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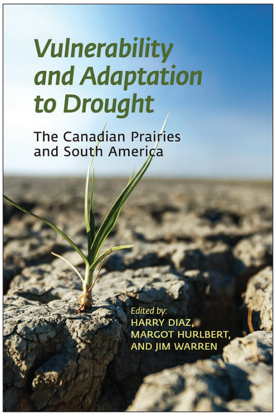

VULNERABILITY AND ADAPTATION:
The Canadian Prairies and South America Edited by Harry Diaz, Margot Hurlbert, and Jim Warren

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PART 3

DEALING WITH PRAIRIE DROUGHTS: CRISES AND ADAPTIVE RESPONSES

CHAPTER 4

THE IMPACTS OF THE 2001–2 DROUGHT IN RURAL ALBERTA AND SASKATCHEWAN, AND CANADA

Suren Kulshreshtha, Elaine Wheaton, and Virginia Wittrock

Droughts are a recurring event in the Canadian Prairie provinces. The paleoclimatic data indicate that severe droughts (of long duration) have been observed in the nineteenth century.[1] Although droughts occur in many regions of North America, the Prairie region is the most susceptible. Droughts also occur in all seasons as part of normal climate variability; however, the effects are most severe during the warmer seasons because of the increased demand for water due to higher temperatures.

This chapter focuses on droughts in the Prairie region, which includes the agricultural portion of Alberta, Saskatchewan, and Manitoba. Its primary objective is to synthesize and discuss information on impacts of droughts and adaptation to them in the Prairie provinces. In particular, this chapter focuses on the 2001–2 drought, with emphasis on the following: first, to illustrate the conceptual economic and social impacts of droughts on various economic sectors; second, to link the sectoral impacts to economic and social impacts on rural communities in Saskatchewan and Alberta; third, to identify adaptation measures undertaken by producers and communities in response to droughts; and finally, to present knowledge gaps in drought impacts and adaptation to droughts and implications for policy makers for future drought planning and policy formulation. Addressing these knowledge gaps is key to advancing future drought impacts and adaptations research. In addition, the chapter briefly reviews the major characteristics of droughts in the region as well as some conceptual issues regarding drought impacts. The nature of these droughts is compared with the most recent intense and extensive drought, which occurred in 2001–2 and is used here as a case study for discussing impacts on communities.

The empirical results presented in this chapter are based on earlier studies[2] dealing with economic and social impacts of the 2001–2 drought on various economic sectors and on government institutions.[3] These results are complemented by community-level research under the auspices of two projects—Institutional Adaptation to Climate Change (IACC) and Rural Communities Adaptation to Drought (RCAD).[4]

Background on Droughts and Their Impacts

An improved understanding of droughts is needed so that the information can be used to enhance adaptation to droughts and thereby lessen vulnerability. Improved adaptation to drought is required because drought causes severe and extensive socio-economic and ecological disruption and damage. Drought is more costly than any other form of natural disaster (Wilhite 2000). This is especially true of the Canadian Prairies where drought is more frequent, intense, extensive, and damaging than in other parts of Canada (Wheaton et al. 2008).

In terms of frequency and chronology, several extensive, multi-year droughts on the Prairies have been identified, including those of the 1890s, 1910s, 1930s, 1980s, and 1999–2005 (with 2001–2 being the peak of the drought) (Bonsal et al. 2011). A comparative spatial incidence of these droughts is shown in Figure 1. These droughts represent five major episodes during 120 years. Shorter but severe droughts have also occurred during this period (e.g., 1961). During the recent drought of 2001–2, which affected not only the Prairies but also other areas of Canada, parts of the Canadian Prairies experienced their most severe dry conditions for the last 100 years. Some locations, such as Saskatoon, had their lowest annual precipitation on record in 2001, and others had their lowest Palmer

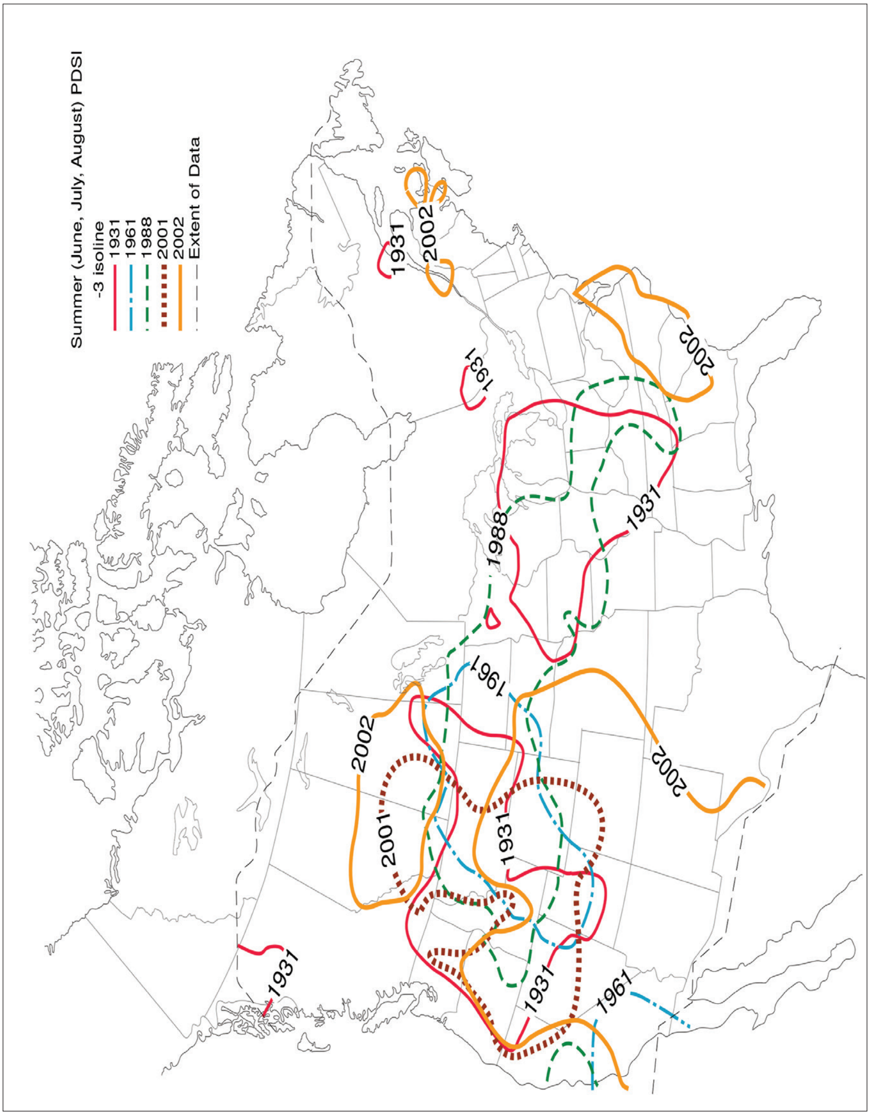


Figure 1. Spatial patterns of selected droughts in Canada, 1931–2002 (Source: Wheaton et al. 2008)

Drought Severity Index (PDSI) scores (indicating worst drought) on record (Wheaton et al. 2008). Hanesiak et al. (2011) examined many databases for several drought characteristics and found that the 1999–2005 drought on the Prairies was one of the driest meteorological and hydrological events on record.

Not only is drought an intrinsic part of the variable climate of the Prairies, but the potential for future droughts is increasing because of human-induced climate change and increasing water demand (see Chapter 3 by Wheaton et al. in this volume). Therefore, it is critical that adaptation measures, strategies, and policies consider increasing droughts and their impacts in future years.

Droughts, particularly those lasting over a period of a few years, can completely devastate a region, in terms of biophysical changes as well as economic and social impacts. Some parts of the world are more prone to droughts than others. In Canada, the southern part of the Prairie provinces (Manitoba, Saskatchewan, and Alberta) belongs to this group of regions. Here, droughts have represented a major natural disaster. Of the top 11 most costly natural disasters in Canada, 7 of them were Prairie droughts (Table 1). In fact, the most costly natural disaster in Canada was the 2001–2 drought, which had a direct impact of $5.8 billion (Wheaton et al. 2008).

Significant changes in the hydrological cycle have the biggest impact on agricultural production, but these changes also have other social and economic impacts. Among these are health effects; as Stern (2007: 89) indicated, "droughts (and floods) are harbingers of diseases, as well as causing death from dehydration."

Conceptual Framework to Describe Impacts of Agricultural Droughts

As discussed in Chapter 1, there are different perspectives on droughts—biophysical perspectives and socio-economic–political perspectives. The biophysical perspective includes studies of drought patterns, their severity and frequency, and their impacts on the physical environment, while the socio-economic–political perspective focuses on identifying the effects of precipitation deficiencies on people and their institutions. Initially, drought impacts are felt in terms of biophysical changes and experienced

Table 1. Estimated economic cost of Canadian droughts compared with other hazards

Date of occurrence	Event	Location	Estimated total cost (billion*)
2001–2	Drought	Prairies, Ontario, Nova Scotia, Prince Edward Island	\$5.8
1980	Drought		\$5.8
	Freezing rain	Ontario to New Brunswick	\$5.4
1988	Drought	Prairies	\$4.1
1979	Drought	Prairies	\$3.4
1984	Drought	Prairies	\$1.9
	Flood	Québec	\$1.6
May 1950	Flood	Manitoba	\$1.1
	Hurricane Hazel	Toronto and southern Ontario	\$1.1
1931–38	Drought	Prairies	\$1.0
1989	Drought	Prairies	\$1.0

* For comparison purposes, all values from various studies were converted into constant dollars using 2000 as the base.

Source: Koshida 2010.

by local people and their communities, but over time, their impacts are exacerbated and extend to the larger regional, national, and even international settings. These impacts have two dimensions, a sectoral/spatial dimension and a temporal dimension, both of which are discussed below.

Parry and Carter (1987) distinguish between two types of approaches to study drought impacts:[5] the impact approach and the interaction approach. The impact approach is based on the assumption of direct cause and effect. Here an activity (economic or social) is exposed to a climatic event (such as a drought) and then experiences an impact. This approach could be unrealistic (and perhaps misleading), since many other factors affect the socio-economic activities. The interaction approach assumes that a drought (or other climate-related event) is just one of many processes that may affect the exposure unit. Furthermore, the impact may be multi-dimensional through various interaction processes.

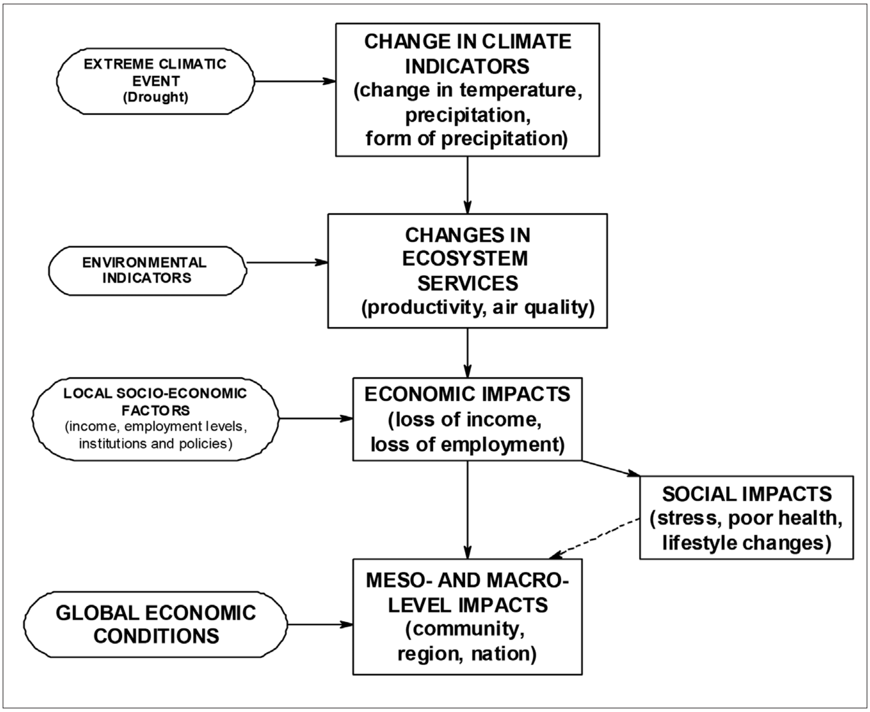


Figure 2. Interaction between drought and various sectors

For a hypothetical drought, an interactive process is shown in Figure 2. Here, three-level impacts are hypothesized. The initial order of impact during the drought period is biophysical in nature—temperature and precipitation regimes change both in terms of amount and timing. These biological changes would have an impact first on the ecosystem services (level of productivity of natural resources) and, through these changes, on the socio-economic system. These impacts are called second-order impacts. These impacts would vary according to the type of socio-economic activities that are present in a region. These second-order impacts may also lead to third-order impacts (such as changes in regional-level productivity of resources and level of income of people, as well as changes at the national economy level). For a country with open borders (such as Canada), economic impacts of the drought (negative or positive) will also be felt at the international level.

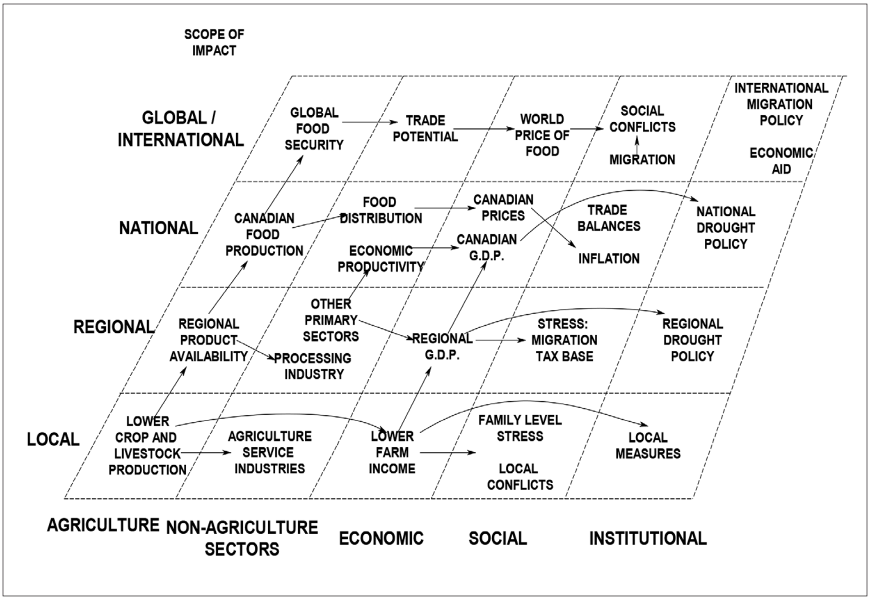


Figure 3. Hypothesized pathways of a drought incident
(Source: Adapted from Parry and Carter 1987)

A case in point is the recent experiences of the Australian drought of 2006 and the US drought of 2010. During these periods, farm-level wheat price in Saskatchewan rose from a five-year average (2002–6) of $142.20 per tonne to $301 per tonne in 2007 (more than doubling) and to $256 per tonne in 2010 (an increase of 80%).[6] Both of these situations illustrate the international connections in commodity markets. Price booms like this are welcomed by exporting nations, but they may create social hardships in other parts of the world and may initiate a series of changes leading even to inter-regional or international migration of people. A more detailed account of these changes is presented in Figure 3.

When an agricultural drought occurs, more than just agriculture suffers from the lack of water. Rural communities, municipalities, industries, and processors are also affected. In some local regions, rationing may be required, but unless the water source becomes completely depleted, the right to the use of the water is relatively secure for the users. Overall, the economic conditions during the drought period and immediately after that would be adverse, either through economic losses or through impacts on ecosystem services. Impacts can be hypothesized to occur in two dimensions—sectoral and spatial.

For the purposes of studying droughts, the economy should be segregated into two sectors: agricultural and non-agricultural. Some non-agricultural sectors may experience two types of impacts—direct impacts of droughts and indirect impacts induced by losses in agricultural production. These impacts would lead to several other types of impacts within the local region, culminating in regional and national (as well as international) impacts. For example, loss of agricultural production (e.g., livestock production) would affect agricultural processing industries and then affect the rest of the food supply chain. Some of these industries would suffer from higher processing costs and would also need to import their required raw material from other regions. Social impacts might be experienced from lower economic conditions for some people, communities, and businesses, which might lead to higher stress levels and might even culminate in health impacts.

Although droughts are typically confined to a certain period of time, their impacts are not necessarily limited only to that time period. For example, Figure 4 depicts a hypothetical region that has been experiencing economic growth over the past few time periods (as shown by line *Oa* in the figure). The region suddenly experiences a severe drought[7] in time period t_1. If the region did not experience that drought, it would have moved along line *Oac* to time period t_2. The direct (one period) impact of the drought is measured by the vertical line *ab*. However, the actual cost of the drought would depend on the path of recovery taken by the economy. If the economy reaches the same point where it would have been without that drought occurring, then the cost of the drought is approximated by the area *abc*. However, if the growth rate is sluggish and the economy needs more time to recover, the cost would likely be higher than approximated by that area.

In addition to changes in economic activities, drought may also affect ecosystem goods and services. Changes in land productivity resulting from drought, or loss of vegetation and wildlife resulting from drought, would also affect many other socio-economic activities in the future (such as recreation, hunting, and tourism). A true total cost of a drought must therefore sum all economic and environmentally induced costs over a

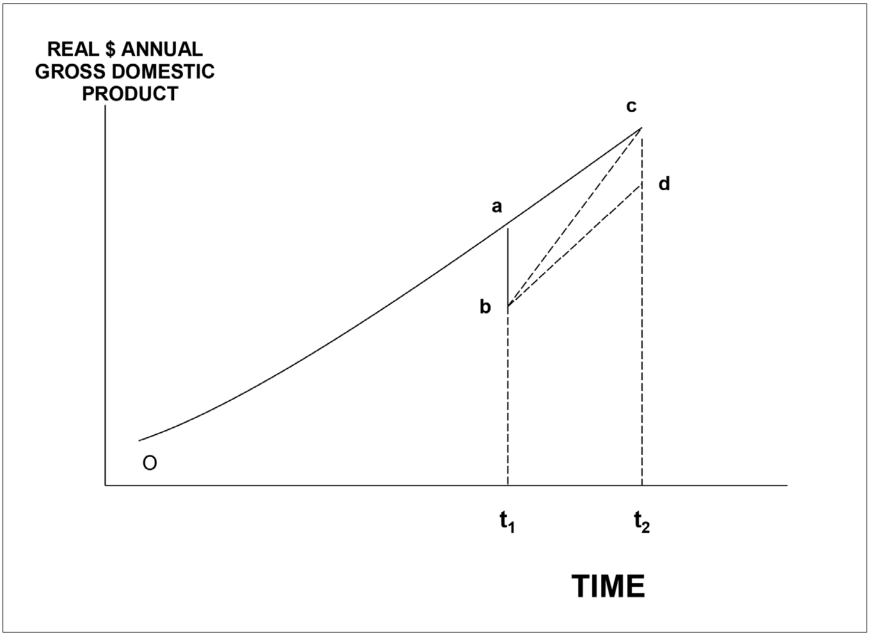


Figure 4. Time path of adjustment in regional economy resulting from a drought (Source: Adapted from Dore and Etkin 2000)

period of time. However, such a study has yet to be undertaken for the Prairie provinces.

