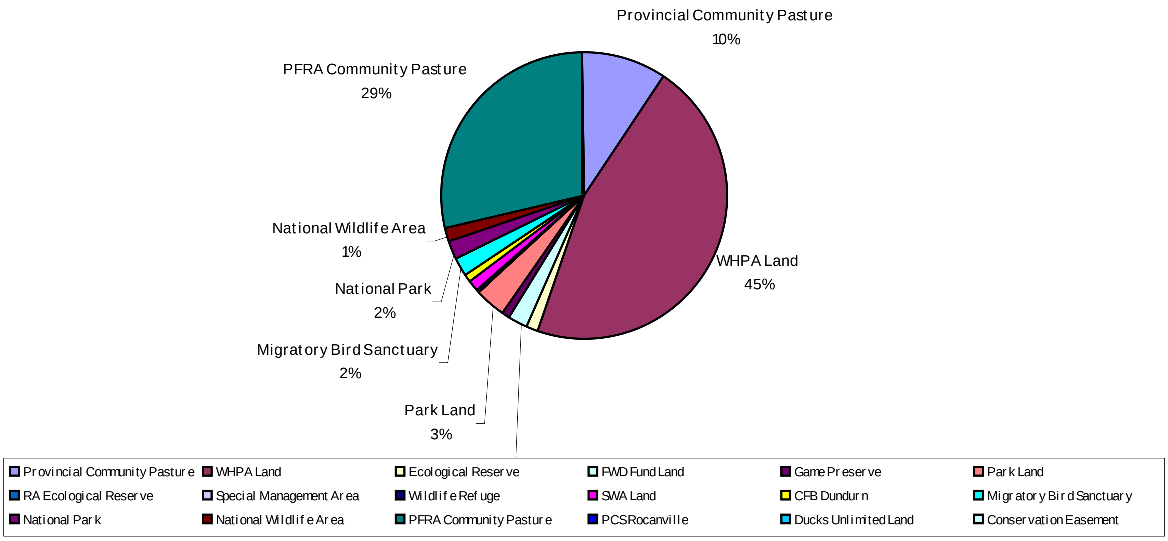

Figure 1: Percentage of Area by Type of Protected Area in the Prairie Ecozone

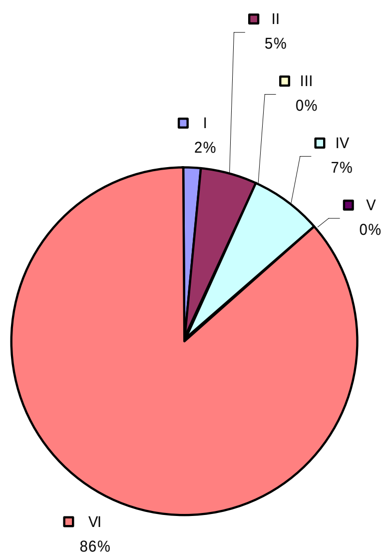

Figure 2: Percentage of Area by IUCN Class of Protected Areas in the Prairie Ecozone

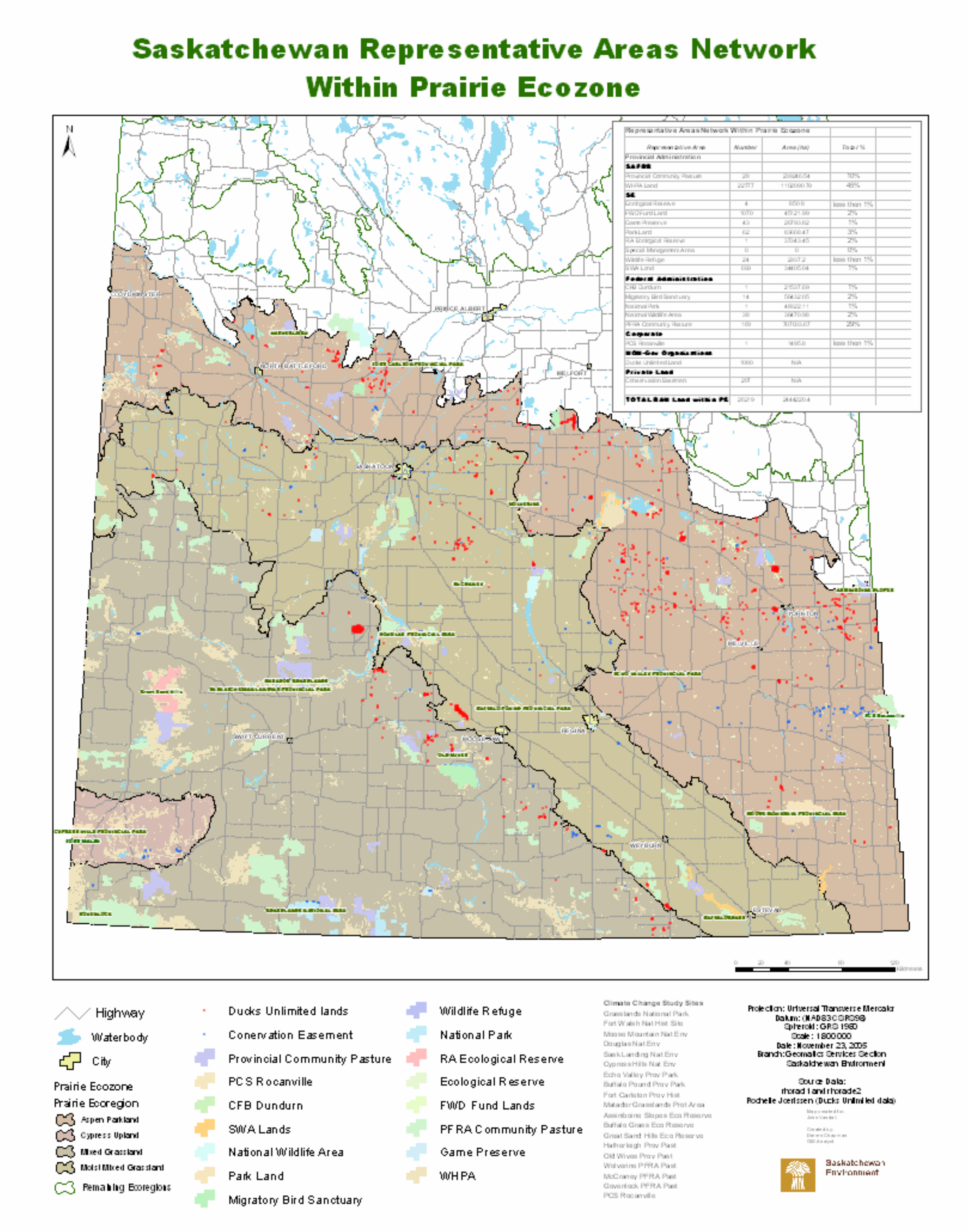

Figure 3: Saskatchewan Representative Areas Network within the Prairie Ecozone

Within the Prairie Ecozone, the percentage of each of the four ecoregions included in the RAN varies from a high of 20% in the smallest (Cypress Upland) to just over 5.5% for the Moist Mixed Grassland and the Aspen Parkland (Table 3).

Table 3: Percentages of each ecoregion included in the Representative Areas Network

ECOREGION	PERCENT OF AREA
Cypress Upland	20.7
Mixed Grassland	14.8
Moist Mixed Grassland	5.9
Aspen Parkland	5.6

The objectives of the RAN program are relevant to climate change adaptation: the commitment to meet the 12% target, and enhanced natural resource management of individual sites. Provincially, the RAN program has identified that the major "gaps" in the protected areas system are primarily within the settled or agricultural portion of the province (i.e. the Prairie Ecozone) and specifically the three major Prairie Ecoregions. There is therefore an opportunity to consider the potential impacts of climate change on the Prairie Ecozone and adapt the protected area system at the same time as it is expanded. Management planning "is another challenge that must be addressed" (Saskatchewan environment 2005). A consideration of climate change in the management planning process will have implications for planning, public consultation, implementation (e.g. emulation of natural disturbance), and monitoring.

2.2 Adaptation to Climate Change

Much has been written about climate change, the impacts now being experienced or anticipated around the world, and the need for both mitigation and adaptation by all sectors of society. Significant efforts are being expended across the globe to mitigate against climate change by reducing emissions and sequestering carbon. Now that the Kyoto Accord has been ratified, mitigation efforts are expected to increase. Canada has developed its plan to respond to Kyoto: "Project Green: Moving Forward on Climate Change – A Plan for Honouring our Kyoto Commitments" (Canada 2005). Saskatchewan has yet to develop its plan. Although mitigation efforts can help reduce the rate of climate change, it cannot reverse it.

Another strategy to respond to climate change is adaptation. Adaptation to climate change involves the adjustments in ecological, social or economic systems in response to climatic stimuli, their effects or impacts (IPCC 2001). It also refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Adaptations depend greatly on the adaptive capacity of an affected region, community or system to cope with the impacts and risk of climate change (Smith et al. 2001).

The most challenging aspects of adapting to future climate changes for Saskatchewan are the expected increase in aridity and shifts in climate variability, including more droughts and increased risk of water shortages. Social and biophysical systems typically react to shorter-term climate variability and to extreme events long before they respond to gradual changes in mean conditions. Extreme events can exceed ecological and engineering thresholds, beyond which the impacts of climate change are more severe. Although there is some uncertainty about the future probability of extreme events, most of the evidence suggests that they are increasing in frequency and intensity. Social and natural systems must cope with such extremes. Changes in the range of climatic variability will require adaptation to minimize impacts on infrastructure, communities and sustainable use of soil, water and forests.

Burton, 1996 has argued that attention should be given to adaptation now and identified six reasons to adapt to climate change:

- Climate change cannot be totally avoided;
- Early actions to reduce risks will likely be less costly and buy more time to adapt;
- Anticipatory adaptive actions can also reduce risks by preparing for adverse effects and capitalizing on benefits;
- The more rapid the warming, the greater the challenge to adapt;
- Immediate benefits can be gained from better adaptation to climate variability and extreme atmospheric events; and
- Immediate benefit can also be gained by removing maladaptive policies and practices.

2.3 Protected Areas and Climate Change

Knowing that the climate is going to change, society, the economy and ecosystems will adapt in either an unplanned (i.e. spontaneous) or planned manner. This research is concerned with reviewing existing policy, among public and private institutions responsible for protected areas, to identify the opportunity or barriers to adapt to climate change in a planned manner. Ideally, agencies should be aware of the impending impacts that will result from climate change and make a conscious, informed response. In the absence of any management action, the environment will naturally or spontaneously “adapt” to climate change. However, the changes to the renewable natural resource sector (e.g. fish, forest, wildlife and grassland) may be undesirable, as climate change may negatively impact both the quality and quantity of the resource.

Biodiversity encompasses all of life at the genetic, species and ecosystems level. Biodiversity conservation is now recognized as a major environmental objective internationally (Convention on Biodiversity [http://www.biodiv.org/doc/legal/cbd-un-en.pdf]), nationally (Canadian Biodiversity Strategy [Biodiversity Working Group 1994]) and provincially (Biodiversity Action Plan [Saskatchewan Environment 2004]). Biodiversity is complex and impossible to manage. However management efforts to conserve biodiversity can focus on managing human activities which threaten biodiversity: habitat loss, habitat fragmentation, invasive exotic species and over-use of resources. Climate change is also recognized as a threat to biodiversity and it tends to exacerbate the other threats when they occur in tandem.

Assuming that it is human-induced, climate change is unlike the other four threats to biodiversity since it is virtually irreversible, and its impact is so large-scale and all-pervasive that any action at the local level to reduce climate change will be masked by what is happening at the regional and global scale. Climate change cannot be managed, hence the need for an adaptation strategy. Climate change directly challenges the fundamental objective of many protected areas; that is trying to protect them from human impacts. "Most protected areas have been designed to represent (and in theory protect for perpetuity) specific natural features, species and communities in-situ, and have not taken into account potential shifts in ecosystem distribution and composition that could be induced by global climatic change" (Scott and Lemieux 2005, p. 696).

3. POLICY REVIEW – SYSTEM PLAN AND SITE MANAGEMENT

The principle focus of this research is to identify the capacity of protected areas policy to represent and sustain ecological health under climate change. Three tasks were undertaken to identify the policy opportunity and barriers for protected areas to adapt to climate change. The first task was a survey of site managers who are responsible for protected areas within Saskatchewan's Prairie Ecozone. A sample of managers were contacted and interviewed to ascertain their knowledge and their agency's awareness and response to climate change. The second task was a review of protected area policy from both a system perspective and individual protected area types. Provincially, Saskatchewan Environment is responsible for protected area system planning within the Representative Areas Network (RAN) program[4]. The public policy instruments available for all protected land types found within the Prairie Ecozone were also reviewed. This included legislation, regulations, major public policy documents, management plans, agreements, and public information. Lastly, the policy review was shared with protected areas managers at a climate change workshop. Feedback received has been incorporated into the report.

3.1 Manager's Survey

A manager's survey was conducted in the fall of 2004. It was designed to communicate with individual site managers to ascertain their and their agency's management policy instruments, their awareness of climate change impacts and what has been the management response to date. The survey was conducted with 15 individuals responsible for nine protected area types within the Prairie Ecozone representing a diversity of management agencies and sites (Table 4). The survey was first mailed out to the responsible agencies and then each individual was personally interviewed.

[4] The RAN encompasses a variety of land designations administered federally, provincially and privately. The network does not include all of the province's protected areas as defined by the IUCN. For example, historic sites and parks, regional and urban parks are not included. This is unfortunate since all of the province's protected areas, either individually or as a system have the potential to contribute to the maintenance of biodiversity. The RAN MOUs for community pastures and PCS Rocanville set out clear policy objectives related to ecological integrity. These MOUs could serve as model for all protected areas in the province and set a high standard of ecological management that could contribute towards meeting the goals of the RAN.

Table 4: Protected Areas included in the Manager's Survey

- Provincial Parks – Saskatchewan Environment
  - Moose Mountain Provincial Park
  - Cypress Hills Provincial Park
  - Lower Qu'Appelle (e.g. Echo Valley Provincial Park)
  - Upper Qu'Appelle (e.g. Crooked Lake Provincial Park)
  - Saskatoon/Battlefords (The Battlefords Provincial Park)
- Provincial Community Pastures – Saskatchewan Agriculture and Food
  - Matador
  - Old Wives
- PFRA Community Pastures – Agriculture and Agri-Food Canada
- Migratory Bird Sanctuary – Environment Canada
- Game Preserves – Saskatchewan Environment
- Fish and Wildlife Development Fund (FWDF) Lands – Saskatchewan Environment
- Nature Conservancy of Canada Lands
- Grasslands National Park – Parks Canada
- Fort Walsh National Historic Site – Parks Canada

The individuals contacted in the survey, as well as the survey questions and highlights, are found in Appendix 2. The results of the survey are summarized below:

- Managers were first asked to identify the policy instruments that they use to manage individual protected areas. Most respondents identified their governing legislation and regulations, area-specific policy and management plans. Provincial agencies also identified two general provincial policy documents, namely the Fire, and Forest Insect and Disease Management Policy Framework and the Water Management Framework.
- For most of the surveyed protected areas, site-specific management plans are either being developed or updated.
- The managers identified climate change "as an issue, which requires an adaptation response".
- Climate change was perceived to be a management concern, based on general awareness of the issue and of several studies that have either been completed (e.g. Henderson et al. 2002) or are underway.
- Climate change was seen to be a moderate-priority issue at the site level. The impacts of climate change were generally perceived to be the result of a decrease in precipitation. The resultant change in the water balance was recognized to influence water levels and vegetation composition.
- No action has been taken to adapt to climate change, nor were managers aware of any potential strategies for making the protected area more resistant or resilient.
- Two barriers to adapting to climate change were noted: lack of information as to potential impacts, and lack of resources to apply to the problem.
- It was noted that there is a need for policy change to address the expected shifts in vegetation zone and the impact on fire regime.

- At the agency level, climate change is perceived as a high priority, as evidenced by the resources being expended on studies, planning and the level of internal discussions.
- Managers were interested in participating in a climate change workshop and generally networking with other protected area managers recognized within the Representative Areas Network.

3.2 Review of the Representative Areas Network – Systems Policy

In 1997, the Representative Areas Network (RAN) program initially recognized about three million hectares encompassing nearly 6% of the province. This included national and provincial parks, ecological reserves and wildlife habitat lands. Since then, the RAN has grown to nearly 9% of the province and includes a greater diversity of protected lands types such as federal and provincial community pastures and private lands (Saskatchewan environment 2005). In its Biodiversity Action Plan, the province committed to “continue implementation of the Representative Areas Network (RAN) to ensure adequate representation of the province's natural ecosystems” and protect 12% of Saskatchewan’s lands and waters (Saskatchewan Environment 2004).

The RAN has been designed to represent enduring features, which are considered to be “very stable over long periods of time”, and which are defined by four specific factors: soil development, origin of parent material, surface form and slope (Saskatchewan environment 2005). Climate change will have less effect on these features than on distributions of species or communities. In light of the potential for climate change, Saskatchewan’s RAN may have some benefit over other systems that have been “designed to represent specific natural features, species and communities in-situ”. For example, the natural regions framework used by Parks Canada includes vegetation as one of the enduring features in its classification system. Regardless, neither system “have taken into account potential shifts in ecosystem distribution and composition that could be induced by climate change” (Scott and Lemieux 2005, pp.696–697).

All public policy guiding the expansion or management of Representative Areas is found within general policy documents and specific memoranda of understanding and partnership agreements. Although no policy is enshrined within legislation or regulation, the general policy foundation is fairly robust – biodiversity is to be protected through designation of protected areas that are either representative of the Province’s ecosystems or encompass unique features, and there are to be clear management goals to manage for ecological integrity. It is also the intent of the province to “develop management policies and standards that apply to all sites recognized in the RAN program” by 2005 and identify which sites will be established as ecological benchmarks. (Saskatchewan Environment 2004, p. 11). Representative Areas do not exclude human activities or resource uses such as hunting, fishing, trapping, grazing and logging.

From the perspective of adapting to climate change, there are a number of important opportunities afforded by the current RAN policy so long as climate change impacts and adaptations are incorporated into decision making:

1) Having a 12% target and being only at 9% provides an opportunity to expand the land and water base within the RAN and ensure that climate change impacts are recognized and that adaptation is considered.
2) Having used enduring features such as landform as the basis of the RAN, and not including vegetation specifically, provides a strong foundation to theoretically continue expanding the system based on representation of the current ecological framework.
3) Saskatchewan is committed to establish management policies and standards for the RAN. This provides the opportunity to demonstrate leadership in planning and adapting to climate change.
4) Saskatchewan is committed, through the RAN program to identify which sites are to be used as ecological benchmarks[5]. An ecological benchmark implies that some level of monitoring will occur, and this could involve monitoring for climate change. The information will be used to undertake management of the protected area and the surrounding landscape.

The policy barriers for the RAN system to adapt to climate change are:

1) Ecological representation is the driving principle behind the RAN. There is no specific commitment to address potential climate change impacts and adapt the system framework.
2) There is a lack of information on climate change impacts and system planning, upon which to design the RAN to adapt to climate change.
3) There is a lack of specific enabling or prescriptive policy dealing with resource management planning and management enshrined within legislation and regulation.
4) Long-term agreements/commitments to resource users may prove to be a barrier to change in area management.

3.3 Individual Protected Areas Policy Review

The final assessment of policy consisted of reviewing public policy instruments for all protected lands types found within the Prairie Ecozone. The range of policy instruments included legislation, regulations, major policy documents, management plans, agreements (e.g. Memoranda of Understanding – MOUs) and public information. For this assessment it was assumed that "public" policy documents are those readily available to the public via the internet. This assessment was used to determine the policy opportunities or barriers that exist for each

[5] An ecological benchmark is a defined natural ecosystem, encompassing land, water, plants, animals, and nutrient and energy flows, representative of a larger ecological unit. Even though benchmarks are affected by human-altered air and water quality, they, like all ecosystems, are resilient and dynamic. A benchmark is a standard against which to compare impacts of activities or events in other areas. From an ecosystem management perspective, benchmarks are control sites against which ecosystem responses to human impacts are measured on the broader working, or more broadly impacted, landscape.

type of protected area and to develop a model template that can be adopted by other agencies to conduct a similar policy review.

The following are the key questions that were addressed in the policy review:

- Is there any reference to natural resources within the policy instrument? It is assumed that if there is no reference, this in itself is a barrier to climate change adaptation as there is no foundation upon which to address the issue.
- Is there policy that addresses a response to climate change (i.e adaptation)? This indicates whether or not there is awareness of the issue, some level of public engagement and possibly the potential to take action.
- Is there policy which sets out natural resource management goals or objectives that may be considered either an opportunity or barrier to climate change adaptation? A reference to specific management objectives or goals is considered relevant to adapting to climate change. For example, a goal or objective to maintain a particular species that may be impacted by climate change may be considered a barrier to adaptation.
- Is there a goal related to managing the resource base? Is a management outcome articulated that would impact on climate change adaptation? For example, the management outcomes could range from maintaining the status quo (processes and landscapes building in resilience and resistance) to restoring past landscapes or processes (e.g. re-introduction of disturbance regime) or to establishing new processes and landscapes (e.g. species introductions)?
- Is there a goal that would enable system planning, or guide the development or management of the system?
- Is there enabling or directed policy to undertake natural resource management planning, implementation and/or monitoring?
- Is there any mention of ecosystem management or biodiversity? The two concepts are considered key to protected areas designation and management. Absence of a reference to either might indicate limited capacity to address climate change or lack of knowledge or interest on behalf of the agency or the public.
- Is there any reference to conducting monitoring and assessment? A key feature of ecosystem management, in light of imperfect information such as climate change, is adaptive management. This should be a key feature of any climate change adaptation strategy. Is there a policy commitment at the provincial level, and does the program refer to monitoring for climate change?
- Is there alignment among the policy instruments that support adaptation to climate change, for each type of protected area?
- What is the current management regime? These are divided into four types for the purposes of assessing adaptation to climate change.
    - Passive – this characterizes the management regime for all those protected areas which have no active natural resource management although land use may be controlled. An example would be crown land administered by Saskatchewan Agriculture and Food, designated under the Wildlife Habitat Protection Act, and most likely leased for grazing.
    - Active – this characterizes the management regime for lands that are subject to natural resource management planning and/or implementation. This could be

under the guise of ecosystem management or vegetation management. Usually the goal or objectives are to maintain or protect a special natural feature or ecological integrity. The impact of climate change has not been assessed nor has any adaptation response been anticipated. This regime would be characteristic of most park areas.

- Reactive – this characterizes the management regime for areas that are subject to some on-going resource monitoring with a goal to maintain a sustainable resource use (e.g. grazing). Use levels may be established to respond to changing conditions such as climatic change. This would be characteristic of most community pastures.
- Proactive – this characterizes the management regime for areas where natural resource management planning is occurring, climate change has been anticipated, and there is a management response that can encompass a variety of adaptations ranging from resisting change (e.g. resistance, resilience) to embracing the anticipated change.

The detailed policy assessments for each type of protected area included within the RAN are summarized in Table 5.

Table 5.1: Review of Protected Area Policies for Ecological Reserves

<table>
<tr><th>IUCN Class</th><th>Percentage of Protected Areas in the Prairie Ecozone</th></tr>
<tr><td>Class I</td><td>1.6%</td></tr>
<tr><td colspan="2">Policy Instruments: legislation, regulations and management plans
▪ Ecological Reserves Act
▪ Assiniboine Slopes Provincial Ecological Reserve Regulations
▪ Qu'Appelle Coulee Provincial Ecological Reserve Regulations
▪ Buffalograss Provincial Ecological Reserve Designation Regulations
▪ Provincial Ecological Reserves Regulations
▪ Representative Area Ecological Reserves Regulations
▪ A proposed Management Plan for the Assiniboine Slopes Ecological Reserve, 1987
▪ Management Plan for Buffalograss Ecological Reserve, 1994</td></tr>
<tr><td colspan="2">General Description and Management Regime:
▪ Ecological Reserves are designated by regulation and includes small sites that were designated early in the program to protect specific features, and large sites that are representative of an Ecoregion.
▪ Ecological reserves are administered by Saskatchewan Environment.
▪ The management regime can be characterized as passive, except for the Great Sand Hills which is subject to a regional environmental study.</td></tr>
<tr><td colspan="2">Summary of Policy:
▪ The Act is very strong protectionist act that prohibits all activity unless authorized through regulations.
▪ The Ecological Reserves (ER) Act establishes a high level of protection but there is no specific resource management goal. The act provides the authority for regulations to control the "conduct of an activity" including management activities and use.
▪ The regulations are generally silent on management. The Representative Area regulations provide a goal/objective for ER's as benchmarks and to preserve ecological resources and geologic features. The regulation is silent on resource management policy and planning, although it permits the use of management tools and research, and acknowledges that there may be a management plan. It also alludes to no species introduction.
▪ Management plans are ecosystem-based but focus on maintenance of specific features.</td></tr>
<tr><td colspan="2">Policy Barriers:
▪ No resource management plan required by policy
▪ No resource management goals/objectives
▪ No reference to ecosystem/biodiversity/monitoring or climate change
▪ Prohibits introduction of exotic species
▪ Requires a regulation to manage individual sites</td></tr>
<tr><td colspan="2">Policy Opportunities:
▪ General alignment of policy instruments
▪ Monitoring and active resource management is anticipated</td></tr>
<tr><td colspan="2">Comments:
▪ Sites with lessees may be a barrier to management for climate change</td></tr>
</table>

Table 5.2: Review of Protected Area Policies for Provincial Parks

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
Class Ib/II/V/VI	**3.4%**

Policy Instruments: legislation, regulations and management plans
- Parks Act
- Park Regulations
- Recreation Site Regulations
- Directions for the 21st Century, 1999?
- Conservation Action Plan for Saskatchewan's Park Lands, 2001

General Description and Management Regime:
- Provincial Park Lands encompass provincial parks, recreation sites, historic sites and protected areas. They are designated by legislation. First established in 1931and currently administered by Saskatchewan Environment. The system is a foundation piece for the Representative Area Network.
- The management regime can be characterized as active.

Summary of Policy:
- The Parks Act and Regulations have a strong resource protection goal and restricts damage to vegetation and alteration to land, but provides no direction as to how it will be achieved (e.g. no requirement for management plans, etc.)
- Use is limited to recreational activities and traditional activities – grazing, haying, and trapping. Timber harvesting is allowed as a vegetation management tool.
- Major policy documents provide considerable direction for resource management in light of climate change.
- Resource management planning is usually addressed within a Park Management Strategy or Vegetation Management Plan. The more current the plans the more likely they are to take an ecosystem management approach, address biodiversity conservation, climate change and recognize the need for monitoring.
- The individual park plans have a stronger, systems and ecological focus and provide clear management direction associated with maintaining a dynamic but species-specific ecosystem.

Policy Barriers:
- No resource management plan required by policy
- No specific resource management goals/objectives
- Permitted traditional activities may prove to be a barrier to climate change adaptation.
- The current policy of re-introducing natural disturbances and prohibiting the introduction of exotic species may be a barrier to adapting to climate change.

Policy Opportunities:
- Major policy documents provide considerable direction for resource management at the site level in light of climate change.
- The existing policy instruments are in general alignment, but recent policy efforts and strength lies at the system and park level. Legislation and regulations could be strengthened to address resource management.

Comments:
- Parks have a strong education role that can support climate change adaptation efforts.

