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Chapter 6

CLIMATE CHANGE IMPACTS ON AGRICULTURE IN THE PRAIRIES REGION

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6.1 Introduction

Prairie agriculture is exposed to large climate variability, extreme weather events and to the climate sensitivity of production systems, agri-ecosystems and the soil and water resources that support agriculture. A high adaptive capacity in the agricultural sector has been attributed to a history of adaptation to climate risks. This chapter adopts mainly the impact-based approach described in Chapter 2 of this volume. The material presented here considers the potential and net impacts from climate change by examining the exposure of prairie agriculture to risks and the related climate sensitivity of the soil, water and ecological resources that enable crop and livestock production. Adaptive capacity in the agriculture sector is consistently described as high; therefore the key component of this chapter is the discussion of net or residual impacts, that is, the degree of climate variability that could exceed the coping capacity of prairie farmers above and beyond adaptation in anticipation of climate change.

6.2 Prairie Agriculture

More than 80 per cent of Canada's agricultural land is in the Prairie Provinces. With the exception of early settlements on the rivers of southern Manitoba, prairie agriculture was first introduced and exposed to the dry and variable climate of the Canadian interior in the late 19th and early 20th centuries. The EuroCanadian agrarian settlement of the prairies was largely preceded and enabled by the Dominion Land Survey and building of the transcontinental railway. Establishing agriculture in the western interior was a national policy priority with Canadian Pacific Railway (CPR) as a significant supporter. A network of agriculture research stations, created to develop dryland farming practices, were among the first government institutions in western Canada. Thus government and industry invested heavily in the region and in communication to dispel the notion that the climate was unfavourable for farming or as John Palliser declared in 1859, that a large area was “comparatively useless”. (Palliser reported this to the Royal Geographical Society in London.). In 1881, the influential British journal, *Truth*, stated, "The Canadian Pacific Railway, if it is ever finished, will run through a country about as forbidding as any on earth”. The Government of Canada had a different perspective and, with the CPR, sponsored favourable surveys such as one by John Macoun, who concluded that the prairies were "well suited to agriculture" (Macoun, 1882; Wilson and Tyrchniewicz, 1995).

Dryland hydrography, soils and agricultural adaptation are visible from space. Figure 6.1 is a satellite image of southwestern Saskatchewan. Most of the white patches are dry lake beds; water is black. The linear water bodies are reservoirs. The darkest shades are pasture. They are not cropped because the soil landscapes are sand dunes. Some of the small white patches in these areas are active dunes. The dominant geographic feature throughout the satellite image is the rectangular fields of varying tone (crop and fallow land) oriented perpendicular to the prevailing winds to trap drifting snow and soil. This strip cropping, along with shelterbelts and impounding of water are among the adaptations of farming practices imported originally from the more humid climates of Europe and eastern Canada.

Prairie agriculture is inherently sensitive to climate. A normal growing season has sufficient heat and moisture to produce cereal and oilseed crops and forage throughout the Prairie Ecozone. However, “normal” seasons are rare. This region is mid-latitude continental, a climate regime, which is among the earth’s most variable climates and is forecast to change in this century to a greater extent than in the rest of southern Canada. Climate varies among farms according to topography, for example with the collection of cold air in hollows and valley bottoms, and the warmer, drier climate on south- and west-facing slopes.