The 2001-2 Drought Impacts in Canada

Past droughts in Canada have been more spatially fragmented, less intense, and shorter than what was witnessed in Canada in 2001-2. This drought was exceptional by many measures: it was unusually large in area, severe, and embedded in a long dry period (Wheaton et al. 2008). As a result, it affected many sectors and people residing in a large part of Canada. The two Prairie provinces—Saskatchewan and Alberta—were particularly hard hit by these back-to-back droughts. In 2001, Canada experienced one of the worst droughts on record by many standards, including its coverage across Canada and its intensity. Further details on its impacts are provided below.

The genesis of the 2001–2 drought was in the autumn of 2000 in southern to southeastern Alberta. The drought then spread across into central-western Saskatchewan, but the province of Manitoba had near normal temperature and precipitation conditions. The drought intensified in spring and summer 2001 in Alberta and Saskatchewan. Only the northwestern agricultural portion of Manitoba was dry in spring and summer 2001. The warm, dry trend continued into the autumn and winter of 2001–2. Conditions changed in spring 2002, but only in temperature, resulting in an unusually dry and severely cold spring across western Canada. The 2001 drought was confined to a smaller region—primarily located in the southern and east-central parts of the province (Wheaton et al. 2008). The 2002 drought in Alberta covered most of the province at some point in time during the agricultural season.

The higher temperatures accompanied by lack of precipitation resulted in several biophysical impacts, such as wind erosion, reduced streamflows, dry dugouts, and groundwater reductions. More prominent impacts in the region included the following:

- The areas of most frequent wind erosion were estimated to have occurred in the drought areas of southern Alberta and in Saskatchewan, particularly in the central area along the provincial border. The month of peak wind erosion occurred in May for both 2001 and 2002, but was nearly as high in April 2002. Alberta had the most wind erosion events during 2001, while Saskatchewan had more in 2002.

- Many rivers and streams in Alberta and Saskatchewan had well-below-average flows in 2000, 2001, and 2002.

- Many of the 19 groundwater observation wells examined in the Canadian Prairies (7 in Alberta, 8 in Saskatchewan, and 4 in Manitoba) recorded declining water level trends, depending on location of the observation well.

- Dry dugouts were first reported in the fall of 2000, with the area of dry to one–quarter-full dugouts expanding through 2001. In 2002, the area of dry dugouts shifted northward (Wheaton et al. 2008).

Table 2. Impact of the 2001–2 drought on agricultural production in Saskatchewan and Alberta

Particulars	Alberta		Saskatchewan	
	2001	2002	2001	2002
Reduction in value of production before government payments (millions)	$412.90	$1,400.70	$925.30	$1,520.10
Reduction in value of production after government payments and other adjustments (millions)	$271.16	$1,008.50	$654.90	$1,001.00
Drought losses as a percentage of average 1998–2000 value of production	5.97	20.26	16.14	26.52

Source: Wheaton et al. 2004.

These biophysical impacts led to other second-order impacts on the socio-economic activities in the two provinces, such as adverse impacts on agricultural production in Alberta and Saskatchewan. In both provinces, crop yields and harvested areas were below average for 2001 and 2002. This led to reduced farm cash income in both years. The overall impact of the drought was a loss in gross farm cash receipts of $413 million in 2001 and $1,401 million in 2002 for Alberta and $925 million in 2001 and $1,520 million in 2002 for Saskatchewan (Table 2). These losses included changes in crop production and in livestock production.

Producers also reduced input costs in response to drought conditions. A reduction in fertilizer application occurred in 2002 because the 2001 crop did not use the nutrients that were applied to it. Fuel purchases were down in 2002 because of reduced harvested area. Adjusting for the reduction in cost of production (through reduced farm input costs) and for payments received under various safety-net programs (mainly crop insurance), the net effect of the drought on crop production was estimated. Adjusting for losses in livestock production and adding them to adjusted crop production effects, net losses to Alberta producers were estimated at $271 million in 2001 and $1,009 million in 2002. Similar estimates for Saskatchewan producers were $655 million in 2001 and $1,001 million in 2002. Total losses of producers in the region were therefore around $926 million in 2001 and $2,010 million in 2002. In both provinces, these losses were over 16% of average 1998–2000 net farm income.

The 2001–2 drought had profound impacts on the water supply in some parts of the Prairie provinces. At the farm level, dugouts were affected the most, although domestic water supplies were also at risk. The hardest-hit regions were southern Alberta (in 2001) and central Saskatchewan (during 2001 and 2002). Producers used various methods to supplement water, including hauling, drilling new wells, and sourcing new water supplies, such as pipelines from distant secure sources.

As a direct consequence of loss in production and lower farm incomes, non-agriculture sectors were also affected. In Alberta, major changes on non-agricultural industries included the following:

- New investment in 2001 was down by 4.6% in agriculture, forestry, fishing, and hunting activities.
- Some negative impacts of the drought were noted on sales of new farm machinery and equipment in these areas.
- Agricultural processing firms reported no change in their sales, but they faced higher prices for their raw materials, thereby affecting their profit margin.
- Some firms had to find new suppliers for their raw materials.
- Forest-fire occurrences were five times higher than the previous 10-year average during 2002 in Alberta.
- Some recreational areas were affected due to low water levels in water bodies and open-fire restrictions in some areas (Wheaton et al. 2008).

Table 3. Reduction in gross domestic product and employment resulting from the 2001–2 drought in the Prairies

Particulars	Unit	2001*	2002*
Loss of gross domestic product	Millions of dollars	$1,434.62	$3,108.33
Loss of employment	No. of workers	10,083	17,803

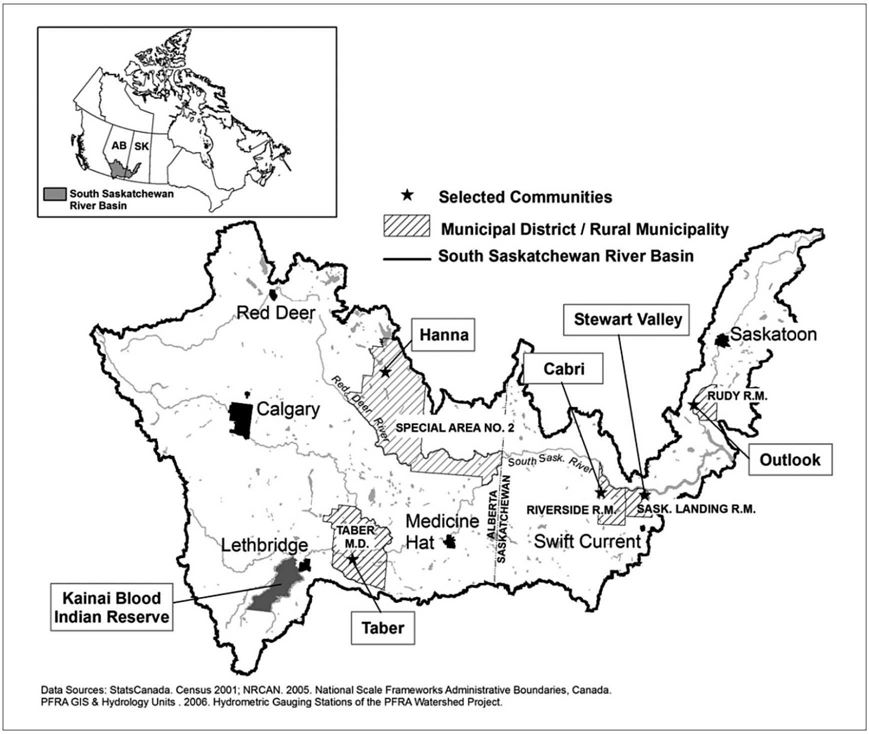
* These estimates include data for Manitoba; however, direct impacts in Manitoba were relatively small and accounted for only 0.7% of total impacts on the Prairie region in 2001 and 1.3% in 2002. Thus, these estimates for the Prairie region largely reflect impacts for Alberta and Saskatchewan. Source: Wheaton et al. 2004.

In Saskatchewan, impacts of the drought were very similar to those noted above for Alberta, but there was also a reduction in the amount of hydroelectric power generated, requiring the Saskatchewan Power Corporation to purchase additional power from other sources.

The Canadian economy (and within that the economy of the Prairie provinces) represents an integrated system of activities. Regions depend on each other for raw materials as well as for markets for the good produced. Loss of production in Alberta and Saskatchewan therefore had consequences for other sectors in other parts of Canada. Using an input-output model, total loss for the region was estimated. Results for the Prairies are summarized in Table 3. The region lost a total of $1.4 billion in 2001 and $3.1 billion in 2002. These losses also culminated in loss of employment. About 10,000–17,000 jobs were lost in the region.

Droughts and Rural Communities

As previously mentioned, community-level research was carried out through two main projects: the IACC project and the RCAD project. Under the umbrella of the IACC, studies examined five rural communities in Saskatchewan and Alberta, as well as one First Nation reserve in Alberta (Figure 5). The five rural communities were Taber (Taber Municipal District [MD]), Hanna (Special Area No. 2), Cabri (Riverside Rural Municipality [RM]), Stewart Valley (Saskatchewan Landing RM), and Outlook (Rudy RM). The First Nation reserve in Alberta was the Kainai Blood Indian Reserve (KBIR). The RCAD studies occurred in six different



Data Sources: StatsCanada. Census 2001; NRCAN. 2005. National Scale Frameworks Administrative Boundaries, Canada. PFRA GIS & Hydrology Units . 2006. Hydrometric Gauging Stations of the PFRA Watershed Project.

Figure 5. Communities in the Institutional Adaptation to Climate Change project (Source: Adapted from Patino 2011)

communities in Saskatchewan: five were located in the Palliser Triangle area, a well-documented location of reoccurring drought, and one was located just south of the North Saskatchewan River. Communities in the Palliser Triangle included Shaunavon (Grassy Creek RM and Arlington RM), Coronach (Hart Butte RM), Gravelbourg (Gravelbourg RM), Kindersley (Kindersley RM), and Maple Creek (Maple Creek RM). The other community was Maidstone (Eldon RM) (Figure 6).

This section details how the 2001–2 drought impacted the case-study communities both economically and socially. Because the IACC and RCAD projects used different methods, non-standard information, with an attempt at standardization, is provided here.

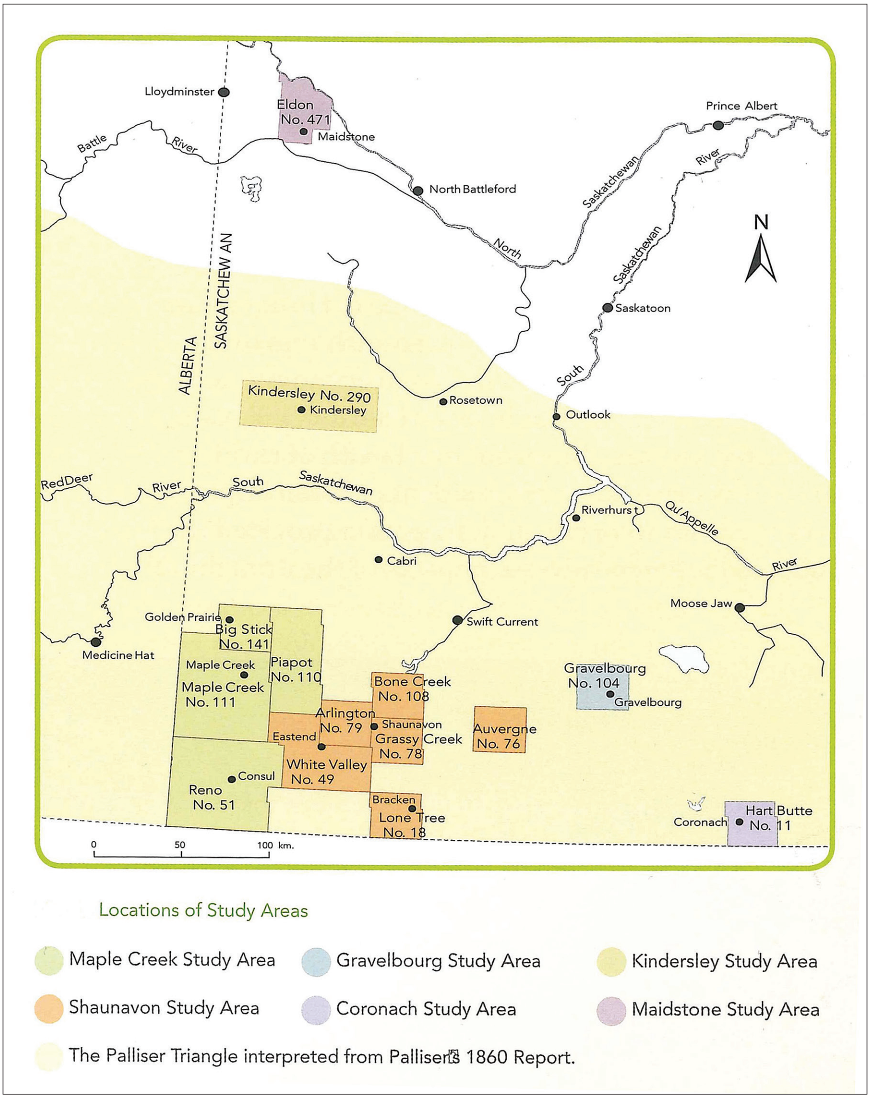


Figure 6. Communities in the Rural Communities Adaptation to Drought project (Source: Perrick 2012)

Table 4. Cost of the 2001–2 drought through lost crop production

Year	Value in dollars per hectare				
	Taber MD	Special Area No. 2	RM of Rudy	RM of Riverside	RM of Saskatchewan Landing
2001	-38.38	-87.93	-76.61	-78.03	-63.48
2002	-35.12	-171.08	-62.91	-20.44	-7.09

Sources: Wittrock et al. 2012; Wittrock et al. 2007.

Economic Costs to Communities

The cost of the 2001–2 drought for all of Canada was estimated to be nearly $6 billion (Table 1). The economic cost breakdown was carried out for the local study areas by the IACC project. The largest crop production losses of the 2001–2 drought were in Special Area No. 2 (in central-west Alberta), with a nearly $88 per hectare loss in 2001 and nearly double that amount in 2002 (Table 4). The Special Areas in Alberta were established under the auspices of the Special Areas Board in response to previous negative impacts from droughts in the early twentieth century (see Marchildon et al. 2008; see also Chapter 8 by Marchildon in this volume). The second-highest crop production losses occurred in the RM of Rudy when both 2001 and 2002 are examined together. While 2001 losses in the RM of Rudy were not as extreme (crop production loss of $76.61 per hectare or $4.23 million) as for the RM of Riverside, the drought conditions continued to plague the RM of Rudy in 2002, resulting in a continued loss of crop production by nearly $63 per hectare ($3.48 million). Taber MD also suffered crop losses but not as extreme as those in these other areas. In 2001, the loss was about $38 per hectare ($7.48 million) and in 2002 was about $35 per hectare ($6.84 million) (Wittrock et al. 2012; Wittrock et al. 2007).

A large rainstorm went through southern Alberta and southwestern Saskatchewan on 8–11 June 2002 (Szeto et al. 2011). Partly because of this event, crops recovered somewhat and the negative financial impact of crop loss was reduced in the RM of Riverside and the RM of Saskatchewan

Landing in southwestern Saskatchewan. The crop production loss in 2001 was about $78 per hectare in 2001 (or $8.57 million) in the RM of Riverside, but this value greatly improved to a loss of just over $20 per hectare in 2002 ($4.60 million). The RM of Saskatchewan Landing's financial situation improved between 2001 and 2002; loss in crop production was more than $63 per hectare in 2001 ($5.55 million), but the RM had near normal production in 2002 (Table 4).

Other economic costs were incurred by the communities but were not quantified. These included reduced fertilizer sales (Taber), reduced advertising in local newspapers (Taber), increased costs for market-garden operations (RM of Rudy), reduced new farm-machinery sales (Outlook), and increased water costs for the oil and gas industry (Special Area No. 2). Some industries that were more severely impacted by the drought moved out of the regions, such as grain brokers (RM of Rudy). Other sectors benefited from the drought, such as financial institutions, which profited because demand for money rose with the drought (Taber) (Wittrock et al. 2012; Pittman et al. 2010; Wittrock et al. 2007). The economic impact on the livestock industry could not be estimated due to a lack of data (Wittrock et al. 2012).

The RCAD project examined economic impacts though loss of crop production in the RMs surrounding the communities. Kindersley suffered decreases of more than 50% in 2001 and almost 100% crop loss in 2002 for wheat and canola (Abbasi 2014). The RM of Eldon (Maidstone) had crop losses of more than 70% in both 2001 and 2002 (Abbasi 2014). Prior to 2002, the RM of Eldon had not been severely impacted by an extreme drought, because this region in northwestern Saskatchewan's agricultural region generally has crop yields above the provincial average (Warren 2013). Producers in the RM of Gravelbourg did not perceive any major impact due to the 2001–2 drought conditions. They found that the adaptation measures they implemented due to the drought conditions in the late 1980s lessened their vulnerability to the 2001–2 drought (Luk 2011).

Other economic challenges emerged, in part, because of the 2001–2 drought, including those associated with upgrading water supply systems at various locations after the drought. Such improvements took place at Maple Creek (at a cost of $3.7 million) (Warren 2013), at Cabri (Wittrock et al. 2006), Maidstone (Abbasi 2014; Warren 2013) and Kindersley (Abbasi 2014; Warren 2013).

The KBIR stands out as a special case of drought impact because of its own style of governance, including that related to property rights. It is one of the largest reserves in Canada, with a population between 4,000 and 10,000 people. Agriculture is the predominant land use with some irrigation. However, much of the irrigated lands are leased out to non–First Nations people. The KBIR also has a beef cattle operation.

During the 2001–2 drought, the KBIR was affected in several ways (Kulshreshtha et al. 2011): i) local government costs increased from delivering water to homes on the reserve; ii) some road maintenance equipment was damaged due to extremely dry road conditions; iii) the livestock operation had higher feed costs resulting in some cattle being culled; and iv) residents on the reserve faced increased costs and time to obtain water.

Social Impacts of Droughts on Communities

Social and economic vulnerabilities to communities co-exist and tend to be accentuated by exposure to extreme climatic events including drought (Diaz et al. 2009). All the communities examined in the IACC and RCAD projects are relatively small, ranging in population from just over 100 (Stewart Valley) to 6,000 (Taber). Many of the communities have similar social issues, including depopulation—particularly of the younger generation—and centralization of services, which make the communities more vulnerable to external stressors and reduce their adaptive capacity (Diaz et al. 2009). Drought is one of these added stressors and creates additional impacts on the communities. A common impact of drought and resulting stressors throughout most of the communities was the lack of water (Wittrock et al. 2011). The meteorological and hydrological drought of 2001–2 resulted in low water supplies affecting available water for activities for some farmers and in some towns and villages across the Canadian Prairies. Low water supplies resulted in water use restrictions for some towns as well as restrictions on the agricultural community's access to town water. These restrictions resulted in agricultural producers having to find alternative water sources and the government (both federal and provincial) providing some assistance to farmers/ranchers to find adequate quality water for their livestock (Wittrock et al. 2012; Wittrock et al. 2011; Wheaton et al. 2008). This scenario played out in many of the communities examined in this chapter. For example, the towns of Taber and Cabri imposed water rationing (Wittrock et al. 2007; Wittrock et al. 2006). The town of Cabri took the additional step of not allowing agricultural producers to access the town's potable water supply (Diaz et al. 2009; Wittrock et al. 2006). The water rationing in Taber may have negatively impacted production by some industries or resulted in them having to invest in water conservation technology (Wittrock et al. 2006). The communities of Kindersley, Maidstone, Maple Creek, Gravelbourg, and Coronach all had water supply issues due to the drought (Abbasi 2014; Warren 2013; Luk 2011). The town of Outlook had easier access to water through the development of Lake Diefenbaker. Dry conditions increased demand for domestic water use and increased the revenues of the water utility of Outlook. This situation improved the town's financial position (Wittrock et al. 2007). In addition to impacts on communities as a whole, the drought of 2001–2 impacted individuals' well-being. For example, community officials had difficulty coping at the personal level with the cumulative effects of the drought and the associated secondary and tertiary impacts (Maple Creek) (Warren 2013).