Table 5.3: Review of Protected Area Policies for National Parks

<table>
<tr><th>IUCN Class</th><th>Percentage of Protected Areas in the Prairie Ecozone</th></tr>
<tr><td>Class II</td><td>2%</td></tr>
<tr><td colspan="2">Policy Instruments:
▪ Canada National Parks Act, 2000
▪ The Grasslands National Park Act, 2000
▪ Historic Sites and Monuments Act, 1995
▪ National Historic Parks Order
▪ National Parks General Regulations
▪ Guiding Principles and Operational Policies</td></tr>
<tr><td colspan="2">General Description and Management Regime:
▪ National Parks, including historic parks, are designated under federal legislation and administered by the federal government.
▪ The management regime is characterized as active to proactive.</td></tr>
<tr><td colspan="2">Summary of Policy:
▪ National Parks have a strong policy foundation to system planning (based on natural regions), protecting ecological integrity, active management/management planning and adapting to climate change.
▪ To date, the response to climate change has been relatively significant – with there being research to assess climate impacts and possible adaptations and action taken to reduce CO_2 emissions.</td></tr>
<tr><td colspan="2">Policy Barriers:
▪ The policy barrier to climate change may be – what does the park represent given the natural regions foundation that includes existing vegetation, but does not anticipate climate change. Application of particular tools or adaptations (introduction of exotics) will be limited by policy that focus on ecological integrity.</td></tr>
<tr><td colspan="2">Policy Opportunities:
▪ Major policy documents provide considerable direction for resource management at the site level in light of climate change.
▪ The existing policy instruments are in general alignment, but recent policy efforts and strength lies at the system and park level.</td></tr>
<tr><td colspan="2">Comments:
▪ At a systems level, the policy barriers to adapting to climate change relates to its foundation - based on representation of natural regions that includes vegetation and does not anticipate climate change.
▪ Parks Canada was provided with increased funding to support efforts to enhance ecological integrity within the system.
▪ It's mandate to undertake research and provide public education are key features that will support adaptation to climate change.</td></tr>
</table>

Table 5.4: Review of Protected Area Policies for Fish and Wildlife Development Fund Land

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**1.8%**
Policy Instruments: ▪ Natural Resources Act ▪ The Fish and Wildlife Development Fund Wildlife and Fisheries Component Accomplishments 2003-4	
General Description and Management Regime: ▪ The Fish and Wildlife Development Fund (FWDF) is provincial legislation that provides the ability to purchase land for fish and wildlife purposes. ▪ The lands are recognized by policy as protected areas under the RAN program. ▪ The management regime can be characterized as active.	
Summary of Policy: ▪ FWDF lands have a broad mandate to be managed for fish and wildlife purposes and are not restricted in their use. ▪ The activities of the fund indicate that management is undertaken to maintain wildlife habitat often in partnership with other environmental groups. ▪ Recent activities, including the ecological risk assessment, indicate that a more systematic approach to resource management is being adopted. There has been some work related to climate change. ▪ FWDF lands have the benefit of having direct access to dedicated funding and partnerships.	
Policy Barriers: ▪ No resource management plan required by policy, ▪ No resource management goals/objectives, ▪ No reference to ecosystem/biodiversity/or climate change	
Policy Opportunities: ▪ Resource management plans have recently been initiated.	

Table 5.5: Review of Protected Area Policies for Game Preserves and Wildlife Refuges

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**Game Preserves: 1.1%** **Wildlife Refuges: 0.1%**
Policy Instruments: ▪ The Wildlife Act, 1998 ▪ Wildlife Regulations, 1981 ▪ Wildlife Management Zones and Special Areas Boundaries Regulations, 1990	
General Description and Management Regime: ▪ Game preserves and wildlife refuges are provincially designated, by regulation and administered by Saskatchewan Environment. The primary purpose for both is to prohibit hunting. The management regime is considered passive.	
Summary of Policy: ▪ The Wildlife Act provides the authority to establish areas for the protection of wildlife, species at risk and habitat, and, regulating use of the area by hunters, trappers and others. ▪ The Regulations define and designate game preserves and wildlife refuge and prohibits hunting in both. ▪ There are no policies relative to resource management, biodiversity protection, climate change or monitoring.	
Policy Barriers: ▪ No enabling policy for resource management ▪ No resource management plan required by policy ▪ No resource management goals/objectives ▪ No reference to ecosystem/biodiversity/monitoring or climate change	
Policy Opportunities: ▪ The policy opportunity arise from legislation protects wildlife habitat and species at risk.	
Comments: ▪ This encompass a small land base, with a weak policy foundation and narrow focus related to resource use.	

Table 5.6: Review of Protected Area Policies for Migratory Bird Sanctuaries

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**2.3%**

Policy Instruments:
- Migratory Birds Convention Act, 1994
- Migratory Bird Sanctuary Regulations

General Description and Management Regime:
- Migratory Bird Sanctuaries encompass private, provincial and federal lands to "protect migratory birds against physical disturbance and hunting" [6]. On federal land the regulations prohibit disturbance to migratory bird habitat. The areas are administered by the Canadian Wildlife Service, Environment Canada. The management regime is considered passive.

Summary of Policy:
- The federal legislation – The Migratory Birds Convention Act, establishes the authority for regulations to designate and manage Migratory Bird Sanctuaries.
- Establishes "protection measures for migratory birds within bird sanctuaries".
- "Management includes monitoring wildlife, maintaining and improving wildlife habitat, periodic inspections, enforcement of hunting prohibitions and regulations."

Policy Barriers:
- Narrow focus on migratory birds and not ecosystem-based
- No authority over the habitat on non-federal land
- No resource management plan required by policy
- No resource management goals/objectives
- No reference to ecosystem/biodiversity/monitoring or climate change

Policy Opportunities:
- There is a policy opportunity to address migratory species needs to adapt to climate change on a continental scale.

[6] http://www.hww.ca/hww2.asp?id=231

Table 5.7: Review of Protected Area Policies for National Wildlife Areas

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**2.0%**

Policy Instruments:
- Canada Wildlife Act
- Wildlife Area Regulations
- National Wildlife Areas website

General Description and Management Regime:
- National Wildlife Areas (NWAs) are federal lands designated to protect nationally significant wildlife, including species at risk, and wildlife habitat, including migratory bird habitat.
- They are managed by the Canadian Wildlife Service (CWS) of Environment Canada.
- The management regime is considered active, particularly as it relates to Last Mountain Lake NWA which has been subject to considerable management including a Native Prairie Conservation Program.

Summary of Policy:
- The Canada Wildlife Act provides the authority for purchase or lease of private lands and regulating their use and management.
- Wildlife Area Regulations and management plans specify activities that are generally allowed, activities allowed under permit, and habitat improvements.
- The CWS is active in management planning, monitoring and research but there is no specific legislative or regulatory reference.

Policy Barriers:
- No resource management plans, nor resource management goals/objectives required by policy
- No specific reference to ecosystem/biodiversity

Policy Opportunities:
- Given the CWS interest in research and education, there is significant opportunity to undertake research, monitoring and interpretation for climate change impacts and adaptation.

Table 5.8: Review of Protected Area Policies for Wildlife Habitation Protection Act Lands

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**43.8%**

Policy Instruments:

- The Wildlife Habitat Protection Act
- The Wildlife Habitat Lands Disposition and Alteration Regulations
- The Wildlife Habitat Protection Act Backgrounder
- The Provincial Lands Act
- The Provincial Lands Regulations

General Description and Management Regime:

- Wildlife Habitat Protection Act (WHPA) lands are provincial crown lands that encompass some of the best remaining wildlife habitat in Southern Saskatchewan. The lands are administered by Saskatchewan Agriculture, Saskatchewan Environment and the Saskatchewan Watershed Authority, and are available for lease. Most of the land is leased for agricultural purposes. The lands are recognized as protected areas by RAN policy. Although certain activities are prohibited, the resource management regime from a provincial perspective is passive.

Summary of Policy:

- The lands are protected through legislation. The legislation places restrictions on alteration of the land and enables the setting of regulations for their use and management. There is no resource management goal/objective, although it is implied in the title.
- By regulation, use is restricted to agriculture, public roads and utilities, and a variety of grand-fathered activities (e.g. oil and gas exploration and extraction). There are no resource management provisions under the regulations. Fees for grazing permits and leases as set by regulation are based on the carrying capacity of the land (Section 2 (9)). If carrying capacities do not reflect drying conditions, the fees may be a disincentive to reduce grazing levels.
- A passive response to climate change is expected, although management action by the lessee, if so motivated, could be authorized.
- No public management of WHPA lands is currently being anticipated or possible given existing policy. The Lands Act (Section 32) does allow the Minister to authorize the use of crown land "in connections with any project undertaken by or on behalf of any department"
- The large area and dispersed distribution of the WHPA lands, if systematically managed, may provide an opportunity for the RAN to adapt to Climate Change.

Policy Barriers:

- No resource management plan required by policy
- No resource management goals/objectives
- No reference to ecosystem/biodiversity/monitoring or climate change
- possibly the fee structure
- Existing disposition holders

Policy Opportunities:

- Public lands are expected to be used sustainably over the long term.
- Grazing carrying capacities are assessed.
- Adaptation to climate change should be fully embraced by the management regime (and patrons).

Table 5.9: Review of Protected Area Policies for PFRA Community Pastures

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
VI	**28.1%**

Policy Instruments:
- Prairie Farm Rehabilitation Act
- Memorandum of Understanding – Government of Canada and Saskatchewan
- PFRA Community Pastrues Program
- Community Pastures

General Description and Management Regime:
- Similar to WHPA lands, PFRA Community Pastures "represent some of the largest contiguous blocks of healthy native grasslands in Canada". The program was initiated in 1937 to "reclaim badly eroded areas" and now encompasses "in excess of 900,000 ha of rangeland"[7]. Most PFRA Community Pastures are provincial lands administered federally and are recognized as protected by RAN policy. The management regime, with regular grazing assessments is characterized as reactive.

Summary of Policy:
- PFRA was formed to address adaptation to drought conditions.
- The lands are recognized as contributing to the RAN by agreement. The Memorandum of Understanding between PFRA and Saskatchewan Environment recognizes that native rangeland vegetation should be managed to maintain ecological integrity and biodiversity.
- PFRA prepares range management plans that incorporate a range assessment and recommendations to meet PFRA pasture standards. Drought conditions trigger lower carrying capacities, so there is some adaptation to climate change already underway.

Policy Barriers:
- No resource management plan required by policy
- No reference to ecosystem/biodiversity/monitoring or climate change
- Existing patrons
- There could be further alignment of all policy instruments to address resource management.

Policy Opportunities:
- Current policy provides significant opportunity to address climate change.

[7] http://www.agr.gc.ca/pfra/land/cpasture_e.htm

Table 5.10: Review of Protected Area Policies for Provincial Community Pastures

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
VI	**9.5%**

Policy Instruments:

- The Pastures Act, 2000
- The Pasture Regulations
- Saskatchewan Pastures Program[8]
- Letter of Understanding Sask Ag and Food and Sask Environment and Resources Management.
- Hatherleigh Community Pasture Range Management Plan, 1998
- Old Wives Community Pasture Inventory and Range Plan, 2004

General Description and Management Regime:

- Provincial Community Pastures have "been in operation since 1922 with a primary focus of supporting livestock producers through the provision of summer grazing on Crown Lands".
- Saskatchewan Agriculture and Food (SAF) administers the land.
- The management regime, with regular grazing assessments is characterized as proactive or reactive.

Summary of Policy:

- The Pastures Act includes a broad sustainable development–type program objective referring "to developing, protecting and promoting the environmental, social and economic use of pastures".
- The lands are recognized as contributing to the RAN by agreement. The Memorandum of Understanding between SAF and Saskatchewan Environment indicates that native rangeland vegetation should be managed to maintain ecological integrity and biodiversity. Existing dispositions will be honored. Management plans are to be developed and monitoring of ecological resources is to occur.
- Management plans reference biodiversity conservation and sustainable use of biological resources as objectives.
- Drought conditions trigger lower carrying capacities, so there is some adaptation to climate change already underway.

Policy Barriers:

- No specific reference to climate change
- There could be further alignment of all policy instruments to address resource management.

Policy Opportunities:

- Current policy is generally well aligned and provides significant opportunity to address climate change.
- Monitoring will allow for reviewing carrying capacities.

Comments:

- Areas have a Pasture Manager who can provide ongoing monitoring.
- Existing patrons may or may not be a barrier to adaptation.

[8] http://www.agr.gov.sk.ca/docs/crownlandspastures/pastures/pastureprogram02.asp

Table 5.11: Review of Protected Area Policies for Saskatchewan Watershed Authority Lands

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
IV	**1.4%**
Policy Instruments: ▪ The Saskatchewan Watershed Authority Act, 2005 ▪ Prairie Stewardship[9]	
General Description and Management Regime: ▪ The Saskatchewan Watershed Authority (SWA) is a landowner with a mandate to manage, protect and conserve water, watersheds and related land resources. The lands are not specifically designated either by legislation or regulation. ▪ The management regime is active.	
Summary of Policy: ▪ The Saskatchewan Watershed Authority Act provides the authority for the corporation to purchase lands and collect moneys to undertake a variety of management activities related to the management, conservation and protection of water, watershed and related land resources and conservation programs.	
Policy Barriers: ▪ No resource management plans are required by policy ▪ Although conservation and protection of habitat are identified in the act there are no specific resource management goals/objectives ▪ No reference to ecosystem/biodiversity/monitoring or climate change	
Policy Opportunities: ▪ Enables a variety of resource management activities that could support climate change adaptation. ▪ Ability to purchase land ▪ SWA has a mandate to undertake conservation activities in partnership with other individuals and agencies.	
Comments: ▪ SWA is heavily involved in stewardship activities in partnership with local landowners and conservation groups. ▪ SWA has the ability to collect public money for conservation. ▪ Resource management program is very active and aware of climate change and other threats to biodiversity.	

[9] http://www.swa.ca/Stewardship/PrairieStewardship/Default.asp

Table 5.12: Review of Protected Area Policies for PCS Rocanville

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
	0.1%

Policy Instruments:
- From the Ground Up 2003 Potash Corporation of Saskatchewan (PCS) Sustainability Report
- Memorandum of Understanding between the PCS and Saskatchewan Environment

General Description and Management Regime:
- PCS has an agreement with Saskatchewan Environment to protect some of its lands consistent with the objectives of the RAN program. The agreement is referenced on the companies web site where it refers to "Preservation of 3,500 acres of aspen parkland as a major community activity. The land is subject to grazing.
- The management regime is considered passive.

Summary of Policy:
- There is no specific act or regulations governing the agreement.
- The Memorandum of Understanding (MOU) outlines as a key objective the need to manage native rangeland vegetation to maintain ecological integrity and biodiversity. Grazing is expected to continue as a sustainable management tool.

Policy Barriers:
- No resource management plan required by policy
- No reference to ecosystem/biodiversity/monitoring or climate change

Policy Opportunities:
- Resource management goals/objectives are established by the MOU.

Comments:
- PCS may have the resources to prepare resource management plan and monitor the site for climate change.

Table 5.13: Review of Protected Area Policies for Conservation Easements

IUCN Class	Percentage of Protected Areas in the Prairie Ecozone
VI	**?**

Policy Instruments: legislation and regulations
- The Conservation Easements Act
- The Conservation Easements Regulations

General Description and Management Regime:
- Conservation easements are legal instruments that recognize an agreement between a landowner and a conservation agency to protect certain land values for a specified time or in perpetuity without transferring title.
- Saskatchewan Environment administers the provincial legislation, and the lands are recognized as protected by policy under the RAN program.
- The management regime can vary from passive to proactive.

Summary of Policy:
- The Conservation Easements Act provides authority for the crown or private landowner to voluntarily grant and register rights and privileges to a third party to protect, enhance or restore “natural ecosystems” or other conservation values.
- The regulations specify information to be addressed in a conservation easement, including land use practices and allowable conservation practices.

Policy Barriers:
- The purpose of a conservation easement are broad and include “the protection, enhancement or restoration of natural ecosystems, wildlife habitat or habitat or rare, threatened or endangered plant or animal species”. However, there is no specific reference to biodiversity conservation, ecological monitoring or climate change.
- Most existing conservation easements do not provide legal authority for lands to be actively management to address changes that may result from climate change.

Policy Opportunities:
- The act is very enabling and supportive of managing for conservation values.
- Agreements provides for monitoring to ensure compliance with the agreement.
- Opportunity for private land owners and conservation agencies with management expertise to contribute to the objectives of the Representatives Areas Network.
- There is strong alignment of the policy instruments and includes a need to register the agreement.

Comments:
- Agreements usually grants the holder access to monitor compliance with the conditions of the conservation easement (e.g. no break, no drain).
- Where grazing occurs, some holders may assess range condition.

3.3.1 Summary of Policy Review

Saskatchewan's Representative Areas Network encompasses a relatively broad range of federal, provincial and private land designations that are consistent with the IUCN definition of protected areas. The area classified as IUCN Class 1 to 3, namely national parks, provincial parks and ecological reserves, only encompass 7% of the protected lands within the Prairie Ecozone but have a strong policy foundation for adaptation to climate change. The remainder, classified as IUCN 4-6, includes Wildlife Habitat Protection Act Lands, PFRA and provincial community pastures and National Wildlife Areas. Among these areas the community pastures have a good policy foundation for adaptation to climate change.

This policy assessment is based on the assumption that, for effective adaptation to climate change, policy instruments must:

- Have a natural resources mandate
- Provide specific resource management goals and objectives (i.e. ecological integrity, ecological benchmarks)
- Reference an ecosystem management approach
- Reference biodiversity conservation or address the threats to biodiversity – habitat loss, habitat fragmentation, exotic species invasion and resource exploitation, and pesticides and pollution.
- Reference climate change as a management issue
- Mandate or require ecological monitoring

Secondly, the assessment considered whether or not there is alignment among the full range of policy instruments – legislation, regulation, policy documents, management plans, etc. If there is policy alignment, then a clear mandate exists from executive government level (i.e. legislative), and presumably with significant public support, to require "good" resource management, regular management planning focusing on protection/ conservation/ ecological integrity, and a commitment to implement the plans and undertake the regular monitoring. Monitoring should assess the impacts of management actions and/or serve a benchmark purpose, including measuring climate change and ecological response. Where there is strong alignment among the policy instruments to support ecosystem management – particularly planning, implementation, monitoring, adaptive feedback loops, and associated funding – this should be an opportunity to support the assessment of climate change impacts and planning for adaptation to climate change (e.g. Parks Canada). Poor alignment among policy instruments a barrier to adaptation. Usually management policy at the site or agency level will be sound, but prescriptive or enabling legislation, regulations and associated funding to support ecological management is missing. This can result in management planning, and climate change in particular, being a lower priority for agency attention and funding. Where there is poor alignment among the policy instruments, "good" resource management still occurs, but it may be more difficult to establish resource management as a priority, ensure that there is a long term commitment to allow for monitoring, and/or compete for the requisite staff time and resources. Climate change provides another compelling reason for protected area agencies to ensure that they have strong, well-aligned resource management program.

The following are key observations from the policy review:

- Where they exist, most agencies' resource management policies are found at the program or site level.
- Within legislation, most agencies have a natural resource conservation/protection mandate but few either require management plans or have clearly articulated goals or objectives, and do not reference ecosystem management, biodiversity conservation, or climate change.
- Resource management goals and objectives and management planning are referenced in major policy documents for most agencies which are actively involved in day to day management of areas.
- Where management plans exist, ecosystem management, biodiversity conservation and climate change may be referenced, particularly among the more recent plans.
- Although the value of ecological monitoring is recognized and it occurs among some agencies, there is little policy directing that it occur.
- The Representative Areas Network program has brought a wide range of partners into the network. For those protected areas where there is an MOU with the RAN program, there is a strong foundation for active management to meet ecological integrity objectives. The RAN program has not yet adopted a leadership role to guide resource management planning, implementation, or monitoring across the system. The provincial government has made a commitment to establish RAN management policies and standards, and the system is an excellent framework for demonstrating leadership and communications.
- The policies framework for national parks is noteworthy. Parks Canada exhibits the ideal range and alignment of policies to adapt to climate change and, not surprisingly, Parks Canada is among the most active of protected area agencies in addressing climate change.
- Sustainable resource use objectives and management for community pastures are consistent with protected area biodiversity conservation objectives.
- Where lands are leased (e.g. WHPA lands), this may be the biggest barrier to climate change adaptation. However with education, those farmers and ranchers grazing cattle may be the best opportunity for climate change adaptation, as they have a vested economic interest in maintaining the best possible range condition, and there is on-going monitoring.

3.3.2 Barriers

A number of barriers to adaptation were observed to exist among the various policy instruments.

- No full alignment of natural resources management policies from legislation to site management level. Usually resource management policy only exists at one level, the site level or major policy level.
- No specific resource management goals/objectives – although ecosystem management and biodiversity conservation are generally recognized among the various management agencies responsible for protected areas.
- No prescriptive policy requiring resource management planning, addressing climate change, or monitoring.

3.4 Managers Workshop

A workshop was held in March 2006 with protected areas managers who participated in the Representatives Areas Network. The workshop was intended to engage at least one representative from each agency having responsibility for the management of a protected area(s), located within the Prairie Ecozone of Saskatchewan, and present the results of the research. The workshop encompassed the following topics:

- What are the current efforts of the federal and provincial government around climate change?
- What are climate models predicting as to impacts on vegetation over the next 50 years for Saskatchewan and for Protected Areas in the Prairie Ecozone?
- What are the implications of climate change for site management?
- What is climate change adaptation? What are alternative adaptation strategies?
- What are the opportunities or barriers to adaptation presented by various policy instruments guiding protected area management?
- What should be a climate change policy for protected areas for Saskatchewan?

Copies of the material presented both in advance of the workshop and during the workshop are found in Appendix 3.

The workshop was attended by over 20 protected area managers and individuals with an interest in climate change adaptation. The response to the findings of the research was generally positive, but specific issues were raised:

- What is the expected impact of climate change on noxious weeds?
- What is the value of the RAN designation in light of climate change?
- Legislation "prescribing" management plans may be problematic.
- Expansion of RAN in the south may require restoration – what is the impact of climate change on this activity?
- Explain what is meant by “ecosystem management”.
- Need to identify the policy instruments reviewed for each type of designation.

4 BIOPHYSICAL IMPACTS OF CLIMATE CHANGE ON PROTECTED AREAS IN SASKATCHEWAN’S PRAIRIE ECOZONE

4.1 Approach

One of the critical questions for protected area policy is the impact of climate change on the natural ecosystems that are being protected. In order to address this question, we analyzed the potential future changes in vegetation zonation in the Prairie Ecozone of Saskatchewan.

The best model for the current vegetation zones of the prairie region is Hogg’s (1994) Climatic Moisture Index (CMI), which is defined as annual precipitation minus annual potential evapotranspiration (estimated by the Jensen-Haise method). Hogg (1994) showed that CMI = 0 correlates well with the boundary between boreal forest and aspen parkland, while CMI = -15 cm correlates with the southern edge of the aspen parkland. R. Anderson (Saskatchewan

Environment, personal communication) is using this approach to predict deterioration in grasslands and croplands as climate change produces drier conditions (lower values of CMI) than are currently found in this region.

One way of extending this work is to look at the major grassland types occurring in the Great Plains of the United States. Similar climates to those predicted by the climate change scenarios for the Canadian Prairies can presently be found in the central and northern Great Plains. Therefore, the vegetation types that occur in those climates can be used as analogues for the future vegetation of our region. Analogues cannot be taken as exact predictions, because of lags in migration of species and other factors, but they can show the direction of future changes. One advantage of this approach is that it allows us to visualize future changes in relation to actual vegetation types for which information on species composition and productivity are available. The approach of the current project has been to model the climatic envelopes of these U.S. vegetation types, and use this to estimate the most probable vegetation type under future climates that are beyond the range currently found in the Canadian prairies.

4.2 Methods

4.2.1 Modelling the distribution of U.S. vegetation types

A variety of maps are available showing U.S. vegetation zones or ecoregions. Review of these maps showed that most of them (Bailey 1978, 1981; Risser et al. 1981; Ricketts et al. 1999) are based at some level on Kuchler's (1964) classic map of the potential natural vegetation of the U.S. The exception is the classification of Omernik (1987), which is based largely on physiography rather than vegetation. Therefore, the types used in the current project were based directly on Kuchler's types. Rather than using Kuchler's type names, which are based on plant species that may not be familiar to everyone, we have used more familiar descriptive names for these zones. The major zonal types occurring in the central and northern Great Plains (excluding those associated with unusual landscape features such as the Nebraska Sandhills), are listed in Table 6. In addition to the Great Plains grasslands, we also considered three types occurring immediately west of the continental divide (K55, K56, and K53 in Table 6), to account for a somewhat wider range of possible future climates. The spatial distribution of these types is shown in Figure 4.

The Foothills Prairie type occurs in the foothills of the Montana Rockies, at the western edge of the Great Plains and extending into intermountain valleys west of the continental divide. The Northern Mixed Prairie extends from eastern Montana and eastern Wyoming through North and South Dakota and Nebraska. The Shortgrass Prairie extends from southeastern Wyoming and southwestern Nebraska through eastern Colorado and New Mexico and western Kansas, Oklahoma, and Texas. The Southern Mixed Prairie is found in moister climates east of the Shortgrass Prairie in Kansas and Oklahoma. The Tallgrass Prairie is found at the eastern edge of the Great Plains, from eastern North Dakota and western Minnesota down through western Iowa and eastern South Dakota, Nebraska and Kansas. The Sagebrush Steppe occurs in western Wyoming and northwestern Colorado, as well as further west in Idaho, Washington, Oregon, Nevada, and Arizona. However, for the analysis, only the portions in Wyoming and Colorado were considered. The Desert Steppe type considered (Kuchler's Grama-Galeta type) occurs mainly in intermountain valleys in New Mexico.

Table 6: Major zonal grassland types in and adjacent to the central and northern Great Plains of the United States, after Kuchler (1964).

DESCRIPTIVE NAME	KUCHLER TYPES	
Foothills Prairie	K63	Foothills Prairie
Northern Mixed Prairie (dry)	K64	Grama-Needlegrass-Wheatgrass
Northern Mixed Prairie (intermediate)	K66	Wheatgrass-Needlegrass
Northern Mixed Prairie (moist)	K67	Wheatgrass-Bluestem-Needlegrass
Shortgrass Prairie	K65	Grama-Buffalo Grass
Southern Mixed Prairie	K69	Bluestem-Grama
Tallgrass Prairie	K74	Bluestem
Sagebrush Steppe	K55	Sagebrush Steppe
Sagebrush Steppe	K56	Wheatgrass-Needlegrass Shrubsteppe
Desert Steppe	K53	Grama-Galleta Steppe

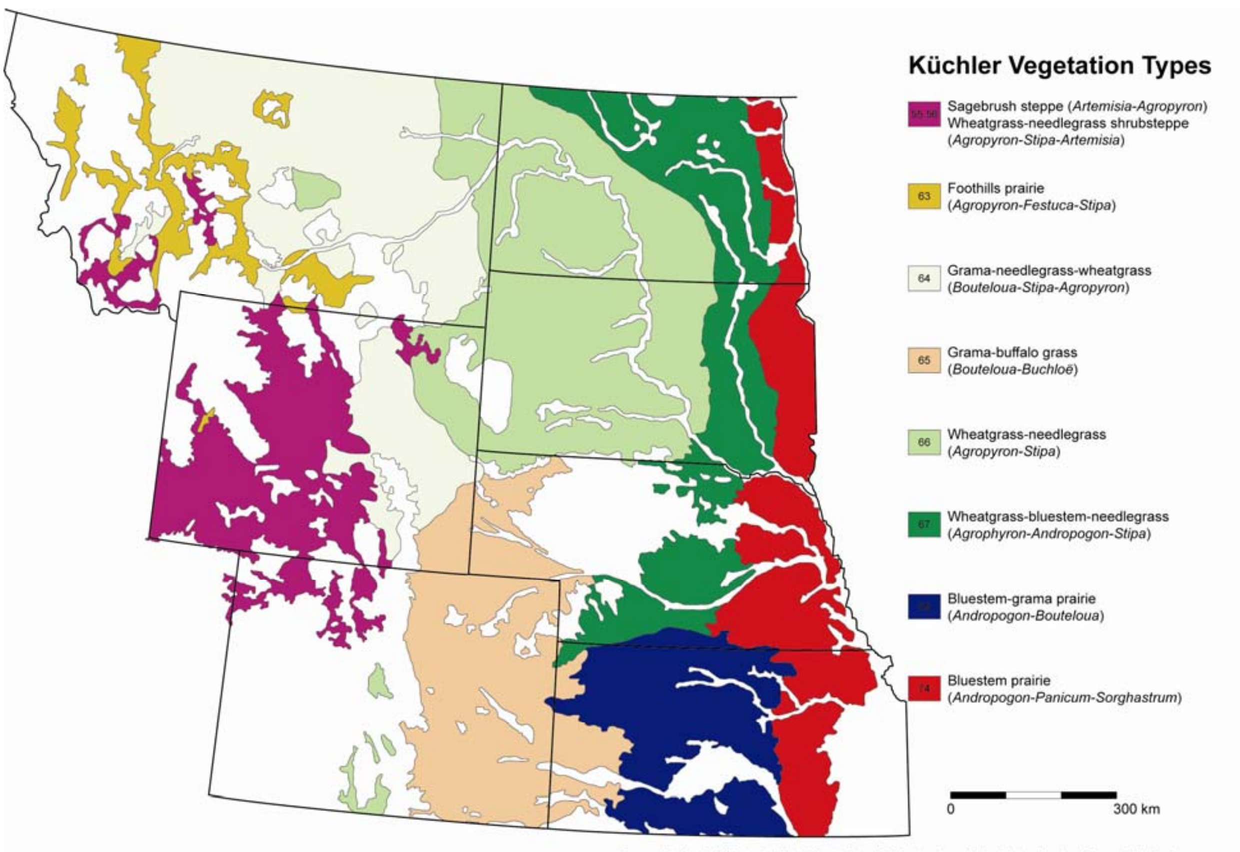

Figure 4: Major zonal grassland types in and adjacent to the central and northern Great Plains, after Kuchler (1964).