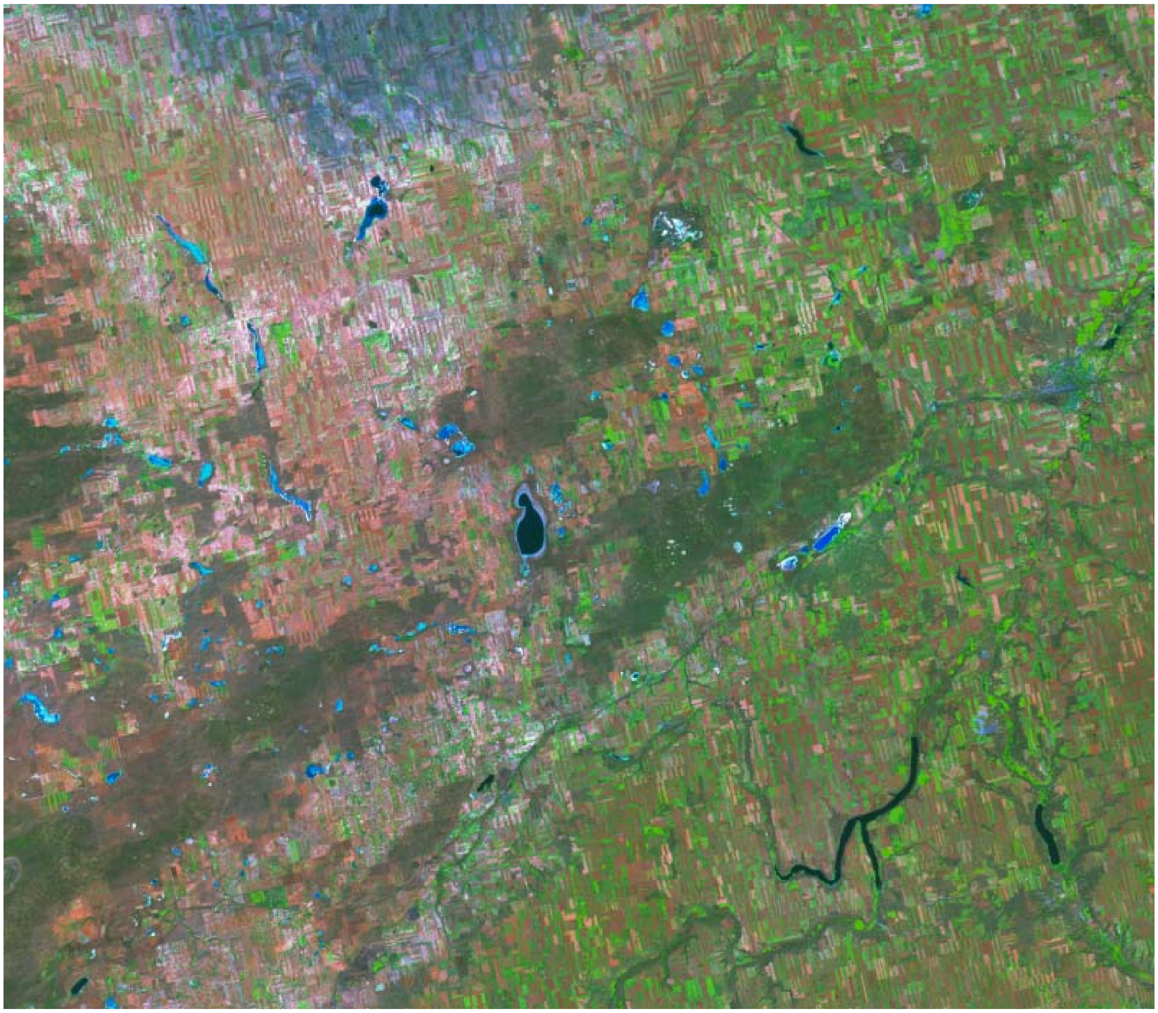

Figure 6.1. A summer 1992 Landsat (Thematic Mapper) image of southwestern Saskatchewan; the Trans-Canada highway corridor passes diagonally through the image. Water is black. Most of the water bodies are reservoirs (*e.g*. Reid Lake on Swift Current Creek – bottom right). The dark green and most continuous land cover is pasture. It coincides with the sand dune fields. Active sand dunes and saline seeps (dry sloughs and the shores of Antelope Lake – upper center) are white to blue. The pattern of brown (summerfallow) and green (crops) tones show the strip cropping that prevents wind erosion and captures blowing snow.

Because agricultural programs are generally implemented according to the varying productivity of farmland, the suitability of soil landscapes for crop production has been classified beginning in the 1960s with the Canada Land Inventory (CLI). The CLI was used in the 1990s to define marginal land under the Permanent Cover Program (Vaissey *et al*.,1996). Whereas CLI ratings were based mainly on soil factors, the Land Suitability Rating System (LSRS) includes climate factors influencing the production of spring-seeded small grains (Pettapiece, 1995). Under the LSRS, the climatic rating of land reflects the variable that is most limiting.

The moisture index, precipitation minus potential evapotranspiration (P-PE), ranges from no (-150 mm) to severe (-500 mm) limitation. The temperature index, effective growing degree days, is derived from growing season length, growing degree days and day length. The growing season is defined as beginning ten days after the average date of mean daily temperature of 5^{o} C and ending on the average date of first frost after July 15. Growing degree days are adjusted to account for longer day lengths with increasing latitude. A few modifying factors are recognized as lowering climatic suitability. These regional factors include excess spring and fall moisture and fall frost, which shorten the growing season or interfere with harvest.

The LSRS climate variables are listed in Table 6.1 next to a comprehensive list of climate variables that determine agricultural productivity in the Prairie Provinces. This list of all relevant variables was compiled from information in the Agroclimatic Atlas of Alberta (Chetner, 2003) and from a survey to assess information needs for seasonal climate prediction conducted by the Prairie Farm Rehabilitation Association (PFRA) and the Canadian Institute for Climate Studies (CICS) prior to workshops in Winnipeg, Regina and Calgary (Stewart and O’Brien, 2001).

Length of the growing season is a consideration on the northern reaches of prairie agriculture. Otherwise a shortage of water is by far the dominant limitation on crop and livestock production. The western interior is the major region of Canada where periodic deficits of soil and surface water define the ecosystems and soil landscapes and have determined most of the adaptation in the agriculture sector. Summer moisture deficits are characteristic of the climate. Droughts fail to meet the water demands of plants, ecosystems and/or human activities for a season or longer (Wilhite, 2005).