Adaptation to Droughts: Overview

Extreme climatic events can have devastating consequences for agriculture as well as the accompanying community. Adapting to these extreme climatic events is critical in reducing vulnerability and decreasing the recovery time. An adaptation framework was formulated in Wittrock and Wheaton (2007) and is used here to assess the various strategies implemented.[8]

In general, two types of adaptation strategies exist: short term and long term. These strategies can also be subdivided into subcategories, including technology/research, government programs, farm management, farm and agriculture financial management, and community support—for crops, livestock, and water. These subcategories can then be assessed based on key topics. For example, some key topics for cropping adaptation strategies may include weed control, pest control, or crop rotation (see also Chapter 5 by Warren on minimum till in this volume). Many secondary impacts to both agricultural producers and/or communities may also require adaptation strategies.

Adaptation by Producers

Canadian Prairie agricultural producers have always been impacted by droughts. Some of the historic droughts have been short, such as the drought in 1961, while other droughts have lasted for extended periods, such as the droughts in the 1920s and 1930s (Marchildon et al. 2008) and more recently in 1999–2005 (Bonsal et al. 2011). Consequently, many adaptation measures have been implemented, resulting in a moderately proactive response leading to lower vulnerability and fewer or less negative impacts. Other portions of the study region (such as northern Saskatchewan and Alberta) have not experienced many severe droughts, resulting in lower implementation of adaptation strategies and thus higher vulnerability to droughts.

Southern Alberta and western Saskatchewan have a history of droughts. This portion of the Canadian Prairies is in the Palliser Triangle, where droughts are frequent. This vulnerability has resulted in many adaptation measures being implemented over several decades, and thus the most recent drought event of 2001–2 had lower negative impacts than might have resulted without this experience.

The agricultural industry reduced its vulnerability to the 2001–2 drought by implementing short- and long-term adaptation strategies. Many adaptation strategies are initially reactive in nature, but turn into proactive strategies when used for long periods of time. Examples of short-term adaptation strategies used by the agricultural community are listed in Table 5.

The long-term adaptation strategies apply to crops, livestock, water, and land use, and include three different groups of adaptations—technology/research, government programs, and farm and agriculture financial management. These strategies have a longer time frame either through implementation (e.g., research into drought-resistant crops and forage crops) and/or usage (e.g., minimum till expansion, conservation cover program). However, even with these extensive adaptation measures, harsh droughts such as the 2001–2 event, can stress coping levels, as indicated earlier, and result in large losses and difficult recoveries at the community to national levels.

Table 5. Examples of short-term adaptation strategies for the agricultural sector

Particulars	Technology / research	Government programs	Farm management	Farm and agriculture financial management	Community support
Crops	Modify equipment to deal with shortened crops	Crop insurance Net Income Stabilization Account Low interest rates	Use cropping strategies (crop rotation, seeding times, crop diversification, drought-tolerant species)	Sell crops when higher commodity prices are available Take off-farm jobs	
Livestock	Use Web to buy and sell livestock and forage	Forage/hay insurance Tax deferral from livestock sales Farm Income Disaster Program	Import feed from non-drought-stricken regions Reduce stocking rates in pastures Use annual feeds	Cull older cattle Increase cow/calf sales	HayWest program, Ducks Unlimited opened its property to livestock producers
Water		Partial funding for installing temporary water pipelines National Water Supply Expansion Initiative	Conserve water in agriculture, urban areas, and industry Ration water Haul water and/or install temporary remote water systems	Temporarily trade or sell water rights to other producers or industry	

Source: Adapted from Wittrock and Wheaton 2007.

Table 6. Examples of longer-term adaptation strategies for the agricultural sector

Particulars	Technology / research	Government programs	Farm and agriculture financial management
Crops	Drought-resistant crop development Long-range weather forecasts Extreme climatic events research to reduce vulnerability	Assessment of future government assistance programs Agriculture Policy Framework	Minimum tillage expansion Increased use of high-efficiency irrigation systems Increase crop diversification
Livestock	Research into drought-resistant forage crops	Conservation Cover Program	Different grass and pasture management strategies Purchase land in different parts of the Prairies Change to different livestock breeds that survive better in drought situations
Water	Hydrologic modelling to assist with planning and operational design Examination of expansion of water storage and irrigation	Modifications in water allocation (Alberta) Moratorium on new water licenses in fully allocated river basins (Alberta) Assistance with building of dugouts and/or groundwater wells	
Land use			Increase acreage under irrigation Increase value-added commodities with more farm level processing activities

Source: Adapted from Wittrock and Wheaton 2007.

Adaptation by Communities

The level of community adaptation to drought varies by length, timing, and intensity of drought; location of the community; and the community's level of adaptive capacity. A community's level of vulnerability is determined by its exposure to environmental and societal stresses and its capacity to adapt to those stressors (Brklacich and Woodrow 2007; see also Chapter 1 in this volume).

Two assessments were undertaken for the IACC project to determine the level of vulnerability through adaptation measures. Diaz et al. (2009) examined how successful various portions/sectors of the community were in responding to drought and the reasons behind their success or failure. Wittrock et al. (2011) examined the adaptive capacity of the communities and rated them based on the method by Brklacich and Woodrow (2007).

The town of Outlook was assessed as the least vulnerable community to the 2001–2 drought mainly due to its secure potable water supply. The community also has an income close to the provincial average and has a higher-than-average formal education base. The community of Cabri was rated as the most vulnerable to the 2001–2 drought mainly due to its inadequate water supply (Wittrock et al. 2011). Because of its inadequate water supply, citizens implemented adaptation measures, including water conservation and use of grey water (e.g., clothes' washing water) to water gardens. The local government implemented additional measures to combat the low potable water supply, including restricting lawn watering and restricting agricultural producers from accessing the town's limited water supply (Diaz et al. 2009).

The drought of 2001–2 triggered initial reactive adaptation strategies in many of the communities mainly due to the lack of potable water. For example, Kindersley had a historic adaptation to limited potable water supply by installing a water pipeline from the South Saskatchewan River in the 1960s. This infrastructure required an upgrade to maintain a feasible level of potable water for the community. Maidstone was perhaps most severely impacted by the drought due to the extreme negative effect on its potable water supply. This may also have been an effect of a reactive adaptation strategy used by the town. This strategy was to drill more groundwater wells and install a potable water pipeline, thus decreasing the vulnerability of the community to future extreme drought events.

Areas for Further Research

This overview of research on drought impacts and of adaptation strategies to reduce these impacts was based on available data, which was sometimes limited. This section provides several suggestions for planning and undertaking future research on drought impacts to provide more comprehensive information and understanding.

The timeline of impacts was not included in past studies. This timeline would likely illustrate the cumulative impacts that occurred due to the drought. These impacts could have a dampening effect on the economy in the future, particularly for livestock production. Results on livestock production were based on provincial-level data. Regional data, particularly on the drought regions, were not available, thus limiting the analysis of regional level drought impacts.

In addition to the agricultural sector, drought may affect other sectors (e.g., forestry; hydroelectric power generation; transportation industries, including water transportation; tourism and recreation; food processing industries; and farm input industries). Attempts should be made to collect more information on these sectors to enable a more comprehensive analysis of the estimated impacts of the drought.

A concern that needs to be more fully explored in the future relates to the impacts of drought on the environment. Various aspects of the environment can be impacted by prolonged droughts (such as soil quality, air quality, water quality). Such changes could affect the sustainability of Prairie agriculture and the associated economy. Another major concern is the looming possibility of future droughts that will make past droughts appear mild in comparison. These more severe droughts would make adequate adaptation much more difficult and would push the limits of adaptation.

Summary

Droughts are frequently experienced in the southern part of the Prairie provinces. Although paleoclimatic data suggest past droughts were of longer duration, recent droughts have been mostly single-year or consecutive-year events. The drought of 1999–2005, which peaked in 2001–2, was a longer event. It created havoc for the agriculture industry and for people associated with it. In addition, many non-agricultural sectors were either directly or indirectly affected by the drought conditions. Overall, the provinces of Saskatchewan and Alberta were the hardest hit in Canada. Drought affected central-west and southwestern Saskatchewan, and central-east Alberta. In the region, total gross domestic product declined by $1.4 billion in 2001 and by $3.1 billion in 2002. These economic losses were associated with employment losses in the agricultural sector and associated industries.

Rural communities in the drought region suffered as a result of losses in the agriculture industry and shortage of water. Many of these communities, as well as agricultural producers, undertook adaptation measures in response to the droughts. In some cases, new sources of water were found, while in other cases, existing sources were improved to secure water. Adaptation to climate change (particularly drought events) represents a challenge for the Prairie economy; however, adaptation can reduce vulnerability to future events, within limits. Although humans have always adapted to changing climate and to non-climatic changes, more can be done to help people to prepare for these conditions.

NOTES

1 In southwestern Saskatchewan and southeastern Alberta, decade-long droughts have been estimated during the early and late 1800s (see Chapter 2 by Sauchyn and Kerr in this volume; see also Sauchyn 2002).

2 Details on these studies can be found in Wheaton et al. (2008, 2004), Wittrock et al. (2012), and Kulshreshtha et al. (2011).

3 For details on historical development of institutions in response to drought, see Marchildon et al. (2008). See also Chapters 9 and 10 by Hurlbert in this volume.

4 Details on the IACC project are reported by Wittrock et al. (2012, 2011, 2007, 2006), Pittman et al. (2010), and Kulshreshtha et al. (2011). Similarly, the RCAD project results are summarized by Diaz and Warren (2012), Abbasi (2014), Luk (2011), and Warren (2013).

5 These approaches were originally suggested by Kates (1985).

6 These data are from the Government of Saskatchewan (2013).

7 Although in this example, we have assumed a drought, any other climate-related natural disaster may have similar impacts.

8 Data regarding the communities and agricultural sector are from the IACC and RCAD projects, as well as from Wheaton et al. (2008).

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CHAPTER 5

THE "MIN TILL" REVOLUTION AND THE CULTURE OF INNOVATION

Jim Warren

Introduction

Over the course of the agricultural period on the Canadian Prairies, extending from the mid-1880s until today, the region has experienced several periods of severe region-wide drought, along with numerous localized episodes (Wheaton et al. 2005; Wheaton 2007; Lemmen et al. 1997; see also Chapter 8 by Marchildon in this volume). As noted in other chapters in this volume, major droughts affecting the region have at times been followed by significant adaptation efforts, including the creation of new institutions such as the Prairie Farm Rehabilitation Administration (PFRA) and Alberta's Special Areas Board (see Chapter 8 by Marchildon on the history of drought in the region). This chapter focuses on the efforts of agricultural producers and local machinery manufacturers to enhance drought resilience through the invention and adoption of new machine technology and land management practices.

The chapter contends that the propensity of dryland agricultural producers in the region to adopt new farming practices and machinery in response to drought has helped reduce their vulnerability. It also proposes that the adoption of innovative practices which enhance resilience to drought has become an institutionalized social value for dryland farmers in the Palliser Triangle. These arguments are supported by an assessment of historical literature on the evolution of farming practices and equipment used in the region (Shepard 2011; Ward 2011; Bruneau et al. 2009; Hall 2003; Dale-Burnett 2002; Wetherell and Corbet 1993; Archer 1980) and by ethnographic fieldwork data obtained in the Rural Communities Adaptation to Drought (RCAD) project, a major study of adaptation to drought in the region (RCAD 2012; see the introduction to this volume for a discussion of the RCAD project). The chapter makes frequent reference to Warren and Diaz (2012), a book which assesses research conducted for the RCAD project as well as the final report of the RCAD project itself (RCAD 2012). The principal task of this chapter is to view the RCAD data through the lens of the diffusion of innovations theory developed by Rogers (1962).

Min Till

A recent manifestation of widely embraced adaptation in response to agricultural drought on the Canadian Prairies has been the near universal adoption of a family of farming practices collectively referred to as “min till”—an abbreviation for minimum tillage, also referred to as conservation tillage and less accurately as zero till (Bruneau et al. 2009; Hall 2003).

Min till describes a set of technological innovations that reduce soil disturbance and conserve soil moisture, often without the need for mechanical summer fallowing. Reducing mechanical summer fallowing and seedbed disturbance prior to and during planting (referred to as direct seeding) helps retain moisture and reduce wind-driven soil erosion typically associated with severe drought. Min till relies on specialized farming equipment and chemical applications that reduce soil disturbance as well as the frequency of field operations.

Min till methods also include continuous cropping practices, which have significantly reduced the amount of land formerly dedicated annually to summer fallow. Where soil and climate conditions are considered inappropriate for continuous cropping, the application of chemical herbicides (chem fallow) has replaced mechanical weed control methods.

Continuous cropping has increased the need to apply chemical fertilizer. However, crop rotations also help replace lost nutrients and control crop-specific pathogens. Increased use of crop rotations has been facilitated by the adoption of a host of new crops and crop varieties, primarily in the 1990s. Crop diversification in the Palliser Triangle is represented by a significant increase in the acreage devoted to heat-resistant canola varieties and nitrogen-fixing legume crops (referred to as pulse crops), such as field peas, chickpeas, and lentils—crops that were relatively unknown in the region prior to the 1990s.

Min till's advocates contend that leaving standing stubble and trash (crop residue) on the soil surface helps capture winter snow, reduces wind-driven soil erosion, and provides an insulating mulch, which helps reduce evapotranspiration and thereby conserves soil moisture. The mulch is eventually incorporated back into the soil, contributing to soil nutrient and fibre levels.

The adoption of straw spreading attachments for combine harvesters has facilitated the retention of trash. Prior to widespread adoption of this innovation, straw was deposited in windrows, which allowed for the baling for livestock feed and bedding. Particularly thick windrows that were not baled could make spring field work difficult, and they were often burned. Straw spreading has reduced stubble burning as well as the availability of straw for the livestock industry.

The adoption of soil conservation and drought mitigation practices has a long history in the Palliser Triangle, extending back to the early decades of agricultural settlement on the Prairies, the period from the mid-1880s up to World War I (Ward 2011; Shepard 2011; Wetherell and Corbet 1993; Archer 1980). However, the adoption of the collection of min till practices currently in use began in the late 1980s and became widespread over the course of the late 1990s, partly in response to a series of severe drought years in the second half of the 1980s.

Crop yield data and other agronomic observations suggest that min till practices have enhanced the drought resilience of dryland agriculture in the Palliser Triangle. The vast majority of RCAD respondents, including farmers and agrologists, reported that when severe region-wide drought conditions returned to the area in 2001–2, the impacts on crop yields and soil conditions were relatively less severe in some areas than conditions experienced in the 1980s. Many respondents indicated that dust storms, while they did occur, were less common and severe during the drought of 2001–2 compared with the dry years of the late 1980s and the 1930s (see also Luk 2011 and Bruneau et al. 2009: 142–43).

Notwithstanding the contribution of min till to drought resilience and soil conservation, it is not a panacea. In the second consecutive year of a severe drought, yields on min till fields can be significantly reduced. By the second or third consecutive year of severe drought, crop failures can occur on min till fields. Most RCAD respondents reckoned that after two to three consecutive years of severe drought most of the farmers and ranchers in the Palliser Triangle would be experiencing considerable economic hardship. They predicted that three years of severe back-to-back droughts would force many producers to exit agriculture. This grim forecast was thought to apply to producers in general, including those employing min till practices, but with the possible exception of irrigators. Nevertheless, most RCAD respondents also attested to the ability of min till to reduce wind-driven soil erosion and conserve moisture in the early stages of a prolonged drought better than would typically be the case for methods used prior to the 1990s.

It is also noteworthy that min till practices are suited to a particular agricultural production model in a particular climatic environment—dryland annual crop production in a semi-arid climate region that experiences accumulations of snow over winter and periodic drought. Min till practices are not as well-suited to irrigation agriculture and are somewhat less popular among dryland farmers operating in the moister regions of the Prairies outside the Palliser Triangle. And, as will be discussed later in the chapter, min till has detractors who contend that while it may reduce soil erosion and conserve moisture, those benefits come at the cost of increased dependency on fertilizer and herbicide price levels. Critics of min till also maintain that it generates chemical and nutrient pollution, which is harmful to ecosystems and human health.

Furthermore, while min till may indeed produce economically beneficial yield improvements and input cost reductions, there are many other factors besides crop yield that affect the survival of individual agriculture units, including the cost-price squeeze described in Chapter 7 by Fletcher and Knuttila in this volume. Despite widespread adoption of min till, there has been a significant reduction in the number of farms on the Canadian Prairies. In the early 1990s, when min till was in the initial stages of widespread adoption, there were approximately 60,000 farm units in Saskatchewan; in 2015, there were less than 37,000 farms (Saskatchewan Ministry of Agriculture 2015). Diverse factors such as commodity price fluctuations or changes to government farm support programs can have at least as much impact on the survival of a farm as the yield and input cost benefits attributed to min till.

Notwithstanding the qualifications just noted, the principal purpose of this chapter is not to assess the economic and agronomic benefits of min till in a precise way, but rather to describe how and why it emerged as a widespread adaptation to drought on the Canadian Prairies.

Imagining Innovation as a Cultural Value

Interview data collected by the RCAD project and by Warren and Diaz (2012) provide examples of the socio-economic conditions and decision-making processes that supported the widespread adoption of min till technology. That research shows that farmer adoption of min till on the Canadian Prairies reflects the influence of many of the factors contributing to innovation identified under the diffusion of innovation theory famously described by Rogers (1962).

Rogers assesses the processes through which innovation in agricultural technology occurs and provides a list of socio-cultural conditions that can contribute to or detract from the diffusion of innovations. The propensity to innovate is described along a temporal continuum that begins with "the innovator." Innovators are individuals or groups of individuals who are "the first to adopt new ideas in their social system" (Rogers 1962: 193). The affinity of others for the innovations adopted by innovators, which Rogers refers to as "innovativeness," is ordered along the time continuum, beginning with early adopters, followed by the early majority and the late majority adopters, and finally, by laggards who may never adopt the innovation (Rogers 1962: 19).

According to Rogers, the adoption of technological innovations by farmers usually depends on the relative advantage of the innovation over existing practices—measured primarily in economic terms (Rogers 1962: 312). He adds that relative advantage can be emphasized by crises such as drought-induced crop failure. Clearly, the desire to capture potential economic advantages is a facet of innovation that is especially applicable in the Palliser Triangle. Notwithstanding the foregoing, the apparent economic utility (or relative advantage) of any particular agricultural innovation, while important, can by itself be insufficient to generate widespread adoption. No less important in fostering diffusion are embedded cultural factors (Rogers 1962: 57–75). For example, Rogers contends that the "innovativeness of individuals is related to a modern rather than traditional orientation" and that "an individual's innovativeness varies directly with the norms of his social system on innovativeness" (Rogers 1962: 311).