For the analysis, types K55 and K56 were combined into a Sagebrush Steppe type. Shortgrass Prairie (Type K65) was split into northern (K65N: Wyoming, Colorado, Nebraska, Kansas) and southern (K65S: Oklahoma, Texas, New Mexico) parts because of its great latitudinal extent.

The main climatic variables considered were annual precipitation (PPT) and annual potential evapotranspiration (PET), because these are the variables used in Hogg's (1994) CMI model. In addition, we were interested in seasonal distribution of precipitation, because of research from the U.S. showing that this differentiates some vegetation types (Paruelo and Lauenroth 1996, Winslow et al. 2003). Kuchler vegetation types and 1961-90 monthly climatic normals on a half-degree grid for the United States were available from www.cgd.ucar.edu/vemap/. Monthly values of precipitation were used to calculate the proportion of the annual precipitation falling in summer (June, July, and August). Potential evapotranspiration by the Jensen-Haise method (the method used in Hogg's work) was obtained for the same gridpoints from http://eos-webster.sr.unh.edu.

Figure 5 shows the distribution of PPT and PET values (interquartile ranges) at gridpoints falling in each Kuchler type. This confirms that most of the types can be separated using these variables. The diagonal lines on the diagram show the deficit (PPT – PET, i.e. Hogg's CMI). This gradient separates some of the types, but there are cases where different types occur at similar levels of deficit, showing that CMI alone would not be sufficient to separate them.

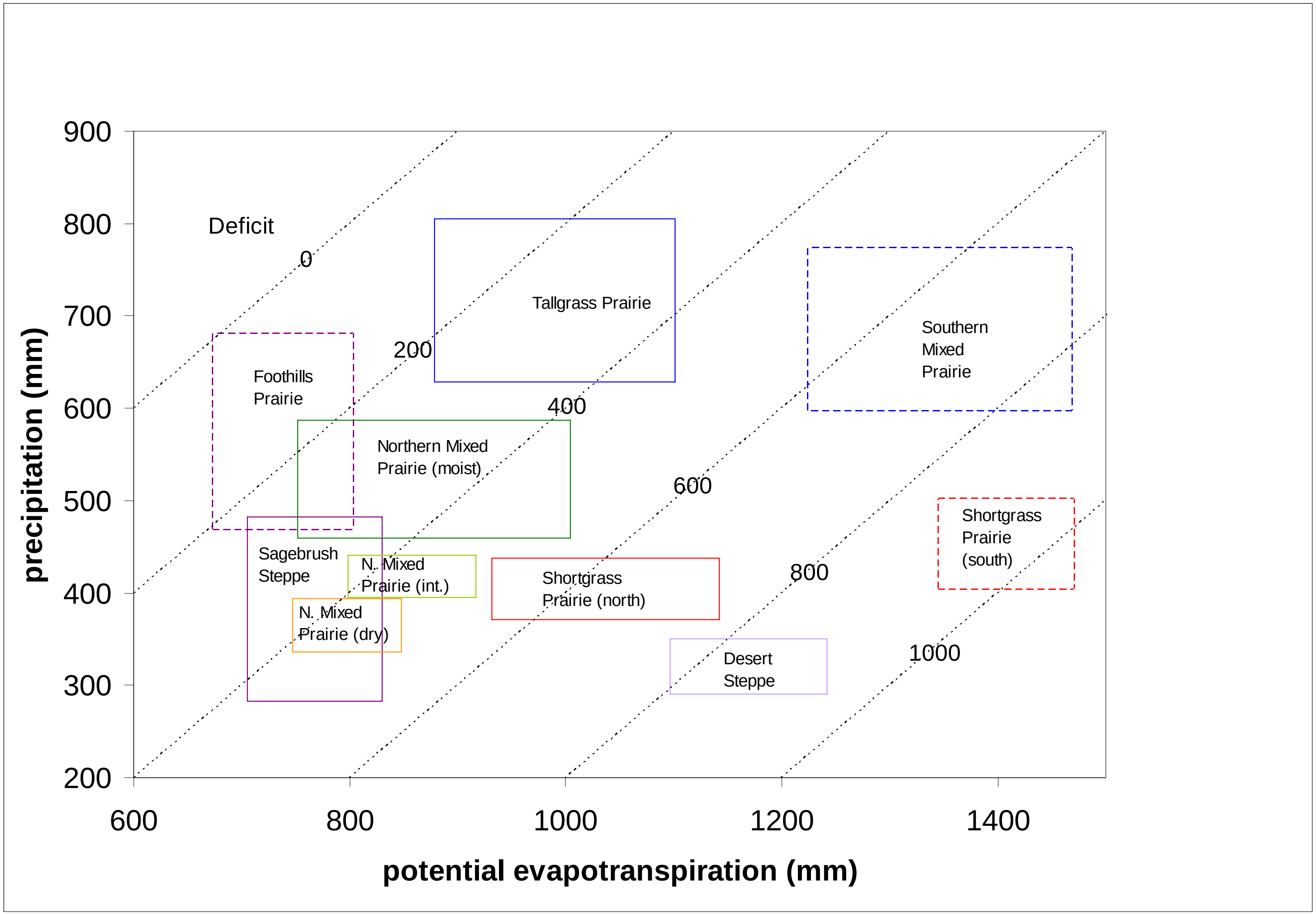

Figure 5: **Interquartile ranges of annual precipitation and annual potential evapotranspiration for 11 major vegetation zones in the U.S. Great Plains and adjacent areas. The diagonal dashed lines represent levels of the Climatic Moisture Index (precipitation minus potential evapotranspiration).**

The next step was to develop a mathematical model to predict vegetation types from climate variables. For predicting group membership on the basis of continuous variables, McCune et al. (2002) recommended using classification and regression trees, discriminant analysis, or multinomial logistic regression. Classification and regression trees require specialized software that we did not have. Discriminant analysis requires a number of statistical assumptions that are rarely met in ecological data. Therefore, multinomial logistic regression (nominal regression in SPSS) was used to predict vegetation types as a function of continuous climatic variables. The program in SPSS arbitrarily picks one of the types as a reference category, and calculates the probability of each type relative to that reference. For each vegetation type, the model gives a regression equation of the following form:

$$\ln(P_{type} / P_{reference}) = b_0 + (b_1 * PPT) + (b_2 * PET) + (b_3 * SUMMERPPT)$$

where P_{type} is the probability of the type in question, $P_{reference}$ is the probability of the reference type, PPT is annual precipitation, PET is annual potential evapotranspiration, SUMMERPPT is the proportion of precipitation falling in summer, and b_0, b_1, b_2, b_3 are regression coefficients. The interpretation is that, for a given set of climatic variables, the type with the highest value of $\ln(P_{type} / P_{reference})$ is the most probable type. Types that are more probable than the reference type will have positive values of $\ln(P_{type} / P_{reference})$, while types that are less probable will have negative values. If all of the other types have negative values, the reference type, with $\ln(P_{type} / P_{reference}) = 0$, is the most probable type.

The regression model showed a good fit to the data (Cox and Snell pseudo R-square = 0.954). Because the SUMMERPPT variable has not been used in Hogg's (1994) work, we also calculated a logistic regression using only PPT and PET. This model gave poor fits for types west of the continental divide, consistent with the idea that seasonal distribution of precipitation (higher proportion falling in winter) helps to differentiate these types. Therefore, the model was rerun using only the Great Plains types. This also gave an acceptable model (Cox and Snell pseudo R-square = 0.918), but could give misleading results if the scenarios gave climates more like the western types that have been excluded. Therefore, it was decided to use the model based on all three independent variables.

Preliminary application of this model to Canadian climate data (both 1961-90 normals and three 2050s scenarios; see Section 2.2) showed that the southernmost U.S. types (K53, K65S, and K69) are not projected to occur in Canada under any of the scenarios. Comparison of precipitation and potential evapotranspiration values for the three 2050s scenarios with those in the U.S. types confirmed that these three types are outside of the range predicted for Canada in the 2050s. Therefore, the logistic regression was recalculated leaving out these types. The final logistic regression also showed a good fit to the data (Cox and Snell pseudo R-square=0.924), and appeared to fit slightly better for certain types. The coefficients of the model are shown in Table 7.

Table 7: Coefficients of logistic regression model for predicting membership of U.S. grassland types from climatic variables.

Type	K63 Foothills Prairie	K64 Northern Mixed Prairie (dry)	K66 Northern Mixed Prairie (intermediate)	K67 Northern Mixed Prairie (moist)	K74 Tallgrass Prairie	K65N Shortgrass Prairie	K55,56 Sagebrush Steppe
Constant	-37.298	-29.53	-67.219	-190.354	-252.386	-73.987	0
PPT	.027	.001	.031	.102	.163	.002	0
PET	.004	.007	.017	.023	.01	.04	0
SUMMERPPT	70.895	78.182	121.6	310.128	399.599	114.753	0

4.2.2 Current and future climates

Current climates in the Canadian prairies were represented by 1961-90 normals. The station data have been used to develop continuous data surfaces for temperature and precipiation by D. McKenney of the Canadian Forest Service (available from the website of the Canadian Climate Impacts and Scenarios project (http://www.cics.uvic.ca/scenarios/index/cgi). These surfaces are represented by a fine grid of points (0.14 degrees latitude by 0.14 degrees longitude). A subset of these gridpoints encompassing the Prairie Ecozone in Alberta, Saskatchewan, and Manitoba was selected for further analysis. This subset extended from 49.125° to 54.125° north latitude and from 96.0972° to 115.125° west longitude. Global solar radiation, needed for calculation of Jensen-Haise potential evapotranspiration, was interpolated to this grid from monthly contour maps presented by McKay and Morris (1985), following the approach used by Hogg (1994). Elevation, also needed for Jensen-Haise PET, was interpolated to the same grid from a digital elevation model.

Future climates for the period 2040-2069 (referred to as the 2050s) were obtained using three climate change scenarios available from the Canadian Climate Impacts and Scenarios project:

- CGCM2 A21
- CSIROMk2b B11
- HadCM3 B21

These scenarios were selected by Henderson et al. (2002) because they represent the range of results from the most recent GCM scenarios published. These are "warm-start" scenarios that initially run using the known atmospheric composition over the past century, then continue using an emissions scenario for the coming century. Emissions are based on the SRES scenarios (IPCC 2000). The scenarios give change values from the present (1961-90) to the future (2040-2069) for temperature, precipitation, solar radiation, and other variables. The change values were applied through inverse distance-weighted interpolation to the 1961-90 normals as represented by McKenney's grid, to give gridded 2050s climate values.

Monthly Jensen-Haise potential evapotranspiration was calculated for each grid point from temperature, solar radiation, and elevation, using formulas given by Jensen et al. (1990). Monthly values were summed to give annual potential evapotranspiration. Hogg's (1994) CMI was calculated as annual precipitation minus annual potential evapotranspiration. The proportion of annual precipitation falling in June, July, and August (SUMMERPPT) was calculated from monthly precipitation data.

4.2.3 Prediction of future vegetation types

The next step was to use the climate data to predict vegetation types. If the climate data were within the range currently found within Canada, the approach used by Hogg (1994) was followed. Vegetation zones, which largely follow the description in the Atlas of Saskatchewan (Thorpe 1999), were defined by values of the climatic moisture index (CMI) (Table 8).

Table 8: Thresholds of the climatic moisture index (CMI) used to define Canadian vegetation zones.

CMI	Vegetation zone
>0	Forest
0 to -150 mm	Aspen Parkland
-150 to -300 mm	Mixed Prairie
<-300 mm	Dry Mixed Prairie

In addition, the Foothills Fescue region of southwestern Alberta falls within the same range of CMI values as Aspen Parkland. By trial and error, it was found that this region could be discriminated from the rest of the Aspen Parkland by a lower proportion of precipitation in summer (SUMMPPT <0.35).

Climates were considered to be outside of the range of current Canadian climates if PET was higher than values calculated along the 49th parallel using 1961-90 normals. In this case, the logistic regression described in Section 2.1 was used to predict the occurrence of Kuchler's U.S. vegetation types.

Vegetation types predicted by the models were mapped using MapMaker GIS software with the Universal Transverse Mercator projection (Saskatchewan extended zone 13).

4.2.4 Application of results to selected protected areas

Nineteen protected areas were selected to represent a variety of ecoregions and management types (Table 9). Locations of these types were obtained from Saskatchewan Environment (G. Bahr, personal communication) and plotted on the maps of predicted vegetation types to estimate the change in vegetation zonation from the present to the 2050s. Climatic variables for the case study areas were taken from the nearest gridpoint to each.

Current ecosystems at the case study areas were summarized from literature review and personal knowledge of the authors. Impacts of climate change were interpreted by considering both the current ecosystems and the predicted change in vegetation zonation at the case study locations.

Table 9: Protected areas selected as case studies, in relation to ecoregion and management type.

	ECOREGION			
MANAGEMENT TYPE	**Aspen Parkland**	**Moist Mixed Grassland**	**Mixed Grassland**	**Cypress Upland**
National Park			Grasslands	
National Historic Site				Fort Walsh
Provincial Park (Natural Environment)	Moose Mountain	Douglas	Saskatchewan Landing	Cypress Hills
Provincial Park (Recreation)	Echo Valley	Buffalo Pound		
Provincial Park (Historic)	Fort Carlton			
Provincial Protected Area			Matador Grasslands	
Provincial Ecological Reserve	Assiniboine Slopes	Buffalograss	Great Sand Hills	
Provincial Pasture	Hatherleigh		Old Wives	
PFRA Pasture	Wolverine	McCraney	Govenlock	
Corporate	PCS Rocanville			

4.3 Results

4.3.1 Vegetation types in the Great Plains

Figure 6 shows the distribution of the Canadian and U.S. vegetation types in relation to climatic variables. The main types found in Saskatchewan (Aspen Parkland, Mixed Prairie, and Dry Mixed Prairie) follow a gradient of decreasing CMI, which is associated both with decreasing precipitation and increasing potential evapotranspiration. U.S. Northern Mixed Prairie and U.S. Shortgrass Prairie are separated from the Canadian types along a gradient of increasing PET, resulting in lower CMI. The Canadian Foothills Fescue and the similar U.S. Foothills Prairie occur at higher precipitation, but were differentiated in the models mainly by a lower proportion of precipitation falling in summer.

The plant species and other features that characterize these vegetation zones have been summarized in Appendix 4. This is a prairie region. Tree cover in natural areas declines sharply at the northern edge of the region, from forest (continuous tree cover) to aspen parkland (mosaic of woodland and grassland) to mixed prairie. From Canada – Mixed Prairie southward to U.S. – Shortgrass Prairie, the natural vegetation is predominantly open grassland with little tree cover, except in unusual sites such as riparian areas or steep valley-slopes. There is also a decline in shrub cover in the grassland (e.g. snowberry, rose, wolf-willow) from Aspen Parkland through Mixed Prairie to very little shrub cover in Dry Mixed Prairie, U.S. Northern Mixed Prairie (dry) and U.S. Shortgrass Prairie. However sagebrush cover increases on some soils in these drier grassland types.

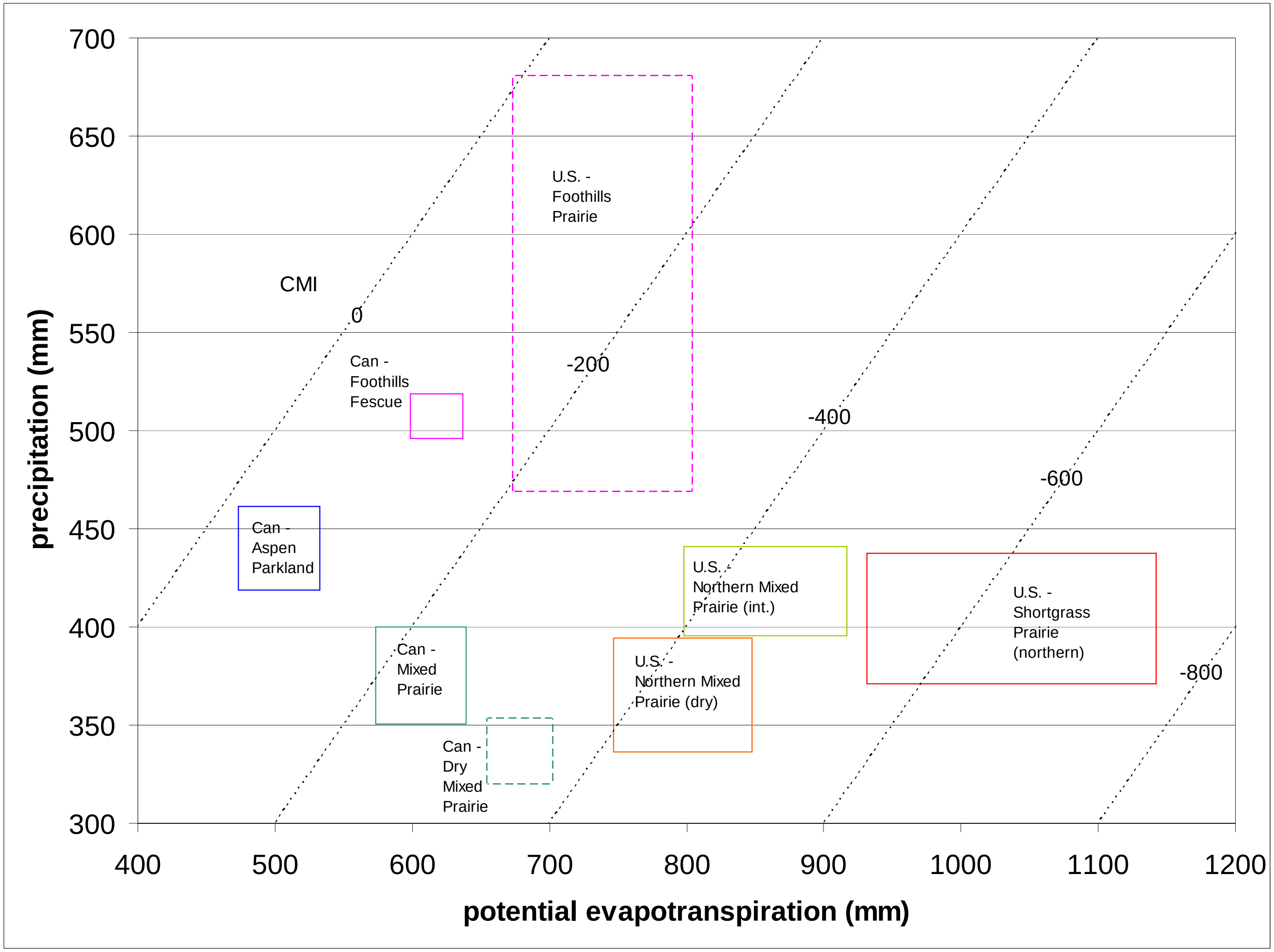

Figure 6: Interquartile ranges of annual precipitation and annual potential evapotranspiration for four major vegetation zones in the Canadian Prairies and four in the U.S. Great Plains. The diagonal dashed lines represent levels of the Climatic Moisture Index (precipitation minus potential evapotranspiration).

Within the grassland, the most obvious trend is in the height of the grass. Medium-height grasses or midgrasses are dominant in Foothills Fescue/ U.S. Foothills Prairie, Aspen Parkland, Mixed Prairie, and U.S. Northern Mixed Prairie (dry and intermediate). The proportion of shortgrasses increases southward/westward in the warmer/drier types (Dry Mixed Prairie, U.S. Northern Mixed Prairie (dry)), and shortgrasses become dominant in U.S. Shortgrass Prairie. The proportion of tallgrasses increases eastward, in the eastern part of the Aspen Parkland and in U.S. Northern Mixed Prairie (moist), and tallgrasses become dominant in U.S. Tallgrass Prairie. The tallgrass prairie actually comes a little way into Canada, in the Red River Valley of southern Manitoba.

Less obvious is the shift from cool-season to warm-season grasses. Cool-season plants (e.g. needlegrasses, wheatgrasses, fescues) have the C_3 photosynthetic pathway, and grow best at cooler temperatures. Warm-season plants (e.g. gramas, bluestems, dropseeds) have the C_4 pathway and grow best at warmer temperatures. Cool-season grasses are highly dominant in Foothills Fescue / U.S. Foothills Prairie, Aspen Parkland, and Mixed Prairie. Warm-season grasses become more important in the plant community in Dry Mixed Prairie, in the southeastern end of Aspen Parkland, and in U.S. Northern Mixed Prairie. U.S. Shortgrass Prairie and U.S. Tallgrass Prairie are dominated by warm-season grasses.

Review of the species lists in Appendix 4 shows that many species are wide-ranging, occurring at varying levels of dominance in many of the vegetation zones. Examples include: western wheatgrass, needle-and-thread, blue grama, June grass, sedges, sand reedgrass (on sandy soils), pasture sage, prairie sage, scarlet mallow, moss-phlox, dotted blazing-star, broomweed, hairy golden-aster, plains prickly-pear, lance-leaved psoralea, skeletonweed, prairie coneflower, scarlet gaura, purple prairie-clover, western snowberry, and prairie rose. Other wide-ranging species, such as western porcupine grass, northern wheatgrass, and wolf-willow, are somewhat more concentrated in the northern vegetation types. Plains rough fescue is more narrowly concentrated at the northern fringe of the region. A number of species, including foothills rough fescue, Idaho fescue, Columbia needlegrass, Richardson's needlegrass, Parry oatgrass, bluebunch wheatgrass, lupines, larkspurs, cranesbill, and shrubby cinquefoil are concentrated in the Foothills Fescue and U.S. Foothills Prairie. Arrowleaf balsamroot occurs in both U.S. Foothills Prairie and U.S. Sagebrush Steppe. Some species are important in both Foothills Fescue and Aspen Parkland: awned wheatgrass, Hooker's oatgrass, timber oatgrass, mouse-ear chickweed, and northern bedstraw. Kentucky bluegrass (which is predominantly exotic in origin) is concentrated in the moister regions, both northern and southern: Foothills Fescue, Aspen Parkland, U.S. Northern Mixed Prairie (intermediate and moist), and U.S. Tallgrass Prairie.

Other species are more characteristic of warmer climates. Little bluestem occurs widely in Canada (Mixed Prairie and Aspen Parkland), but increases southward, especially in U.S. Northern Mixed Prairie (moist) and U.S. Tallgrass Prairie. Big bluestem, porcupine grass, and prairie dropseed are more restricted in Canada (occurring mainly in the southeastern part of the Aspen Parkland), and increase southward into U.S. Northern Mixed Prairie (moist) and U.S. Tallgrass Prairie. Species that are more restricted to warm, moist types in the U.S. include side-oats grama, Indian grass, switchgrass, prairie cordgrass, ironweed, and leadplant.

Sagebrushes increase in drier regions, from Dry Mixed Prairie (silver sagebrush only) to U.S. Northern Mixed Prairie (dry) (both silver sagebrush and big sagebrush). Big sagebrush reaches its highest concentration in U.S. Sagebrush Steppe, where it is favoured by both a dry climate and a low proportion of precipitation in summer. Other species of warm, dry climates, including buffalograss, yucca, hairy grama, squirreltail, red three-awn, bahia, become most important in U.S. Shortgrass Prairie. These species may also occur in neighbouring types, but are absent or rare in Canada.

4.3.2 Climate change in southern Saskatchewan

Table 10 gives an overview of the climate change predicted by the three scenarios for selected Saskatchewan locations. Growing degree-days (GDD) are an indication of the amount of heat available for plant growth. All scenarios show a large increase in growing degree-days at each location. Potential evapotranspiration (PET) is an estimate of the amount of evaporation that would occur from a vegetated surface if there was always an ample supply of moisture. Because evaporation depends on temperature, PET also increases significantly under all three scenarios. Precipitation (PPT) shows little change under one scenario, or small increases under the other two scenarios. However, moisture conditions for plant growth depend not only on precipitation but also on evaporation. The Climatic Moisture Index (CMI), which is calculated as PPT minus PET, shows significant decreases under all scenarios, driven by the increase in PET. This indicates drier conditions in the future. The proportion of the precipitation occurring in summer decreases slightly under all three scenarios.

Climate changes are presented in map form for the present (1961-90 normals) and one of the 2050s scenarios (CSIROMk2b B11) (Figures 7 to 10). The maps again show the large increase in temperature (as represented by growing degree-days) and the small change in precipitation predicted by the scenarios.

Table 10: Representative climate data for southern Saskatchewan, in 1961-90 normals, and in three scenarios for the 2050s.