Table 6.1. Climate variables that influence prairie agriculture (from Chetner, 2003; O'Brien, 1977), [1]

CLIMATIC PARAMETER	*LSRS VARIABLES*	*CGCM2 VARIABLES*[2]
Temperature/Heat		
daily mean		mean daily
daily maximum(^oC) (T > 30 ^oC)		maximum daily
daily minimum (T < 5 ^oC & T < 0 ^oC)		minimum daily
growing degree days	growing degree days (EGGD[3])	
frost-free period		
growing season length	growing season length (EGGD)	
potential evapotranspiration	potential evapotranspiration (moisture index P-PE)	evaporation (mm/day)
Precipitation / Soil Moisture		
annual precipitation	annual precipitation	precipitation (mm/day)
inter-annual variability	excess spring & fall moisture: (P-PE) index	
growing season precipitation		
overwinter precipitation/ spring soil moisture		snow water content (kg/m^2)
summer soil moisture		soil moisture (capacity fraction)
timing of summer rain		
Other		
extreme weather events		
duration of bright sunshine (hours)	day length (EGGD)	incident solar flux at surface (W/m^2), total cloud (fraction)
mean wind speed		mean wind speed (m/s)
wind gusts		
prevailing wind direction		

[1] This includes corresponding variables used in the evaluation of land suitability (LSRS), and output from the CGCM2 (Canadian Centre for Climate Modelling and Analysis - http://www.cccma.bc.ec.gc.ca/).

[2] Whether measured or modelled, climate variables generally have standard definitions, for example surface temperatures are recorded at 2m height and wind speed is recorded at 10m height. More complex variables, like evaporation and soil moisture can measured or modeled using various methods. Therefore beyond basic temperature and precipiation scenaro, future climate conditions usually are computed from these parameters than using the model results.

[3] EGGD: Effective Growing Degree Days – an index of growing degree days adjusted for day length (Pettapiece, 1995)

The climate sensitivity of ecosystems, soil landscapes and human activities is amplified by droughts; wet conditions act as buffer. There is also a large geographic variation in sensitivity to drought according to type, reliability and accessibility of water supplies. Most of the runoff in the western prairies is from snow and glacier melt in the Rocky Mountains. This water enables irrigation in southern Alberta and parts of Saskatchewan and supplies all the cities in these two provinces. In terms of land area, however, most prairie agriculture is dryland farming dependent on precipitation and local runoff. The driest (semiarid) ecoregion, the mixed grassland, has the highest frequency of drought. In some years, such 1961 and 1988, water deficits affected most of the prairie agricultural zone.

6.3 Past and Current Climate Risks for Prairie Agriculture

The EuroCanadian history of the prairies is punctuated by the impacts of drought. The drought of the 1930s was the most devastating largely because soil and water management had yet to be adjusted for drought and because the prairies had been settled and farmed almost uniformly rather than according to suitability for crop production. These maladaptations have been largely reconciled, initially with the almost total depopulation of the driest areas.

In contrast to the 1930s, the recent droughts of 2000-2003, the most severe on record, had different, largely economic, consequences. Throughout western Saskatchewan and central and northern Alberta, most climate stations recorded the least precipitation for any single year in 2001 and for any three-year period during 2001-03. Wheaton *et al*. (2005) estimated that in 2001, producers in Alberta and Saskatchewan lost \$413 million and \$925 million, respectively, in terms of the value of lost crop production. In 2002, these loses were \$1.33 billion and \$1.49 billion; farm income was zero in Alberta and negative in Saskatchewan. As the impacts of drought in 2001-02 rippled through the economies of these two provinces, the loss in gross domestic product (GDP) was about \$4.5 billion (Wheaton *et al*., 2005: 22).

As these data for 2000-01 suggest, the impacts of drought are cumulative as the water deficit grows. The economic impact was much higher in 2002 even though 2001 had less precipitation. Whereas costs are assigned to fiscal or calendar years, the duration of drought is measured in consecutive seasons and year. As drought persists, soil and surface water deficits grow with increasingly serious consequences. Thus duration is probably the key determinant of drought impacts. Nemanishen (1998) explained the challenge of "Coping with Consecutive-Year Droughts":

> *Modern farming technologies and practices now enable farmers to cope with single-year droughts. Most of the light lands in the drought prone areas are now either community pastures or seeded to permanent cover. Yet even with modern technologies, the current wheatlands are not able to yield sufficient returns to justify cropping in the second drought year. During the consecutive-year droughts, the precipitation deficit accumulates and leads to the depletion of the soil moisture in the root zone to a depth of a metre or more. ... the impact of the accumulated deficit can bring the grainbelt to the verge of desertification, a process which actually occurred in the 1930's. There is no technology, apart from irrigation, which can sustain either cereal grain or hay production during extended drought periods in the Palliser Triangle.*

The historic droughts with the greatest impacts in terms of social and financial consequences occurred during 1939-41 and 2000-03. However, droughts of this magnitude are common in records of the pre-settlement climate of the western interior (Sauchyn *et al*., 2002, 2003). Tree rings from the margins of the Prairie Ecozone are especially good proxies of drought because they are annual data and, in this dry climate, tree growth is sensitive to precipitation and soil moisture. Figure 6.2 is a plot of new tree-ring data (residual ring-width chronology), for the period 1610 to 2004, from Douglas fir (*Pseudotsuga menzeisii*) from the Wildcat Hills near Calgary, Alberta. A negative departure from the mean ring width represents a dry year. The dark grey shading marks periods of more than 10 years without consecutive wet years, *i.e*. only single years with wider than normal tree rings. The lighter shading marks three episodes of 7-9 years of sustained drought.