The RCAD research and the literature on Prairie farm technology shows that the adoption of min till on the Canadian Prairies reflects each of the characteristics just noted. Min till practices offered practical economic and agronomic advantages. Severe drought in the late 1980s made innovation more desirable, and there were important socio-cultural conditions on the Prairies that facilitated its adoption. For example, not only is there a population of active innovators on the Prairies, but hundreds of them have been both inventors and manufacturers of farming equipment. In addition, a pattern of historical learning combined with the utility of numerous previous innovations has fostered a propensity for abandoning traditional practices in favour of new ideas that make economic and agronomic sense.

The data compiled in association with the RCAD project suggest that the min till adoption process was facilitated by cultural values supporting innovativeness, which extend across a wide section of the agricultural population of the Palliser Triangle. Over the past century, innovativeness has become institutionalized—a recognized and valued social characteristic relevant to achieving socially important goals. Dryland farmers in the region understand that being adaptive is a key contributor to the long-term, typically multi-generational, survival of agricultural production units on the Prairies. In other words, adaptive capacity resides within a reflexive process whereby agricultural producers recognize the value of being innovative and understand themselves to be innovators and enthusiastic adopters of ideas they perceive will enhance their resilience. This encourages ongoing innovation and adaptation, further reinforcing the value of the "innovative norm."

The propensity of dryland farmers in the Palliser Triangle to adopt innovations stands as an important dimension of the human capital available to enhance resilience to drought in a dry land. Human capital has been described by the Intergovernmental Panel on Climate Change as one of the determinants of adaptive capacity (IPCC 2001: 893). It includes the knowledge, skills, and expertise available to people dealing with adversity:

> This [human] capital includes not only knowledge obtained in the formal education system, but also local knowledge and experiences that could be used to employ, modify and develop other types of resources. Important in this context of human capital are the capacities to wisely manage materials and human resources, learning from experience, as well as the ability to gain access to and process information. (Warren and Diaz 2012: xviii)

In the context of drought in the Palliser Triangle, the propensity to innovate constitutes a key component of the human capital available for reducing vulnerability and enhancing the sustainability of dryland agriculture.

Historical Learning and Innovation

The discussion that follows in this section describes the evolution of tillage practices on the Canadian Prairies from the 1880s to the present. Table 1 presents a timeline of the adoption of new farming practices and machinery from the innovator to early and late majority stages of diffusion.

The first few decades of the agriculture settlement period in the Palliser Triangle, extending from the mid-1880s until the early 1920s, were relatively drought-free. Prior to the 1920s, one of the few more notable incidences of severe region-wide drought in the settled portion of the Prairies occurred in 1886 (Archer 1980: 102). Nonetheless, a number of influential pioneer farmers and government researchers recognized that farming methods and crop varieties developed in the settled regions of North America and Europe would need to be adjusted to account for the relatively dry average conditions and short growing season typical of the Palliser Triangle.

Archer (1980: 99, 102) writes that during the early phase of the settlement period, "the agricultural potential and limitations of the physical environment were not yet understood, with the result that settlers groped

Table 1. The evolution of tillage technology on the Canadian Prairies

Type of innovation	Approximate date for adoption by innovators	Climate and economic conditions at the innovator stage	Approximate period of early and late majority adoption stages	Climate and economic conditions at the early and late majority adoption stages
Mechanical summer fallowing	Late 1880s	Severe drought in 1885 and dry average conditions/early stages of settlement period	Over the course of the settlement period 1886–1913, as new arrivals became familiar with local practices	The period 1886–1913 had no exceptional episodes of widespread severe drought.
Duck-foot cultivators, one-way disc plows, chisel plows, and hoe drills	1920s	Severe droughts and soil drifting in certain regions, and a decline in grain prices following a peak in 1919	Lengthy adoption period from the 1920s to the early 1950s	Adoption was hampered by drought and low farm incomes in the 1930s and later by shortages of steel due to World War II.
Combination of reduced tillage, seeding, and fertilizer application implements	1950s	Increasing farm size and post-war increase in implement manufacturing	1950s	Increasing farm size and post-war increase in implement manufacturing encourage adaptation

Mega-sized tillage implements and tractors	1970s	The increase in farm size continues.	1970s–1980s	Low farm commodity prices encourage farmers to seek economies of scale through farming more acres.
Continuous cropping and trash conservation	1970s	Severe widespread drought in late 1980s hampers adoption until moister conditions return.	1990s	Low farm commodity prices encourage farmers to seek economies of scale through farming more acres.
New crops and varieties facilitate continuous cropping via rotations)	1970s	Severe widespread drought in late 1980s hampers adoption in drier regions until moister conditions return.	1990s	Low farm commodity prices encourage farmers to seek economies of scale through farming more acres. Marketing companies begin offering contracts for specialty crops.
Min till air seeder technology along with advanced minimum tillage and packing tools	1980s	Prairie manufacturers master the technology, but severe drought in late 1980s affects rate of adoption.	1990s	Equipment purchased in the 1960s and 1970s is exceeding useful life spans, and air seeders allow for combined operations with large minimum tillage type equipment.
Chem fallow, trash conservation, and larger chemical applicators	1970s	The high cost of herbicides and low farm commodity prices retard adoption.	1980s–1990s	A 50% decline in herbicide prices and high diesel prices makes chem fallow economically attractive.

toward a suitable agricultural technology." Archer adds that the conditions settlers encountered on the Prairies required them "to adapt or leave."

That initial phase of adaptation involved collaboration between inventive farmers and agronomists working for the federal government. Farmer-agronomist collaboration is reflected in the adoption of regular summer fallowing as a method for conserving moisture, controlling weeds, and enhancing crop yields in a dry country. One of the early experimenters was Angus MacKay, whose fields left fallow in 1885 produced relatively good wheat yields despite drought conditions in 1886. MacKay's innovativeness was recognized by the federal government, which placed him in charge of one of the first agricultural research stations established on the Prairies in 1887. Similarly, Marquis Wheat—a quicker-ripening variety suited to dry conditions and the short growing season on the Prairies—was developed through the combined efforts of farmers (the Saunders family) and the Dominion Experimental Farms (Archer 1980: 102, 121).

According to Archer (1980: 102), notwithstanding the subsequent adoption of locally developed innovations, agricultural practices in western Canada during the settlement period "were largely an extension of traditional [eastern and mid-western North American] methods of wheat cultivation" (see also Ward 2011: Dale-Burnett 2002; Wetherell and Corbet 1993). Imported moldboard plows and peg and disc harrows were the principal tillage tools during the settlement period (Ward 2011: 149; Wetherell and Corbet 1993: 121). By the early 1920s, duck-foot cultivators and chisel plows were beginning to replace moldboard plows and disc harrows for use in summer fallowing and seedbed preparation. Experience with dry conditions suggested that plowing followed by excessive harrowing dried and pulverized the soil, making it subject to wind erosion and moisture loss. A series of droughts during the 1920s in southern Alberta and southwestern Saskatchewan had confirmed this for a growing number of producers. The nine dry years of the 1930s made the observation apparent to many more.

Growing interest among farmers in new tillage implements and practices was supplemented by the efforts of government and university extension agrologists. The PFRA, established by the federal government in 1935, promoted the use of strip farming and the establishment of treed shelterbelts to reduce wind erosion. The PFRA also developed irrigation projects in the handful of neighbourhoods where reasonably dependable surface water supplies were available. The PFRA also took thousands of acres of lighter land (presumed to be unsuited to annual field crop agriculture) out of crop production altogether, reseeding it to grass and establishing community pastures (Gray 1967; see also Chapter 8 by Marchildon in this volume).

A number of locally designed innovative tillage implements were developed on the Canadian Prairies in response to drought conditions in the 1920s and 1930s. Prominent innovations included the Noble blade, the one-way disc plow, the rod weeder, and a variety of high-clearance cultivators (including duck-foot cultivators and chisel plows). Nearly all of these new implements were being designed and manufactured by innovative farmers and machine-shop operators located on the Canadian Prairies (Wetherell and Corbet 1993: 120–121). The development of these implements reflected the beginnings of a shift in practice away from "black summer fallowing," whereby fields were tilled and harrowed to the point that weeds and crop residues were no longer visible on a smooth, clean soil surface. The new thinking supported tillage methods that retained trash (stubble and crop residue) on, or at least near, the soil surface—and left an irregular as opposed to smooth soil surface (Wetherell and Corbet 1993: 118). An important goal of these innovations was to reduce wind-driven soil erosion—a particularly serious problem during drought years. However, the adoption of these implements throughout the farming community was delayed by adverse on-farm economic conditions during the Depression of the 1930s and by limits on the availability of steel for farm implement manufacturing during World War II (Warren and Diaz 2012: 43; Dale-Burnett 2002; Wetherell and Corbet 1993). The first post-war decades coincided with a return to relative prosperity on the farm, enabling producers to take full advantage of innovations such as the combine harvester and improved tillage equipment, which had been invented as far back as the 1920s.

A farmer who participated in the RCAD project described how learning based on experience with severe drought prompted the development of new approaches to soil management. In this instance, the drought which encouraged adaptation occurred in 1961—a year of severe widespread drought in southern portions of the Palliser Triangle:

> There have been some important changes in farming since I started and a number of them were prompted by drought. We used to summer fallow 50–50 around here. In 1961 there was a serious drought. The ground dried out and the wind blew the dirt away right down to the hard pan in places. It blew out whole 40-acre strips in places. In some places dirt drifted up over the top wire on fences. To this day you can still see the effects. I can still show you which fields were in summer fallow that year. And once the topsoil is gone, it's gone. Oh sure, it is starting to come back in places, but it will never be back to what it was in my lifetime. . . That's the sort of experience that led people to come up with solutions like minimum tillage and continuous cropping. Adaptations like those were borne out of necessity. . . Years like 1961 taught my dad that summer fallowing just so you could watch your topsoil blow away afterwards was a good way to go broke. (Warren and Diaz 2012: 5)

Local Innovation and Local Farm Equipment Manufacturing

The adoption of new tillage technologies was supported by the development of a regional farm equipment manufacturing industry on the Canadian Prairies. Local manufacturers understood their neighbours' needs and produced equipment suited to the region's climate and soil conditions. Wetherell and Corbet (1993) indicate that the growth of the local implement manufacturing industry was spurred in part by the reluctance of most major farm machinery manufacturers based in central North America to develop equipment specifically suited to dryland farming on the Canadian Prairies (and the northern plains of the United States). Major manufacturers apparently did not consider the northern plains to be a large enough market to warrant investment in new regionally specialized lines of implements. Farmers and repair shop operators on the Canadian Prairies perceived the value of new types of tillage equipment and were well positioned to cost-effectively service local markets. The region's harsh winters had an influence as well. With several months of downtime, when field work was impossible, innovative farmers had the time to think and tinker.

Rogers (1962: 196) reports that well-equipped farm shops and a population of mechanically adept farmers contributed to the pace of innovation and adaptation in North American farming communities. This was clearly the case on the Canadian Prairies, where mechanical aptitude and the availability of shop equipment, particularly welding equipment, contributed to on-farm modification of existing machinery and the invention of new implements.

One of the RCAD project respondents epitomized the level of mechanical and welding skills resident in the farm population of the region. In 1955, this respondent and his neighbour purchased a dilapidated antique well drilling rig, refurbished it, and dug hundreds of water wells in their neighbourhood. In addition to being able to repair and modify his own farm equipment, this respondent put his technical skills to work for his community.

> I suppose . . . having the ability to meet our own well drilling needs here in the neighbourhood says something about our ability to respond to different challenges. We've done a lot of that sort of thing in this area. Back when I was Reeve. . . we decided we needed a new fire truck for the RM [rural municipality]. Buying one was too expensive so we got together, modified a used truck and had ourselves a fire engine. I was on the rink board when we decided we should get a Zamboni. Well, as usual, money was tight so we got an old Volkswagen car and converted it into a Zamboni. When I was on the hospital board we found ourselves in need of an ambulance. For some time we'd been borrowing the hearse from the local funeral home and that wasn't always the best situation. So, we built our own ambulance by modifying a van. (Warren and Diaz 2012: 45)

An early adopter of min till practices interviewed for the RCAD project described how the capacity to develop and modify machinery on the farm contributed to adaptation:

> We got into continuous cropping on this farm by the mid-70s. In fact my dad put together a little invention of his own to help us do it. We were having trouble running our hoe drills through stubble. The disturbed stubble was piling up and plugging up the works. It was like you were pulling a rake. He rigged up a cycle mower blade run by the power take-off that rode ahead of the drills and cut the stubble off so it would be reduced enough to pass easily through the drills. . . Some years later I was looking over the new inventions on display at the *Farm Progress Show* in Regina [Canada's largest annual farm machinery exhibition] (I try to get over there to see that when I can). There was a guy there with the exact same deal on display—a mower blade that travelled ahead of the drills. I told him he was behind the times. (Warren and Diaz 2012: 5)

As noted above, over the course of the twentieth century, a growing population of farmer-inventors and repair shop operators began supplementing their incomes by building and marketing farm equipment. By the early 1990s, 267 farm equipment manufacturers were reported to be in business on the Canadian Prairies (Wetherell and Corbet 1993: 231–52).

Difficult times in agriculture resulting from drought and low commodity prices, combined with the relative hardships of rural versus urban life, contributed to a significant reduction in the number of farmers in the Palliser Triangle region. The number of people living on farms in Saskatchewan, for example, peaked at 573,894 in 1936. By 1951, only 398,279 people were living on 119,451 farms in Saskatchewan. The number of farms in Saskatchewan declined to 60,000 by the close of the 1980s, and, as of 2011, the number of farms in Saskatchewan was 36,952 (Saskatchewan Ministry of Agriculture 2015; Shepard 2011: 182, 183).

Those farmers who remained in business in the immediate post–World War II period were typically farming more land. It was assumed that economies of scale could improve the profitability of farms. The relative dearth of farm labourers during World War II and into the post-war period stimulated the adoption of labour-saving technology. These pressures prompted the invention and diffusion of new tillage and seeding machinery that combined two or more functions into a single implement and field operation.

For example, seeding equipment was attached to minimal soil disturbance tillage implements, such as the one-way disc plows already coming into widespread use. Saskatchewan-based Canadian Co-operative Implements began manufacturing discers with attached seed boxes in 1950—the first major manufacturer in North America to do so. Mounting seeding and packing attachments to discers and cultivators allowed farmers to combine pre-planting tillage, seeding, and seedbed packing into a single operation—saving person-hours (always an important consideration on the Prairies given the short growing season) and diesel fuel. The hoe drill was the second most popular seeding implement in use on the Prairies prior to the 1990s (after disc seeders). By the 1980s, farmers were experimenting with tillage tools and soil packers that allowed them to seed with hoe drills without having to pre- or post-till the seedbed (a min till practice referred to as direct seeding). While disc drills kept trash close to the soil surface, appropriately modified hoe drills left more residue directly on the surface.

The need to cover more acres within the short growing season available on the northern plains prompted local manufacturers such as Olaf Friggstad of Frontier, Saskatchewan, to manufacture and market huge tillage implements, including one of the largest field cultivators (80 feet) ever marketed in North America. Larger implements required larger tractors, and manufacturers on the US and Canadian northern plains responded in the 1970s and 1980s by building large, articulated four-wheel drive tractors—years ahead of the major full line equipment manufacturers (e.g., Versatile Manufacturing of Winnipeg, Manitoba; Steiger Tractor of Fargo, North Dakota; and Big Bud Tractors of Havre, Montana).

An RCAD project respondent recalled the move to larger tillage machinery that occurred on the Prairies in the 1970s and 1980s:

> I can't recall exactly who started the minimal till thing around here. I remember that just before minimal till caught on, the race was on to buy bigger cultivators. Buy as many feet of cultivator as you can, that was good management then. We've got one of the biggest cultivators ever made, we've got an 80 footer. But then it turned out that it was better to summer fallow with chemicals instead of cultivators. I can't say precisely when that was we began to use chemical summer

> fallow, but it was back in the Glean [a brand name herbicide] days, maybe the early 90s. (Warren and Diaz 2012: 35)

By the close of the 1980s, Prairie equipment manufacturers had made considerable strides in developing air seeder technology. Companies including Ezee-On Manufacturing of Vegreville, Alberta; Bourgault Industries of St. Brieux, Saskatchewan; and Saskatoon-based Flexi-Coil, among others, had developed implements that combined high-capacity seed/fertilizer tanks, pneumatic seed delivery systems, and large tillage equipment. New tillage and packing tools were developed in conjunction with pneumatic seed delivery, allowing for minimal disturbance of trash and soil and precision application of fertilizer and seed in a single operation.

A parallel development in the post-war period was growth in the use of chemical fertilizers, herbicides, and pesticides (Argue et al. 2003). After decades of farming, which included periods of drought-induced soil erosion, farmers in the post–World War II period increasingly relied on fertilizer to replace depleted soil nutrients. New chemical herbicides and pesticides capable of controlling weeds and pathogens in growing crops and on summer fallow were becoming available and were marketed to farmers. Not surprisingly, new implements were developed for applying fertilizer, herbicides, and pesticides on increasingly larger farms. A number of manufacturers on the Canadian Prairies specialized in manufacturing large-capacity field sprayers, and as noted above, tillage implements were adapted to combine seeding and fertilizer application operations (Wetherell and Corbet 1993: 152–57).

An initially controversial innovation receiving attention during the post-war period was continuous cropping. A minority of farmers and agrologists had begun to challenge long-standing conventional wisdom regarding the need to leave land fallow every other year or every third year. A farmer from southern Saskatchewan described how his family became early adopters of continuous cropping and other min till practices in response to drought conditions in the 1960s:

> Summer fallow was supposed to be a great moisture conservation measure. But it didn't help you much if your soil blew away. The best Dad did when summer fallowing, the best crop I think he ever grew, was probably about 35 bushels an

> acre. Okay, but it took him two years to grow that. When you divide that by two it gives you 17½ bushels an acre. So with continuous cropping I'm getting 20, 24 bushels an acre. Sure, you'd maybe get more out of a summer fallow crop. But I still get my 20–24 bushels per acre and I get it every year. So the summer fallow guy, he's getting his 35 once every two years. I'm getting my 40 or 50 when you take it over two years. You don't have to be a rocket scientist or mathematician to figure that one out. (Warren and Diaz 2012: 4, 5)

By the late 1980s, government researchers were conducting studies that questioned the benefits of tilled summer fallow. In its 1987 *Guide to Farm Practice in Saskatchewan*, Saskatchewan's Department of Agriculture was reporting on studies from the federal research station at Swift Current, Saskatchewan, which suggested that leaving standing stubble on fields over the winter was possibly a more effective method for retaining moisture than leaving land idle for a year as tilled summer fallow (Saskatchewan Agriculture 1987: 100). Researchers had begun to speculate that the increased yield effects associated with summer fallowing were more likely due to the nitrogen-accumulating effects of tilled summer fallow than to the long-held assumption that it was entirely the result of moisture retention. If this was indeed the case, it could prove more cost-effective to forego summer fallowing in favour of continuous cropping combined with increased applications of nitrogen fertilizer. As we have seen, summer fallowing had been among the first innovations adopted by farmers on the Prairies during the early days of settlement. Now it appeared that it was a traditional practice that should be abandoned in the face of new and better information—and that is precisely what would happen on a large scale in the 1990s.