		2050s scenarios:		
city	**1961-90 normals**	**CGCM2 A21**	**CSIROMk2b B11**	**HadCM3 B21**
	Growing degree-days:			
Prince Albert	1408	2023	1894	1870
Saskatoon	1618	2303	2107	2139
Regina	1575	2334	2109	2116
Estevan	1759	2626	2334	2356
Consul	1544	2232	2005	2167
	Potential evapotranspiration (mm):			
Prince Albert	468	585	618	615
Saskatoon	545	679	721	724
Regina	622	821	833	828
Estevan	650	880	887	881
Consul	711	917	940	990

		2050s scenarios:		
city	**1961-90 normals**	**CGCM2 A21**	**CSIROMk2b B11**	**HadCM3 B21**
	Precipitation (mm):			
Prince Albert	409	404	431	428
Saskatoon	359	357	372	369
Regina	362	363	370	370
Estevan	407	411	402	418
Consul	315	317	332	320
	Climatic Moisture Index (mm):			
Prince Albert	-60	-182	-187	-187
Saskatoon	-186	-322	-349	-356
Regina	-259	-457	-463	-458
Estevan	-242	-469	-485	-463
Consul	-396	-600	-608	-670
	Proportion of precipitation in summer:			
Prince Albert	0.47	0.45	0.44	0.43
Saskatoon	0.44	0.41	0.40	0.39
Regina	0.43	0.40	0.39	0.38
Estevan	0.43	0.39	0.38	0.37
Consul	0.40	0.36	0.35	0.35

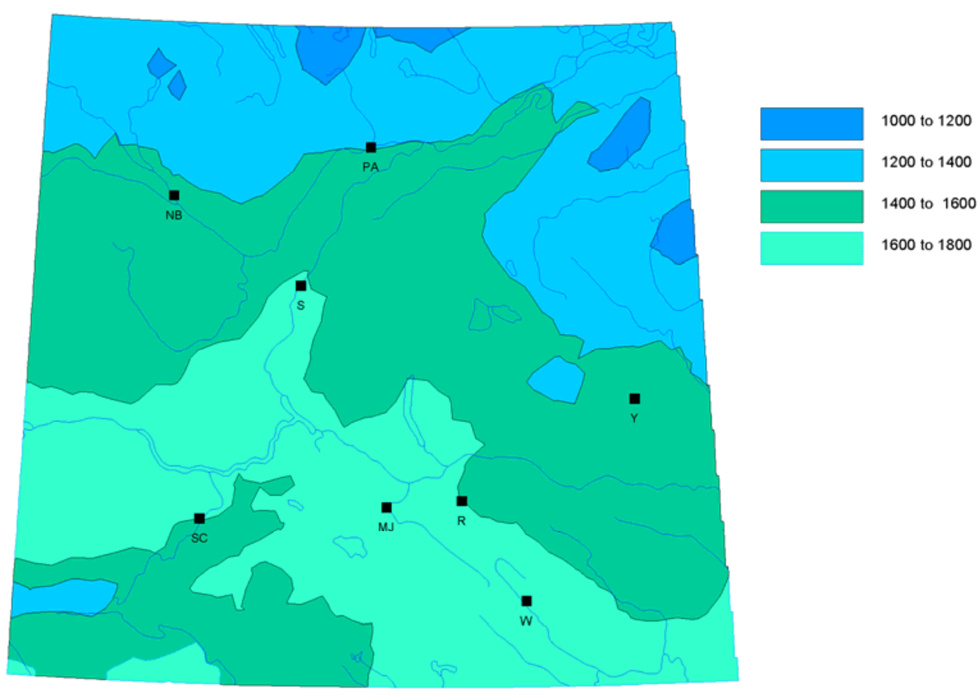

Figure 7: Growing degree-days in southern Saskatchewan based on 1961-90 normals. Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

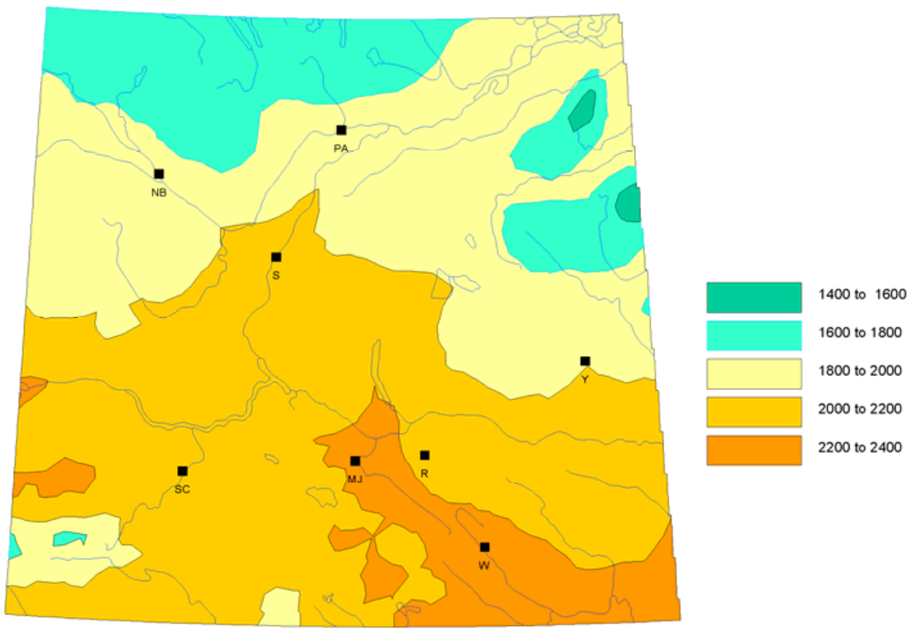

Figure 8: Growing degree-days in southern Saskatchewan in the 2050s based on the CSIROMk2b B11 scenario. Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

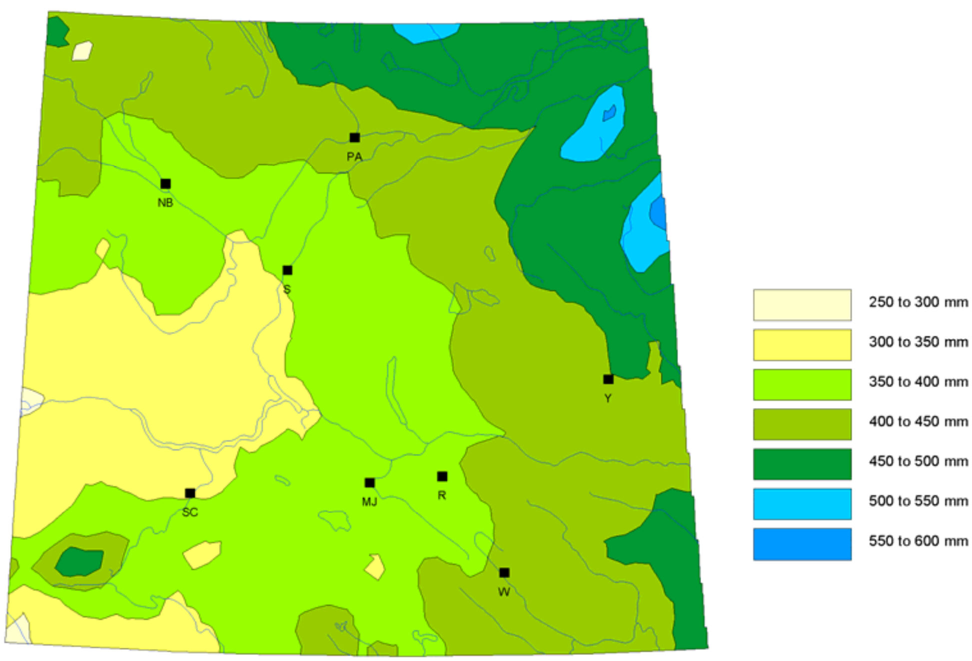

Figure 9: Annual precipitation in southern Saskatchewan based on 1961-90 normals. Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

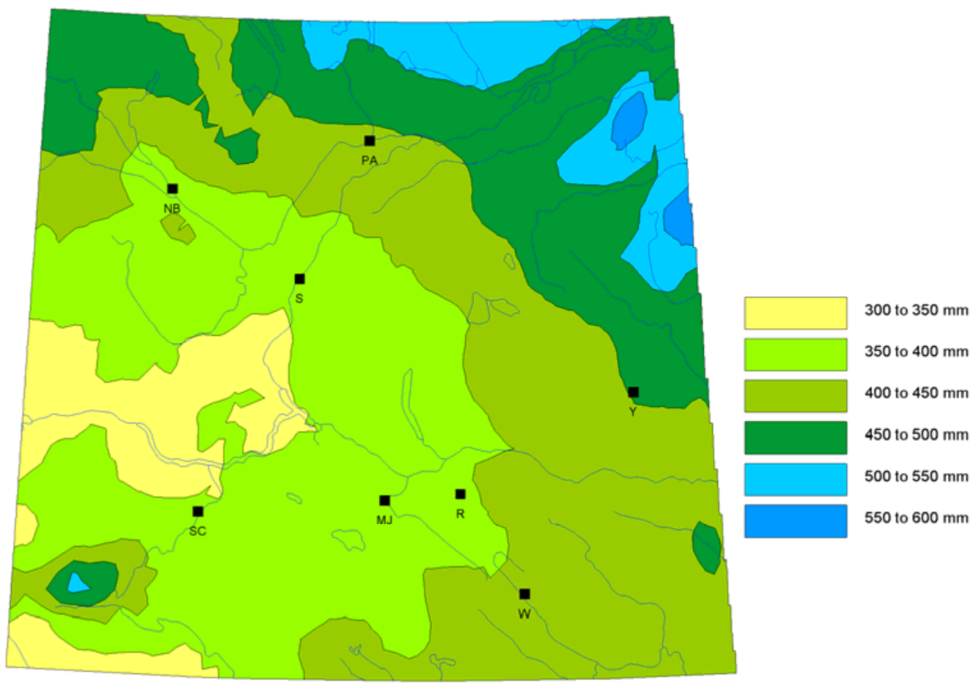

Figure 10: Annual precipitation in southern Saskatchewan in the 2050s based on the CSIROMk2b B11 scenario. Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

4.3.3 Predicted changes in vegetation zonation

Figure 11 shows the predicted vegetation zones in southern Saskatchewan under the current climate. Also shown are the locations of the case study areas, using the abbreviations shown in Table 11.

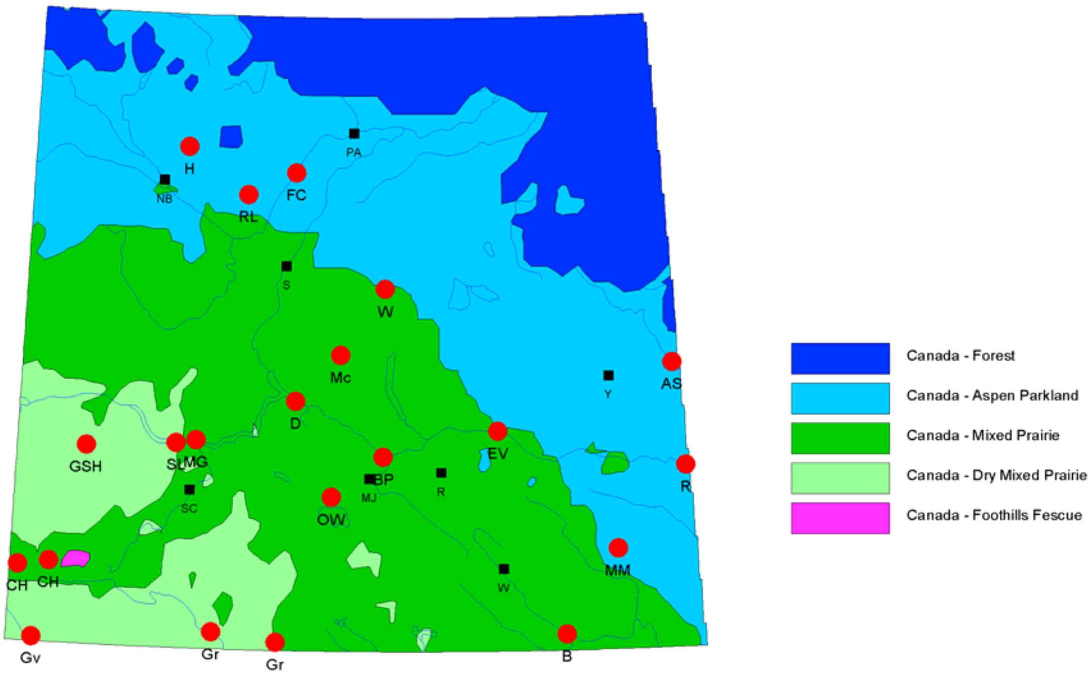

Figure 11: Predicted vegetation zones in southern Saskatchewan under the current climate (1961-90 normals). Red dots indicate case study areas (full names in Table 11). Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

Table 11: Case study areas, with abbreviations used on vegetation zonation maps.

AS	Assiniboine Slopes Ecological Reserve
B	Buffalograss Ecological Reserve
BP	Buffalo Pound Provincial Park
CH	Cypress Hills Provincial Park (West Block and Centre Block)
D	Douglas Provincial Park
EV	Echo Valley Provincial Park
FC	Fort Carlton Provincial Park
FW	Fort Walsh National Historic Site
Gr	Grasslands National Park (West Block and East Block)
GSH	Great Sand Hills Ecological Reserve (proposed)
Gv	Govenlock Community Pasture
H	Hatherleigh Community Pasture
Mc	McCraney Community Pasture
MG	Matador Grasslands Provincial Protected Area
MM	Moose Mountain Provincial Park
OW	Old Wives Community Pasture
R	PCS Rocanville (private stewardship area)
SL	Saskatchewan Landing Provincial Park
W	Wolverine Community Pasture

On the whole, the predicted vegetation zones in Figure 11 correspond with the actual distribution as shown in the Atlas of Saskatchewan (Thorpe 1999), indicating that the model works reasonably well for the current situation. The main exception is that the Aspen Parkland is shown extending too far north in the western part of the province, into areas that are actually boreal forest. Note that Figure 11 shows Canadian Foothills Fescue in the Cypress Hills. While most of this vegetation zone occurs in the foothills of the Rockies, the fescue grassland of the higher elevations in the Cypress Hills is essentially the same type of vegetation.

Figures 12, 13, and 14 show the shifts in vegetation zones expected by the 2050s, using three different climate change scenarios. Most of the Forest in the region mapped (south of 54° latitude) is replaced by Aspen Parkland. Most of the Aspen Parkland is replaced by Canada - Mixed Prairie, and in the eastern part of the province by the dry or the intermediate variants of U.S. - Northern Mixed Prairie. Of the area currently mapped as Canada - Mixed Prairie, the northern fringe shifts to Canada - Dry Mixed Prairie, but most of it shifts to the drier form of U.S. - Northern Mixed Prairie. Most of the area currently mapped as Canada Dry Mixed Prairie shifts to the drier form of U.S. - Northern Mixed Prairie. The driest part, in the southwest corner of the province, shifts to U.S. - Shortgrass Prairie. The Canada - Foothills Fescue in the Cypress Hills shifts to the similar U.S. - Foothills Prairie type. While there are differences in the sizes of the shifts among the three climate change scenarios, they all show approximately the same changes.

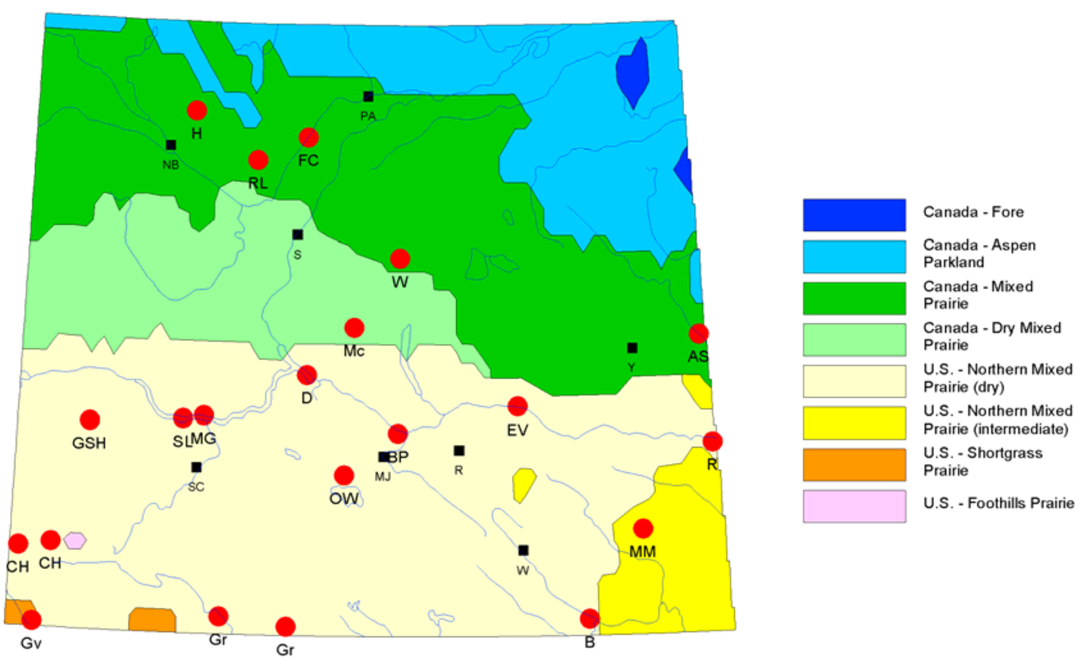

Figure 12: Predicted vegetation zones in southern Saskatchewan in the 2050s under the CGCM2 A21 Scenario. Red dots indicate case study areas (full names in Table 11). Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

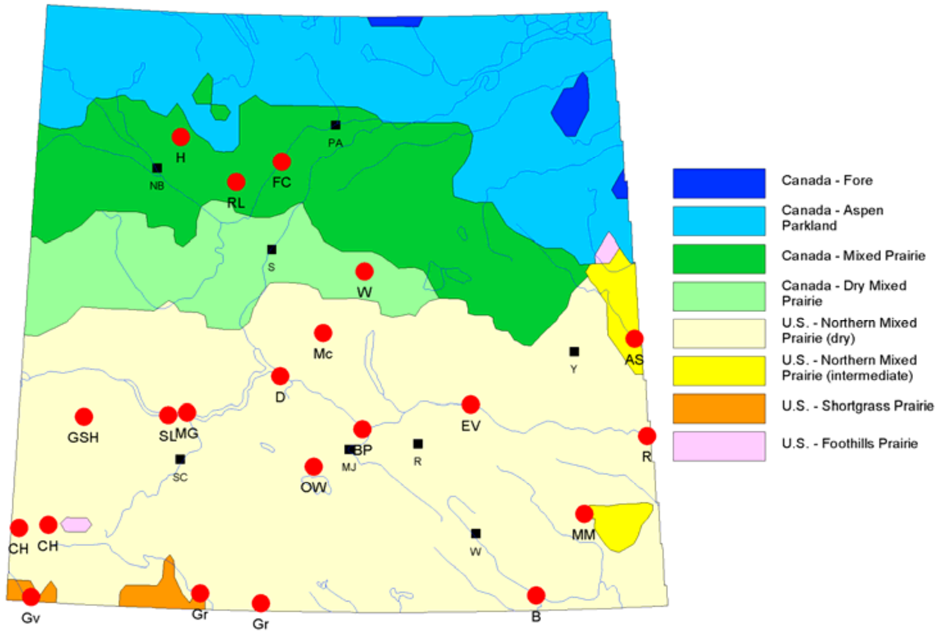

Figure 13: Predicted vegetation zones in southern Saskatchewan in the 2050s under the CSIRO Mk2b B11 scenario. Red dots indicate case study areas (full names in Table 11). Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

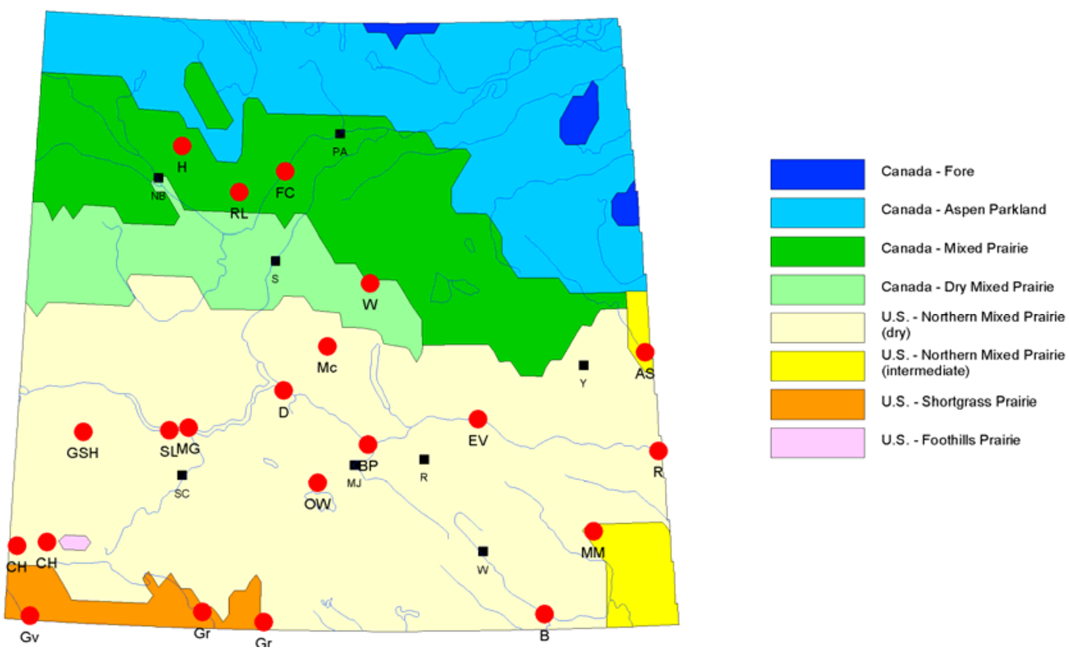

Figure 14: Predicted vegetation zones in southern Saskatchewan in the 2050s under the Hadley CM3 B21 scenario. Red dots indicate case study areas (full names in Table 11). Rivers and selected cities (NB - North Battleford, PA - Prince Albert, S - Saskatoon, Y - Yorkton, R - Regina, MJ - Moose Jaw, SC - Swift Current, W - Weyburn) are shown for reference.

Comparison of Figure 8 with Figures 9, 10, and 11 shows the change in vegetation zonation for a given case study area. More detailed analysis of the case study areas is presented in Section 4.4.

4.3.4 Discussion

While the results have been discussed as shifts in vegetation zones, it would be more accurate to describe them as "shifts to a climate that is capable of supporting a different vegetation zone". Even if these climatic shifts occur by the 2050s, there may be a lag in the change in vegetation composition. The current vegetation occupying a site has "inertia". In other words, the perennial plants already established may persist for some time while the climate gradually becomes less suitable for them. Similarly, the new southern plant species may be unable to migrate northward as fast as the climate changes. The rate and success of migration will vary among species because of differences in environmental tolerance, genetic variation, and dispersal rates. This variation implies that new combinations of species (i.e. new plant communities) could emerge (Singh and Wheaton 1991, Peters 1992). This has been demonstrated in the case of the northward migration of North American tree species following deglaciation (Davis 1981). McCarty (2001) documented rapid northward range expansions of some animal species, and local extinctions at the southern edges of ranges, that have occurred with recent warming. For plants, many wind-dispersed species can easily migrate fast enough to keep up with climatic warming, but others may be limited by slow dispersal or restriction to particular habitats (Malcolm and Pitelka 2000).

Some adjustment will occur through changes in the abundances of species that are already present. For example, the shift from mixed prairie to shortgrass prairie will probably occur initially by increase in the proportion of blue grama (*Bouteloua gracilis*), which is already a widely distributed shortgrass in Canadian grassland. Migration of buffalo grass (*Buchloe dactyloides*), the other major component of U.S. Shortgrass Prairie, into the region can be expected to be a much slower process.

The adjustment to climatic change may also occur at the level of genetic variation within species. For example, Rehfeldt et al. (1999) showed that a wide-ranging species such as lodgepole pine (*Pinus contorta*) includes populations that differ widely in climatic adaptation. Climate change may lead to northward migration of southern genotypes within such a species. Successful migration may also require evolutionary change within species (Davis and Shaw 2001). For example, southern species may be adapted to the warmer temperatures that will be found in Canada in the future, but not to the longer summer days in Canada. Northward migration may be accompanied by selection for new genetic combinations of photoperiod and temperature responses.

Because of these factors that complicate the adjustment of vegetation to climate change, the results should not be interpreted as showing the actual composition of the vegetation in the 2050s, but rather as showing the direction of change.

One of the major expected trends relates to the proportions of warm-season and cool-season plant species. Warm-season species have the C_4 photosynthetic pathway, and are adapted to growth at higher temperatures. Cool-season species have the C_3 pathway, and grow best when it is cooler. Where warm-season and cool-season species growth together, the cool-season species tend to grow earlier in the season. These temperature adaptations are also reflected in the geographic distributions of species. Across the Canadian and U.S. Great Plains, Thorpe et al. (2004) found that dominance by warm-season species increases with annual growing degree-days, and is higher on sand than on loam. Canadian and northern U.S. grasslands with cooler regional climates are dominated by cool-season grasses such as *Stipa* spp., *Agropyron* spp., and *Festuca* spp., while warm-season grasses such as *Andropogon* spp., *Panicum* spp., and *Bouteloua* spp. become more abundant in the warmer climates further south. The relationship with soil texture can be seen even in Canadian grasslands, where warm-season grasses such as sand reedgrass (*Calamovilfa longifolia*) and sand dropseed (*Sporobolus cryptandrus*) are much more common on sands than on finer-textured soils. Other studies based on U.S. data have obtained similar results (Paruelo and Lauenroth 1996, Epstein et al. 1997, 1998). Collatz et al. (1998) and Winslow et al. (2003) developed physiological models to explain the differences in distribution. Models of the impacts of climate change have predicted decreasing proportions of cool-season species and shifts toward warm-season dominance in the northern Great Plains (Coffin and Lauenroth 1996, Epstein et al. 2002). The direct fertilization effect of rising CO_2 concentrations theoretically provides a greater relative benefit to cool-season than warm-season species (Long and Hutchin 1991, Parton et al. 1994). However, experimental results have shown that this advantage is eliminated under dry grassland conditions (Nie et al. 1992; Campbell and Stafford Smith 2000).

The decrease in moisture indices such as Hogg's (1994) CMI, and the shift from mixed prairie towards shortgrass prairie, appears to imply decreases in grassland productivity and carrying capacity for grazers. However, Thorpe et al. (2004) found that models of this relationship gave ambiguous results, and concluded that changes in productivity are likely to be modest. Lengthening growing seasons, reduced competition from shrubs and trees, and increase in warm-season grasses with higher water use efficiency could all contribute to higher grass production. The conclusion that large decreases in productivity under climatic warming are unlikely receives support from several ecosystem simulation studies in U.S. grasslands using older GCM scenarios. Schimel et al. (1990) applied the CENTURY model to a site in central U.S., using the GISS scenario for CO_2 doubling. Both temperature and precipitation increased in this scenario. The model predicted an increase in net primary productivity, related to both the increase in precipitation and the increase in nitrogen availability with faster decomposition at warmer temperatures. Schimel et al. (1991) extended CENTURY simulations to the entire Great Plains using spatial data for climate and soil texture. This again showed an increase in net primary productivity for the northern plains, attributed to the increase in precipitation in the GISS scenario. Parton et al. (1996) and Ojima et al. (1996) applied CENTURY to grassland sites around the world, using the GFDL and CCC climate change scenarios, and obtained similar results to the Schimel studies for sites in Montana and Colorado. Similar results were obtained by Baker et al. (1993), who applied the SPUR model to U.S. rangelands, using the GISS, GFDL, and UKMO climate change scenarios. All of the simulations resulted in an increase in grassland production in the northern part of the Great Plains, except that the GFDL scenario showed a decrease in the eastern part of the northern plains (North and South Dakota). The three climate change scenarios showed a decrease in soil organic matter in the northern plains, related to faster decomposition at higher temperatures, and a decrease in the carbon:nitrogen ratio in soil (Baker et al. 1993).

In summary, the following trends over the period from the present to the 2050s seem probable:

- Gradual reduction in tree cover.
- Expansion of grassland patches in the forest region.
- Regeneration failure in dry years in the forest region.
- Reduction in tree growth in the forest regions to the slower growth and lower maximum size typical of the aspen parkland.
- Shrinking of aspen groves in the aspen parkland.
- Less invasion of grassland patches by shrubs and poplar sprouts in the aspen parkland.
- Decreasing shrub cover in aspen parkland and mixed prairie.
- Decreases in animal species dependent on woody cover.
- Increases in animal species dependent on open grassland.
- Shifts in structure of grasslands: decrease of midgrasses, increase of shortgrasses.
- Decrease in cool-season grasses, increase in warm-season grasses.
- Gradual introduction of plant and animal species currently found only in the U.S.
- Modest changes in grass production and grazing capacity. Lower moisture indices and shift from midgrasses to shortgrasses will favour loss of productivity. Longer growing seasons, reduction of woody cover, and increase in warm-season grasses will favour increase in productivity.

4.4 Detailed Case Study Analysis

NAME	**Grasslands National Park**
CLASSIFICATION	National Park
AREA (ha)	48,822
ECOREGION	Mixed Grassland

CLIMATE – West Block	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	717	325	-393	0.40	Canada - Dry Mixed Prairie
2050s scenarios:					
- CGCM2 A21	944	330	-614	0.36	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	963	340	-624	0.35	U.S. - Shortgrass Prairie
- HadCM3 B21	986	333	-653	0.36	U.S. - Shortgrass Prairie

CLIMATE – East Block	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	672	380	-293	0.40	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	898	385	-513	0.36	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	899	392	-507	0.35	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	943	389	-554	0.36	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Michalsky and Ellis (1994).

- Represents prairie grassland in the National Park system.
- Climate is transitional from Mixed Prairie at the east end of the Park to Dry Mixed Prairie at the west end. The Park is mostly open grassland.
- Upland clay soils are dominated by needle-and-thread, blue grama, June grass, and wheatgrasses, with the proportion of western wheatgrass increasing on Solonetzic soils. Scattered silver sagebrush may occur, especially on Solonetzic soils. Western porcupine grass becomes more common in the eastern part of the Park, reflecting the somewhat moister climate eastward.
- Extensive valley complexes, with species such as green needlegrass and creeping juniper increasing on slopes. Scattered silver sagebrush on some slopes.
- Extensive silver sagebrush stands with western wheatgrass and blue grama on alluvial soils of valley bottoms.
- Greasewood stands on more saline valley bottom sites.
- Areas of eroded marine shale- (“badlands”) which are bare or sparsely vegetated (e.g. rillscale, rabbitbrush, povertyweed).
- Small stands of snowberry and rose mainly along edges of streams, with taller willow and buffaloberry stands along the Frenchman River.
- Small areas of aspen groves with moister grassland in the higher-elevation northeast corner of the Park.