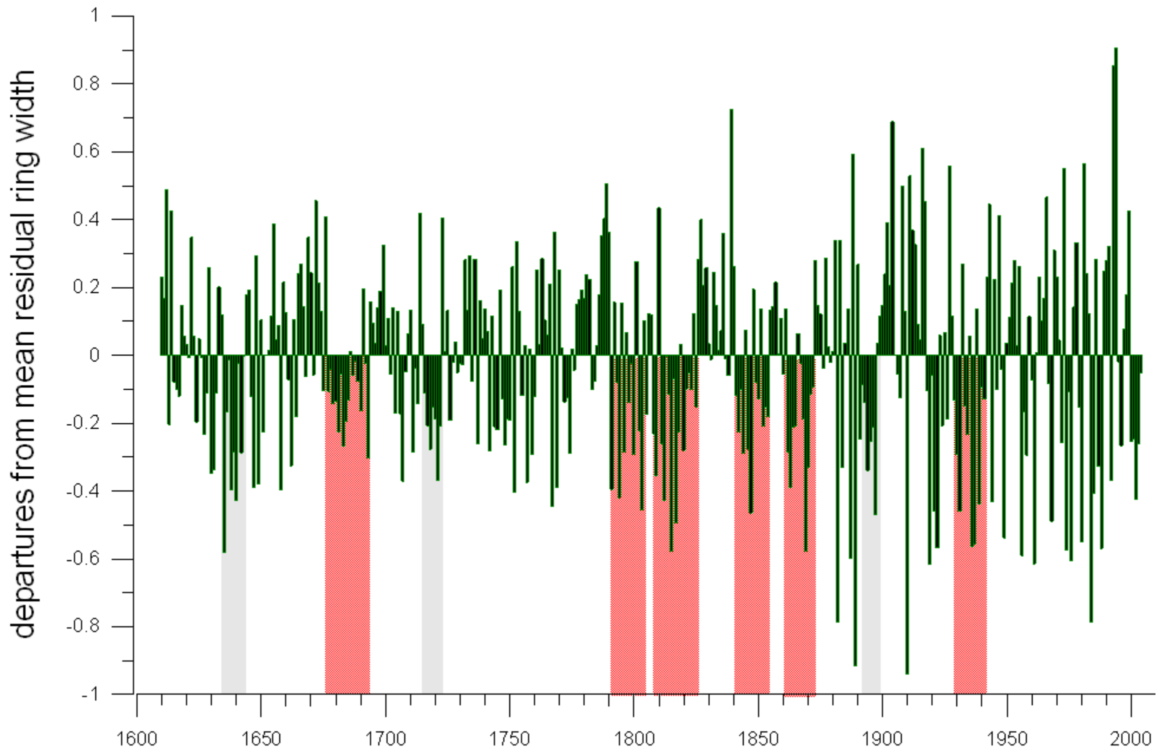

Figure 6.2. These tree-ring data (residual ring-width chronology), for the period 1610 to 2004, are from Douglas fir (*Pseudotsuga menzeisii*) from the Wildcat Hills near Calgary, Alberta. A negative departure from the mean ring width represents a dry year. The red shading marks periods of more than 10 years without consecutive wet years, *i.e*. wider than normal tree rings. The lighter shading marks three episodes of 7-9 years of sustained drought.

This tree-ring record reveals that prolonged drought is more common than the instrumental weather records indicate. 1929 to 1941 was the one long period in the 20th century lacking consecutive wet years. Droughts of similar or longer duration occurred four times between 1791 and 1872, shortly before agriculture was introduced to the western plains. This includes a drought of the 1790s when the North Saskatchewan River at Fort Edmonton was too low to enable the transport of furs by canoe, and the droughts of the mid-19th century when John Palliser declared a large area “forever comparatively useless” (Sauchyn *et al*., 2002; 2003). Sustained drought from 1891 to 1898, preceded by four very dry years in the 1880s, delayed settlement by thwarting early attempts to farm in this region (Jones, 1987).

6.4 Future Exposure and Sensitivities for Prairie Agriculture

Scenarios derived from global climate models are considered the most reliable forecasts of future climate. The current generation of GCMs are coupled ocean-atmosphere models with greenhouse gas (GHG) forcing estimated for a series of social and economic scenarios as described in the Special Report on Emission Scenarios (SRES) commissioned by the IPCC. The climate change data in Figures 6.5 a) and b) are derived from CGCM2 B21 (that is, version 2 of the Canadian GCM with GHG forcing specified by SRES scenario B21). This emission scenario emphasizes global solutions to environmental and social sustainability and therefore produces relatively conservative temperature trends. Figures 6.3a and 6.3b show, respectively, mean annual and spring temperatures for 1961-90, the 2020s, 2050s and 2080s. These data are averages for the 10 GCM cells that comprise the prairie agricultural zone. They illustrate the significant warming that is expected for the Canadian interior, even using the optimistic B21 emission scenario. Figure 6.4 is a scatterplot of the change in temperature and precipitation from 1961-90 to 2050s as forecast by 25 GCM experiments for the GCM grid cell that occupies southeastern Saskatchewan. Plots for other grid cells in the Prairie Provinces show a similar scatter of scenarios. Most of the model simulations are concentrated in the range of a 2.5-4° C increase in temperature and 2-10 per cent increase in precipitation. CGCM2 B21 plots slightly above the median forecast for temperature and below the median forecast for precipitation.