The series of dry years experienced in the 1980s frustrated proponents of continuous cropping. However, evidence was mounting that, under average moisture conditions or even moderate drought, continuous cropping could out-produce summer fallow farming—particularly in moister areas of the Palliser Triangle.

An RCAD respondent reflected upon the diffusion of continuous cropping in his neighbourhood:

> I knew a guy who was an early adopter of continuous cropping, but he was trying it in the 80s and it wasn't working. The idea was right but it was just too dry. Everybody was looking and saying, "see it doesn't work." But on further reflection people started to say, "I think it would have worked but we needed a little bit more rain." (Warren and Diaz 2012: 92)

The Convergence of Forces in the Early 1990s

By the mid-1980s, the technological ingredients required to support the family of minimum tillage technologies in use today were essentially in place. Nonetheless, the explosion of widespread adoption, typical of the early and late majority phases described by Rogers (1962: 11), did not occur until the 1990s. Farmers interviewed for the RCAD (2012) project and by Warren and Diaz (2012: 5–6, 35, 60–61) attributed the rapid pace of change in the 1990s to the convergence of several key factors, including

- heightened interest in increasing drought resilience in the aftermath of the severe droughts of the 1980s;
- availability and awareness of locally manufactured, specialized minimum tillage and seeding equipment and chemical applicators suited to the large farm sizes typical of the Palliser Triangle region;
- a significant reduction in the cost of glyphosate herbicides in the early 1990s (i.e., glyphosate dropped in price from approximately $25 per litre in the 1980s to $10 per litre in the 1990s), which made chemical summer fallowing for weed control more cost-competitive with mechanical summer fallowing practices reliant on higher diesel fuel consumption and more labour;
- research and promotional activities, including on-farm field days, of farmer-operated soil conservation associations (sometimes supported by government extension agrologists, local manufacturers, and herbicide marketers), which en-

couraged min till practices including greater use of continuous cropping and chemical summer fallowing;

- development and promotion of new crop varieties such as pulses (annual legumes such as peas, beans, and lentils) that facilitated continuous cropping through crop rotations; and
- a population of innovative farmers and ready adopters who were amenable to developing and implementing new farming practices.

One of the notable differences in the pattern of diffusion associated with min till in the 1990s and previous phases of agricultural adaptation on the Prairies was the relative increase in the influence of farmer innovators as opposed to innovation co-led by extension agrologists from universities and government. While government agencies contributed funds toward the field testing of min till techniques and new crop varieties, government-backed crop insurance programs initially penalized producers who experimented with continuous cropping. Also of significant importance was the role played by Prairie manufacturers who built and marketed the necessary equipment and by chemical manufacturers and distributors who encouraged the shift to more chemical-intensive agriculture.

Min Till as the Product of an Adaptive Culture

The converging factors described above correspond to characteristics that Rogers (1962: 124–33) attributes to innovations that are likely to be widely adopted. These characteristics include the relative advantage offered by the innovation, often measured in terms of its ability to enhance economic profitability. Min till practices met this criterion by virtue of their capacity to conserve moisture, sustain yields, and protect soil from erosion more cost-effectively than conventional practices.

Another characteristic identified by Rogers (1962: 57–75) is the compatibility of an innovation with the values and past experiences of the adopters. This characteristic is reflected in the historical pattern of adaptation and the wide acceptance of inventiveness and adaptability as positive social attributes on the Canadian Prairies. An important contributor to the adaptive culture is the fact that most farms operating on the Prairies are second- or third-generation operations. Intergenerational learning within families and communities has contributed to an appreciation of adaptation as an iterative process that has helped enable succeeding generations to survive in agriculture. The valuable lessons provided by previous generations are not so much the particular innovations they adopted, but that they were flexible enough to adapt.

A producer from Wardlow, Alberta, reported that the experience of earlier generations was valuable because it demonstrated that being prepared to do things differently than one's antecedents was integral to survival—and indeed it was that attitude which enabled subsequent generations of survivors in agriculture to succeed:

> There are plenty of things that the older generations of ranchers and farmers learned about how to survive in this country and you have to respect that. But you don't want to get into that mindset where you start to think their way is the only way. It's tough to make a buck in this industry, and it doesn't seem to be getting any easier . . . The point is, you need to keep adapting if you want to survive. A fellow told me one time that if you run into one of these guys who says, "If it was good enough for grandpa, and it was good enough for dad, it is good enough for me," you can bet if he carries on like that, before too long there will be a "For Sale" sign on his gate. (Warren and Diaz 2012: 249)

An early adopter of min till technology characterized the reflexive mindset required for survival in family farm agriculture as *planning that accommodates flexibility*:

> You need to spend some time on your butt thinking . . . A lot of fellows get into trouble because they fly out into the field and go to work without thinking. Another thing is to always have a plan B. Don't go down the road there, with hard and fast rules that this is what's going to be done come hell or high water. You've got to stay flexible and roll with the punches. You have to stay flexible or you're history. (Warren and Diaz 2012: 5)

Interestingly, farmers interviewed for the RCAD project sometimes employed the language and concepts used by academics to describe the diffusion of innovations. Echoing Rogers' (1962: 196) characterizations, inventors, innovators, and early adopters from the Palliser Triangle understand that they march to a different drummer and are somewhat deviant—but that theirs is a socially beneficial form of deviance. A farmer who was active in the promotion of min till practices in southwest Saskatchewan in the 1980s and 1990s describes how innovators appreciate that their early efforts can be met with skepticism but nonetheless proceed:

> And of course there are those bright, eccentric, inventive farmers that you find here and there around the country who aren't afraid to be criticized by their neighbours for trying something radically different. I recall talking to one of the first direct seeders in the country, a fellow who farmed up near Biggar. He told me how at first people thought his new methods were pretty goofy, but within a short time virtually everyone was into direct seeding. He said, "I went from wing nut to innovator in about five years." (Warren and Diaz 2012: 60)

Many of the dozens of producers interviewed in connection with the RCAD project understood the importance of innovation and adaptation to survival in Prairie agriculture. They also demonstrated an understanding of how the process works. The following comments are not untypical:

> That's what happens, out of necessity somebody comes up with a new idea. His neighbours watch him for a while to see if it really works, and if it does, before long they're doing it too. That's what's happened with lots of equipment. I remember the first time I saw an air seeder. A fellow had one in at the *Farm Progress Show* one year and before long all sorts of companies like Flexi-Coil were making them. It was the same with Friggstad's from Frontier [Saskatchewan], they came up with a better header [a harvest machinery attachment] and pretty soon other people wanted them too. Some farmers are good at doing that in this country, not all the good ideas come from the universities or government research stations—we

> come up with a lot of them on the farm; especially new machinery. (Warren and Diaz 2012: 5)

Currently, min till practices have been adopted by most dryland farmers in the Palliser Triangle. Bruneau et al. (2009: 143) report that as of the first decade of the twenty-first century, conventional tillage was used on just 18% of the cropland in Saskatchewan and 25% in Alberta. Given that there are moister cropland areas outside the boundaries of the Palliser Triangle in both provinces, it is reasonable to assume that within the drier regions the proportion of farmers using min till is higher than the proportions reflected in the provincial averages.

Laggards as Innovators

Rogers (1962) contends that innovators, opinion leaders, and early adopters tend to be more cosmopolitan and modern in their thinking compared with those who are especially slow to adopt a new idea. There are indeed dryland farmers operating in the Palliser Triangle who have not fully embraced min till technology. That being said, many of these producers do not consider themselves to be atavistic Luddites but rather as innovators in their own right. They reject the heavy use of herbicides and chemical fertilizer associated with min till, preferring to farm organically. Organic producers interviewed in association with the RCAD project argued that chem fallow and continuous cropping were inimical to soil health—the very thing that those methods were intended to protect. Also influential are the human and ecological health concerns that organic farmers and many consumers associate with agricultural chemicals. Another detriment identified by RCAD respondents and the literature is that the cost-effective implementation of min till technology depends on the prices of fertilizers and chemicals, which are largely beyond the control of individual farmers (Argue et al. 2003). A spike in these prices has the potential to reduce the economic advantages of min till relative to mechanical weed control and summer fallowing.

The fact that min till mitigates wind-driven soil erosion during droughts is generally considered to be an environmental benefit. However, organic producers contend that this advantage needs to be considered within the context of the environmental problems it exacerbates.

For example, the increased application of fertilizer required under min till farming has been identified as a factor that contributes to eutrophication (nutrient pollution) in prairie lakes (Environment Canada 2014; Carpenter et al. 1998).

Organic farmers argue that their products can obtain premium prices from health-conscious and environmentally conscious consumers, which offset differences in yield. They have, indeed, developed niche markets throughout North America and in Europe. One might reasonably assert that their ingenuity as marketers is equivalent to that of conventional min till producers. Notwithstanding the relative strength of the arguments advanced by organic agriculture over chemically supported agriculture, organic producers remain a minority of the farming population in the Palliser Triangle. For example, as of 2013, approximately 2,000 certified organic farms were operating in Saskatchewan, out of a total of about 37,000 farms (Saskatchewan Ministry of Agriculture 2013).

Organic farmers do not view themselves as backward-thinking but rather as innovators striving to avoid widespread maladaptation. Indeed, some RCAD respondents wondered whether the success of min till might encourage a sort of drought-defying hubris whereby overconfident farmers break lighter, erosion-prone land that had been seeded to grass in the wake of the droughts of the 1930s (RCAD 2012). Shifting land from permanent grass cover to cultivation was reportedly occurring at some locations in southwest Saskatchewan. The suspected danger is that crops and soil resources on this type of land could be vulnerable to erosion under severe drought conditions that exceed recent experience on the Canadian Prairies. Min till is assumed to have enhanced drought resilience since the 1980s. However, none of the droughts occurring since the 1980s have lasted as long as the drought of the 1930s or the megadroughts identified in paleoclimatic records by Sauchyn and Kerr (see Chapter 2 in this volume).

The min till versus organic debate suggests that Rogers' characterization of laggards may not apply to everyone who fails to innovate. Rogers' classification casts laggards as less cosmopolitan and economically astute than early adopters. These aspersions would be difficult to apply across the board with respect to organic producers in the Prairie provinces. That being said, during a long and severe drought the ongoing use of mechanical summer fallowing in organic farming on the Prairies would contribute to soil erosion and a reduction in drought resilience.

Conclusion

Agricultural producers in the Palliser Triangle have been adapting to dry conditions and drought for over a century. Farmers in the region understand that survival in agriculture under dry climate conditions, drought, and frequently unfavourable markets has benefited from adopting a series of technological innovations. Within the dryland farming community, innovation and adaptation are well understood and valued processes. Multi-generational survival of farming units is a matter of some pride, especially since tens of thousands of family operations have failed to survive. The governments of Alberta, Saskatchewan, and Manitoba honour "century farms"—operations that have remained under the ownership of the same family for 100 years. Multi-generational survival suggests that intergenerational transmission of adaptive capacity has occurred.

The capacity to innovate is a matter of considerable pride as well. The contributions of farmer innovators, including those who developed local machinery manufacturing concerns such as Charles Noble, George Morris, Olaf Friggstad, and many others, are widely recognized. Innovation and the diffusion of innovations have been enhanced by the recognition of flexibility and adaptability as important values, as well as by the technological and mechanical proficiency available in dryland farming communities in the region. These are important facets of the human capital available in the region that have facilitated drought resilience, reducing vulnerability under the range of climate conditions experienced over the past century. Indeed, the adaptation-enhancing features of the culture of agriculture on the Canadian Prairies are largely consistent with Rogers' contention that innovativeness "varies directly with the norms of his social system on innovativeness" (Rogers 1962: 311). Whether these cultural assets will prove sufficient in providing the resilience required to adapt to the climate conditions projected for the upcoming century is unclear (see Chapter 3 by Wheaton et al. in this volume)—but they should help.

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CHAPTER 6

THE TROUBLED STATE OF IRRIGATION IN SOUTHWESTERN SASKATCHEWAN: THE EFFECTS OF CLIMATE VARIABILITY AND GOVERNMENT OFFLOADING ON A VULNERABLE COMMUNITY

Jim Warren

Introduction

Irrigation has facilitated the development of agriculture in many of the world's drier regions. It is often associated with areas where agricultural production would be difficult or impossible without the water resources and infrastructure that allow for the delivery of water to land that receives inadequate precipitation to support crops. Similarly, in areas such as the Palliser Triangle, the driest region in the Canadian Prairies, where precipitation can be unreliable, irrigation purportedly allows for crop production in those years when rainfall is scarce. The ability to irrigate in a region that experiences periodic severe droughts might reasonably be considered to be the consummate adaptation to drought. However, the experience of farmers and ranchers in the southwest corner of Saskatchewan demonstrates that investment in irrigation infrastructure alone does not always ensure drought resilience.

The history of irrigation in this region underlines the importance of context when considering the utility of various strategies for enhancing drought resilience. In Chapter 5 on min till in this volume, we observe how the adoption of new farming practices and machinery has reduced the impact of drought on crop yields and soil health in the context of dryland annual field crop production. The adoption of min till practices was attributed in part to the adaptive proclivities of dryland farmers and local machinery manufacturers. However, climate and soil conditions in portions of the southwest corner of Saskatchewan are frequently different from those areas where min till farming is predominant. In the southwest, cattle ranching is the dominant agricultural activity, partly because local conditions are frequently considered too dry to facilitate dryland crop production. Thus, the adoption of grazing-based agriculture stands as one of the principal long-term adaptations to drought in the region. Dry conditions also limit the ability of ranchers to produce dryland hay to feed their cattle over winter. Irrigation is attractive since irrigated hay land typically produces yields that are 200% or more above those available from dryland hay production. Furthermore, irrigation supposedly ensures that hay crops will not fail due to the moisture deficits normally associated with agricultural drought.

Notwithstanding the purported drought resilience available through irrigation, the fortunes of irrigation agriculture in Saskatchewan's dry southwest have been frustrated by three consecutive decades of hydrological drought—reflected in low streamflows and reservoir levels. From 1979 until 2010, there were several years when irrigation farmers in the southwest of the province struggled with reductions in the amount of water available for irrigation and, in some years, had to contend with a total lack of water (RCAD 2012: 23–29; Warren and Diaz 2012: 124–49, 322–30). The changing availability of water illustrates the impact of a significant reduction in the value of natural capital available to ranchers in the region.

Infrastructure improvements, which promised to compensate for reduced water availability in the 1990s and 2000s, have not been made (Warren and Diaz 2012; PFRA 1992). The effects of this irrigation infrastructure deficit have been exacerbated by the Canadian government's decision to end its six-decade history of financial and technical support for irrigation infrastructure in southwest Saskatchewan. It is uncertain whether the necessary investments in infrastructure enhancement can be made without support from senior government. This situation reflects a significant decline in the institutional capital available to producers in their efforts to deal with drought.

The experience of irrigators in Saskatchewan's southwest presented in this chapter also demonstrates how understanding drought through the lens of appropriate definitions (as discussed in Chapter 1 of this volume) is beneficial in appreciating its impacts on communities. The previous chapter on min till shows how changes in tillage technology moderated the impacts of agricultural drought under dryland farming conditions. However, we find that irrigated forage production in southwest Saskatchewan is primarily vulnerable to hazards associated with hydrological drought, such as low streamflows and reservoir levels. Indeed, there have been many years in which well-timed precipitation allowed for normal grazing and average dryland farming yields in the region, yet at the same time irrigation activity was reduced. Later in this chapter we will see how the failure of a government support program to extend assistance to producers under a 2010 drought support program was in part a failure to adequately consider the effects of hydrological drought on forage production.

The previous chapter emphasized the resilience-enhancing benefits of a culture of innovation on the capacity of dryland farmers to adapt to drought. That process demonstrated the importance of human capital for communities adapting to drought. The innovations associated with min till were attributed in large part to local farmer innovators and machinery manufacturers on the Prairies. These innovations were not driven primarily by the institutions and agencies of government. While governments occasionally supported the adoption of min till, they also put barriers in the path of innovators in the form of crop insurance penalties.

In the case of irrigation in southwest Saskatchewan, government agencies assumed responsibility for most infrastructure development after the 1930s (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). Systems that had been developed by farmers and ranchers without government assistance in the first decades of the twentieth century were largely absorbed into the government-managed irrigation projects. The assessment presented in this chapter suggests that government involvement, while necessary for the creation of many projects, did not require producers to engage in self-reliant innovation to the same degree as their dryland counterparts. Some observers suggest that this may have contributed to an unhealthy dependency, which is now inhibiting the development of producer-driven solutions to the region's irrigation problems. Producer reliance on government support for irrigation is especially troublesome today, as Canada's governments reduce financial support for primary agricultural production.

In summary, this chapter describes how drought resilience of irrigation farmers in southwestern Saskatchewan has declined due to a combination of forces, including hydrological drought, infrastructure deficits, poor system management, low cattle prices, rising input costs, and the unwillingness of senior governments to provide ongoing support for irrigation. It also suggests measures that could enhance the coping capacity of irrigators in the region. Furthermore, it contends that the mixed success of irrigation in the region underlines the importance of incorporating long-range climate records and forecasts into adaptation planning.

The chapter relies on a substantial store of ethnographic field research data produced in association with the Rural Communities Adaptation to Drought (RCAD) project (RCAD 2012) and the Institutional Adaptation to Climate Change project (IACC 2009), and collected by Warren and Diaz (2012).

Historical and Climatic Context

When the Canadian federal government responded to a succession of severe droughts on the Prairies during the 1930s, the development of irrigation infrastructure was one of the pathways it took to increasing the drought resilience of farmers. In 1935, a new federal government agency, the Prairie Farm Rehabilitation Administration (PFRA), was established to ameliorate the combined effects of a succession of years that featured low prices for farm commodities and crop failures due to drought (Gray 1967; see also Chapter 8 by Marchildon in this volume). Over the course of the next six decades, the PFRA developed and operated 11 irrigation projects in southwestern Saskatchewan, providing irrigation opportunities for hundreds of farmers and ranchers. However, in 2007, the PFRA informed the producers who rely on these projects that it intended to abandon its irrigation responsibilities and turn the project infrastructure over to the irrigators (Warren and Diaz 2012: 322–30). The impacts of that departure are described later in this chapter, following a brief overview of the development of irrigation agriculture in Saskatchewan and Alberta.

Irrigation before PFRA

Prior to the megadroughts of the 1930s, farmers, ranchers, and farmland speculators had developed a number of individual (single farm) irrigation systems as well as larger, multiple-user projects (Warren and Diaz 2012: 245; SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). Two natural conditions prompted development of irrigation systems on the Canadian Prairies. First, these systems tended to emerge where conditions were driest—areas such as the Palliser Triangle, where even in years when moisture conditions were average, crop yields were low compared to less dry portions of the Prairies (see Chapter 8 by Marchildon in this volume). Second, development relied on the availability of readily accessible source water. An area with an especially dry climate adjacent to a reliable stream was the most likely sort of neighbourhood to acquire an irrigation system (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004).