PROBABLE CLIMATE CHANGE IMPACTS

- Shifts in species composition: decrease in cool-season midgrasses (needle-and-thread, June grass, wheatgrasses) and increase in blue grama (warm-season shortgrass).
- More gradually, big sagebrush, buffalograss and other southern species (e.g. hairy grama, side-oats grama, red three-awn, squirreltail, yucca) may appear in grassland communities.
- Long-term trend for upland grasslands could range from dominance by midgrasses with a significant shortgrass component (e.g. western wheatgrass - blue grama) to dominance by shortgrasses (e.g. blue grama – buffalograss).
- Vegetation types controlled by azonal site conditions (e.g. alluvial, saline, and badland communities) may not change much.
- In moister northeastern part of Park, decrease in aspen and western porcupine grass, replaced by drier grassland as above.
- Changes in animal communities in response to warmer climate and changes in plant communities.

MANAGEMENT IMPLICATIONS

- Monitoring will be needed to detect long-term changes in species composition and productivity.
- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components (e.g. aspen stands) as inevitable.

NAME	**Fort Walsh National Historic Site**
CLASSIFICATION	National Historic Park
AREA (ha)	648
ECOREGION	Cypress Upland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	645	385	-260	0.38	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	843	390	-454	0.34	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	837	408	-429	0.34	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	922	396	-527	0.33	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- This area is primarily a historic site, but includes the surrounding area of typical Cypress Hills vegetation on the slopes and bottomland of the Battle Creek valley.
- Most of the area consists of fescue grassland on valley-slopes.
- Smaller area of valley-slope forest with white spruce, lodgepole pine, and aspen.
- Tall willow and moist grassland along creek-bottom.

PROBABLE CLIMATE CHANGE IMPACTS

- Similar to Cypress Hills Provincial Park (see below).

MANAGEMENT IMPLICATIONS

- Change in landscape setting for the Historic Site.

NAME	**Cypress Hills Provincial Park**
CLASSIFICATION	Provincial Park (Natural Environment)
AREA (ha)	13,805
ECOREGION	Cypress Upland

CLIMATE – West Block	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	682	364	-318	0.38	Canada - Dry Mixed Prairie
2050s scenarios:					
- CGCM2 A21	884	368	-517	0.34	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	877	386	-491	0.34	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	958	372	-586	0.33	U.S. - Northern Mixed Prairie (dry)

CLIMATE – Centre Block	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	657	462	-196	0.34	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	861	467	-394	0.30	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	855	492	-363	0.30	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	940	474	-466	0.29	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Sources: Godwin and Thorpe (1994), Henderson et al. (2002).
- Park includes two areas, the larger and less-developed West Block and the smaller Centre Block where the resort village has been developed.
- Upper plateau is predominantly fescue grassland with abundant shrubby cinquefoil, but aspen groves and lodgepole pine forest are also extensive, especially in the Centre Block.
- Convex and south-facing valley-slopes are fescue grassland, while concave and north-facing slopes are forested (lodgepole pine, aspen, white spruce).
- Alluvial bottomlands have white spruce, tall shrubs (willow, wolf-willow), and moist grassland.
- Pine and aspen forests have expanded into grasslands in the absence of fire.
- At lower elevations on the slopes of the Cypress Upland, tree cover disappears (except in riparian areas), and fescue grassland is replaced by Mixed Prairie (western porcupine grass, wheatgrasses), which in turn is replaced by Dry Mixed Prairie (needle-and-thread, wheatgrasses, blue grama) on the surrounding plains.

PROBABLE CLIMATE CHANGE IMPACTS

- Climate and predicted vegetation of this small high-altitude area are poorly represented by the resolution of the current model. Climate change impacts (based on the same three climate change scenarios as in the current study) were assessed by more detailed modeling in relation to elevation by Henderson et al. (2002). Their model projected 2050s CMI values at the top of the Cypress Hills in the range of -150 to -300 mm. They interpreted the following impacts:
  - Decline of tree cover, especially of pine and spruce, as climate becomes too dry for tree regeneration. However, areas with enhanced moisture, such as north-facing slopes, are more likely to retain trees.
  - Most likely 2050s landscape is one of "…small patches of stressed woodland persisting only in the most favourable sheltered sites".
  - Reduced forest encroachment into grassland.
  - Increased vulnerability of lodgepole pine to mountain pine beetle.
- Changes in grassland communities were not discussed by Henderson et al. (2002). However, the drier climate projected in their modeling implies that the fescue prairie at the top of the hills will be replaced by Mixed Prairie, while the transition from Mixed Prairie to Dry Mixed Prairie / U.S. Northern Mixed Prairie will also shift upward.
- Forest-dependent wildlife will decline and be replaced by open grassland species.
- Cordilleran biodiversity components (e.g. lodgepole pine, heart-leaved arnica, shiny-leaved meadowsweet) may disappear.
- Grazing capacity for livestock may increase because of the greater area of grassland.
- Milder winters.

MANAGEMENT IMPLICATIONS

- Monitoring will be needed to detect long-term changes in proportions of forest and grassland, species composition, and productivity.
- Livestock grazing which is applied over most of the Park may have to be modified if monitoring indicates changes in grazing capacity, grazing season, etc.
- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components (e.g. Cordilleran species, fescue prairie, extensive forest cover) as inevitable.
- Management of sport hunting may have to be modified if game species and populations change.
- Decisions will have to be made about vegetation management in response to climate change. Should we just let nature take its course? Should we use intensive management practices to maintain forest cover? Should we introduce new tree species that may be better adapted to the warmer and drier climate?

NAME	**Douglas Provincial Park**
CLASSIFICATION	Provincial Park (Natural Environment)
AREA (ha)	6,723
ECOREGION	Moist Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	606	340	-266	0.44	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	788	338	-450	0.41	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	810	348	-461	0.40	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	805	347	-458	0.39	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Thorpe and Godwin (1992).
- Mixed Prairie climate, but sand dunes result in vegetation more like Aspen Parkland.
- Most of the park is sand dunes which support a complex mosaic of vegetation types: grassland (sand

reedgrass, needle-and-thread, forbs), shrubland (snowberry, chokecherry, creeping juniper), and stunted aspen groves.
- One large active dune has extensive bare sand with a fringe of early-successional plants (e.g. lance-leaved psoralea).
- Flats on the periphery of the Park support open grassland, much of which has been seeded to crested wheatgrass.
- Small seepage areas at the edge of the dunes support taller forest (balsam poplar, green ash, Manitoba maple, red-osier dogwood, and other shrubs).

PROBABLE CLIMATE CHANGE IMPACTS
- Climate change impacts on sand dune ecosystems were assessed in more detail by Thorpe et al. (2001). That study identified the sandsage prarie of northeastern Colorado and western Nebraska as a 2050s analogue for the driest Canadian sand dunes, including the Great Sand Hills and the Dundurn Sand Hills. The Elbow Sand Hills (including Douglas Provincial Park) were not studied in particular, but would be expected to be comparable to the Dundurn Sand Hills. Comparison with this 2050s analogue suggests the following directions of change.
- Reduction of tree cover (currently around 20-30% of the dune area) to near zero; possibly also reduction of tall shrub cover (e.g. river birch). Seepage woods type may be eliminated, although supply of water from seepage may tend to buffer this type against changes in the regional climate.
- Gradual arrival of southern shrub species (sandsage, inland ceanothus, small soapweed, leadplant, sand cherry), eventually displacing current shrubs.
- Most of the current dominant grasses will continue to be abundant, but there may be a shift towards increasing proportions of warm-season species. There is already a substantial warm-season component (sand reedgrass, sand dropseed, blue grama, little bluestem), which can respond to climatic warming by increasing their relative abundance.
- Gradual arrival of southern warm-season grasses (sand bluestem, switch grass, sandhill muhly, sand lovegrass, hairy grama, blowout grass, Scribner panicum), with sand bluestem having the potential to eventually become a dominant species.
- Gradual arrival of southern forb species.
- Little change in grazing capacity for livestock, with reduction in woody cover and increasing proportion of warm-season grasses tending to compensate for drier climate.
- A model discussed by Thorpe et al. (2001) suggests that the shift to a drier climate may increase the potential for dune activation (i.e. currently stabilized dunes becoming active as a result of reduced plant cover). This is most likely to occur during prolonged droughts.
- Increased fire hazard.
- Shift to drier climate may lower water tables, reducing watering sources for livestock.

MANAGEMENT IMPLICATIONS
- Field monitoring programs will be required to detect any long-term changes in grassland productivity and composition; also air-photo monitoring to detect changes in proportions of grassland/shrubland/forest.
- Livestock grazing currently applied in portions of the Park may have to be modified as conditions change.
- Better fire-fighting capabilities may be required.
- Additional water development for livestock may be needed.
- Increased potential for dune activation may increase habitat for species (including plants, mammals, and arthropods) that require active dunes.
- Interpretive opportunity associated with active dunes should continue.
- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components (e.g. aspen forest) as inevitable.
- Additional management inputs may be required to maintain tree cover in the campground.

NAME	**Moose Mountain Provincial Park**
CLASSIFICATION	Provincial Park (Natural Environment)
AREA (ha)	39,430
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	555	464	-91	0.43	Canada - Aspen Parkland
2050s scenarios:					
- CGCM2 A21	778	460	-318	0.39	U.S. - Northern Mixed Prairie (int.)
- CSIROMk2b B11	785	455	-329	0.38	U.S. - Northern Mixed Prairie (int.)
- HadCM3 B21	764	481	-283	0.37	U.S. - Northern Mixed Prairie (int.)

CURRENT ECOSYSTEMS

- Sources: Thorpe (1994), Henderson et al. (2002).
- Included in the Aspen Parkland Ecoregion, but occupying an elevated upland with a climate moist enough to support continuous forest. Locally, the terrain is strongly hummocky.
- Upland sites support aspen forest, with some stands of white birch. Balsam poplar stands are found in moist sites. Particularly in the eastern part of the Park, the aspen forest has an understory of green ash and occasionally Manitoba maple, which will become increasingly dominant in the absence of fire.
- Depressions in the hummocky terrain support an extensive network of lakes and wetlands. Water levels in lakes have fluctuated widely over the years with changes in weather, reflecting the Park's intermediate position between a forest climate (where lakes tend to be stable) and a grassland climate (where lakes tend to be intermittent).

PROBABLE CLIMATE CHANGE IMPACTS

- Climate change impacts on Moose Mountain were also studied by Henderson et al. (2002), using the same three scenarios as in the present study. Their results have been used in interpreting the following impacts.
- Decrease in tree cover through dieback of mature stands and failure of regeneration, especially during drought years. The scenarios show the regional climate shifting from Aspen Parkland to Northern Mixed Prairie (intermediate). However, the Moose Mountain upland is somewhat cooler and moister than the general region (continuous forest rather than parkland), and so in the future will be more likely to maintain some tree cover than the general region.
- Elimination of birch forest (more drought-sensitive than aspen).
- Expansion of upland grasslands, starting on south-facing slopes and gradually expanding to other slopes.
- Grasslands dominated by cool-season midgrasses (wheatgrasses, western porcupine grass, needle-and-thread, green needlegrass).
- Reduced runoff resulting in shrinkage of water-bodies. Drying of existing wetlands.
- The overall result will be a downward shifting of vegetation types, with grassland replacing forest, forest invading the drying wetlands, and new wetlands replacing open water.
- Reduction in forest wildlife (e.g. moose, forest birds). Possibly reduction in beaver, waterfowl, other wetland wildlife. Increase in grassland wildlife.

MANAGEMENT IMPLICATIONS

- Monitoring will be needed to detect long-term changes in proportions of forest and grassland, species composition, and productivity.
- Need for management of declining forests (e.g. salvage logging, control of fire hazard).
- Policies will have to address the question of how much management effort should be expended to maintain tree cover (e.g. should tree species tolerant of warmer/drier conditions be intentionally introduced to maintain tree cover?).
- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components (e.g. forest species) as inevitable.

- Opportunities for water-based recreation may be reduced by shrinkage of lakes.
- Declining opportunities for forest-based recreation (cross-country skiing, snowmobiling).
- Sport hunting opportunities may change with changes in animal communities.
- Grazing capacity for livestock will increase because of increased area of grassland (resulting from loss of forest cover) and wetland (resulting from shrinkage of water bodies).

NAME	**Saskatchewan Landing Provincial Park**
CLASSIFICATION	Provincial Park (Natural Environment)
AREA (ha)	5,897
ECOREGION	Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	627	322	-305	0.45	Canada - Dry Mixed Prairie
2050s scenarios:					
- CGCM2 A21	812	321	-491	0.42	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	809	336	-473	0.41	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	840	328	-512	0.40	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Godwin and Thorpe (2002).
- Park largely consists of the steep, dissected valley of the South Saskatchewan River.
- Small areas of level upland with heavy clay soils support unusual northern wheatgrass grassland.
- Dry valley-slopes support sparse grasslands (needle-and-thread, thread-leaved sedge, plains muhly).
- Concave and north-facing valley-slopes support moister grasslands (northern wheatgrass, June grass, forbs), shrublands (chokecherry, snowberry, rose), and forest (aspen, green ash).
- Alluvial sites in bottoms of coulees support shrubland (chokecherry, snowberry, rose) and forest (Manitoba maple).
- Broader alluvial terraces along the river support open grassland (wheatgrasses, needle-and-thread, blue grama). Some of this has been converted to crested wheatgrass. Some areas of sagebrush-grassland on lower river terraces.
- Small areas of eroded marine shales support sparse “badland” vegetation”.

PROBABLE CLIMATE CHANGE IMPACTS

- Most grassland types may not change much—possibly some decrease of midgrasses (wheatgrasses, needle-and-thread) and increase of shortgrasses (blue grama).
- Northern wheatgrass community on heavy clays may shift towards western wheatgrass.
- Southern species may gradually appear in the grassland (e.g. buffalograss, big sagebrush).
- Forest and shrubland types may decrease in woody cover. However, azonal sites with which these types are associated (coulees, steep north-facing slopes) may maintain woody cover even as regional climate becomes drier.
- Animal communities may not change much, depending on vegetation changes. However, gradual appearance of southern species (e.g. birds, arthropods).

MANAGEMENT IMPLICATIONS

- Monitoring will be needed to detect long-term changes in species composition and productivity.
- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components as inevitable (e.g. northern wheatgrass grasslands).
- Livestock grazing which is applied over most of the Park may have to be modified if monitoring indicates changes in grazing capacity, grazing season, etc.
- Current recreation is largely lake-related (boating and fishing, camping and golfing adjacent to lake) and will not be affected much by change in vegetation.

- Opportunities for nature interpretation will continue, with changes in content to reflect ecological changes.
- Deer hunting opportunities could be altered by changes in deer habitat.

NAME	**Buffalo Pound Provincial Park**
CLASSIFICATION	Provincial Park (Recreation)
AREA (ha)	2,244
ECOREGION	Moist Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	622	362	-259	0.43	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	821	363	-457	0.40	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	833	370	-463	0.39	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	828	370	-458	0.38	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- This park includes a small part of the Qu'appelle Valley, with north-facing slopes, valley bottom, and south-facing slopes.
- The valley slopes are steep and dissected, with grassland on the ridges and forest and shrubland in the coulees.
- Most of the valley bottom is occupied by Buffalo Pound Lake. However, beyond the east end of the lake is Nicolle Flats, a large marsh that supports wetland wildlife.
- This area east of the lake also includes riparian woodland along the Qu'appelle River and Moose Jaw Creek. Forests in the park include aspen, Manitoba maple, green ash, and American elm.

PROBABLE CLIMATE CHANGE IMPACTS

- Decrease in tree cover, increase in grassland on the slopes.
- Appearance of valley slopes may come to resemble Saskatchewan Landing Provincial Park.

NAME	**Echo Valley Provincial Park**
CLASSIFICATION	Provincial Park (Recreation)
AREA (ha)	585
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	573	389	-185	0.44	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	767	390	-378	0.41	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	781	394	-388	0.40	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	761	405	-357	0.39	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- This park consists of Aspen Parkland on the dissected north-facing valley slopes of the Qu'Appelle Valley.
- Ridges on these dissected slopes have grassland, while coulees support stands of trees.
- The park also includes area on the level upland above the valley slope, and an alluvial fan forming an "isthmus" that separates Pasqua and Echo Lakes. Both of these latter areas are mostly non-natural vegetation such as tree plantations.

PROBABLE CLIMATE CHANGE IMPACTS

- Decrease in tree cover, increase in grassland on the slopes.
- Appearance of valley slopes may come to resemble Saskatchewan Landing Provincial Park.

NAME	**Fort Carlton Provincial Park**
CLASSIFICATION	Provincial Park (Historic)
AREA (ha)	141
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	488	387	-101	0.46	Canada - Aspen Parkland
2050s scenarios:					
- CGCM2 A21	610	382	-229	0.44	Canada - Mixed Prairie
- CSIROMk2b B11	642	406	-236	0.43	Canada - Mixed Prairie
- HadCM3 B21	639	406	-232	0.42	Canada - Mixed Prairie

CURRENT ECOSYSTEMS

This park is focused on the historic site, but includes a small area of Aspen Parkland on valley slopes of the North Saskatchewan River.

PROBABLE CLIMATE CHANGE IMPACTS

- Decrease in tree cover, increase in grassland on the slopes.

MANAGEMENT IMPLICATIONS

NAME	**Matador Grasslands**
CLASSIFICATION	Provincial Protected Area
AREA (ha)	786
ECOREGION	Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	620	328	-292	0.45	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	805	326	-479	0.42	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	801	341	-460	0.41	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	826	333	-493	0.40	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Small area of unusual northern wheatgrass grassland found on level heavy clay soils. This area was set aside for research on grassland ecosystems. Most of this grassland type elsewhere in Saskatchewan has been cultivated.
- The protected area also includes some of the steep dissected valley-slopes of the South Saskatchewan River, with vegetation similar to that of Saskatchewan Landing Provincial Park.

PROBABLE CLIMATE CHANGE IMPACTS

- Shift in grassland composition towards dominance by western wheatgrass.
- Moderate decrease in grassland productivity.

MANAGEMENT IMPLICATIONS

- Ecosystem processes (e.g. production, nutrient cycling) that have been studied at Matador since the late 1960s may change with shifts in the regional climate.
- The excellent baseline of information for this area under the current climate presents an opportunity for documenting the response of a grassland ecosystem to climate change.

NAME	**Assiniboine Slopes Ecological Reserve**
CLASSIFICATION	Provincial Ecological Reserve
AREA (ha)	775
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	500	456	-44	0.45	Canada - Aspen Parkland
2050s scenarios:					
- CGCM2 A21	661	447	-214	0.43	Canada - Mixed Prairie
- CSIROMk2b B11	696	459	-237	0.41	U.S. - Northern Mixed Prairie (int.)
- HadCM3 B21	668	476	-192	0.40	U.S. - Northern Mixed Prairie (int.)

CURRENT ECOSYSTEMS

- Source: Adam et al. (1982)
- Valley complex on the Assiniboine River.
- Slopes mostly covered with deciduous forest (aspen, white birch, balsam poplar).
- Small areas of grassland (blue grama, June grass, little bluestem, big bluestem, forbs) and shrubland (western snowberry, Saskatoon, chokecherry, Woods rose) on south-facing slopes.
- Slope fens fed by seepage (speckled alder, river birch, alder-leaved buckthorn, Labrador-tea, forbs).
- River terraces seeded to tame forage.

PROBABLE CLIMATE CHANGE IMPACTS

- Expansion of grassland patches and dieback of forest, especially on south-facing slopes.
- Continued importance of warm-season grasses such as little bluestem.
- Possible drying of slope fens, resulting in loss of wetland species.
- Possible elimination of northern species such as speckled alder, Labrador-tea, and tamarack.

MANAGEMENT IMPLICATIONS

- Biodiversity goals for the park may change as new plant and animal species arrive.
- Park policy may have to be modified to accept the loss of some biodiversity components as inevitable.

NAME	**Buffalograss Ecological Reserve**
CLASSIFICATION	Provincial Ecological Reserve
AREA (ha)	15
ECOREGION	Moist Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	650	407	-242	0.43	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	880	411	-469	0.39	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	887	402	-485	0.38	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	881	418	-463	0.37	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Baschak and Vandall (1994)
- This Ecological Reserve was created to protect a small population of buffalograss, currently a rare species in Saskatchewan.
- Mostly mixed prairie dominated by western porcupine grass, blue grama, and northern wheatgrass on eroded glacial till.
- Small areas of shrubland with western snowberry and wolfwillow.
- Small areas of thin soils and exposed Cretaceous bedrock, with sparse variable vegetation, including patches of buffalograss.
- Small areas of saline depressions.

PROBABLE CLIMATE CHANGE IMPACTS

- Shift in species composition of upland grassland: decrease in cool-season midgrasses, especially western porcupine grass, increase in blue grama.
- Decrease in area of shrubland.
- Areas of thin soil and exposed bedrock will continue to support sparser, more variable grasslands, possibly becoming even more arid with warmer and drier climate.
- The climate of southern Saskatchewan will gradually become more suitable for buffalograss, possibly resulting in expansion and increased vigour of the population in the Reserve.
- More generally, buffalgrass is expected to gradually expand in range and increase in abundance over a wide range of grasslands in southern Saskatchewan.

MANAGEMENT IMPLICATIONS

- If buffalograss becomes a common species in Saskatchewan grasslands, the purpose of this Ecological Reserve may no longer exist.

NAME	**Great Sand Hills Ecological Reserve**
CLASSIFICATION	Provincial Ecological Reserve (proposed)
AREA (ha)	37,343
ECOREGION	Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	652	344	-308	0.42	Canada - Dry Mixed Prairie
2050s scenarios:					
- CGCM2 A21	831	345	-486	0.38	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	834	361	-473	0.38	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	877	348	-529	0.37	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Thorpe and Godwin (1997).
- This area represents the natural vegetation of sand dunes in a Dry Mixed Prairie climate.
- There are a few areas of active dunes with extensive bare sand undergoing invasion by lance-leaved psoralea.
- Most of the area consists of stabilized sand dunes with a mosaic of grassland (sand reedgrass, needle-and-thread, forbs), sagebrush-grassland (with scattered silver sagebrush), and juniper-grassland (with a mat of creeping juniper).
- Small areas of tall shrubs (chokecherry, Saskatoon) occur on north-facing slopes.
- Interdune depressions support small aspen groves.
- Flats between the dunes and around the edge of the dunefield support open grassland or juniper-grassland.
- Some low-lying flats support a tall-shrub type (river birch, buffaloberry).

PROBABLE CLIMATE CHANGE IMPACTS

- Climate change impacts on sand dune ecosystems were assessed in more detail by Thorpe et al. (2001). That study identified the sandsage prarie of northeastern Colorado and western Nebraska as a 2050s analogue for the driest Canadian sand dunes (including the Great Sand Hills). Comparison with this analogue suggests the following directions of change.
- Reduction of aspen cover; possibly also reduction of tall shrub cover (e.g. river birch).
- Gradual arrival of southern shrub species (sandsage, inland ceanothus, small soapweed, leadplant, sand cherry), eventually displacing current shrubs.
- Most of the current dominant grasses will continue to be abundant, but there may be a shift towards increasing proportions of warm-season species. There is already a substantial warm-season component (sand reedgrass, sand dropseed, blue grama, little bluestem), which can respond to climatic warming by increasing their relative abundance.
- Gradual arrival of southern warm-season grasses (sand bluestem, switch grass, sandhill muhly, sand lovegrass, hairy grama, blowout grass, Scribner panicum), with sand bluestem having the potential to eventually become a dominant species.
- Gradual arrival of southern forb species.
- Little change in grazing capacity for livestock, with reduction in woody cover and increasing proportion of warm-season grasses tending to compensate for drier climate.
- A model discussed by Thorpe et al. (2001) suggests that the shift to a drier climate may increase the potential for dune activation (i.e. currently stabilized dunes becoming active as a result of reduced plant cover). This is most likely to occur during prolonged droughts.
- Increased fire hazard.
- Shift to drier climate may lower water tables, reducing watering sources for livestock.

MANAGEMENT IMPLICATIONS

- Field monitoring programs will be required to detect any long-term changes in grassland productivity and composition; also air-photo monitoring to detect changes in proportions of grassland/shrubland/forest.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Benefits and ecological consequences of introducing warm-season grasses from nearby North American ranges (e.g. sand bluestem) should be assessed.
- Grazing seasons may be lengthened, possibly including winter grazing.
- Better fire-fighting capabilities may be required.
- Additional water development for livestock may be needed.
- Increased potential for dune activation may support continued exclusion of oil/gas activities from the Ecological Reserve.
- Increased potential for dune activation may increase habitat for species (including plants, mammals, and arthropods) that require active dunes.

NAME	**Govenlock Community Pasture**
CLASSIFICATION	PFRA Pasture
AREA (ha)	28,125
ECOREGION	Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	739	294	-445	0.40	Canada - Dry Mixed Prairie
2050s scenarios:					
- CGCM2 A21	950	296	-654	0.37	U.S. - Shortgrass Prairie
- CSIROMk2b B11	972	310	-662	0.36	U.S. - Shortgrass Prairie

- HadCM3 B21	1028	298	-730	0.36	U.S. - Shortgrass Prairie

CURRENT ECOSYSTEMS

- Source: Boyle (1994)
- This community pasture is in the extreme southwest corner of Saskatchewan, and consists of Dry Mixed Prairie on fine-textured, mostly Solonetzic soils.
- The grassland on the level uplands is dominated by northern and western wheatgrass, June grass, blue grama, and needle-and-thread, sometimes with scattered silver sagebrush.
- There are a few creek valleys with narrow alluvial sagebrush stands, as well as snowberry in the riparian zone.
- About 10% of the area has been converted to tame forages (crested wheatgrass, Russian wild-rye).
- Range condition is mostly good.

PROBABLE CLIMATE CHANGE IMPACTS

- Shifts in species composition: decrease in cool-season midgrasses (wheatgrasses, needle-and-thread, June grass) and increase in blue grama (warm-season shortgrass). More gradually, big sagebrush, buffalograss and other southern species (e.g. hairy grama, side-oats grama, red three-awn, squirreltail) may appear in the grassland. The long-term trend will be towards a blue grama-buffalograss community, but this may take a long time to come about.
- Longer growing season and milder winters.
- Moderate decrease in grassland productivity.
- Possible decrease in runoff, affecting watering sources.
- Possible increase in heat stress on cattle in hotter summers.

MANAGEMENT IMPLICATIONS

- Monitoring programs will be required to detect any long-term changes in grassland productivity and composition.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity.
- Even greater need to maintain litter cover to protect soil against direct evaporation.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Grazing seasons may be lengthened, possibly including winter grazing.
- Additional water development may be needed.

NAME	**McCraney Community Pasture**
CLASSIFICATION	PFRA Pasture
AREA (ha)	4,375
ECOREGION	Moist Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	566	371	-195	0.44	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	715	369	-345	0.41	Canada - Dry Mixed Prairie
- CSIROMk2b B11	763	381	-382	0.39	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	756	380	-376	0.39	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS

- Source: Houston (1994).
- This pasture is centred around a large meltwater channel (the Arm River Valley) but includes adjacent uplands.
- Most of the area is Mixed Prairie (needle-and-thread, western porcupine grass, northern wheatgrass, June grass, sedges) on gravelly or sandy soils, or on eroded valley-slopes.
- Wetlands occur along the valley bottom.

- A large area on the upland has been seeded to introduced forages (crested wheatgrass, Russian wild-rye, meadow bromegrass, alfalfa).
- Range condition is mostly good.

PROBABLE CLIMATE CHANGE IMPACTS

- Moderate shifts in species composition: decrease in western porcupine grass; increase in warm-season grasses (blue grama, little bluestem); possible gradual arrival of southern species such as buffalograss. Long-term trend will be towards mixed prairie dominated by midgrasses (wheatgrasses, needle-and-thread), but with significant shortgrass component (blue grama).
- Longer growing season and milder winters.
- Moderate decrease in grassland productivity.
- Possible decrease in runoff, affecting watering sources.
- Possible increase in heat stress on cattle in hotter summers.

MANAGEMENT IMPLICATIONS

- Monitoring programs will be required to detect any long-term changes in grassland productivity and composition.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity.
- Greater need to maintain litter cover to protect soil against direct evaporation.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Grazing seasons may be lengthened, possibly including winter grazing.
- Additional water development may be needed.