The best case scenario for prairie agriculture is based on climate models (*e.g*. Hadcm3; see Figure 6.4) that forecast enhanced precipitation with a moderate increase in temperature and water loss by evapotranspiration (McGinn *et al*., 2001). Higher productivity would result from the longer growing season, higher temperatures and concentrations of CO_2, elevated soil moisture, advanced seeding, and accelerated growth and maturation of crops before peak summer aridity. McGinn *et al*. (1999) projected that these conditions would produce a 21-124 per cent increase in the yields of canola, corn and wheat in Alberta.

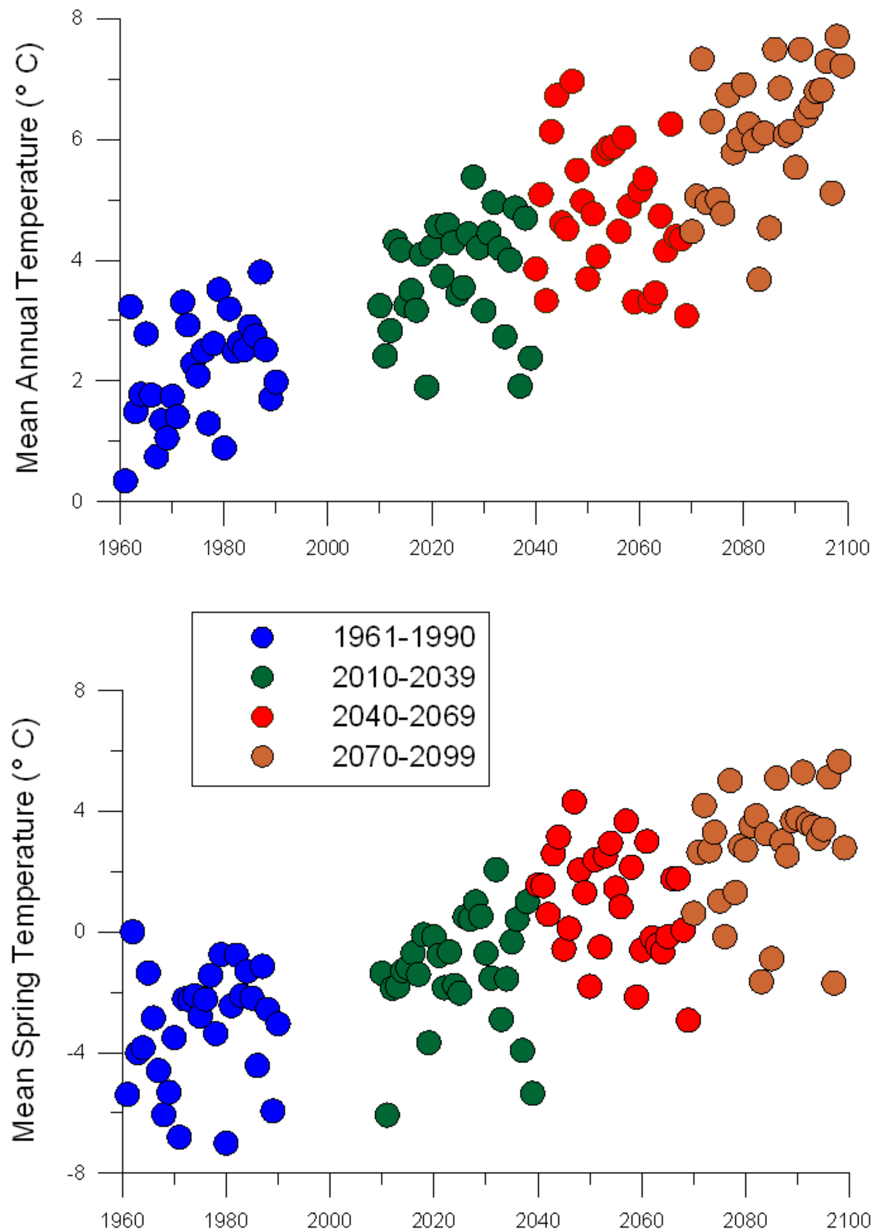

Figure 6.3. Mean annual (a) and spring (b) temperatures for 1961-90, the 2020s, 2050s and 2080s averaged over the 10 GCM cells that comprise the prairie agricultural zone. Future temperatures are from the CGCM2 B21. The SRES B21 emission scenario emphasizes global solutions to environmental and social sustainability. Therefore the temperature trends plotted here are conservative and the rate of warming could be greater.