Agricultural pioneers on the Prairies of what would become southern Alberta had access to several reliable streams originating in the Rocky Mountains and their foothills. In southern Alberta, farmers and ranchers choosing to irrigate sometimes developed individual private systems, but more often, they partnered with neighbours to share the cost of constructing and maintaining the necessary "works"—the infrastructure required for irrigation such as dams, reservoirs, canals, and ditches. Real-estate speculators, including the Canadian Pacific Railway (CPR), also invested in the development of multiple-user irrigation projects. The CPR anticipated that the availability of irrigation would attract immigrants and traffic to some of the drier regions traversed by its rail lines. As the surrounding communities became settled, the railway's irrigation infrastructure was transferred to producer-operated district irrigation associations (Warren and Diaz 2012: 245; Brownsey 2008; SIPA 2008a, 2008b, 2000; Saskatchewan AgriVision 2004).

Irrigation developed at a much slower and more erratic pace in the section of the Prairies that became the province of Saskatchewan. In the drier regions of Saskatchewan, where investment in irrigation made the most agronomic sense, reliable supplies of source water were far less abundant than was the case in southwestern Alberta (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). Exceptions included lands transected by the South Saskatchewan River and streams originating in the Cypress Hills. One of the first multiple-user irrigation projects in Saskatchewan was developed in 1903 by the Richardson and MacKinnon families along Battle Creek between the Cypress Hills, where the creek originates, and the boundary with the United States (SIPA 2000: 8, 9).

The creation of the PFRA facilitated a significant increase in irrigation development on the Canadian Prairies. Federal funds and engineering expertise were directed at expanding and intensifying irrigation activity in Alberta and Saskatchewan. In Alberta, new project areas were brought on-stream with PFRA support, including those near the communities of Rolling Hills and Brooks (Gray 1967: 199; see also Chapter 8 by Marchildon in this volume). From the late 1930s on through the 1940s and 1950s, the PFRA built dozens of dams and reservoirs in Alberta and Saskatchewan, along with 11 flood irrigation projects in the dry southwestern corner of Saskatchewan (SIPA 2008a; 2000).

Most of the PFRA's irrigation projects in southwestern Saskatchewan were supplied by streams originating in the Cypress Hills. Flows on these streams were assumed to be reliable enough to support irrigation, and until 1979, they essentially were (Warren and Diaz 2012: 124–49, 322–30). Streamflows in the southwestern corner of Saskatchewan are considerably smaller than those that supplied irrigators in southwestern Alberta. Consequently, the total area irrigated in southwestern Saskatchewan was much smaller than in Alberta. The difference in the scope of irrigation activity in the two provinces has persisted to the present. Approximately 1.3 million acres of land is irrigated in Alberta compared with just 350,000 acres in Saskatchewan (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004).

As far back as the 1930s, it was widely assumed that the amount of irrigated land in Saskatchewan would expand exponentially if infrastructure was developed to provide farmers with access to flows on the South Saskatchewan River. Since that river originates in the Rockies, its flows are less vulnerable to drought than streams that originate in the Palliser Triangle. PFRA planners supported by powerful political champions of Prairie agriculture envisioned a massive dam and reservoir project on the South Saskatchewan River as a means to launch much larger irrigation projects in Saskatchewan (Herriot 2000; Archer 1980). Construction work on the South Saskatchewan River Dam project (now Gardiner Dam and Lake Diefenbaker Reservoir) began in 1959, and by the early 1970s, infrastructure was in place to facilitate the development of Alberta-size irrigation projects in Saskatchewan. By the close of the 1980s, over 20,000 acres of land were under irrigation in the Outlook area (SIPA 2008a).

Nonetheless, irrigation proponents were disappointed in the rate of irrigation uptake by farmers who had access to Lake Diefenbaker water. There was far more water and irrigation infrastructure available for use in the Lake Diefenbaker area than farmers willing to use it. Low uptake was attributed, in part, to the fact that irrigation works associated with Lake Diefenbaker were located in an area that straddled the northern boundary of the Palliser Triangle, where moisture conditions allowed for the production of acceptable crops using less capital-intensive dryland methods (Suderman 1966).

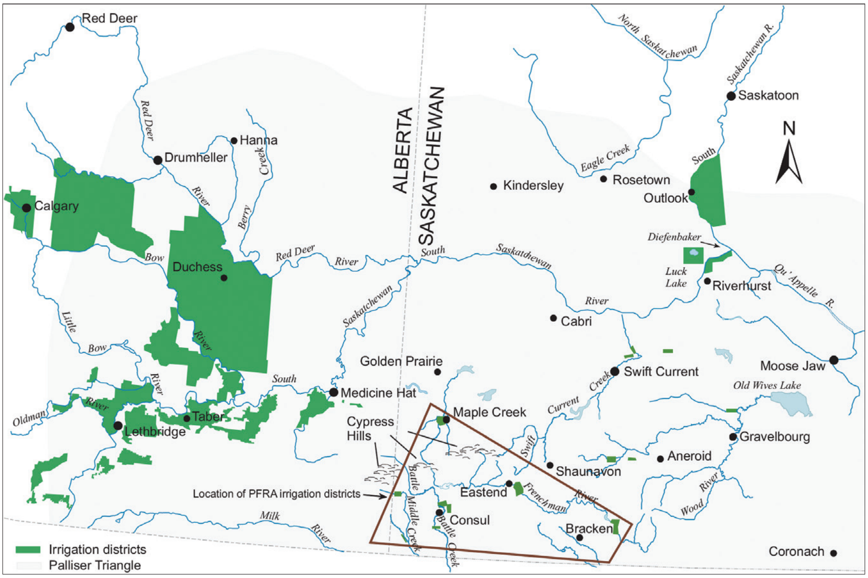
Notwithstanding the disappointing growth in the number of farmers irrigating, the Lake Diefenbaker projects provided irrigators with highly reliable water supplies. Producers were essentially able to apply as much water as they wanted whenever they wanted it. This was not the case for the PFRA projects in the southwestern corner of Saskatchewan (RCAD 2012; Warren and Diaz 2012).

The PFRA Projects in Southwestern Saskatchewan

Following construction of the infrastructure supporting the PFRA's projects in southwestern Saskatchewan, individual producers were encouraged to purchase flood irrigation plots on approximately 10,000 available acres. Purchasers would be required to pay an annual fee for the delivery of water to their plots. Under normal operations, water would be delivered twice annually—allowing participants to harvest two irrigated hay crops per year. The PFRA retained responsibility for the maintenance of system infrastructure, including dams, reservoirs, ditches, and gates. As well, PFRA employees performed "ditch riding" functions—managing the canals, ditches, and gates that distributed water to each participant's plot.

As of 2010, approximately 300 producers had plots on the PFRA projects or on projects reliant on PFRA infrastructure—there are approximately 1,200 irrigators in the whole of the province (Warren 2013;

Map 1. Irrigation districts in the Palliser Triangle



Sources: The boundaries of the Palliser Triangle were derived from Spry (1995).

The location of irrigation districts in Saskatchewan were derived from Thraves et al. (2007: Plate 39). The location of irrigation districts in Alberta were derived from Alberta Agriculture and Rural Development (2013).

SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). Individual plot sizes on the various projects supplied by PFRA infrastructure in the southwest range in size from as little as 20 acres to 320 acres.

Irrigation was a welcome development in the dry southwestern corner of Saskatchewan. During drought years, such as those experienced in the 1920s and 1930s, it had been virtually impossible to grow winter feed for the region's beef cattle herds using dryland methods. Not surprisingly, interest in irrigation was relatively high; there were more producers requesting access to water for irrigation than there was water to allocate. As of today, streamflows in southwestern Saskatchewan are deemed fully allocated, whereas only 11% of the water available for use in Lake Diefenbaker is being used (Warren 2013: 214). In the southwest, irrigation appeared to provide a welcome assurance that feed could be grown locally, even during especially dry years. And from the early 1950s until 1979, the projects generally met producers' expectations.

Map 1 locates the multiple-user irrigation projects and districts in the Palliser Triangle described above.

The Impact of Three Dry Decades

The year 1979 marked a major turning point in the operation of irrigation agriculture in the southwestern corner of Saskatchewan. It was the first in a succession of years extending to 2009 when the availability of water for irrigation became unreliable (RCAD 2012; Warren and Diaz 2012). It was the last year that irrigators on three of the largest projects in the southwest (the Consul, Vidora, and Eastend projects) could count on two full water allocations per year. PFRA managers determined that there simply was not enough water available in streams and reservoirs to flood fields twice per season. Making matters worse, in some years there was only enough water available to irrigate half the available land once per year on some of the projects. Worse yet, there were some years during the three-decade period when water supplies were too low to allow for any irrigation at all. The inability of producers to irrigate all of their land twice per year and the complete lack of water in some years had significant economic implications for the region's ranchers.

Comments provided by a rancher who relies on irrigated hay for overwintering her cattle reflect those of most RCAD interviewees who rely on PFRA irrigation infrastructure:

> When Cecil and I were first married, we used to get two full irrigations. And we've been married since 1977. Now we're lucky if we get to irrigate half our land once a year. Last year we had no irrigation at all and we had just a single half-irrigation during each of the four years prior to that. The problem is there's just been no water. Cypress Lake [reservoir] was drained down to where we couldn't pump from it last year. It used to have a lot of water but the weather has become drier and the lake doesn't provide adequate storage, because it is so shallow. There has been less snow and less runoff—we haven't had two full irrigations since 1979 . . . So the end

> result of reduced irrigation is that we've been buying feed. And we're pretty well at the end of our rope with that option. You can't sustain a cow-calf and backgrounding [feeding calves over their first winter] operation down here if you are buying feed. The prices you pay for the feed and having it hauled don't match what you get at the market for your cattle . . . We probably spent $30,000 on feed last year. If there was any profit to be made with the cattle, that pretty well used it up. And we're not alone. I mean, everybody who counts on irrigation down here is using every strategy they can think of to make ends meet. They're trying to get the banks to increase their operating loans—just to try and get through to next year. (Warren and Diaz 2012: 126)

The principal culprit identified by irrigators and government water managers was a multi-decadal decline in the depth of the region's annual winter snowpack, which resulted in reduced spring runoff and streamflows. However, irrigators and water managers also identified system design and management flaws as contributing factors. By the mid-1980s, irrigators and PFRA officials had concluded that the development of additional reservoir capacity could solve much of the problem produced by drier conditions. During the 1980s, PFRA engineers worked on plans for three major infrastructure projects to increase water storage capacity. These included a new dam and reservoir on Battle Creek, a new dam at Cypress Lake Reservoir, and the enlargement of the Eastend Reservoir on the Frenchman River. As of 2013, the only project to proceed to completion was an enhancement of the Eastend Reservoir. However, that project fell short of the original design specifications, resulting in minimal water supply benefit for irrigators (Warren and Diaz 2012: 328).

The seriousness of the problem varies between projects and the various streams with which they are associated. RCAD respondents reported that a few individual irrigators along the Frenchman River were able to irrigate at least once per year every year between 1979 and 2010. At the other extreme, some irrigation systems on the south slope of the Cypress Hills rarely provided water for two irrigations over the three dry decades. One of the RCAD respondents with a privately owned and operated irrigation system described this situation:

> We have a 70-acre parcel of land . . . that is irrigated in theory. In the 20 years that Dad had it he only missed irrigating one year—just one year without water. After Lou and I took it over in 1974 there have only been about four years when we have had enough water to irrigate it . . . Yes, there were only four or five years out of 35 years that we got enough water to irrigate that piece. That is no kidding. That is how things have changed. There hasn't been any snowpack to speak of for a lot of winters. It is as simple as that. (Warren and Diaz 2012: 115)

Irrigators were also critical of ineffective management of streamflows on the part of the Saskatchewan Watershed Authority (SWA) and PFRA water managers. RCAD respondents reported that allocation management was haphazard. There were people who regularly irrigated without having an official allocation or having to pay for the water they used, while at the same time, there were irrigators who received no water at all despite making annual infrastructure upkeep payments (Warren and Diaz 2012: 135–37). Irrigators questioned the competence and capacity of senior water managers located in distant cities to supervise the water management decisions of PFRA employees located onsite at the irrigation projects. Producers also suspected that provincial and federal water managers were far more committed to meeting treaty obligations requiring that 50% of the flows on transboundary streams be available to the United States than they were to supporting Canadian irrigators (Warren and Diaz 2012: 26–30, 124–141, 322–30).

The Challenge of Uncertainty

Irrigators on the PFRA projects were presented with additional frustration and uncertainty in 2007 when the PFRA announced it intended to transfer responsibility for its irrigation projects to patrons effective 2017. Patrons were concerned that a number of infrastructure components were in need of upgrading and wondered if they could afford to make the necessary enhancements. They also wondered how they would be able to finance system improvements, such as the three new dams that had been planned by the PFRA in the 1980s and 1990s (Warren and Diaz 2012: 124–49, 322–30; PFRA 1992). In addition, the PFRA informed patrons that when they assumed ownership they would become legally responsible for any environmental cleanup associated with the projects that provincial or federal environmental authorities might require. This prospect was troubling given that many of the irrigation works built by the PFRA incorporated creosote-treated timbers. When the works were constructed, creosote was not deemed as environmentally harmful as it is today. Some irrigators worry that the cost of environmental rehabilitation could exceed the actual value of the existing works. Furthermore, the economic condition of the area's agricultural producers has been compromised by successive years when they have been required to purchase feed due to irrigation restrictions. Problems with the irrigation systems coincided with perennially increasing input costs and years of depressed cattle prices, including the price collapse associated with the 2003–7 bovine spongiform encephalopathy (BSE) crisis.

According to several RCAD respondents from Saskatchewan's southwest, insult was added to injury in 2010 when they discovered they would not be eligible for assistance under a federal-provincial drought relief program. The program was intended to assist producers affected by drought in parts of southeastern Alberta and southwest Saskatchewan in 2008–9. Apparently, government officials applied standard agricultural drought indices to determine which municipalities had suffered drought. As was discussed in Chapter 1 of this volume, agricultural drought is closely associated with low soil moisture conditions, especially at the time of seeding and early crop development. Apparently most dryland farmers in the southwest had received adequate moisture at the right time. Irrigation agriculture in southwest Saskatchewan, on the other hand, principally depends on accumulations of snow over winter and a well-timed runoff. Since hydrological conditions in the southwest did not enter into the program eligibility equation, irrigators did not receive drought support despite the fact that many of them were unable to irrigate in 2009.

An RCAD respondent commented on the apparent irrationality of program eligibility requirements and the frustrations felt by producers:

> I can tell you that we've had problems getting senior levels of government to recognize that we've been affected by drought in this area. This latest drought assistance program [2010 Canada-Saskatchewan Pasture Recovery Initiative] didn't include

> producers from RMs 51 and 111 [the RMs in the southwest corner of the province]. After four years of restricted irrigation you think we'd have been included within the drought disaster area. Going into this year they didn't think we were going to be able to irrigate anything again. We had no water whatsoever [in 2009] and still we weren't included. (Warren and Diaz 2012: 127)

This situation underlines the importance of applying the appropriate definitions of drought and understanding how drought affects producers using different production models. There is probably no one-size-fits-all model that will improve drought resilience in all contexts. Indeed, the economic success of agricultural producers using different production models on the Canadian Prairies is often at cross purposes. For example, when grain prices are higher than average, dryland farmers can generate higher-than-average gross incomes. However, higher grain prices often translate into lower calf prices for ranchers since the cost of finishing cattle to slaughter weight (by feeding them grain) increases. Similarly, there are occasions when dryland farmers may experience drought (perhaps due to low springtime precipitation), yet at the same time, irrigation agriculture can operate at near optimal levels. Again, reservoir levels often depend on factors such as winter snow accumulations or precipitation occurring outside the Palliser Triangle along the east slope of the Rockies. If dryland producers across a wide portion of the Palliser Triangle experience drought-induced crop failures due to low early growing season precipitation, there can be shortfalls in the supplies of commodities such as livestock forage and feed grain and a corresponding spike in prices. If irrigators are still able to water their crops during such a drought, they can take advantage of the associated price increases.

Chapters 13 and 14 in this volume, which discuss drought in Chile and Argentina, similarly describe how drought can sometimes produce both winners and losers depending on local conditions and the production models involved. In Chile, below-average moisture conditions can improve some fruit qualities desired by certain grape growers while causing harmful yield reductions for others. In Argentina, improved irrigation has mitigated the impact of drought for irrigators at higher elevations while at the same time causing adverse effects for downstream goat ranchers.

Another frustration for irrigators in the southwest is criticism of the agronomic and hydrological practices used on the projects. Government agrologists and water managers, as well as irrigators, operating on the larger districts associated with Lake Diefenbaker are generally critical of flood systems, seeing them as wasteful of water. Furthermore, the projects in the southwest had been situated on land that was suited to gravity-flow flood irrigation (the principal irrigation method available at the time) but did not necessarily have soils that were optimally suited to irrigation. Consequently, hay yields on the PFRA projects tend to be lower than yields obtained by irrigators in other areas where mechanical pivots apply water on better-suited soils. In conjunction with the widespread adoption of sprinkler pivot irrigation in most of western Canada in the 1970s and 1980s, agronomic best practices evolved to suggest water should be conveyed from its source to the most appropriate soils available.

Irrigators from the southwest have responded to critics of their flood systems and soil conditions:

> Sure, we don't have the best land in the world, but we're still getting a lot more production out of it than we would if it wasn't irrigated. We feed a lot of cows in the wintertime out of this project [Eastend project]. People count on it. Just think about how much dryland it would it take to replace all that irrigation production in a dry year . . . Right now, our project works off gravity. Mother Nature's doing all the work. So I wonder if they take that into account when they say flood irrigation isn't environmentally friendly. If we went to pivots we'd be using a whole lot of energy and that leaves a footprint too. Currently, the energy footprint for this system is about zero. I think that's a reasonable trade-off; we might be using more water than we would with pivots, but we're not consuming any electricity. (Warren and Diaz 2012: 325, 327)

One of the most daunting issues for irrigators on the PFRA projects is that the SWA has not yet agreed to transfer the water allocation currently awarded to the PFRA to the producers should they agree to assume ownership of the projects (Warren and Diaz 2012: 324). Producers face the prospect of taking over projects in need of costly infrastructure upgrades (and potential environmental cleanup costs), with no assurance that they will be allocated the water required to irrigate. Irrigators are uncertain about precisely why the allocation has not been guaranteed. Some suspect it is because provincial water managers are reluctant to endorse flood irrigation on suboptimal land. Others imagine that provincial authorities are reluctant to become involved because the province does not want to incur additional financial responsibilities. The uncertainty has led some producers to argue that the PFRA should simply buy out existing irrigators, compensating them for paying premium prices for irrigated land that the PFRA is no longer prepared to irrigate (Warren and Diaz 2012: 138–139).