NAME	**Wolverine Community Pasture**
CLASSIFICATION	PFRA Pasture
AREA (ha)	6,965
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	531	373	-158	0.46	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	668	371	-297	0.43	Canada - Mixed Prairie
- CSIROMk2b B11	718	382	-336	0.42	Canada - Dry Mixed Prairie
- HadCM3 B21	706	382	-325	0.41	Canada - Dry Mixed Prairie

CURRENT ECOSYSTEMS

- Source: Nykoluk (2001).
- This pasture consists of Aspen Parkland on hummocky loam soils.
- About 56% is native grassland dominated by rough fescue, western porcupine grass and sedges.
- About 30% is covered with aspen groves, which tend to expand into the grassland in the absence of fire..
- About 11% has been converted to tame forage (crested wheatgrass, alfalfa). Range condition varies from fair to excellent.

PROBABLE CLIMATE CHANGE IMPACTS

- Decrease in aspen cover through dieback of mature trees during drought years, reduced sprouting.
- Shifts in grassland species composition: decrease in rough fescue and possibly western porcupine grass; increase in needle-and-thread; increase in warm-season grasses (blue grama, little bluestem). Long-term trend will be toward a mixed prairie community dominated by midgrasses (needle-and-thread, wheatgrasses, possibly western porcupine grass) but with a significant component of shortgrass (blue grama).
- Longer growing season and milder winters.

- Moderate decrease in grassland productivity.
- Possible decrease in runoff, affecting watering sources.
- Possible increase in heat stress on cattle in hotter summers.

MANAGEMENT IMPLICATIONS
- Reduced need for brush control.
- Monitoring programs will be required to detect any long-term changes in grassland productivity and composition.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity. However, any reduction in aspen cover will increase the proportion of the pasture in grassland, possibly allowing increased stocking rates.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Grazing seasons may be lengthened.
- Additional water development may be needed.

NAME	**Hatherleigh Community Pasture**
CLASSIFICATION	Provincial Community Pasture
AREA (ha)	7,336
ECOREGION	Aspen Parkland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	467	400	-67	0.48	Canada - Aspen Parkland
2050s scenarios:					
- CGCM2 A21	590	390	-200	0.45	Canada - Mixed Prairie
- CSIROMk2b B11	611	421	-190	0.44	Canada - Mixed Prairie
- HadCM3 B21	618	418	-201	0.43	Canada - Mixed Prairie

CURRENT ECOSYSTEMS
- Source: Fontaine (1998).
- This pasture consists of Aspen Parkland on rolling loam soils.
- Most of the area is grassland dominated by rough fescue.
- This is interspersed with aspen groves, which expand into the grassland in the absence of fire.
- Range condition varies from good on the uplands to fair/poor in low areas.
- More than one quarter of the area has been converted to tame forage (smooth bromegrass, meadow bromegrass, alfalfa).
- A creek system with a narrow belt of wetlands and willows runs through the middle of the pasture.

PROBABLE CLIMATE CHANGE IMPACTS
- Decrease in aspen cover through dieback of mature trees during drought years, reduced sprouting.
- Shifts in grassland species composition: decrease in rough fescue; increase in western porcupine grass, needle-and-thread, wheatgrasses.
- Longer growing season and milder winters.
- Moderate decrease in grassland productivity.
- Possible decrease in runoff, affecting watering sources for livestock.
- Possible increase in heat stress on cattle in hotter summers.

MANAGEMENT IMPLICATIONS
- Reduced need for brush control.
- Monitoring programs will be required to detect any long-term changes in grassland productivity and composition.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity.

However, any reduction in aspen cover will increase the proportion of the pasture in grassland, possibly allowing increased stocking rates.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Grazing seasons may be lengthened.
- Additional water development may be needed.

NAME	**Old Wives Community Pasture**
CLASSIFICATION	Provincial Community Pasture
AREA (ha)	5,670
ECOREGION	Mixed Grassland

CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	626	376	-251	0.42	Canada - Mixed Prairie
2050s scenarios:					
- CGCM2 A21	826	376	-451	0.39	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	841	385	-456	0.38	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	839	385	-454	0.37	U.S. - Northern Mixed Prairie (dry)

CURRENT ECOSYSTEMS
- Source: Spearing and Townsend-Fraser (2004).
- This pasture consists of Mixed Prairie on hummocky clay loam soils.
- Most of the area is open grassland (western porcupine grass, needle-and-thread, northern wheatgrass, western wheatgrass), with little shrub or tree cover.
- Range condition is generally good to excellent.
- Small areas have been seeded to tame forages.
- Small wetlands are found in depressions in the hummocky terrain.

PROBABLE CLIMATE CHANGE IMPACTS
- Shifts in species composition: decrease in western porcupine grass; increase in needle-and-thread; increase in blue grama (warm-season shortgrass); more gradually, introduction of southern species such as buffalograss. Long-term trend will be towards a mixed prairie community dominated by midgrasses, but with a significant component of shortgrasses.
- Longer growing season and milder winters.
- Moderate decrease in grassland productivity.
- Possible decrease in runoff, affecting watering sources.
- Possible increase in heat stress on cattle in hotter summers.

MANAGEMENT IMPLICATIONS
- Monitoring programs will be required to detect any long-term changes in grassland productivity and composition.
- Recommended stocking rates may have to be changed if monitoring shows changes in productivity.
- Even greater need to maintain litter cover to protect soil against direct evaporation.
- Range condition standards may have to be changed because of shifts in potential species composition.
- Grazing seasons may be lengthened, possibly including winter grazing.
- Additional water development may be needed.

NAME			**PCS Rocanville**		
CLASSIFICATION			Corporate		
AREA (ha)			1,496		
ECOREGION			Aspen Parkland		
CLIMATE	**PET (mm)**	**PPT (mm)**	**CMI (mm)**	**SUMMER PPT**	**Modeled Vegetation Type**
1961-90 normals	548	432	-117	0.44	Canada - Aspen Parkland
2050s scenarios:					
- CGCM2 A21	735	418	-317	0.41	U.S. - Northern Mixed Prairie (dry)
- CSIROMk2b B11	763	426	-337	0.39	U.S. - Northern Mixed Prairie (dry)
- HadCM3 B21	731	451	-280	0.38	U.S. - Northern Mixed Prairie (dry)
CURRENT ECOSYSTEMS					
PROBABLE CLIMATE CHANGE IMPACTS					
MANAGEMENT IMPLICATIONS					

5. RECOMMENDATIONS

This final chapter encompasses both key policy evaluation questions and specific protected area policy recommendations for adaptation to climate change. The recommendations include a policy review template, and a protected areas climate change policy/policy framework addressing both mitigation and adaptation.

5.1 Climate Change Protected Area Policy Review Template

The recommended policy review template is based on the review of the policies governing protected areas within Saskatchewan's Representative Areas Network, the feedback received at the workshop, and subsequent analysis. The objective is to identify policy barriers or opportunities to climate change adaptation.

Key Evaluation Questions

1) Policy Instruments

What policy instruments are available for each type of protected area within a jurisdiction or protected area system? The review should encompass all public policy instruments including: legislation, regulations, major policy and system plans, site management plans and key public information documents.

2) Policy Scope and Alignment

- Is there prescriptive or enabling legislation, regulations and associated funding to support ecosystem management? Does it establish management responsibility and an accountability framework?
- Is there strong alignment among the policy instruments to support ecosystem management – particularly planning, implementation, monitoring, an adaptive feedback loop and associated funding?

3) Systems Plan

- Is there a system plan to guide designation of protected areas within a jurisdiction (e.g. Saskatchewan's Representative Areas Network) or type of protected area (e.g. Saskatchewan Provincial Parks) being considered and does the plan address climate change mitigation or adaptations?
- If climate change is not addressed or anticipated, is the foundation of the system plan challenged by climate change? For example is the system planning framework based on enduring features such as physiography, or less enduring features like vegetation that will be directly impacted by climate change in the short term?
- Are there set management objectives/standards that need to be met for lands to be included within the protected area system? If so, are these objectives/standards a barrier or opportunity to adapting to climate change? For example, a management objective to protect a specific feature that may be lost to climate change may be a policy barrier to adaptation.

4) IUCN Classification

What IUCN classification is assigned to the protected area and what are the management implications for climate change adaptation? Class I to III protected areas are generally more prescriptive and have a multiple mandate encompassing resource protection/conservation, public education, recreation and education/interpretation. Climate change causes impacts on all mandates; they can all contribute to raising awareness and support planning for climate change adaptation. Class IV to Class VI protected areas generally have a more focused mandate, which may or may not be directly impacted by climate change. Where there is a direct impact and there is active management, such as for community pastures, management activities – planning, monitoring and research – can directly support climate adaptation.

5) Mandate

- For each type of protected area within the system, is there a protection/conservation, recreation, or research/education mandate? These mandates all provide opportunities for assessing impacts and adaptation to climate change.
- Is the protection mandate species- or ecosystem-specific? A species-specific mandate may be a challenge to realize in light of climate change, since the species may be vulnerable whereas the overall ecosystem is not.

6) Natural Resource Management References

- Are there specific ecological goals and objectives?
- Is ecosystem management or other holistic management approach adopted?
- Is biodiversity or biodiversity conservation an objective?
- Is climate change referenced as a management issue?
- Is ecological monitoring anticipated and/or occurring?
- Is ecological management not required and/or absent at either the system or site level?

Without these references to natural resource management it is a major challenge to address not only climate change adaptation but resource management generally.

7) Site Management Plans

- Is management planning prescribed or enabled by policy and is there a requirement to review and update the plan regularly?
- Is site management planning occurring, and if so does it address climate change and other threats to biodiversity?
- Is public consultation prescribed or enabled, and did it occur?
- Were threats to biodiversity, including climate change, addressed?

8) Revenue Sources

- Is there a policy reference as to how revenue will be generated to offset natural resource management costs? This can provide an opportunity to support implementation of “good” management including climate change adaptation.

9) Permits and Leases

- Are there dispositions allowed, and for which activities?
- By providing access to resources or specific rights, do these dispositions pose a barrier to climate change adaptation? Does the nature of the dispositions compel the management agency to involve the disposition holder in planning for climate change adaptation?
- Are the dispositions based on consumption of the resources, and is there a policy to sustain the resource base, monitor and then adjust use levels accordingly? For example, grazing dispositions should be subject to management presecriptions in response to climate change (e.g. adjustment to carrying capacity and grazing seasons).

10) Management Regime

- What is the current management regime?
- What are the opportunities or barriers to climate change adaptation posed by the management regime?

5.2 Policy Recommendations for Adaptation to Climate Change by Saskatchewan's Representative Areas Network (RAN)

1) Expansion – Representation and Connectivity

   Continue expansion of the RAN to ensure representation of all 11 ecoregions in Saskatchewan, and build in connectivity. This would involve conducting a gap analysis in consideration of climate change impacts. Priority should be given to high diversity sites – mix of land and water, variation in topography, etc. Less diverse areas in terms of relief and species richness would be of lower priority as they are more vulnerable to climate change.

2) Legislation and Regulation
3)

   Establish a legislative and regulatory framework and funding, for the RAN program, to encourage and support ecosystem management and research on biodiversity conservation and climate change across all protected areas within the RAN.

4) Performance Management Guidelines / MOU

   Establish performance management guidelines for all protected areas within the RAN in light of climate change; incorporate these within a standard MOU and establish agreements with all RAN management agencies.

5) Alternative Adaptation Strategies

   Establish a common framework to depict alternative adaptation strategies for management of protected areas in light of climate change. This could include:
   - Wilderness – unmanaged change – benchmark areas
   - Frozen Landscape – manage to meet a specific landscape objective
   - Targeted management – ecological integrity (change is allowed but the system is resilient) or maintenance of a specific feature – for example a healthy range that supports grazing on a sustainable basis.

   The framework should address biodiversity conservation and whether or not maintenance or loss of some species is acceptable.

6) Education and Interpretation

   Among protected area agencies with an education/interpretation mandate, develop common messages around climate change impacts and adaptations for protected areas and encourage their use by all agencies when communicating to their stakeholders, general public, etc.

7) Priority Protected Areas for Management

Undertake a risk assessment of climate change on protected areas within the RAN to identify priority management areas and develop management guidelines for the RAN program to respond.

8) Ecological Benchmarks and Monitoring

Identify sites to be used as ecological benchmarks and establish a monitoring program sensitive to climate change. Many different variables could be monitored, for example:

- Temperature
- Precipitation
- Frost Free Period
- Lake Temperature
- Lake water quality
- Grassland productivity
- Shifts in vegetation (e.g. dieback of trees and shrubs)
- Populations of selected animal species

9) Research

Identify sites where there is a good baseline of biophysical data that could be used to demonstrate climate change impacts and encourage related research (e.g. Matador Provincial Protected Area).

5.3 Recommendations for Protected Area Agencies for Adaptation to Climate Change

1) Management Priorities – Biodiversity Conservation and Climate Change

- Actively manage sites to minimize other threats to biodiversity (overuse, pesticide and pollutions, habitat loss and fragmentation)
- Incorporate climate change mitigation, impacts and adaptation into management planning, including public and stakeholder consultation.

2) Management Zones/Response Monitoring

Management zones should be established in larger protected areas to accommodate a diversity of management approaches to maintain maximum ecosystem diversity and to increase resiliency to climate change. Alternative management objectives and tools could be applied to individual zones resulting in a varied response to climate change. Response monitoring and assessment could lead to improved management.

3) Management Review

Undertake a review of active management activities in light of climate change and determine if changes are necessary. Possible adaptations to current management efforts inclue:

- Reduced management effort for an endangered species which is expected to expand as a natural response to climate change (e.g. buffalograss).
- Reduced need to control woody invasion of grasslands (e.g poplar and lodgepole pine).
- A need to manage for declining forests, including: salvage logging, control of fire hazard, and site regeneration.
- The introduction of exotic species which are adapted to warmer or drier climates into protected areas which are not used for benchmark monitoring. (e.g. provides an opportunity to maintain forest cover, but with different species).
- Increased fire protection where required for safety purposes.
- Increased management inputs to maintain trees for amenity purposes (e.g. campgrounds, picnic areas).

4) Grazing Guidelines

In protected areas with lands subject to grazing:

- develop range condition standards for the area under climate change
- reassess grazing capacity
- reassess water needs and supply
- reassess grazing season – it may be extended because of milder winters.

5.4 General Recommendations for Adaptation to Climate Change

1) Restoration Plant Species

In light of the need for restoration of prairie upland habitat and adaptation to climate change, identify plant species for propagation and develop seed quality standards. Choose restoration species or varieties based on adaptation to future climate, rather than recreating historic plant communities.

2) Exotic Species Introductions

Allow exotic species introduction experiments within isolated areas where the spread can be controlled.

4) Management Legislation

For Class I through Class III protected areas (Ecological Reserves and Provincial Park Lands), establish a well aligned management planning policy framework within the full range of policy instruments beginning with enabling or prescribing management planning in legislation and/or regulation. Revise the Provincial Parks Act and the Ecological Reserves Act.

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Appendix 1: IUCN Classification and Protected Areas in Saskatchewan

The following is a summary table of the types of protected lands in Saskatchewan under the Representative Areas Network. The protected areas include examples of the majority of Saskatchewan's biological and landscape types. Management of theses lands are based on the IUCN's (World Conservation Union) management categories. These categories are six-part system for classifying protected areas and promoting the use of an international system. The six IUCN Protected Areas Management Categories are:

Category **I a**	Strict Nature Reserve: protected area managed mainly for science.
Category **I b**	Wilderness Area: protected area managed mainly for wilderness protection.
Category **II**	National/Provincial/Territorial Park: protected area managed mainly for ecosystem protection and recreation.
Category **III**	Natural Monument: protected area managed mainly for conservation of specific natural features.
Category **IV**	Habitat/Species Management Area: protected area managed mainly for conservation of specific natural features.
Category **V**	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation.
Category **VI**	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems.
Category **VII**	This additional Non-IUCN Land Base Inventory Category includes parks/protected areas where the primary focus of management is to provide facility-based, outdoor recreation opportunities (e.g. campgrounds, picnic sites, golf courses, public swimming beaches, etc.).

When applying the IUCN Protected Areas Management Categories, the basis of categorization is by primary management objective. A protected area should be assigned to a particular category on the basis of the primary management objective as contained in the legal definitions on which it was established. The goal of Saskatchewan Environment is to develop and clarify management objectives based on these IUCN categories for protected areas. This will ensure that protected areas will be managed so that the long-term protection and maintenance of its biodiversity is a priority.

Appendix 2: Climate Change and Protected Areas Survey of Protected Areas Managers-Saskatchewan Prairie Ecozone

Prepared by Heidi Kessler, Research Assistant
(under contract to Saskatchewan Research Council)

Individuals Interviewed in the Manager's Survey

Area Designation	Site/Contact	Individual Repondent
Provincial Parks – Saskatchewan Environment	Moose Mountain	Marty Halpape
	Cypress Hills	Brad Mason
	Lower Qu'Appelle (e.g. Echo Valley P.P.)	Kevin Coleridge
	Upper Qu'appelle (e.g. Crooked Lake P.P.)	Cindy MacDonald
	Saskatoon/Battlefords (The Battlefords P.P.)	Barry Stubbington
Provincial Community Pastures – Saskatchewan Agriculture and Food	Matador	Wayne McNeill
	Old Wives	Trevor Johnson
	Program Manager	Rick Ashton- AFRR
PFRA Community Pastures – Agriculture and Food Canada	Program Manager	Bill Bristol
Migratory Bird Sanctuary – Environment Canada		Phil Taylor
Game Preserves – Saskatchewan Environment		Marvin Hlady
Fish and Wildlife Development Fund (FWDF) Lands – Environment Canada		Conrad Olson Bob
Nature Conservancy of Canada Lands		MacFarlen
Grasslands National Park – Parks Canada		Rob Sissons
Fort Walsh – Parks Canada		Fort Walsh

Manager's Survey Results

Legislations

- *The Natural Resources Act*
- *The Provincial Lands Act*
- *The Wildlife Habitat Protection Act*
- *The Forest Resources Management Act*
- *The Conservation Easements Act*
- *The Parks Act, 1997*
- *Wildfire Act, 1998*
- *The Prairie and Forest Fires Act, 1982*
- *The Environmental Management Protection Act*
- *The Wildlife Act*
- *The National Parks Act The Grasslands National Park Act*

Regulations

- The Wildlife Habitat Lands Disposition and Alteration Regulations
- The Conservation Easements Regulations
- The Wildlife Management Zones and Special Areas Boundaries Regulations
- National Park Domestic Animal Regulations 1998

Policy Documents

- The National Park Policy Grasslands National Park's Wildfire Policy The Cultural Resource Management Policy
- Fire and Forest Insect and Disease Management Policy Framework

Management Plan(s)

- Grasslands National Park Management Plan
- Vegetation Management Plans
- Grazing Management Plans
- Fire Management Plans
- Great Sand Hills Land Use Strategy
- Water Management Framework

What year was the management plan last prepared or updated?

Specific management plans/range plans are related to individual parcels and developed on an as needed and on-going basis. However, most management plans are in the draft stage of being updated.

Is Climate Change addressed in your management plan?

Climate change was identified as an issue, which requires an adaptation response.

Do you perceive climate change to be a management issue for your park or protected area?

CC is a considered a management issue based on a general awareness of the issue and an awareness of specific research/reports for the region/area. I.e., Canadian Forest Service is conducting research on climate change impacts on aspen forests (Mike Michaelian) and Norm Henderson's . "Climate Change Impacts on the Island Forests of the Great Plains and Implications for Nature Conservation Policy: The Outlook for Sweet Grass Hills (Montana), Cypress Hills (Alberta-Saskatchewan), Moose Mountain (Saskatchewan), Spruce Woods (Manitoba) and Turtle Mountain (Manitoba-North Dakota)"

How would you rank climate change as a management issue relative to other issues?

Average response was medium.

How do you think the climate will change for your site over the next 50 years?

Precipitation Decreased

What do you think will be the impacts at your site?

CC will affect resources such as vegetation, water levels, etc. I.e., a drying of water bodies, change in species composition.

Has any action been taken at your site to respond or adapt to climate change?

No action has been taken site to respond or adapt to climate change.

Are you aware of any potential strategies for making your protected area more resilient to climate change?

No one was aware of any potential strategies for making a protected area more resilient to climate change.

What, if any, are the barriers to you implementing the strategies/taking action?

There is a need for more information on the potential climate change impacts. There is a lack of resources needed to be applied to this problem.

Do you think there is a need for policy change to address climate change?

Yes, policy change needs to address the probable shifts in vegetation and that impact on fire management within protected areas.

How important is climate change to your agency?

All responses reported their agency feels CC is a high priority

What's the evidence?

This is based on resources spent/available on studying the issue, resources spent/available to planning for the issue, resources spent/available to take action, internal discussions, and personal viewpoints.

Workshop

Are you interested in participating in a workshop to address the linkage between protected area policy and climate change?

Everyone showed interest in participating in a workshop but the suggestion was made to hold it in the fall of 2005. Attention should focus on increasing the protected areas network.

Appendix 3a: Workshop Invitation

Climate Change Adaptation and Protected Areas Policy, Prairie Adaptation Research Collaborative (PARC), University of Regina
Wednesday, March 22, 2006

The research team of John Vandall, Jeff Thorpe and Norm Henderson wishes to invite you and/or other members of your agency to participate in a workshop dealing with Protected Areas Policy and Adaptation to Climate Change. The workshop will take place Wednesday, March 22, 2006 at the Prairie Adaptation Research Collaborative (PARC), suite #150, 10 Research Drive, Regina. Please see the attached research project summary, which includes a map of the prairie ecozone.

The workshop is intended to engage at least one representative from each agency having responsibility for the management of a protected area(s), located within the prairie ecozone. We intend to present the results of our research for discussion at the workshop and based on the feedback finalize a Climate Change and Protected Areas Policy report and recommendations.

The workshop will encompass the following topics which should be of direct interest to you and your agency:

- What are the current efforts of the federal and provincial government around climate change?
- What are climate models predicting as to impacts on vegetation over the next 50 years for Saskatchewan and for Protected Areas in the Prairie Ecozone?
- What are the implications of climate change for site management?
- What is climate change adaptation? What are alternative adaptation strategies?
- What are the opportunities or barriers to adaptation presented by various policy instruments guiding protected area management?
- What should be a climate change policy for protected areas for Saskatchewan?

There is no charge for the workshop. Parking and lunch will be provided. **Please contact Bonnie Pfeifer at PARC to confirm your attendance by Friday, March 10th, 2006. Bonnie can be reached at (306) 337-2300 or bonnie.pfeifer@uregina.ca**

Sincerely,

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

P.S.
For your information, a second related workshop dealing with the potential introduction of exotic tree species into the Saskatchewan boreal forest as an adaptation to climate change is being held the preceding day, Tuesday, March 21, 2005 in Saskatoon. Some of the same background information will be presented there. You are welcome to participate in that workshop as well. For further information contact Jeff Thorpe at (306) 933-8172 or thorpe@src.sk.ca at the Saskatchewan Research Council.

Climate Change Adaptation and Protected Areas Policy Workshop

March 22, 2004
Prairie Adaptation Research Centre (PARC)
(PARC is at suite #150, 10 Research Drive, University of Regina)

Draft Agenda

8:30 AM	Coffee	
9:00 AM	Welcome – Introductions –Objectives for the Day	**Norm Henderson/Jeff Thorpe/John Vandall/**
	Current status of CC and CC response by Canada and Saskatchewan	John Vandall
	CC Modeling and Vegetation Impacts for the Prairie Ecozone	Jeff Thorpe
10:30	Break	
	Adaptation – What is it? Adaptation Alternatives and what does it mean for site management?	Norm Henderson
	Policy Review The Approach and Analysis	John Vandall
	A Protected Area Policy for Saskatchewan	John Vandall
12:00 Noon	Lunch provided on site at no charge to participants	
1:00 PM	Workshop	All
	▪ Vegetation Impacts ▪ Site Management Implications ▪ PA Adaptations ▪ Policy Review Template ▪ Protected Area CC Policy ▪ Recommendations	
4:00 PM	Wrap-up and Next Steps	Henderson / Vandall

Research Project Summary

"Suitability and Adaptability of Current Protected Area Policies under Different Climate Change Scenarios:

The Case of the Prairie Ecozone, Saskatchewan" Feb . 2006

About the Project

Researchers from Saskatchewan Environment, the Prairie Adaptation Research Collaborative (PARC), and the Saskatchewan Research Council (SRC) are collaborating on this project that was approved by the Climate Change Action Fund (Natural Resources Canada) in January 2004. The study area includes a number of protected areas in the Prairie Ecozone of Saskatchewan.

Climate Change's Impact on Protected Area Policies

In order to conserve ecologically significant areas, Saskatchewan currently has established an extensive system of parks and protected areas across the province and is now nearing designating 10% of its land base. The key purpose of these areas is to maintain the ecological integrity of large tracts of prairie ecosystems. However, climate change has been identified as one of the key threats to prairie biodiversity as it could involve rapid change with innumerable impacts. There is a need, therefore, to assess the potential impacts of climate change on protected areas and determine whether existing policies and management guidelines are suitable under future climate conditions.

Purpose and Objectives

This project will address:

1. The capacity of current management structures and practices to sustain ecosystem health under future conditions of climate, and potential new practices that could better address this issue.
2. The implications of climate change for ecosystem and protected areas management, including an identification of priority areas for concern and potential barriers to adaptation.

Importance of Research

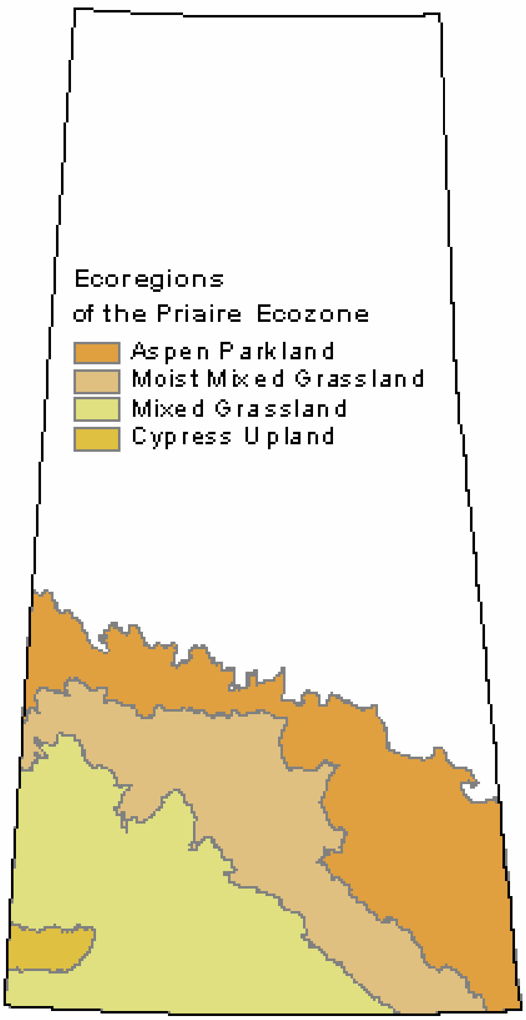
The affects of climate change are already noticeably apparent in Saskatchewan. Drier and warmer conditions, which have characterized recent decades, are expected to become even more severe over time. With regard to protected areas, we know that many of the impacts will be adverse. Forest stands in Cypress Hills, for example, are projected to disappear over time if proper management is not in place.

Even if industrialized countries can meet the commitments in the Kyoto Protocol, it will not be enough to offset the impacts of climate change. Saskatchewan, like any other place in the world, has no other option but to adapt to a warmer climate.
Adaptation to the potential impacts of climate change requires analysis and foresight. First, scientists must use appropriate models to determine potential impacts. Second, based on this knowledge, they must assess whether our current policies and management practices will be effective in adapting to the projected changes.

This project will examine and propose how policies and management can be more effective to deal with the oncoming impacts of climate change. Protected areas in Saskatchewan's Prairies represent a large portion of the province's biodiversity and natural beauty. A proper response is needed if we are to protect the biodiversity in this province that we depend upon and cherish.

Project researchers will consult with protected area land managers and stakeholders to:

1. Develop recommendations for policy and further research to support adaptation by protected areas to climate change
2. Based on the case of the Prairie Ecozone, develop a protected area policy for Saskatchewan under climate change.
3. Develop a template to review protected area policy, under climate change, that could be used by other prairie provinces.