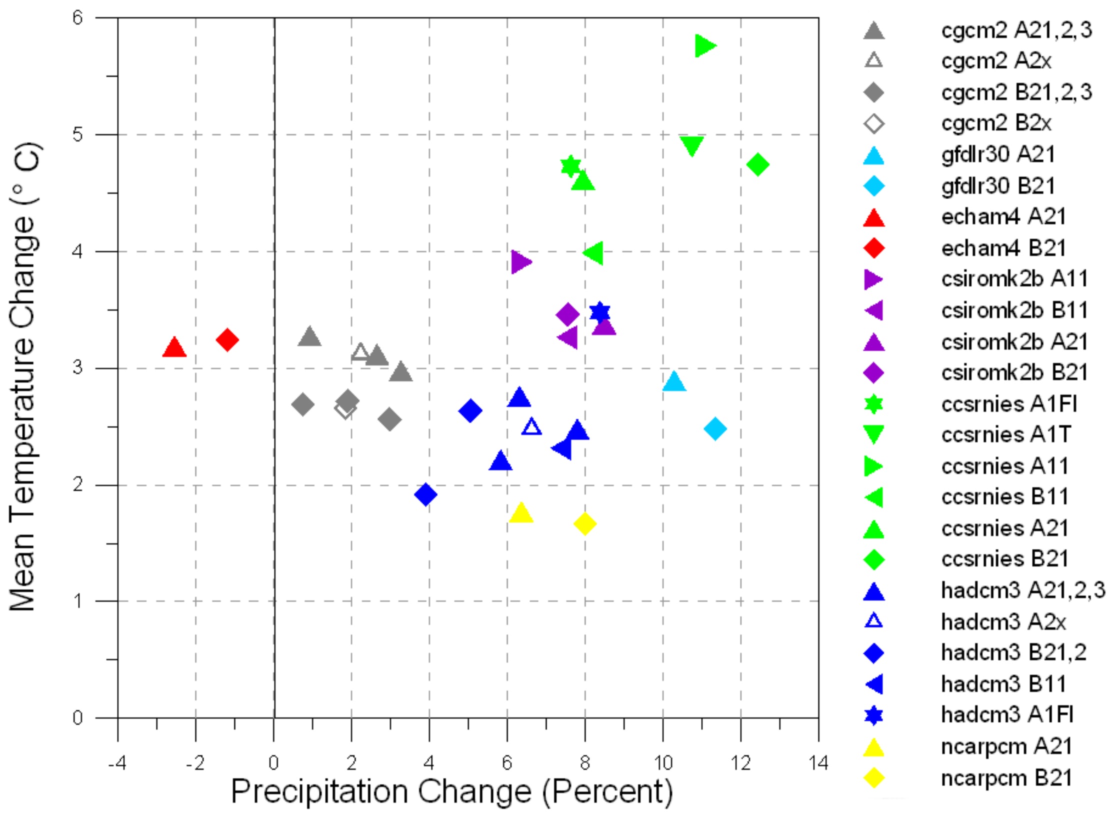

Figure 6.4. This scatterplot of changes in temperature and precipitation for the 2050s illustrates the range of forecasts from 25 GCM experiments using various models and SRES emission scenarios. Most model projections are concentrated in the range of a 2.5-4 degree increase in temperature and 2-10 per cent increase in precipitation. This plot also shows that CGCM2 B21, the model used to produce Figure 3, plots slightly above the median forecast for temperature and below the median forecast for precipitation (i.e. a warmer drier scenario relative to most other models).

Other scenarios, derived from the Canadian GCM for example, suggest that higher temperatures will force accelerated evapotranspiration, and for more hours per year, causing water loss that exceeds a marginal increase in precipitation (Sauchyn *et al*., 2002). Nyirfa and Harron (2001) used output from CGCM1 and the Land Suitability Rating System (LSRS) to simulate changes in land suitability under the forecasted changes in temperature, precipitation, potential evaoptranspiration and effective growing degree days. The result was a significantly higher moisture limitation for the production of spring-seeded small grain crops over much of the agricultural area. They concluded that the warmer and drier conditions will require adaptation to adjust the distribution of production systems to the new land suitability.

Even though most GCM-based climate change scenarios suggest increasing aridity as water loss from soils and plants exceeds the inputs from a marginal increase in precipitation, a recent analysis of 1951-2000 evaporation data for the Prairie Provinces revealed significant decreasing trends in June, July, October and annual evaporation for 30, 40 and 50-year time periods (Hesch and Burn, 2005). Increasing evaporation was recorded only for September over the 30-year period and for April at the longer record length of 50-years. Most of the increase was in the more northern region, while the southern regions showed decreasing trends. The authors did not attempt to explain the decreasing trends, but other studies (*e.g*., Roderick and Farquhar, 2002; Loaiciga *et al*., 1995) point to the increased humidity and cloudiness forecast by GCMs and observed during the past several decades. Furthermore models and measurements show much of the warming is the rise of minimum temperatures, that is, at night and in the spring. This could account for the observation by Hesch and Burn of increasing evaporation in April.

Potential changes in crop yield are the most researched climate impact in the agricultural sector (*e.g*., McGinn, 1999; Thomson *et al*., 2005). Simulations of the affects of changes in temperature, precipitation and CO_2 concentrations produce a wide range of crop yield estimates depending on the climate scenario and the sensitivity of the model to the soil water balance and to changes in plant water use efficiency. These assessments of direct climate impacts on crop productivity have limited application to adaptation planning, because crop yield projections are particularly sensitive to the forecasting of precipitation changes and the parameter that GCMs simulate with the least certainty. Also they are based on annual and seasonal climate conditions but crop yields are strongly influenced by local weather and soil factors and agriculture in general is most vulnerable to climate variability and extremes. Annual crop production is adapted to average conditions and has high adaptive capacity to changes under average conditions. Furthermore, much of the increased productivity is attributable to the positive effects of higher concentrations of CO_2 in terms of fertilizing crops and reducing transpiration and improving water use efficiency (Thomson *et al*., 2005). There are important temperature and CO_2 thresholds, however, where crop yields level off and potentially decline as water and nutrients become limiting factors.