The Return of Snow and Rain

Three decades of relatively dry years were followed by a year of record flooding in the Cypress Hills region in 2010. Indeed, since the spring of 2010, snowfall and runoff levels have increased, and area reservoirs are full. Unfortunately, the 2010 flood damaged irrigation works supplying irrigators on the northern slope of the Cypress Hills. A PFRA weir essential to the operation of the Maple Creek irrigation project washed out and, as of 2015, has not been repaired. No flood irrigation has occurred on the Maple Creek flats portion of the project since 2010, although above-average precipitation from 2011 to 2014 has allowed ranchers to produce hay using dryland methods. The PFRA was disbanded in 2010, and officials from other sections of Agriculture and Agri-Food Canada now have responsibility for the projects. Officials from Agriculture and Agri-Food Canada have not indicated whether the government will replace the weir prior to transfer of the system to the producers. Irrigators who offered to hire their own contractor to repair the weir were informed that this would not be allowed since Agriculture and Agri-Food Canada and Saskatchewan's watershed authority would still require that any repairs would have to be managed according to government engineering parameters, which the locals were apparently deemed unable to meet (SSFIG 2013). Yet the government agencies concerned have not, as of November 2015, offered to provide the necessary engineering support. This is an instance in which the irrigators endeavoured to develop their own self-reliant, innovative response to their circumstances but have been prevented from doing so by government.

The Changing Role of Governments

From the mid-1930s until just recently, Canada's federal government subsidized the development and maintenance of irrigation on the Canadian Prairies. That being said, the PFRA's longstanding involvement in irrigation in southwestern Saskatchewan was something of an anomaly. The management of major projects in Alberta, and the Lake Diefenbaker projects, which initially received considerable federal financial and engineering support, were turned over to provincial authorities and irrigator associations decades ago. As the level of financial and technical support available from the federal government waned, provincial government support was stepped up—particularly in Alberta. The Government of Alberta has entered into long-term funding agreements with irrigation district associations. Under the current agreement, the irrigation districts receive 50% or more of the funds required to upgrade system components from the province (Warren and Diaz 2012: 279; Saskatchewan AgriVision 2004: 10–11).

In Saskatchewan, support from the province has been less generous and less dependable. A number of prominent observers contend that the lack of consistent financial support from the province has retarded irrigation development in Saskatchewan, particularly in the Lake Diefenbaker area (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). On the other hand, as noted above, some observers attribute the slower than anticipated pace of irrigation development in the Lake Diefenbaker area to the fact that moisture conditions in that region generally allow for the production of acceptable crop yields under dryland methods.

Proponents of irrigation enhancement and expansion in Saskatchewan maintain that the economic benefits associated with increased crop production and the development of added-value food processing and livestock feeding associated with more densely concentrated irrigation agriculture far outweigh the initial investment in infrastructure made by governments (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). The Alberta government apparently agrees and continues to make significant investments in irrigation infrastructure. The high level of added-value processing and employment associated with Alberta's irrigation districts is interpreted as evidence of the economic multiplier effect that concentrated irrigation agriculture can generate. Saskatchewan's governments have behaved more erratically. Some governments have actively promoted the expansion of irrigation, only to be followed by new administrations that were less enthusiastic (SIPA 2008a: 4; Saskatchewan AgriVision 2004: 125).

Supporters of expanded irrigation in Saskatchewan, including the Saskatchewan Irrigation Projects Association (SIPA) and Saskatchewan AgriVision Corporation—an agri-business think tank—contend that increasing the amount of irrigated land in the province from the current 350,000 aces to 500,000 acres (with the increase occurring primarily in the Lake Diefenbaker area) would generate a benefit-cost ratio of 14:1. It is assumed that a government investment of $2.9 billion in new infrastructure would generate direct and indirect benefits totalling approximately $60 billion (SIPA 2008a: ii). SIPA contends that the multiplier effect of additional irrigation would generate tax revenues that would more than offset the government's investment.

A 1991 PFRA study by Kulshreshtha (1991) assessed the economic return on the federal government's investment in the irrigation projects in southwestern Saskatchewan and indicated that the projects have not generated the revenues required to fully offset costs. Kulshreshtha (1991: i) reports that even when ancillary benefits such as the use of water by urban municipalities and for recreation are taken into account, the projects have not paid for themselves. He identifies a benefit-cost ratio of 0.85. That being said, Kulshreshtha's analysis does not consider the possibility that low economic productivity on the projects could be significantly enhanced by additional investment in infrastructure. According to the irrigators, increasing reservoir capacity would have resulted in higher yields and revenues over the relatively dry 1970–2010 period. Notwithstanding the modest net deficit he identified, Kulshreshtha underlined the importance of the PFRA projects to the sustainability of cow-calf ranching and communities in southwestern Saskatchewan. This argument is echoed by participants in the projects.

The Impacts of Offloading on the Irrigation Community

The decision by the PFRA to abandon its irrigation responsibilities is just one example of a wider pattern of declining federal government support for Prairie agriculture and the offloading of responsibilities onto provincial governments and producers. In 2010, just three years after the PFRA announced that it was giving up its irrigation responsibilities, the PFRA itself was disbanded. And, in 2011, the federal government informed the provinces that it would cease operating the community pastures and tree nursery formerly managed by the PFRA. Federal officials have indicated that the provinces of Manitoba, Saskatchewan, and Alberta and/or pasture patrons (as is the case for irrigation project patrons) have the opportunity to operate the pastures if they wish but without financial support from the federal government. A concern for pasture patrons and irrigators in Saskatchewan is that the provincial government has been reluctant to assume responsibility for the ongoing operations of the pastures and irrigation projects. This reluctance is evidenced by the SWA's (since renamed Saskatchewan Water Security Agency) failure to promise that the water allocations will be awarded to the patrons.

Irrigation project patrons are worried that without greater government support the projects could cease to operate. The loss of access to irrigation is a daunting prospect for the irrigators who rely on it for winter feed. It could also accelerate the decline of the few urban communities that survive in the southwestern corner of Saskatchewan. One of the irrigators interviewed by RCAD project researchers expressed concern over the potential loss of access to irrigation:

> Without irrigation many of us would simply not be able to survive as cow-calf ranchers. Maybe we could survive by switching to straight grazing operations. Sell off our cows and run calves raised by someone else on our land as yearlings but that would involve a big reduction in a rancher's income. Irrigation is one of the few things that has kept Consul [the only remaining village in Rural Municipality #51] going… I don't know how they expect us to survive down here. There aren't

> that many of us left and if we can't irrigate there will be even fewer of us. (Warren 2013: 241)

Journalist Sheri Monk, who frequently writes on issues affecting agriculture in southwestern Saskatchewan, recently posted the following comments regarding the PFRA's demise:

> Whether intentional or merely the inevitable result of catastrophic policy decisions, the area [southwestern Saskatchewan] is being depopulated. Piece by piece, all the pillars of economic sustainability are being removed. Sure the federal government may be motivated by their economic ideology, but it's the people who are going to suffer for it. Even the staunchest libertarians will admit that maybe it wasn't the government's place so many decades ago to create the framework and infrastructure for the PFRA projects, but now that it's here, ripping it away from the people who have built generations of lives around it is criminal. (Monk 2013)

Some government water managers suggest that the PFRA's operation of irrigation projects in southwestern Saskatchewan resulted in counterproductive dependency and complacency on the part of patrons. For example, patrons did not incorporate their own district irrigation associations until after the PFRA announced its plans to transfer the projects. However, there are irrigators participating in several multiple-user projects in the southwest who have been operating without PFRA management and operational support for decades (these systems are referred to as provincial projects). The producers on provincial projects have always had their own district associations, and with the exception of some major works such as dams and reservoirs (which are managed by the province or PFRA), they look after the full cost of system maintenance and operations. It was not until 2008 that irrigators on the PFRA projects hired their own "ditch riders" (the technicians who manage water distribution on the projects).

Federal officials have reported that the government has been operating the projects in the southwest at a loss (Warren and Diaz 2012: 167). The fees that producers are charged for water and system maintenance do not cover actual costs. Irrigators counter that costs incurred by the PFRA include unnecessarily high head-office staff costs, redundant local employees, and gold-plated engineering and construction costs. Furthermore, the inconsistent delivery of water and the relatively low yields achieved on some projects warrant fees that are somewhat lower than those paid by irrigators on more reliable projects. Indeed, some irrigators interviewed held that some of the PFRA's charges were inordinately excessive. One respondent noted that the PFRA charged participants on the Middle Fork project a system maintenance fee in years when no water was available for irrigation, and no one from the PFRA appeared to have even visited the project over the course of those years (Warren and Diaz 2012: 144, 145).

Some producers speculate that if patrons were required to invest more of their own money in system improvements, they might recognize the value of making yield-increasing improvements on their plots. Indeed, PFRA and SWA officials, as well as some producers interviewed in association with the RCAD project, held that many patrons on the PFRA projects were not regularly renewing hay stands (by reseeding) or applying fertilizer in conformity with widely recognized best management practices.

Notwithstanding the potential benefits of increased producer investment, patrons find themselves locked into a classic "Catch-22" scenario. Given decades of low yields and restricted irrigation, their bottom lines have been stressed. Yields and water availability would probably improve if they invested in new infrastructure and more intensive plot management. But given their experience under existing economic and hydrological conditions, they lack the financial resources required to improve their situation. For example, the construction of a dam across the Cypress Lake Reservoir would allow for deeper, more drought-resistant water containment and would most likely allow for more efficient conveyance of reservoir water to the Consul, Vidora, and Govenlock irrigation projects (Warren and Diaz 2012: 30). Current cost estimates run at up to $4 million. Shared among the approximately 100 irrigators on these projects, the investment per irrigator would be $40,000. Given that some patrons are incurring significant costs to purchase feed when irrigation is restricted (over $30,000 annually for some producers), $40,000 to ensure more regular irrigation might appear to be a good investment. However, this conclusion assumes that producers have access to the required capital. Based on the RCAD interviews, it is apparent that some lack either the savings or access to credit that would be required. And borrowing money to enhance irrigation infrastructure in the absence of a guaranteed water allocation is something that both lenders and borrowers would no doubt finding troubling.

Conclusions

The research suggests a number of preconditions need to be in effect before significant system improvements can be entertained. First, patrons need assurance that the water allocations currently held by Agriculture and Agri-Food Canada will be transferred to the district associations. Second, the transfer of assets to the irrigators should be free of pre-existing environmental cleanup liabilities. If the federal government is prepared to consider its investment in infrastructure a sunk cost, it seems reasonable to treat environmental costs similarly. Third, to make the sort of infrastructure improvements that could enhance the drought resilience of the projects, the producer associations will require access to government grants and/or the sort of patient financing that would forego significant upfront cash contributions by producers (many simply do not have the cash or borrowing capacity today), allowing for the repayment of loans over an extended period of time. However, even with these measures in place, uncertainty about future climate conditions presents planning challenges. Some irrigators see value in "doubling down" on past investments in infrastructure by increasing reservoir capacity in anticipation of the next dry period. But, should future climate conditions exceed past patterns of variability, it is possible that enhanced reservoir capacity could still prove insufficient (see Chapter 3 by Wheaton et al. in this volume). Under this sort of scenario, making additional investments in infrastructure would be a costly mistake.

At the same time, some proponents of expanded irrigation in Saskatchewan take a more optimistic view, speculating that climate change could bring a warmer and longer growing season to the Canadian Prairies. Under irrigation, such conditions could facilitate production of higher-value crops such as corn, sugar beets, and soybeans, which are not particularly well suited to current climate conditions in Saskatchewan (SIPA 2008a, 2008b; Saskatchewan AgriVision 2004). This line of thinking underlines the idea that a changing climate could generate beneficial as well as adverse outcomes depending on the social and geographical context being affected—a notion that Hadarits et al. touch on in Chapter 13 of this volume.

What we are reasonably certain about is that climate change forecasts currently indicate that the Palliser Triangle region will experience more intense droughts in coming decades than have been experienced over the course of the twentieth century (Sauchyn 2010; St. Jacques et al. 2010; Sauchyn and Kulshreshtha 2008; Lemmen et al. 1997; see also Chapter 3 by Wheaton et al. in this volume). Notwithstanding forecasts based on anthropogenic global warming scenarios, paleoclimatic research suggests that the droughts experienced in the Palliser Triangle during the period of agricultural settlement (from approximately 1885 until today) were a virtual walk in the park compared to some of the severe, decades-long droughts of preceding centuries (Sauchyn 2010: 35–37; see also Chapter 2 by Sauchyn and Kerr in this volume).

Planning for the future of irrigation in southwestern Saskatchewan would clearly benefit from additional climate change research that reduces the level of uncertainty (RCAD 2012: 48). Nonetheless, some features of the planning problem seem reasonably certain. For example, most observers assume it is relatively safe to predict that severe multi-year droughts will occur over the course of coming decades, making irrigation both more necessary and more difficult (especially given current infrastructure limitations). It is also reasonable to predict that intense precipitation events, such as the Maple Creek flood of 2010, could reoccur over coming decades. Infrastructure needs to be designed and/or modified accordingly (see Chapter 3 by Wheaton et al. in this volume). Academic assessments of the vulnerability of communities to climate change indicate that resilience is a function of the levels of adaptive capacity available to a given community (Department for International Development 2009; IPCC 2001). The RCAD project found that agricultural communities in the Palliser Triangle had considerable access to certain forms of adaptive capital—forms of capital that tend to be far less accessible to people in less developed parts of the world. Notwithstanding these regional advantages, irrigators in the southwestern corner of Saskatchewan are experiencing an increase in vulnerability. Their coping capacity has been impacted along three principal dimensions. First, changing climate conditions have frustrated their ability to irrigate. Second, they have experienced a decades-long economic struggle, whereby increases in the income they receive for the products they produce have often lagged behind increases in input costs. Indeed, difficult economic conditions in agriculture have contributed to a significant decline in the number of farmers and viable communities in southwestern Saskatchewan (Diaz et al. 2003; Stabler and Olfert 2002). The Rural Municipality of Reno, where three of the PFRA irrigation projects are located, is the largest rural municipality in Saskatchewan, yet it has only 154 farms, down from over 300 in the 1970s (RCAD 2012: 52–53). Long-term trends have more recently been exacerbated by drought and the BSE crisis. These challenges have reduced the amount of capital available to producers for withstanding losses caused by climate hazards and for investing in resilience-enhancing infrastructure. Third, Canada's federal government has walked away from its longstanding commitment in support of irrigation in southwestern Saskatchewan, and the provincial government is apparently reluctant to assume responsibility for the functions abandoned by Ottawa.

The decline in government involvement in management and financial support is symptomatic of a wider process of offloading on the part of Canada's federal government. Under Prime Ministers Jean Chrétien, Paul Martin, and Stephen Harper, the role of the federal government in supporting agriculture on the Canadian Prairies has significantly declined (Warren 2013; Conway 2006; Diaz et al. 2003). Conway (2006), among others, contends that Canadian federal and provincial governments, including New Democratic Party governments in Saskatchewan, have increasingly become associated with neo-liberal economic maxims since the 1980s (see also Brown et al. 1999). A symptom of the neo-liberal turn of governments is the wide acceptance of balanced budget orthodoxy, low taxes, and minimal government, which has limited government's willingness to fund new initiatives and has encouraged cost cutting across a range of programs, including the decommissioning of the PFRA in 2013 and the elimination of the Canadian Wheat Board's marketing monopoly in 2012 (see Chapter 7 by Fletcher and Knuttila in this volume).

Oddly enough, in supposedly conservative Alberta, the provincial government has responded to declining federal government support, ensuring that the province's irrigation sector remains viable. Governments in Saskatchewan have typically been far less active in supporting irrigation agriculture (SIPA 2008a; Saskatchewan AgriVision 2004). Without stronger support from the province and/or the federal government, it is questionable whether irrigation projects in southwest Saskatchewan can survive, let alone prosper.

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CHAPTER 7

GENDERING CHANGE: CANADIAN FARM WOMEN RESPOND TO DROUGHT

Amber J. Fletcher and Erin Knuttila

Climate change is one of the most profound environmental, political, and social issues of our era, particularly given its global scope and direct regional impacts. The threats and vulnerabilities associated with climate change and climate extremes, including drought, are not gender-neutral, and actors' everyday responses to these events can both challenge and reinforce existing gender roles and ideologies. As climate change scenarios become a reality, residents of the Canadian Prairies can expect more dramatic climate extremes—particularly severe, prolonged drought. There is a need for context-specific analyses of gender and drought, which can inform effective and gender-attentive strategies for preparedness and response.

In this chapter, we present a contextualized analysis of gender and drought in the Canadian Prairie province of Saskatchewan. Such contextualization is important because vulnerability and adaptation are shaped by much more than climatological factors. Social, political, and economic stressors interact to create unique situations of vulnerability to climate extremes. We begin our analysis by briefly situating farmers' vulnerability and adaptive strategies within the broader macro-level political-economic context of Prairie agriculture. Next, drawing on a recent qualitative study of farm women in Saskatchewan, we present a micro-level analysis that reveals the gendered dynamics of vulnerability and adaptation in everyday life. Drawing together both levels of analysis, we illustrate that particular political, economic, and social conditions have resulted in unique forms of vulnerability and adaptation on the Canadian Prairies. We suggest several policy implications to strengthen the adaptive capacity of Canadian farm families in the future.

Gendering Climate Extremes

Social factors can significantly shape how humans are affected by climate extremes (Adger 2003; see Chapter 1 by Wandel et al. in this volume) and how they respond to these extremes. Kelly and Adger (2000: 325–26), for example, noted the importance of examining the social dimensions of climate events:

> Climate impact studies have tended to focus on direct physical, chemical or biological effects, yet a full assessment of consequences for human well-being clearly requires evaluation of the manner in which society is likely to respond through the deployment of coping strategies and measures which promote recovery and, in the longer-term, adaptation.

The Intergovernmental Panel on Climate Change (IPCC) has stated that social inequality based on gender, race, age, socio-economic status, and ability can determine a person or system's vulnerability to climate extremes (Field et al. 2012). Disasters can exacerbate existing inequalities in society (Enarson et al. 2007), resulting in different levels of vulnerability and unequal access to resources before, during, and after the climate event. Women have historically played integral roles in food preparation, childcare, and healthcare—roles that are critical during disaster situations but that become more difficult to carry out during such events (Enarson and Chakrabarti 2009). Entrenched gender roles can therefore create different experiences of disaster for women than for men (Dankelman 2010; Enarson and Chakrabarti 2009).

At the same time, some feminist scholars have observed a tendency in the gender and climate change literature to portray "women" and "men" as homogeneous categories while ignoring differences caused by race, socio-economic class, geography, ability, and education (Enarson et al. 2007). Moosa and Tuana (2014) documented the growing importance of intersectional and contextual studies that examine how gender interacts with other forms of social difference, such as socio-economic class or rurality, to create different experiences of climate extremes even within the social categories of "women" and "men." Arora-Jonsson (2011) disputed sweeping and universal statements about the vulnerability of women, calling instead for more contextualized analyses of gender and climate change that address local gender roles and ideologies in specific locations. This includes situations where hegemonic masculinity may render men vulnerable to climate extremes.

Few academic studies have been conducted specifically on gender and drought on the Canadian Prairies. However, the experiences of farm women in the region provide an important window into the gendered dimensions of drought. Because they depend on the land for their livelihoods, farmers are directly and dramatically affected by drought and other climate extremes. Many family farms in the Prairies are structured by a gendered division of labour, in which men are more likely to be positioned as the "main farmer" while farm women's work is construed as "helping" (Fletcher 2013; Faye 2006). In addition to farm work, women are primarily responsible for childcare and other caregiving work (Jaffe and Blakley 1999), household tasks such as cooking and cleaning, and yard work (Fletcher 2013; Kubik and Moore 2005). Through their association with social reproduction tasks and their relative detachment from day-to-day farm decisions (Fletcher 2013; Reinsch 2009), farm women may experience drought disasters differently than men.