Contact Information

Norman Henderson
Phone: (306) 337-2292
E-mail: Norman.Henderson@uregina.ca

Research to be Conducted

Available climate change scenarios and associated vegetation models will be reviewed and assessed for the prairies. Future climates and vegetation types will then be modeled at the ecoregional scale for different time periods.

Adaptation responses will be developed and assessed in consultation with land managers and stakeholders. Some of the responses and strategies that may be considered include an expansion of the protected areas network, introduction of non-native species, and revisions to wildfire management policy.

Literature reviews will be conducted on the current knowledge of climate change impacts and policy adaptations on protected areas in the Great Plains and on provincial protected area policies in Saskatchewan. In conjunction, land managers and stakeholders will be surveyed to ascertain their perceptions of protected area policy issues under climate change. This research will allow for the development of a protected area policy for Saskatchewan as well as a policy review template for other jurisdictions.

Current Project Team Members – February 2006

- Norman Henderson
  Prairie Adaptation Research Collaborative
  Regina, SK
- John Vandall
  Saskatchewan Environment
  Regina, SK
- Jeff Thorpe
  Saskatchewan Research Council
  Saskatoon, SK

Appendix 3c: Workshop Presentation - Introduction

Climate Change Adaptation and Protected Area Policy

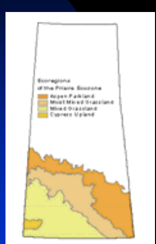
Norm Henderson
Jeff Thorpe
John P. Vandall

Introduction

Objective is to:

- 1) provide overview of current climate change activities by government
- 2) present and the results of work to date on the project.
- 3) questions/discussion

Participants Introductions



Suitability and Adaptability of Current Protected Area Policies under Different Climate Change Scenarios

The Case of the Prairie Ecozone, Saskatchewan

Project Objectives:

- Develop a template to review protected area policy that could be used by other prairie provinces
- Based on the case of the Prairie Ecozone, develop a protected area policy for Saskatchewan under climate change.
- Develop recommendations for policy and further research

Protected Area

- The IUCN definition:
  “an area of land and /or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources and managed through legal or other effective means.

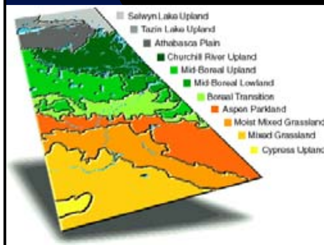
IUCN Categories

- Ia Strict Nature Reserve – managed mainly for science
- Ib Wilderness Area –managed mainly for wilderness protection
- II National/Provincial /Territorial Parks: managed mainly for ecosystem protection and recreation
- III Natural Monument – managed mainly for conservation of specific natural feature
- IV Habitat/Species Management Area: managed mainly for conservation through management intervention.
- V Protected Landscape/Seascape: managed mainly for landscape/seascape conservation and recreation
- VI Resource Protected Area: managed mainly for the sustainable use of natural ecosystems.

Saskatchewan's Representative Areas Network (RAN)

- Encompasses most of Sask's PAs:
  - Ecological Reserves
  - National and Provincial Parks
  - Pastures
  - WHPA and FWDF Lands
  - National Wildlife Areas
  - Conservation Easements, Etc.
- Does not include Urban and Regional Parks and Recreation Sites

Saskatchewan's Representative Areas Network (RAN)



- to ensure representation of 11 Ecoregions
- defined by "enduring features" (soils and landforms) that do not change appreciably over time

Saskatchewan's Representative Areas Network (RAN)

- Encompasses about 9% of province. Target is 12% by 2009 (Sask. Biodiversity Action Plan)

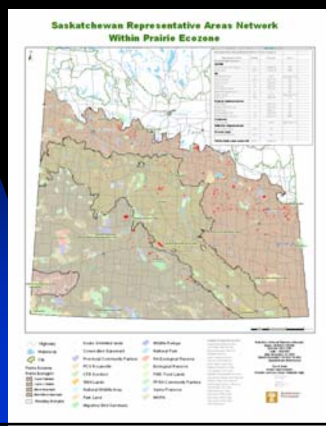
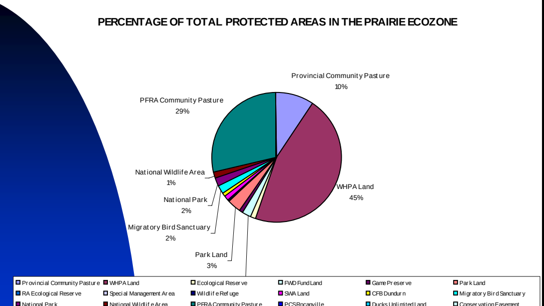
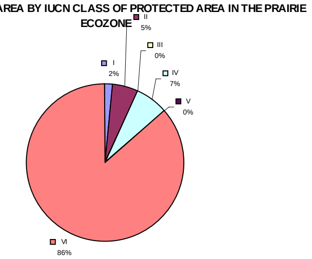


Table 1
Representative Areas Network Within Prairie Ecozone

Representative Area	Number	Area (ha)	IUCN Class	Total %
Provincial Administration				
Saskatchewan Agriculture and Food (SAF)				
Provincial Community Pasture	28	239246.54	VI	10%
Wildlife Habitat Protection Act (WHPA) Land	22777	1102090.79	VI	45%
Saskatchewan Environment (SE)				
Ecological Reserve	4	850.8	Ia	less then 1%
Fish and Wildlife Development (FWD) Fund Land	1070	45121.99	IV	2%
Game Preserve	43	26793.82	IV	1%
Park Land*				
Provincial Parks			Ib	
Protected Areas			II	
Recreation Sites			III	
			VI	
*(Historic Sites and Historic Parks not included)	62	83668.47		3%
Representative Area (RA) Ecological Reserve	1	37343.45	Ia	2%
Special Management Area	0	0	VI	0%
Wildlife Refuge	24	2937.2	VI	less then 1%
Saskatchewan Watershed Authority (SWA)				
Saskatchewan Watershed Authority (SWA) Land	699	34405.04	VI	1%
Federal Administration				
Canadian Forces Base (CFB) Dundurn	1	21537.69	VI	1%
Migratory Bird Sanctuary	14	56432.05	IV	2%
National Park	1	48822.11	II	1%
National Wildlife Area	38	36470.98	IV	2%
Prairie Farm Rehabilitation Act (PFRA)				
Community Pasture	169	707003.67	VI	29%
Corporate				
PCS Rocanville	1	1495.8	VI	less then 1%
NON-Gov Organizations				
Ducks Unlimited Land	1080	N/A	V	
Private Land				
Conservation Easement	207	N/A	VI	
TOTAL RAN Land within PE	26219	2444220.4		





Manager's Survey Methodology

- Contacted 15 Managers for 9 different types of PAs.
- Intended to:
  - ascertain their and their agency's management policy instruments,
  - indicate their awareness of climate change impacts and what has been the management response to date

Manager's Survey Results -1

- Policy Instruments - legislation and regulations, area specific policy and management plans.
- Site-specific management plans are either being developed or updated.
- CC recognized as an management issue which requires an adaptation response – aware of some research
- CC is moderate priority
- CC impact – reduced precipitation leads to lower water levels and change in vegetation

Manager's Survey Results –2

- No CC adaptation measures identified
- Barriers to CC adaptation – lack of information on impact of CC and lack of resources to apply to the problem
- Site-specific management plans are either being developed or updated.
- Need policy change to address shift in vegetation zones and impact on fire regime
- CC priority at agency level, based on resources allocated to studies, planning and level of internal discussion.

Policy Review Methodology

- Objective: identify policy opportunities/barriers to CC adaptation
- Focused on public policy documents available via the internet. Included:
  - Legislation
  - Regulation
  - Major Policy Documents
  - Management Plans
  - Agreements (e.g. MOU's)

Policy Review Methodology - Template

- Natural Resource Mandate?
- Natural Resource Management Goal/Objectives?
  - Ecosystem management
  - Biodiversity conservation
- Climate Change Reference?
- System Planning Goal/Objective?
- Policy on:
  - Natural Resource Management Planning
  - Implementation and/or
  - Monitoring
- Other: Funding? Policy Alignment?

Protected Areas - Resource Management Regimes Relative to CC

- Passive – no active RM, LU may be controlled (e.g. WHPA)
- Active – some RM planning and implementation, LU controlled (e.g. PP)
- Reactive – response to LU such as grazing (e.g. pastures)
- Proactive – planning anticipates CC and response either builds resistance or embraces change

RAN (Systems) Policy Assessment

- Policy Instruments
  - No legislation or regulations
  - Major Policy Documents
  - Agreements
- Objectives focus on biodiversity conservation, representation of ecosystems

RAN (Systems) Policy Assessment

- Opportunities
  - At 9% opportunity to expand to 12% (Moist Mixed Grassland and Aspen Parkland)
  - Enduring features framework is a strong foundation to theoretically continue expanding the system
  - Commitment to establish management policies and standards, and ecological benchmarks (involving monitoring)

RAN (Systems) Policy Assessment

- Barriers
  - No commitment to address climate change and adaptation.
  - Lack of information on which to design the system to address CC.
  - No enabling or prescriptive policy dealing with resource management planning/implementation
  - Long term agreements with resource users could be a barrier to adaptation

Policy Review Results Summary - 1

- Barriers
  - No full alignment of Natural Resource Management Policies from legislation to site management level. Usually only exist only at site level or major policy level.
  - No specific Resource Management Goal/Objectives – although ecosystem management and biodiversity conservation is generally recognized
  - No prescriptive policy requiring planning and/or monitoring

Policy Review Results Summary - 2

- Opportunities
  - RAN program has made a commitment to establish management policies and standards and provides framework for demonstrating leadership and communication.
  - RAN agreement should be extended among all partners.
  - Parks Canada provides a model of where policy alignment has occurred and additional resources have been allocated.
  - Sustainable resource use objectives/management for community pastures are consistent with PA biodiversity conservation objectives.

Protected Area Policy under Climate Change

- Continue expansion of the RAN to ensure representation of all 11 Ecoregions.
- Establish a legislative and regulatory framework to support management of natural resources within the RANetwork
- Identify sites to be used as ecological benchmarks and establish monitoring sensitive to CC.

Protected Area Policy under Climate Change

- Incorporate CC impacts into management planning.
- Awareness, Public Communication and Interpretation re: Climate Change, Impacts, Mitigation and Adaptation
- Minimize other threats to biodiversity (overuse, pesticide and pollution, habitat loss and fragmentation)

Questions

- Are there other questions that should be asked within the policy review template (e.g. exotic species)?

Policy Review Methodology - Template

- Natural Resource Mandate?
- Natural Resource Management Goal/Objectives?
  - Ecosystem management
  - Biodiversity conservation
- Climate Change Reference?
- System Planning Goal/Objective?
- Policy on:
  - Natural Resource Management Planning
  - Implementation and/or
  - Monitoring
- Other: Funding? Policy Alignment?

Questions

- For each PA type have you comments on the summary of opportunities or barriers?

Questions

- What should be included in a PA policy for CC?

Protected Area Policy under Climate Change

- Continue expansion of the RAN to ensure representation of all 11 Ecoregions.
- Establish a legislative and regulatory framework to support management of natural resources within the RANetwork
- Identify sites to be used as ecological benchmarks and establish monitoring sensitive to CC.

Protected Area Policy under Climate Change

- Incorporate CC impacts into management planning.
- Awareness, Public Communication and Interpretation re: Climate Change, Impacts, Mitigation and Adaptation
- Minimize other threats to biodiversity (overuse, pesticide and pollution, habitat loss and fragmentation)

See Presentation on

Climate Change Update March 2006

John Vandall

Policy Review Results

- See individual PA type summary arranged by IUCN Class (pp 28-37)
- Note the percentage of area covered by the individual PA type.

See Presentation on

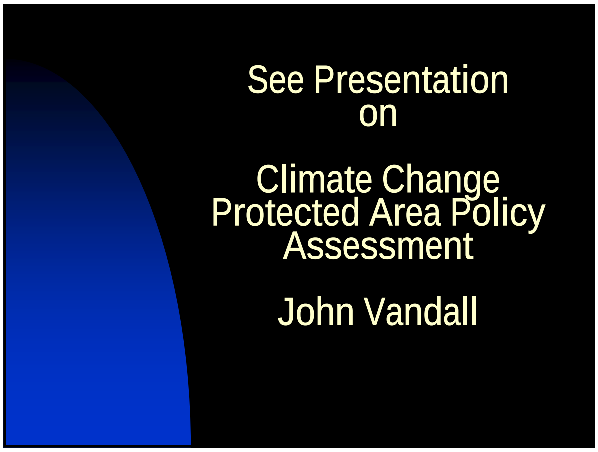
Climate Change Impacts and Adaptation for Prairie Ecozone and Protectec Areas

Jeff Thorpe

See Presentation on

Climate Change Adaptation

Norm Henderson


See Presentation
on
Climate Change
Protected Area Policy
Assessment
John Vandall

Appendix 3d: Workshop Presentation – Climate Change Update

Climate Change - Update

March 2006

Climate Change Update

- **International**
- **National**
- **Provincial**

International

- COP11/MOP1
- US
- European Union

COP11/MOP1

- Montreal Action Plan - 40 decisions
  - Adopted the "rule book" of the KP
  - Streamlined and strengthened the CDM
  - Launched the JI mechanism
- Parties agreed to start discussion new emission targets for post 2012
- 189 UNFCCC parties agreed to begin dialogue on long-term cooperative action against CC

United States…1

- Did not ratify the KP
- US CC Program
  - $20 billion - last 5 years - research & technology development
  - Bilateral initiatives with 15 countries & organizations on projects to reduce GHG emissions
  - Multilateral initiatives in areas of hydrogen, carbon sequestration and nuclear to address the challenge of CC
- Between 1990 and 2003 GHG emissions increased by 13%

United States …2

- Many states are looking at policies that address CC as economic opportunities to:
  - Produce and sell alternative fuels
  - Become renewable energy exporters
  - Attract high-tech businesses
  - Sell carbon emission reduction credits
- Other drivers to state policies to address CC:
  - Efforts to improve air quality
  - Lessen traffic congestion
  - Secure energy supply and reliability

European Union…1

- All 25 member states have ratified the KP
- 23 have emissions reductions targets under the KP
- 17 of the 23 member states are on track to meet their commitment
- Germany & UK are largest emitters of GHG (34%)

European Union…2

- European CC Program:
  - Emissions trading scheme
  - Directive on EE efficiency standards for buildings
  - Legislation on fluorinated industrial gases
  - Capture and storage of carbon emissions
  - Emissions from road vehicles and aviation

National

- Federal climate change plan
- Canada's greenhouse gas emissions
- New government – Ministers

Elements of Federal CC Plan

- Competitive and Sustainable Industries for the 21st Century
- Harnessing Market Forces
- A Partnership among Canada's Governments
- Engaged Citizens
- Sustainable Agricultural and forest Sectors
- Sustainable Cities and Communities

Carbon Sinks

- Overall reduction target of 30 MT
- BAU sinks from soil and forests
  - through continuing existing farming and forestry practices
- Climate Fund can contribute additional tonnes
  - by purchasing sequestered carbon through farming and forestry management projects

Renewable Energy

- Overall reduction target of 15 MT
- Budget 2005 announced $1.8 billion over the next 15 years to:
  - Quadruple Wind power Production Incentive to 4000 megawatts
  - Create Renewable Power Production Incentive to develop solar, small hydro and biomass
  - Introduced tax measures to promote energy efficiency and renewable energy

Consumer Action

- Overall reduction target of 5 MT
- To increase information and incentives to support greener purchasing decisions by Canadians the GoC will:
  - Increase technical advice and service to individuals, businesses and communities
  - Continue to raise awareness through the OTC of simple, cost-effective energy efficient actions
- NREE will consult with Canadians on viability and effectiveness of green consumer initiatives

Green Government

- Overall reduction target of 1.0 MT
- GoC will reduce its own emissions by one third by:
  - Green Procurement Policy to govern all purchases
    - including power
    - by 2006 and making central heating and cooling plants more efficient
  - Ensure new office buildings meet LEED Gold Standard
    - use half of energy needed per building on average today
  - Replace vehicles with more efficient alternatives including hybrids

Funding

Funds & programs	Expenditures to 1012	Budget 2005
Climate Fund	$4-6 billion	$1.0 billion
Partnership Fund	$2.5-3.5 billion	$0.25 billion
LFEs		
GHG Reduction Programs	$2.8 billion	
Carbon Sinks	*	*
Renewable Energy	$1.8 billion	$0.297 billion
Consumer Action	$0.12 billion	
Automotive Industry		$0.03 billion
Green Government		
Total	$11.2 - $14.2 billion	$1.6 billion

* Funding available through Climate change fund and LFE purchase of offset credits.

Overall Reduction Target

Fund/Program	Reduction Target, MT
Climate Fund	75 – 115
Partnership Fund	55 – 85
LFEs	45
GHG Reduction Programs	40
Carbon Sinks	30
Renewable Energy	15
Consumer Action	05
Automotive Industry	05.3
Green Government	01.0
Total	**271.3 – 341.3**

GHG Emissions by P/T, kt CO_2 equivalent

	1990	2003	% Change	% Above Target	Rank kt per capita
NL	9371	10782	15.1	22.4	6
PEI	1936	2088	7.9	14.7	10
NS	19236	21247	10.5	17.5	5
NB	15836	21083	33.1	41.6	3
QC	84891	92381	8.8	15.8	12
ON	179063	206883	15.5	22.9	8
MB	19181	21453	11.8	19.0	7
SK	45075	65316	44.9	54.2	2
AB	167801	224685	33.9	42.4	1
BC	51542	63983	24.1	32.1	9
YK	514	445	-13.4	-7.9	11
NWT	1532	1772	15.7	23.1	4
Canada	597926	742964	24.3	32.2	

New Government - Ministers

- NRCan Minister: Gary Lunn
- Environment Minister: Rona Ambrose
  - President of Conference of Parties to KP
  - Report on Canada's GHG Emissions delayed
  - New CC Plan expected in May 2006
  - Still committed to the KP commitment

Provincial

- MOU on climate change
- Carbon management projects
- Saskatchewan's greenhouse gas emission

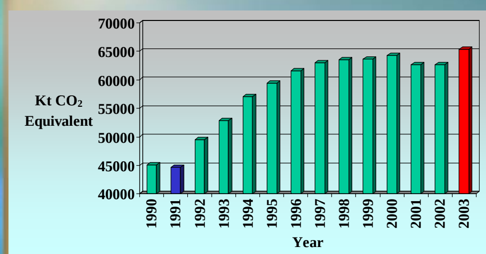
MOU - Priorities

- Signed November 23, 2005
- Priority areas for cooperation:
  1. Carbon management
  2. Oil & gas industry
  3. Renewable energy development
  4. Energy efficiency
  5. GHG mitigation from agriculture industry
  6. Carbon sequestration in agriculture and forestry
  7. Public awareness and education
  8. Impacts and adaptation
  9. Research and innovation

MOU - Carbon Management

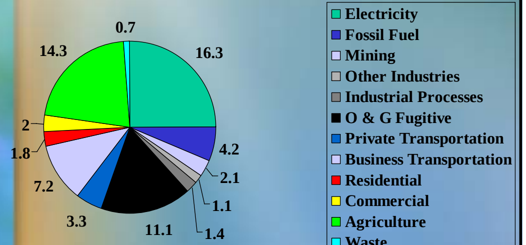
- Feasibility work for Clean Coal Project
- Feasibility work for Polygeneration Project
- Canada will pay 50% share of estimated costs for feasibility studies to $20 million
- Annex parties agree that if the proposals are determined to be feasible they should cooperate to implement proposals

Saskatchewan Greenhouse Gas Emissions, 1990 to 2003



6% below 1990: 42371 Kt CO_2 Equivalent;
LOW: 1991: 44702 Kt CO_2 Equivalent; HIGH: 2003: 65316 Kt CO_2 Equivalent
Since 1990, GHG Emissions in Saskatchewan have increased by 45% [2003]
GHG Emissions in Saskatchewan in 2003 were 54% above the 6% below 1990 level.

SK - GHG Emissions - Sector



Adaptation

- National Framework for Adaptation/ CCME in forming stage
- PARC and SRC initiatives:
  - Adaptation of Prairie Cities
  - Vulnerability Assessments: Alberta, Boreal Forest, Nature-based Tourism
  - Spruce Budworm Outbreak
  - Boreal Forest/Agriculture Fringe
  - Wildfire and Respiratory Ailments in N. Sask
  - PA Policy – Prairie Ecozone
  - Fragment Prairie Biodiversity
- Manitoba – Lake Winnipeg Fishery and transportation infrastructure
- BC – research and modeling and other tools for assessing adaptation options

Information on Climate Change

- **International:**
  - **http://unfccc.int**
- **National**
  - **www.climatechange.gc.ca**
- **Provincial**
  - **www.climatechangesask.com**

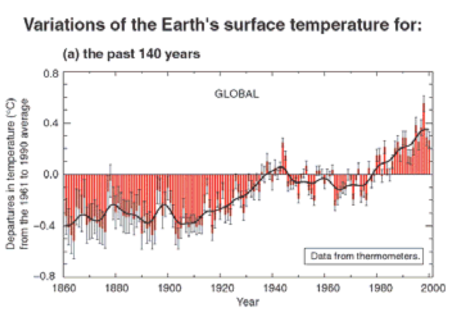
Appendix 3e: Workshop Presentation – Climate Change Modeling and Vegetation Impacts for the Prairie Ecozone

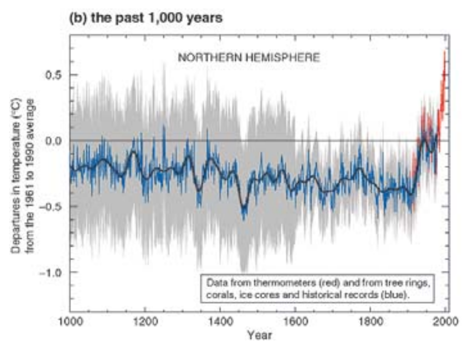
Climate Change Modeling and Vegetation Impacts for the Prairie Ecozone

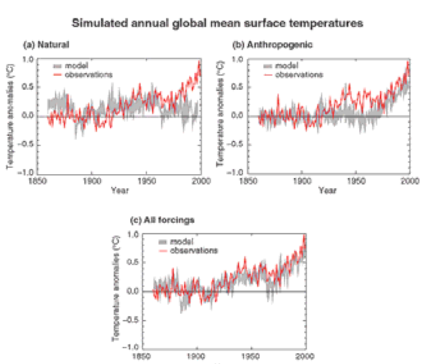
Jeff Thorpe
Saskatchewan Research Council
March 22, 2006

Climate Change

- Global temperatures have increased over the past 140 years.
- Most climate scientists attribute this to the increase in greenhouse gases in the atmosphere.







Global Climate Models (GCMs)

- The main tool for projecting climate change into the future is large computer models of the dynamics of the earth's atmosphere.
- There are a number of different GCMs developed in different countries.
- The best approach is to compare the results from several different GCMs.

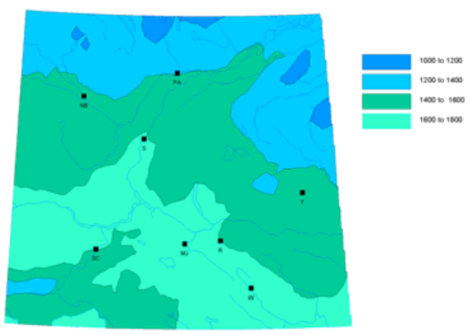
Applying GCMs to the Canadian prairies

- Outputs from GCMs can be applied to a region such as the Canadian prairies.
- All the models show a large increase in temperature in this region over the coming century.
- Changes in precipitation are smaller and more variable.

Climate change - GCMs

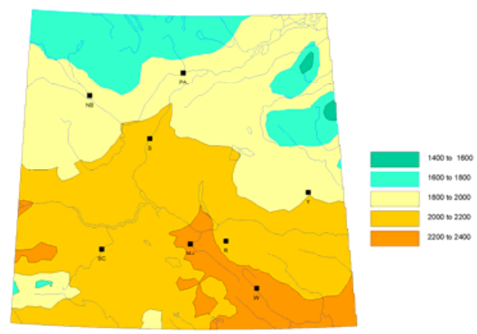
Averages for Canadian Prairies	Mean annual temperature (°C)	Annual precipitation (mm)
1961-90	3.0	404
2050s:		
- HadCM3 B21	5.2	412
- CSIRO Mk2b B11	6.1	412
- CGCM2 A21	6.7	403

Growing Degree-Days, 1961-90

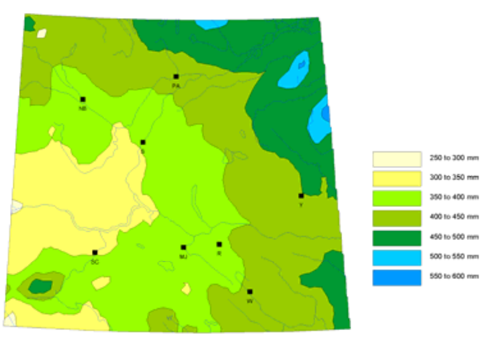


Growing Degree-Days in the 2050s

(CSIRO Mk2b B11 scenario)

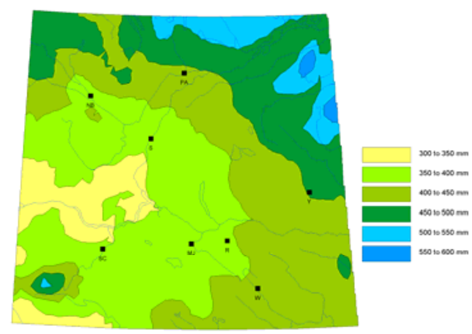


Annual Precipitation, 1961-90



Annual Precipitation in the 2050s

(CSIRO Mk2b B11 scenario)



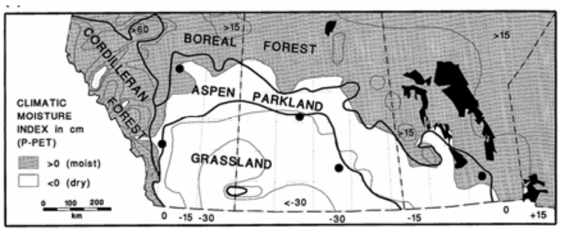
Modelling changes in vegetation zonation in the Canadian prairies

- The zones of natural vegetation in the Prairie Provinces, from grassland in the south to forest in the north, are controlled by climate.
- Climate change is expected to cause changes in these vegetation zones.

Previous work:

- Hogg (1994) defined the Climatic Moisture Index (CMI) as annual precipitation minus annual potential evapotranspiration
- He showed that CMI is positive in the boreal forest and negative in the grassland region, with CMI=0 closely matching the boundary between zones.

Hogg's model of the forest/grassland boundary:



Grassland vegetation zones in southern Saskatchewan

- Hogg (1994) suggested that the vegetation zones in the grassland region could be related to increasingly negative values of CMI.
- We used this approach to model the current vegetation zones:

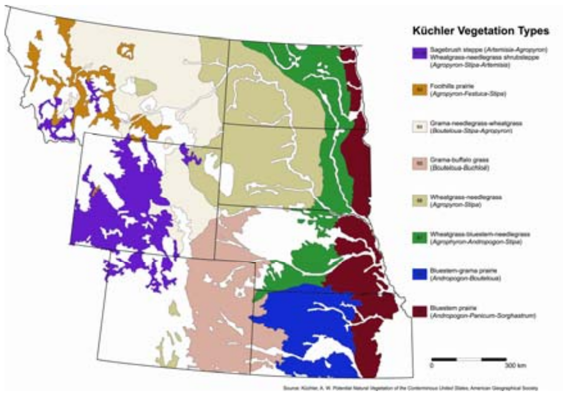
CMI	Zone
>0	Forest
0 to -150 mm	Aspen Parkland
-150 to -300 mm	Mixed Prairie
< -300 mm	Dry Mixed Prairie

Future vegetation zones

- Future climates predicted by GCMs include much warmer conditions than any that currently occur in the Canadian Prairies.
- This implies that future vegetation zones could be different from any of our current zones.
- Therefore, we used vegetation zones found in the warmer climates of the U.S. Great Plains as analogues for the future zones in Canada.