Future crop yields could also depend on the changing effectiveness of herbicides and pesticides with global warming. Increased efficacy of herbicides at higher levels of CO_2 is generally assumed, but research in Saskatchewan (Archambault *et al*., 2001) showed a varied response and that the interactive effects of increased CO_2 and temperature caused a decrease in herbicide efficacy. At current rates of CO_2 emissions, the changes in herbicide efficacy will not be apparent for about another 50 years. Any potential economic losses due to decreased herbicide efficacy could be totally or partially offset by increases in yields from higher CO_2 concentrations.

A shift to climate conditions that favour other crops requires obvious adaptations strategies: substitution of crops or cultivars or a change in land use (Smit and Skinner, 2002). Thus both adverse and positive impacts of higher temperature and CO_2 on crop production can be addressed largely by adaptation. The more serious vulnerability is to conditions that fail to support any crops, that is, insufficient soil or surface water either seasonally (drought) or in the longer-term (aridity). These two scales of water deficit are linked since aridity is a function of the frequency, severity and duration of drought.

While the source of and access to water varies considerably across the prairies, in generally agriculture is most dependent on good quality surface water derived from snow melt runoff and, to a lesser extent, spring and summer rain. Therefore, probably the most revealing and valuable climate impact studies have been those that have examined future water supplies, especially those derived from the Rocky Mountains, since by far the largest user of water in western Canada is the irrigation industry and expanded irrigation is often cited as an effective adaptation to increased aridity under global warming (de Loë and Moraru, 2004). Various studies (Roed and Samuelson, 2005; van der Kamp, 2005) have documented a decline in surface water in recent decades, and especially snowmelt runoff, but the question remains as to whether these recent trends represent natural cycles or the early impacts of global warming. Thus it is useful here to summarize the results of two studies that simulated future water yields from the eastern slopes of the Rocky Mountains, given the major implications for prairie agriculture.

Demuth and Pietroniro (2001) examined the retreat of glaciers in the Rocky Mountains since about 1850 and runoff in the North Saskatchewan River (NSRB) basin during August 1 to October 31, when glacier meltwater is the most significant component of streamflow. They estimated that within 30-50 years, glacier cover will have shrunk to the minimum extent for the past 10,000 years. As the glacial cover has decreased, so have the downstream flow volumes. Warmer temperatures should cause increased glacier runoff in the short-term. Historical stream flow data indicate that this increased flow phase has already past, and that the river basins of the western prairies have entered a potentially long-term trend of declining summer flows.

In the South Saskatchewan River Basin, there is much less glacier ice, snow melt accounts for most of the runoff, and the surface water already is almost fully allocated since most of the irrigated agriculture in western Canada is concentrated in the SSRB. Lapp *et al*. (2005) modeled future snow accumulation and ablation in the Upper Oldman River watershed, in the SSRB, using scenarios of temperature and precipitation derived from CGCM1. Their simulation suggests that climate warming will result in a substantial decrease in snow accumulation in the watershed with a corresponding significant decline in spring runoff volumes. "The resulting water scarcity would be especially problematic where development has been based on a more abundant water supply. The irrigation industry, as the greatest single consumer of water in the region, will likely come under the greatest scrutiny and stress." (Lapp *et al*., 2005).

Another proposed adaptation to increased aridity in western Canada, besides expanded irrigation, is the increasing use of groundwater. Wells currently are the main source of water for rural households and, under drought conditions, groundwater is the alternative to surface water. A lack of knowledge of prairie aquifers limits information on the availability of groundwater and the modeling of changes in quantity and quality with climate change (Thorleifson *et al*., 2001). Shallow aquifers are sensitive to climate variability. Deeper groundwater is less responsive to climate variation, but it tends to be of poor quality, with high concentrations of dissolved minerals.

The studies cited here demonstrate that Prairie agriculture is exposed to large variations in water supply over time and space reflecting the sensitivity of prairie hydrology to climate change and variability. Farming and ranching also are vulnerable to the sensitivity of soil landscapes, which largely is function of climate, since soil degradation is preventable except in situations of aridity and severe drought. Rates of erosion are highest in semiarid landscapes given lesser protection of the soil from wind and rain. Annual crop production accelerates erosion in these landscapes. The semiarid to subhumid mixed grassland ecoregion of western Canada is at risk of desertification by definition: desertification is “Land degradation in arid, semi arid and dry/sub-humid areas, resulting from various factors, including climatic variations and human impact” (UNEP, 1994: p. 1334). When Sauchyn *et al*. (2005) derived climate change scenarios from the CGCM2 (emission scenario B2) and applied these to the modeling and mapping of aridity (P/PET) on the Canadian plains, the area of land at risk of desertification increased by about 50per cent between recent conditions (1961-90) and the 2050s. This impact scenario implies that the soil landscapes of semiarid southeastern Alberta and southwestern Saskatchewan may require further improvements to soil and water management practices to prevent degradation and sustain agriculture.

6.5 Net Impacts from Climate Change on Prairie Agriculture

Scholarship and commentary on prairie agriculture cite the high adaptive capacity of the sector having evolved from the many adjustments of practices and policy in response to climatic, social and institutional crises and change over a relatively short history. Thus prairie agriculture is adapted to the historical range of climatic variability (Hill and Vaissy, 1995) and to the distribution of soil and water resources:

> *Since the settlement of the Canadian Prairies in the 19th and early 20th centuries, land use and farming practices have evolved to match the various climates and soil types on the Prairies and adapted to changing markets, technology and transportation systems. The abandonment of farms in the Special Areas of Alberta during the early 1920s, and southwestern Saskatchewan in the 1930s, provides evidence of these adjustment processes. More recently, since the 1980s, there has been a*

> *reduction in the summerfallow and an expansion of crop varieties, particularly in areas of higher moisture. (PFRA, 2000: 81)*

Current actions and attitudes of producers are further indication of adaptive capacity. For example, when a group of Alberta producers were asked about recent changes to their operations, almost half indicated that it was because of climate change; “the participants also stated they would implement any necessary strategies to adapt to climate change … it is not about if they will adapt, but when they will adapt” (Stroh Consulting, 2005:3).

This suggests a low vulnerability to further climate change and variability if the resilience, adaptability and resourcefulness of prairie producers and institutions are applied to futures trends and events. When de Jong, *et al*. (1999) included adaptive crop management strategies in a simulation of climate impacts on crop yields, the net impacts were found be minimal across Canada. They concluded that there remains room for adaptation, such as more efficient irrigation technology and water distribution and storage, and adjusting planting dates according to the availability of water. However, even improved water management and conservation “are likely to prove effective in mitigating the impacts of extreme climate events, such as the 2002 Prairie drought …” (CCIAD 2002: 11).

Thus, even though prairie agriculture is adapted to the range of historic climate variability of the 20th century, there are always climate thresholds beyond which activities are not economically viable. Further adaptation is required only if climate change is expected to result in variability that will exceed the historical experience. The climate scenarios and impact scenarios reviewed here suggest that a drought of unprecedented duration is the climate event most likely to exceed the coping capacity of prairie producers and agricultural institutions.

Therefore this chapter argues that the greatest climate risk to the future of prairie agriculture will be the recurrence of drought of longer duration than occurred since settlement of the Canadian plains. Both GHG-forced climate change scenarios and proxy records of natural climate variability suggest that severe droughts are probable in the 21st

century. The capacity to cope with threats to the sustainability of prairie agriculture is illustrated by the adjustments made to practices and policy to address the risk of soil degradation.

The “1980s saw not only a new cycle of prairie drought but also a new environmental thrust with enhanced focus on soil conservation and sustainability” (Vaisey, 1996: 2). With the adoption of soil conservation practices, and reduced tillage in particular, the average number of bare soil days dropped by more than 20 per cent in the Prairie Provinces between 1981 and 1996 with a 30 per cent reduction in the extent of land at risk of wind erosion (McRae *et al*., 2000). Institutional responses included the soils component of the Agricultural Green Plan of 1990, and the National Soil Conservation Program (NSCP) of 1989. In the Prairie Provinces, a major component of the NSCP was the Permanent Cover Program (PCP) (Vaisy *et al*., 1996).

6.6 Conclusions

Prairie agriculture has been sustained through the adjustment of land use and management systems to climatic variability (*e.g*., drought, early frosts, storms) to take maximum advantage of soil and water resources (Hill and Vaisey, 1995). There is, however, a perpetual adjustment to weather and climate, and now the agricultural sector is faced with the prospect of climate change, which may include climatic variability that exceeds the historic experience.

Potentially positive impacts of climate warming on agriculture arise from correlated changes in temperature and CO_2. These are the climate parameters that are modeled and measured with greatest certainty. Recent observations of increased mean annual and spring temperatures are consistent with climate change scenarios. The adverse impacts of climate change are mostly related to increasingly variable and declining soil and surface water supplies. These parameters, and precipitation, are measured and modeled with much less certainty.

The agriculture sector in the Prairie Provinces has shown considerable resilience by adapting crop and livestock production to a cold subhumid climate that includes a large area with the least precipitation (< 330 cm) in the continental interior, periodic drought, and seasonal and interannual variations in temperature and precipitation that are among the largest on earth. Marginal conditions over a large area, Palliser's Triangle, have fuelled a long-standing debate over whether agriculture should have been introduced in the first place. Adaptations in recent decades have included widespread soil and water conservation and a new and evolving policy framework. The success of these strategies is reflected in the impact of the drought of 2000-2003. Despite substantial crop losses, the social impacts did not compare to consequences of the less severe droughts of the 1930s.

It may be that because the level of adaptive capacity is sufficiently great, that the net impacts of climate change will be minimal. That is, the producers and government have the capacity to expand the coping range to encompass the forecasted climate trends. This will not occur, however, without planned proactive adaptation unlike the historical circumstances of adjustments to policies and practices largely in response to extreme events, and especially drought. The most challenging future climate will include droughts that are of longer duration than the 1930s but that occurred frequently just before most of region was settled by EuroCanadians. There are few existing strategies other than government assistance to sustain agriculture through these most extreme conditions.

Acknowledgements

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