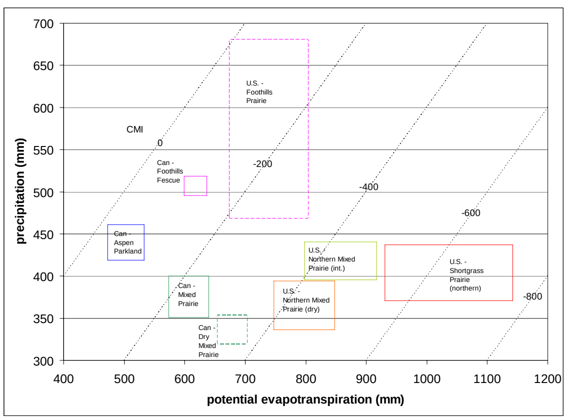
U.S. vegetation types mapped by Kuchler (1964) in the Great Plains:

DESCRIPTIVE NAME	KUCHLER TYPE	
Foothills Prairie	63	Foothills Prairie
Northern Mixed Prairie (drier)	64	Grama – Needlegrass - Wheatgrass
Northern Mixed Prairie (intermediate)	66	Wheatgrass – Needlegrass
Northern Mixed Prairie (moister)	67	Wheatgrass – Bluestem - Needlegrass
Tallgrass Prairie	74	Bluestem
Shortgrass Prairie	64	Grama - Buffalograss
Sagebrush Steppe	55,56	Sagebrush Steppe



Modelling of U.S. vegetation types:

- U.S. vegetation types were modeled in relation to annual precipitation (PPT) and annual potential evapotranspiration (PET).
- Seasonal distribution of precipitation was also represented by the proportion of precipitation falling in summer (SUMMERPPT).
- Logistic regression model was developed to predict the U.S. vegetation type from these climatic variables.



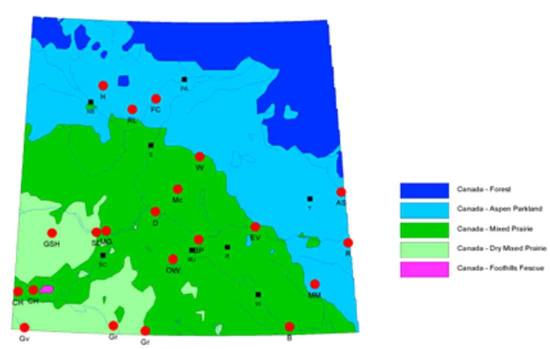
Predicting future vegetation types in Canada

- If future climates fell within the range of current Canadian climates, then Canadian vegetation types based on CMI were predicted.
- If future climates were outside the range of current Canadian climates (warmer), then U.S. vegetation types based on the logistic regression model were predicted.

Results:

- Current vegetation zones are predicted to move northward, with much of the southern forest having a climate more suitable for Aspen Parkland.
- The current Aspen Parkland will shift toward open grassland.
- The southern grassland region will shift toward the kind of Mixed Prairie currently found in Montana, Wyoming, and N. and S. Dakota.
- The driest part of the grassland region will shift toward Shortgrass Prairie, currently found in Colorado and further south.

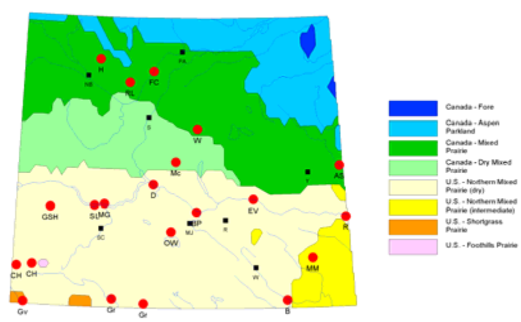
Predicted Vegetation Zones, 1961-90



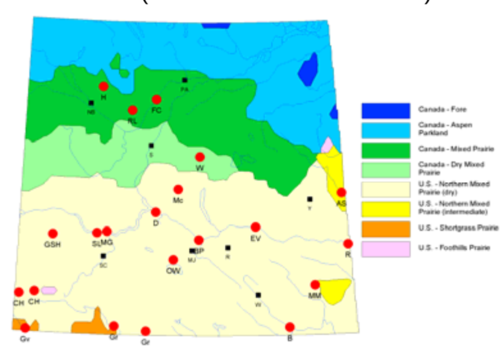
Aspen Parkland	Moist Mixed Grassland	Mixed Grassland	Cypress Upland
		Grasslands National Park	Fort Walsh National Historic Site
Moose Mtn. Prov. Park	Douglas Prov. Park	Sask. Landing Prov. Park	Cypress Hills Prov. Park
Echo Valley Prov. Park Fort Carlton Prov. Park	Buffalo Pound Prov. Park		
Assiniboine Slopes Ecol. Res.	Buffalo Grass Ecol. Res.	Great Sand Hills Ecol. Res., Matador Grasslands Prov. Prot. Area	Assiniboine Ecol. Res.

Aspen Parkland	Moist Mixed Grassland	Mixed Grassland	Cypress Upland
Hatherleigh Prov. Pasture		Old Wives Prov. Pasture	
Wolverine PFRA Pasture	McCraney PFRA Pasture	Govenlock PFRA Pasture	
PCS Rocanville (private stewardship)			

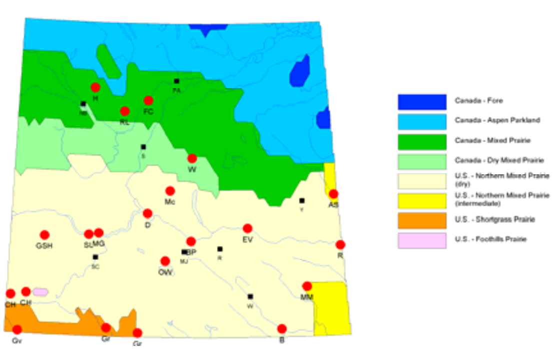
Predicted Vegetation Zones in the 2050s
(CGCM2 A21 scenario)



Predicted Vegetation Zones in the 2050s
(CSIRO Mk2b B11 scenario)



Predicted Vegetation Zones in the 2050s
(HadCM3 B21 scenario)



Ecological Impacts:

- Gradual reduction in tree and shrub cover.
- Reduced invasion of grassland patches by shrubs and poplar sprouts.
- Decrease in animals species dependent on woody cover, increase in grassland species.
- Biggest impact on areas with most tree cover (Hatherleigh, Fort Carlton, Wolverine, Assiniboine Slopes, Moose Mountain, Douglas, Cypress Hills).

Ecological Impacts

- Shifts in structure of grasslands: decrease of midgrasses, increase of shortgrasses.
  - Applies to all areas
- Decrease in cool-season grasses, increase in warm-season grasses.
  - Applies to all areas
- Gradual arrival of plant and animal species currently found only in U.S. (e.g. buffalograss, sand bluestem)

Ecological Impacts

- Reduction in forest production.
- POSSIBLE reduction in grassland production.
  - Drier climate will tend to reduce production
  - However, moderated by increase in warm-season grasses (higher water use efficiency)
- Applies to all areas.

Ecological Impacts

- Increased potential for dune activation (Great Sand Hills, Douglas)
- Shrinkage of water bodies, ponds replaced by wetlands, wetlands invaded by forest (Moose Mountain)

Management Implications

- Need for monitoring to detect long-term changes
- Role in research on climate change (e.g. Matador Prov. Prot. Area)
- Changes in biodiversity goals: do we accept loss of some species, or try to maintain them?
  - e.g. montane species in Cypress Hills

Management Implications

- Changes in vegetation management
- Reduced need to control woody invasion of grasslands.
- Need for management of declining forests (e.g. salvage logging, control of fire hazard) (Moose Mountain, Cypress Hills)
- Should we try to maintain forest cover in some places? Should we introduce exotic species adapted to warmer/drier climate? (Moose Mountain, Cypress Hills)

Management Implications

- Declining opportunities for forest-based recreation (e.g. Moose Mountain)
- Declining opportunities for water-based recreation (Moose Mountain)
- Changes in nature interpretation themes (provincial and national parks)

Management Implications

- Changes in livestock grazing capacity.
  - Grazing capacity of grasslands may decrease in many areas (lower productivity with drier climate).
  - However, in Parkland the loss of tree cover will tend to increase grazing capacity (e.g. Hatherleigh, Wolverine).
- Changes in range condition standards.
- Even great need for litter cover (e.g. Govenlock)
- Possible need for additional water development.
- Grazing season may be extended with milder winters.

Appendix 4: General characteristics of the main zonal vegetation types in the Canadian Prairies and northern and central U.S. Great Plains. Sources: Kuchler 1964, Shiflet 1994, personal knowledge of the authors.

Canada - Aspen Parkland

Physiognomy
Mosaic of mid-height grassland with broad-leaved woodland and shrubland

Dominant grasses
Plains rough fescue (*Festuca hallii*)
Western porcupine grass (*Stipa curtiseta*)

Secondary graminoids
Sedges (*Carex spp*.)
June grass (*Koeleria macrantha*)
Wheatgrasses (*Agropyron dasystachyum, A. subsecundum, A. trachycaulum*)
Hooker's oatgrass (*Helictotrichon hookeri*)
Blue grama (*Bouteloua gracilis*)
Mat muhly (*Muhlenbergia richardsonis*)
Kentucky bluegrass (*Poa pratensis*)
Big bluestem (*Andropogon gerardii*) – eastern part of area.
Porcupine grass (*Stipa spartea*) – eastern part of area.
Prairie dropseed (*Sporobolus heterolepis*) – eastern part of area.

Major forbs & half-shrubs
Goldenrods (*Solidago spp*.)
Pasture sage (*Artemisia frigida*)
Crocus (*Anemone patens*)
Pussytoes (*Antennaria spp*.)
Moss-phlox (*Phlox hoodii*)
Mouse-ear chickweed (*Cerastium arvense*)
Three-flowered avens (*Geum triflorum*)
Northern bedstraw (*Galium boreale*)

Major woody plants
Western snowberry (*Symphoricapos occidentalis*)
Woods rose (*Rosa woodsii*)
Wolf-willow (*Elaeagnus commutata*)

Major forbs in woodland/shrubland:
Sarsaparilla (*Aralia nudicaulis*)
Solomon-seal (*Smilacina stellata*)
Lily-of-the-valley (*Maianthemum canadense*)
Asters (*Aster spp*.)
Goldenrods (*Solidago spp*.)
Violets (*Viola spp*.)
Peavines (*Lathyrus spp*.)
American vetch (*Vicia Americana*)

Major woody plants in woodland/shrubland:
Trembling aspen (*Populus tremuloides*)
Balsam poplar (*Populus balsamifera*)
Chokecherry (*Prunus virginiana*)
Saskatoon (*Amelanchier alnifolia*)
Beaked hazelnut (*Corylus cornuta*)
Hawthorn (*Crataegus chrysocarpa*)
Willows (*Salix* spp.)

Vegetation gradients
Kentucky bluegrass, needlegrasses, blue grama, pasture sage increase with grazing. Woody cover increases in absence of fire.

Canada - Mixed Prairie **Physiognomy** Mixed prairie, with midgrasses dominant **Dominant grasses** Western porcupine grass (*Stipa curtiseta*) Northern wheatgrass (*Agropyron dasystachyum*) Needle-and-thread (*Stipa comata*) Western wheatgrass (*Agropyron smithii*) **Secondary graminoids** June grass (*Koeleria macrantha*) Blue grama (*Bouteloua gracilis*) Sedges (*Carex spp*.) Plains reedgrass (*Calamagrostis montanensis*) Green needlegrass (*Stipa viridula*) Plains rough fescue (*Festuca hallii*)	**Major forbs & half-shrubs** Pasture sage (*Artemisia frigida*) Dense clubmoss (*Selaginella densa*) Moss-phlox (*Phlox hoodii*) Prairie sage (*Artemisia ludoviciana*) Pussytoes (*Antennaria spp*.) Scarlet mallow (*Sphaeralcea coccinea*) Crocus (*Anemone patens*) Low goldenrod (*Solidago missouriensis*) Yarrow (*Achillea millefolium*) Milkvetches (*Astragalus spp*.) Golden-bean (*Thermopsis rhombifolia*) **Major woody plants** Western snowberry (*Symphoricapos occidentalis*) Woods rose (*Rosa woodsii*) Wolf-willow (*Elaeagnus commutata*) **Vegetation gradients** Needle-and-thread, June grass, blue grama, sedges, pasture sage, and forbs increase with grazing.

Canada - Dry Mixed Prairie **Physiognomy** Mixed prairie, with midgrasses dominant but with important component of shortgrasses **Dominant grasses** Needle-and-thread (*Stipa comata*) Western wheatgrass (*Agropyron smithii*) Northern wheatgrass (*Agropyron dasystachum*) Blue grama (*Bouteloua gracilis*) **Secondary graminoids** June grass (*Koeleria macrantha*) Sedges (*Carex spp*.) Plains reedgrass (*Calamagrostis montanensis*) Sandberg's bluegrass (*Poa secunda*) Western porcupine grass (*Stipa curtiseta*) Green needlegrass (*Stipa viridula*)	**Major forbs & half-shrubs** Pasture sage (*Artemisia frigida*) Dense clubmoss (*Selaginella densa*) Moss-phlox (*Phlox hoodii*) Prairie sage (*Artemisia ludoviciana*) Crocus (*Anemone patens*) Low goldenrod (*Solidago missouriensis*) Pussytoes (*Antennaria spp*.) Yarrow (*Achillea millefolium*) Pincushion cactus (*Mamillaria vivipara*) Scarlet mallow (*Sphaeralcea coccinea*) Milkvetches (*Astragalus spp*.) Golden-bean (*Thermopsis rhombifolia*) **Major woody plants** Western snowberry (*Symphoricarpos occidentalis*) Silver sagebrush (*Artemisia cana*) **Vegetation gradients** Similar to U.S. Northern Mixed Prairie (dry), but some species (e.g. buffalograss, big sagebrush) absent. Blue grama, June grass, sedges, pasture sage, and forbs increase with grazing.

Canada - Foothills Fescue **Physiognomy** Dense mid-height grassland **Dominant grasses** Foothills rough fescue (*Festuca campestris*) Parry oatgrass (*Danthonia parryi*) Idaho fescue (*Festuca idahoensis*) **Secondary graminoids** Sedges (*Carex spp*.) Wheatgrasses (*Agropyron smithii, A. dasystachyum, A. subsecundum*) June grass (*Koeleria macrantha*) Needlegrasses (*Stipa curtiseta, S. richardsonii, S. viridula*) Kentucky bluegrass (*Poa pratensis*) California oatgrass (*Danthonia californica*) Northern awnless brome (*Bromus pumpellianus*)	**Major forbs & half-shrubs** Golden-bean (*Thermopsis rhombifolia*) Lupines (*Lupinus spp*.) Three-flowered avens (*Geum triflorum*) Pasture sage (*Artemisia frigida*) Asters (*Aster spp*.) **Major woody plants** Roses (*Rosa spp*.) Western snowberry (*Symphoricarpos occidentalis*) Shrubby cinquefoil (*Potentilla fruticosa*) **Vegetation gradients** Similar to U.S. Foothills Prairie. Needlegrasses and oatgrasses increase with grazing.

U.S. - Foothills Prairie (Kuchler type 63) (SRM type 613) **Physiognomy** Dense mid-height grassland **Dominant grasses** Bluebunch wheatgrass (*Agropyron spicatum*) Idaho fescue (*Festuca idahoensis*) Foothills rough fescue (*Festuca campestris*) Needle-and-thread (*Stipa comata*) **Secondary graminoids** Timber oatgrass (*Danthonia intermedia*) Parry's oatgrass (*Danthonia parryi*) Hooker's oatgrass (*Helictotrichon hookeri*) Slender wheatgrass (*Agropyron trachycaulum*) Northern wheatgrass (*Agropyron dasystachyum*) Western wheatgrass (*Agropyron smithii*) Western porcupine grass (*Stipa curtiseta*) Columbia needlegrass (*Stipa Columbiana*) Green needlegrass (*Stipa viridula*) June grass (*Koeleria macrantha*) Canada reedgrass (*Calamagrostis Canadensis*)	**Major forbs & half-shrubs** Dense clubmoss (*Selaginella densa*) Pasture sage (*Artemisia frigida*) Yarrow (*Achillea millefolium*) Mouse-eared chickweed (*Cerastium arvense*) Northern bedstraw (*Galium boreale*) Pussytoes (*Antennaria spp*.) Three-flowered avens (*Geum triflorum*) Prairie sage (*Artemisia ludoviciana*) Goldenrods (*Solidago spp*.) Crocus (*Anemone patens*) American vetch (*Vicia Americana*) Cinquefoils (*Potentilla spp*.) Lupines (*Lupinus spp*.) Tall larkspur (*Delphinium occidentale*) Viscid cranesbill (*Geranium viscosissimum*) Arrowleaf balsamroot (*Balsamorhiza sagittata*) **Major woody plants** Shrubby cinquefoil (*Potentilla fruticosa*) Western snowberry (*Symphoricarpos occidentalis*) Prairie rose (*Rosa arkansana*) Willows (*Salix spp*.) Silverberry (*Elaeagnus commutata*) **Vegetation gradients** Bluebunch wheatgrass, Idaho fescue, needle-and-thread, Columbia and Richardson's needlegrasses increase southward and eastward. Shrubby cinquefoil decreases northward.

U.S. - Northern Mixed Prairie (dry) (Kuchler type 64) (SRM type 608) **Physiognomy** Mixed prairie dominated by mid-grasses, but with important component of shortgrasses **Dominant grasses** Western wheatgrass (*Agropyron smithii*) Northern wheatgrass (*Agropyron dasystachyum*) Blue grama (*Bouteloua gracilis*) Needle-and-thread (*Stipa comata*) **Secondary graminoids** Porcupine grass (*Stipa spartea*) Green needlegrass (*Stipa viridula*) June grass (*Koeleria macrantha*) Sandberg's bluegrass (*Poa secunda*) Sedges (*C. filifolia*, *C. eleocharis*) Buffalograss (*Buchloe dactyloides*)	**Major forbs & half-shrubs** Plains prickly-pear (*Opuntia polyacantha*) Pasture sage (*Artemisia frigida*) Prairie sage (*Artemisia ludoviciana*) Pussytoes (*Antennaria spp*.) Psoraleas (*Psoralea spp*.) Milkvetches (*Astragalus spp*.) Scarlet mallow (*Sphaeralcea coccinea*) Golden-bean (*Thermopsis rhombifolia*) Wild onion (*Alliums pp*.) Hairy golden-aster (*Chrysopsis villosa*) Broomweed (*Gutierrezia sarothrae*) Gumweed (*Grindelia squarrosa*) Yarrow (*Achillea millefolium*) Phlox (*Phlox spp*.) Cinquefoils (*Potentilla spp*.) Goldenrods (*Solidago spp*.) White prairie aster (*Aster ericoides*) Skeletonweed (*Lygodesmia juncea*) Dotted blazingstar (*Liatris punctata*) Dense clubmoss (*Selaginella densa*) **Major woody plants** Big sagebrush (*Artemisia tridentata*) Silver sagebrush (*Artemisia cana*) Western snowberry (*Symphoricarpos occidentalis*) Prairie wild rose (*Rosa arkansana*) **Vegetation gradients** Needle-and-thread becomes more dominant northward (transition to Canadian Dry Mixed Prairie). Buffalo grass increases southward. Blue grama, buffalo grass, and big sagebrush increase with grazing.

U.S. - Northern Mixed Prairie (intermediate) (Kuchler type 66) (SRM type 607) **Physiognomy** Mixed prairie dominated by mid-grasses. **Dominant grasses** Western wheatgrass (*Agropyron smithii*) Northern wheatgrass (*Agropyron dasystachyum*) Porcupine grass (*Stipa spartea*) Needle-and-thread (*Stipa comata*) Green needlegrass (*Stipa viridula*) **Secondary graminoids** Blue grama (*Bouteloua gracilis*) Sedges (*Carex eleocharis, C. filifolia, C. pensylvanica*) June grass (*Koeleria macrantha*) Plains reedgrass (*Calamagrostis montanensis*) Kentucky bluegrass (*Poa pratensis*) Muhly (*Muhlenbergia spp*.) Sand reedgrass (*Calamovilfa longifolia*) Red three-awn (*Aristida purpurea*) Sandberg's bluegrass (*Poa secunda*) Buffalograss (*Buchloe dactyloides*)	**Major forbs & half-shrubs** Pasture sage (*Artemisia frigida*) Hairy golden-aster (*Chrysopsis villosa*) Scarlet gaura (*Gaura coccinea*) Slimflower psoralea (*Psoralea tenuiflora*) Silverleaf psoralea (*Psoralea argophylla*) Skeletonweed (*Lygodesmia juncea*) Scarlet mallow (*Sphaeralcea occinea*) Locoweeds (*Oxytropis lambertii*, *O. sericea*) Puccoons (*Lithospermum canescens*, *L. incisum*) White wild onion (*Allium textile*) Plains prickly-pear (*Opuntia polyacantha*) **Vegetation gradients** Transition to fescue prairie/aspen parkland in Canada. Needlegrasses become dominant northward. Shortgrasses increase southward. Shortgrasses increase with grazing.

U.S. - Northern Mixed Prairie (moist)

(Kuchler type 67)
(SRM type 606)

Physiognomy
Mixed prairie dominated by mid-grasses, with important component of tall grasses

Dominant grasses
Western wheatgrass (*Agropyron smithii*)
Big bluestem (*Andropogon gerardii*)
Porcupine grass (*Stipa spartea*)

Secondary graminoids
Northern wheatgrass (*Agropyron dasystachum*)
Slender wheatgrass (*Agropyron trachycaulum*)
Little bluestem (*Schizachyrium scoparium*)
Western porcupine grass (*Stipa curtiseta*)
Needle-and-thread (*Stipa comata*)
Green needlegrass (*Stipa viridula*)
Sideoats grama (*Bouteloua curtipendula*)
Blue grama (*Bouteloua gracilis*)
June grass (*Koeleria macrantha*)
Sand reedgrass (*Calamovilfa longifolia*)
Kentucky blue grass (*Poa pratensis*)
Sedges (*Carex eleocharis, C. pensylvanica, C. filifolia*)

Major forbs & half-shrubs
White aster (*Aster ericoides*)
Silverleaf psoralea (*Psoralea argophylla*)
Lance-leaved psoralea (*Psoralea lanceolata*)
Milkvetches (*Astragalus spp*.)
Purple locoweed (*Oxytropis lambertii*)
Purple coneflower (*Echinacea angustifolia*)
Dotted blazingstar (*Liatris punctata*)
Scarlet gaura (*Gaura coccinea*)
Scarlet mallow (*Sphaeralcea coccinea*)
Pasture sage (*Artemisia frigida*)
Prairie sage (*Artemisia ludoviciana*)
Soft goldenrod (*Solidago mollis*)
Low goldenrod (*Solidago missouriensis*)
Gumweed (*Grindelia squarrosa*)
Hairy golden-aster (*Chrysopsis villosa*)
Stiff sunflower (*Helianthus rigidus*)
Moss-phlox (*Phlox hoodii*)

Major woody plants
Western snowberry (*Symphoricarpos occidentalis*)
Willows (*Salix spp*.)
Roses (*Rosa spp*.)
Buffaloberry (*Shepherdia argentea*)
Wolf-willow (*Elaeagnus commutate*)
Chokecherry (*Prunus virginiana*)
Wild plum (*Prunus Americana*)
Northern hawthorn (*Crataegus rotundifolia*)

Vegetation gradients
Tall grasses confined to lower, moister areas. Little bluestem important on uplands. Bluestems decrease northward; transition to fescue prairie/aspen parkland in Canada. Kentucky bluegrass has increased with grazing.

U.S. - Shortgrass Prairie (Kuchler type 65) (SRM type 611) **Physiognomy** Dominated by shortgrasses, but with important component of midgrasses. **Dominant grasses** Blue grama (*Bouteloua gracilis*) Buffalograss (*Buchloe dactyloides*) **Secondary graminoids** Hairy grama (*Bouteloua hirsuta*) Western wheatgrass (*Agropyron smithii*) Side-oats grama (*Bouteloua curtipendula*) Little bluestem (*Schizachyrium scoparium*) Red three-awn (*Aristida purpurea*) Indian ricegrass (*Oryzopsis hymenoides*) Squirreltail (*Sitanion hystrix*)	**Major forbs & half-shrubs** Plains prickly-pear (*Opuntia polyacantha*) Soapweed (*Yucca glauca*) Scarlet mallow (*Sphaeralcea coccinea*) Slimflower psoralea (*Psoralea tenuiflora*) Dotted blazing-star (*Liatris punctata*) Broomweed (*Gutierrezia sarothrae*) Spiny ironplant (*Haplopappus spinulosa*) Scarlet gaura (*Gaura coccinea*) Gumweed (*Grindelia squarrosa*) Prairie coneflower (*Ratibida columnifera*) Bahia (*Picradeniopsis oppositifolia*) Hairy golden-aster (*Chrysopsis villosa*) Skeletonweed (*Lygodesmia juncea*) Grounsels (*Senecio spp*.) Pasture sage (*Artemisia frigida*) **Vegetation gradients** Shortgrass type mainly on fine-textured uplands; broken areas and sandy soils have taller grasses (sand reed grass, sand bluestem, big bluestem, little bluestem, three-awns). Midgrasses decrease southward. Little bluestem, big bluestem, and sideoats grama increase eastward. Needle-and-thread, western wheatgrass, green needlegrass, and little bluestem increase northward and eastward. Midgrasses decrease with grazing.

U.S. - Tallgrass Prairie (Kuchler type 74) (SRM type 601) **Physiognomy** Tall grassland with many forbs **Dominant grasses** Big bluestem (*Andropogon gerardii*) Switchgrass (*Panicum virgatum*) Indian grass (*Sorghastrum nutans*) Little bluestem (*Schizachyrium scoparium*) **Secondary graminoids** Porcupine grass (*Stipa spartea*) Side-oats grama (*Bouteloua curtipendula*) June grass (*Koeleria macrantha*) Canada wild-rye (*Elymus Canadensis*) Sand reedgrass (*Calamovilfa longifolia*) Western wheatgrass (*Agropyron smithii*) Prairie cordgrass (*Spartina pectinata*) Prairie dropseed (*Sporobolus heterolepis*)	**Major forbs & half-shrubs** Sunflowers (*Helianthus spp*.) Goldenrods (*Solidago spp*.) Blazing-stars (*Liatris spp*.) Psoraleas (*Psoralea spp*.) Prairie-clovers (*Dalea spp*.) Asters (*Aster spp*.) Ironweed (*Vernonia fasiculata*) Leadplant (*Amorpha canescens*) **Major woody plants** Prairie rose (*Rosa arkansana*) Meadowsweet (*Spiraea alba*) Willows (*Salix spp*.) Western snowberry (*Symphoricarpos occidentalis*) **Vegetation gradients** Big bluestem, indian grass, switchgrass dominate lowlands; little bluestem, porcupine grass, prairie dropseed dominate uplands. Little bluestem increases westward towards drier climates. Porcupine grass decreases southward. Panic grasses (*Dichanthelium* spp.), sedges (*Carex pensylvanica*, *C. eleocharis*), blue grama, hairy grama, buffalo grass, Kentucky bluegrass increase with grazing.

U.S. - Sagebrush Steppe (Kuchler types 55 & 56) (SRM type 314) **Physiognomy** Mid- and short grasses with dense to open dwarf-shrubs **Dominant grasses** Bluebunch wheatgrass (*Agropyron spicatum*) Western wheatgrass (*Agropyron smithii*) Plains bluegrass (*Poa arida*) Needle-and-thread (*Stipa comata*) **Secondary graminoids** June grass (*Koeleria macrantha*) Sandberg's bluegrass (*Poa secunda*) Blue grama (*Bouteloua gracilis*)	**Major forbs & half-shrubs** Pasture sage (*Artemisia frigida*) Broomweed (*Gutierrezia sarothrae*) Arrowleaf balsamroot (*Balsamorhiza sagittata*) **Major woody plants** Big sagebrush (*Artemisia tridentata*) Rabbitbrush (*Chrysothamnus spp*.) Gray horsebrush (*Tetradymia canescens*) **Vegetation gradients** Shrub cover increases with grazing