In her research on Manitoba farm women's experiences of the bovine spongiform encephalopathy (BSE) crisis, which occurred only one year after the drought of 2001–2, Reinsch (2009) found that farm women experienced high levels of stress as a result of the disaster. The women's stress was due, in part, to their lack of control over major farm decisions and coping strategies (Reinsch 2009). Historical sources, including farm women's own accounts of past droughts, also provide some insight into the gendered dimensions of drought in a historical framework. In an analysis of her great-grandmother's letters from the 1930s, Bye (2005) argued that farm women actively reinforced gendered roles and ideologies during a drought, which had the effect of reproducing gendered inequalities and, therefore, gendered vulnerability. Other authors have documented the importance of farm women's adaptive strategies during the Great Depression, including household resource management strategies, subsistence food production, and off-farm work (Gilbert and McLeman 2010; Schwieder and Fink 1988). In a recent article based on interviews with environmental migrants during the 1930s drought, Laforge and McLeman (2013) suggested that women may have experienced drought-related migration differently than men and that women may have experienced increased isolation due to gender roles that limited their social interaction.

The literature suggests that while women and men can be similarly exposed to the same climate conditions, contextual differences—including gendered divisions of labour—can produce different degrees of sensitivity and different forms of adaptation (Leichenko and O'Brien 2008; Milne 2005). Climate scenarios indicate that the Canadian Prairies will face significant water scarcity as the result of warmer and drier weather and that the region will be exposed to extreme droughts of long duration in the future (Sauchyn et al. 2010; Sauchyn and Kulshreshtha 2008). Programs to reduce vulnerability and encourage adaptation are necessary, but they are only helpful if they are attentive to local social and gender orders. Programs should not exacerbate existing forms of inequality in the community and should, when possible, challenge these inequalities. It is necessary to understand the gendered dimensions of extreme events to create culturally appropriate and gender-attentive approaches to future climate extremes.

Drought on the Canadian Prairies

The Canadian Prairies have the most variable and drought-prone climate in Canada (Sauchyn 2010; Bonsal and Regier 2007; see also Chapter 8 by Marchildon in this volume), yet the region is also one of Canada's key agricultural areas. The province of Saskatchewan, for example, contains 40% of Canada's farmland and exports more than half of the world's lentils, peas, and flaxseed (Government of Saskatchewan 2012a). The region also produces over 30% of the durum, canola seed, and mustard consumed worldwide (Government of Saskatchewan 2012a). The neighbouring Prairie province of Alberta is known for its cattle industry, producing 40% of Canadian beef cattle (Statistics Canada 2011a).

Over the past decade, this important agricultural region has experienced a series of droughts, most notably in the 1930s, 1960s, 1980s, and early 2000s, and most recently in 2009 (Warren and Diaz 2012; Marchildon et al. 2008; Bonsal and Regier 2007; see also Chapter 4 by Kulshreshtha et al. and Chapter 8 by Marchildon in this volume). Dendroclimatic records indicate that even worse droughts occurred before European settlement of the Prairies and thus before instrumental recording began (Sauchyn et al. 2003; see also Chapter 2 by Sauchyn and Kerr in this volume), which suggests that similar extreme droughts could potentially reoccur in the future.

The social and economic impacts of drought on agriculture can be dramatic. Saskatchewan farmers sustained crop production losses of $925 million in 2001 and $1.49 billion in 2002, and the province reported negative net farm income in 2002 (Wheaton et al. 2008). Farmers relied heavily on crop insurance to cope. Insurance payments in Saskatchewan jumped from $331 million in 2001 to $1.1 billion as the drought continued into 2002 (Wheaton et al. 2005).

Climate scientists predict more dramatic changes for the Prairie region in the future. More severe and protracted droughts are expected as overall temperatures continue to rise (Sushama et al. 2010; Bonsal and Regier 2007; see also Chapter 3 by Wheaton et al. in this volume), but the region will also experience more fluctuations and a greater range of extreme climate events as anthropogenic climate change interacts with natural cycles (Sauchyn 2010: 38; Sauchyn and Kulshreshtha 2008). These events will test residents' abilities to cope and adapt.[1]

There is a need for context-specific analyses that highlight the unique forms of vulnerability and adaptation at play in certain locations. Such localized understandings can facilitate policies that are attentive to the strengths and needs of actors in unique circumstances. In the following section, we provide a contextualized analysis of the gendered dimensions of vulnerability and adaptation on the Canadian Prairies. We present the results of a qualitative research project conducted with 30 Saskatchewan farm and ranch women between August and December 2011. The project involved 30 semi-structured interviews, most of which occurred at the participants' farms. For a detailed description of the methods and participant demographics, see Fletcher (2013).

The study's findings reveal the importance of the broader political, social, and economic context shaping farm women's lives, as well as the uniquely gendered dynamics affecting both vulnerability and adaptation. The following sections discuss both of these contexts, macro and micro. Based on these findings, we present recommendations for gender-attentive policies that should benefit Prairie farmers facing climate extremes in the future.

Managing Uncertainty: Vulnerability, Adaptation, and Gender on Saskatchewan Farms

Context: The Changing Face of Prairie Agriculture

Farm women's experiences of climate change must be understood within the broader political and economic context of Prairie agriculture. Vulnerability is not simply a product of climatic factors (see Chapter 1 by Wandel et al. in this volume). Factors such as market prices, input costs, policies, and population trends can increase or decrease farmers' access to much-needed resources, and this subsequently shapes their vulnerability and adaptive capacity in the face of climate extremes.

Farmers have been "squeezed" between high production costs and low commodity prices since the early days of agricultural settlement in the Prairies (McCrorie 1964; Fowke 1957). However, contemporary farmers face a new kind of cost-price squeeze. Large, vertically integrated agricultural corporations have become dominant forces in multiple links of the food chain, from the production of patented seed varieties to processing and export (Fletcher 2013; Kuyek 2007). At the same time, deregulatory policy changes and the elimination of farm support programs have increased both farmers' costs and their susceptibility to the vagaries of international market prices (Roppel et al. 2006).

Farmers have adapted to these macroeconomic changes through farm-based economies of scale and increased production. Farm size growth has reached new heights in recent years, as Prairie farms grow at the fastest rate in history (Figure 1). However, we cannot assume that small or lower-income farming operations are more or less vulnerable to climate

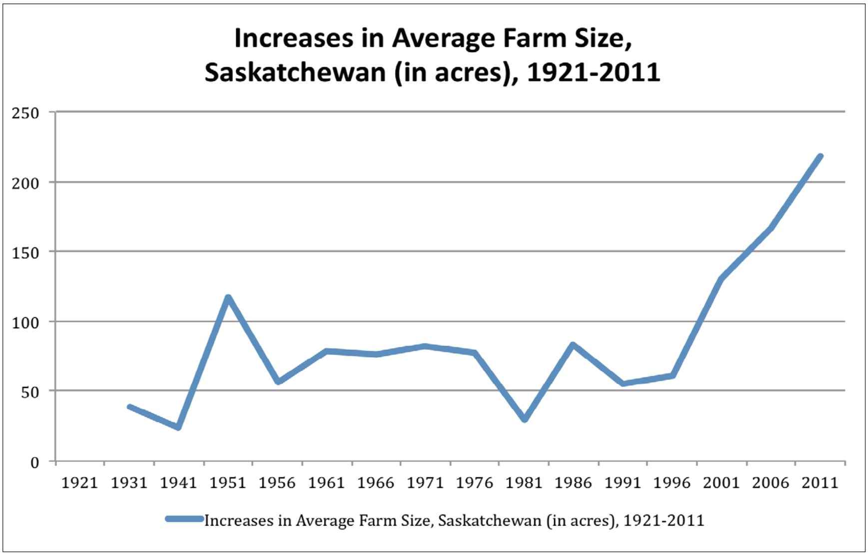

Figure 1. Increase in average farm size in Saskatchewan (in acres), 1921–2011 (Source: Statistics Canada 2011a)

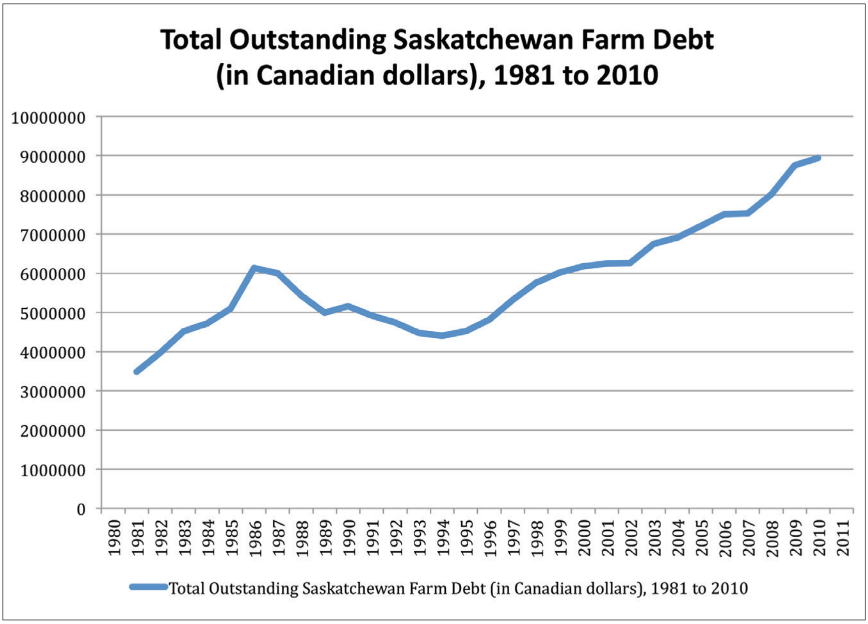

Figure 2. Total outstanding Saskatchewan farm debt (in Canadian dollars), 1981–2010 (Source: Statistics Canada 2011b)

extremes than large, “successful” farms. In fact, the debt levels associated with farm expansion, as well as the cost of expensive inputs intended to enhance productivity, can leave larger or highly industrialized farms even more financially precarious and vulnerable to climate disasters (Figure 2).

Farm women in the study identified debt and high input costs as having “make or break” power during extreme weather events. One participant said the following:

> If you’ve put it all in your land and you don’t get a profit back, every year that you lose is a year that you don’t get back. It takes you longer to regain what you’ve lost. So, I know those years of drought, yes, that’s a farm crisis: when you have nothing to sell but your bills are still coming in. (Fletcher 2013: Interview 20)

The participant also added, “When it’s a drought, of course your income’s down but your expenses still stay the same: the price of fuel, the price of repairs, the price of everything” (Fletcher 2013: Interview 20).

Another participant described the challenges for farmers who had expanded their operations through increased debt: “We’ve got men in their early 20s that are in debt $2.5 million, but they’re one of the biggest farmers in the area” (Fletcher 2013: Interview 7). For some, decreasing their debt was an adaptive strategy to prepare for crises: “So we’re small but at least we own it, we don’t owe any money, we’re not in debt like a lot. Some, they go big and they’re fine, but some go too big and they crash” (Fletcher 2013: Interview 17).

Many participants relied on insurance and government disaster programs in times of environmental crisis. Despite some concerns about the administration of these programs, such as the length of time to receive a payment, participants generally saw the programs as important and necessary. However, insurance is a viable coping mechanism only if it remains affordable for farmers. Many participants expressed concern that current insurance programs were not keeping pace with the rising cost of inputs. Others contemplated the future cost of insurance in a changing climate: “I think that crop insurance is possibly going to get more expensive. It may, it just may not, but I also think it will get more expensive just because of the increased variability in weather. It’s an insurance program and if your weather gets weird it's going to get more expensive" (Fletcher 2013: Interview 8).

Drought also affects farmers' workloads, although the effects are different for cattle and crop producers. Dry years create more work for cattle producers, as they are forced to pump or haul water for the herd. Women are often involved with hauling water for the farm or household during a drought. One participant, who was the sole farmer on her operation, relied on her daughter for assistance with water collection: "When you have cattle, it causes more work because there was no water. We had to water them. [Daughter] was the water girl. Five-hundred gallons a day, every day" (Fletcher 2013: Interview 23). Drought tended to have the opposite effect on grain and oilseed producers, who often found their workload reduced. When crops did not grow, there was simply nothing to be done.

In the case of both cattle and crop producers, the most dramatic consequences of climate extremes were felt internally. Stress was the most commonly mentioned issue in discussions about drought and other climate extremes. As we discuss below, vulnerability and adaptation to these psychological effects takes gendered forms.

The Gendered Dimensions of Vulnerability and Adaptation to Drought

Existing research has documented the historical invisibility and marginalization of North American farm women's contributions to agriculture (e.g., Fletcher 2013; Faye 2006; Kubik and Moore 2005; Kubik 2005, 2004; Rosenfeld 1985; Sachs 1983; Ireland 1983; Koskie 1982). This invisibility persists despite the importance of women's work and despite their rising participation in activities often considered masculine, such as driving large machinery (Martz 2006). The lack of recognition is mostly due to the persistent notion that farming is a "man's job." Participants in the study were asked to name all job titles they identified with. Despite the fact that "farmer" was selected most often (n = 14), it was very common for participants to identify their male partners as the "main" or "primary" farmer while describing their own role as that of "helper," "employee," or "go-for."

With this "helper" identity comes a relative lack of control over the day-to day farm decisions, which are often made by men. As one participant stated, "I think farm women tend to be more supportive, rather than the decision makers. I think, as far as me personally, I'm the sounding board. I do lend some opinions that alter the end decision, but the end decision is generally [husband's]" (Fletcher 2013: Interview 15). Another participant described the phenomenon this way:

> The division of farm work is: he's in charge. He does everything with the farm work, except when he needs me to help him fix something, hold a part, or put it this way—he chooses what he has to do to make money on the farm and I do everything else that he doesn't want to do. (Fletcher 2013: Interview 4)

The farm household is also structured by rigid gender roles. The women in the study performed an average of 88% of all domestic, household, and caregiving work; this is 20% more than the national average for women according to Statistics Canada (Milan et al. 2011). The gendered division of labour is partly due to the concrete realities of farm work. Farming is not a "9 to 5" job, and farmers may work from 4 or 5 a.m. until midnight during busy seasons, such as harvest time. Many rural areas in Saskatchewan lack childcare services, and even if these exist, few service providers can accommodate farming schedules. These material realities combine with historically ingrained gender ideologies that position women as "natural" caregivers and men as providers for the family.

Farm women's roles are thus structured at the confluence of both ideological and material factors. These gendered roles result in different experiences of environmental crisis for farm women and farm men. Only three participants felt that the response to a climate event depends on individual personality and is not gendered; the remainder felt that gender roles make a difference. In contrast to Reinsch's (2009) findings, several participants described how men's closeness to the farm causes them to be more negatively affected by the psychological impacts of climate extremes. Men's typical position as the "main" farmer is a privileged position when times are good, but it can increase their personal vulnerability during a drought. It is they, the "main" farmers, who watch closely as crops wither or livestock suffer. As one farm woman explained, "I'm not in contact with it 24/7 like they [her husband and sons] are. It affects their appetite. It affects their outlook for the next day. They don't rest properly, you know. It's just, it's a battle" (Fletcher 2013: Interview 29).

Farm men's psychological distress is also caused by dominant ideals of masculinity and, in particular, a stoic and independent form of masculinity commonly found in Prairie agricultural communities. Participants described the gendered expectations placed on men to be "providers" and the vulnerability this can cause in times of crisis. One said, "I think when you're the man of the household, ultimately it's your responsibility no matter how much you're supported by your wife and how much she helps, ultimately . . . it sits on your shoulders" (Fletcher 2013: Interview 19).

It should not be assumed that these differences are somehow natural or inherent to men and women. Different forms of vulnerability are the product of entrenched gender ideologies and roles. This is clearly shown in the case of one farm woman who was the main farmer on her operation while her husband worked full-time off the farm. As the main farmer, she was more severely affected by the mental turmoil of a multi-year drought. Her words illustrate not only this mental turmoil but also the interaction of financial and climatological factors in shaping vulnerability:

> It's not the weather itself, it's what the weather does to the bottom line . . . I find it way, way too stressful . . . the financial part is what stresses me . . . I think there were two or three years in there, probably three years there, where I was on anti-depressants. (Fletcher 2013: Interview 23)

More commonly, environmental crises further entrench farm women's historical role as a caregiver for the farm family and community. Participants often used terms like "nurturer," "mediator," "buffer," and even "counsellor" to describe their role during a drought. One farm woman described this role:

> We try and keep everybody on the level and you know, don't try to irritate them. Try and keep it a peaceful atmosphere, like 'maybe tomorrow will be better,' 'next year will be better,' or . . . 'we can deal with this.' . . . You have to take the role of a matriarch kind of thing, you know? I don't know if that's a good word, but . . . try and be the buffer I guess. (Fletcher 2013: Interview 3)

This raises the question of who supports the supporters. To whom did farm women turn for support? For many, gendered ideologies made it easier for women, as opposed to men, to talk about their concerns with friends or family members. As one participant said, "I think farm men tend to keep more inside and I think farm women tend to network" (Fletcher 2013: Interview 15). These social networks, however, are rapidly disappearing. As agricultural production becomes more competitive and industrialized, many small and medium-size farms have disappeared, unable to compete in the current conditions. Many farm women reported the loss of neighbours and other social support networks.

Although women's relative disconnection from farm control could help buffer them somewhat from the psychological effects of climate extremes, it can also give them less agency over practical strategies for coping and adaptation on the farm. As the "main" farmers, men are more likely to make coping and adaptation decisions, such as which crops to plant or whether to spend more on new seeds that promise drought resistance. Although participants felt that gender roles made it easier for women to network and talk about their concerns with friends and family, the constant pressure to support others resulted in hidden stress for many women. As one woman described it, "The physical strain and the emotional strain that the wife carries is not something that can ever be measured, but it is something that she wears all the time" (Fletcher 2013: Interview 7).

Drought also exacerbated women's work responsibilities. Women often hauled water for the farm and household, a task they combined with their existing responsibilities. One participant described the difficulties of raising a small child during the drought of 2001 and 2002:

> I had to get a water tank and haul water from the city to fill up my well so I could bathe and do laundry. It was terrible. About once every three days I had to haul water from the city. One load of water would take me about two hours . . . at the time I had a child who was in diapers. Then you're trying to entertain her and I'd bring along games, tic-tac-toe. (Fletcher 2013: Interview 5)

Participants often tried to save money during difficult times by changing household practices. Strategies included growing more vegetables and preserving them through canning or freezing, mending clothes and other household items instead of buying new things, and accepting temporary work or self-employment to bring in extra income. According to one farm woman, “We put off farm-related purchases and applied heavy restrictions on personal entertainment, fuel, power, telephone, groceries. . . ” (Fletcher 2013: Interview 30).

Some women had taken an off-farm job as a form of adaptation to the uncertainties of farming. However, few participants saw their off-farm income as directly supporting the farm operation. This income was usually seen as a way to pay household expenses when the farm could not sustain such expenses or as money to support lifestyle preferences and extra “wants.” For many women, off-farm work was also a source of self-fulfillment and a place to pursue their own goals. However, working off-farm is rarely accompanied by a decrease in household or farm responsibilities. Despite the personal fulfillment it offers, farm women who find their work increasingly stretched in multiple directions can experience increased levels of stress.

These findings support Arora-Jonsson’s (2011) argument about the importance of context; they respond to her recommendation for a nuanced analysis of gender and climate change. We cannot assume that vulnerability can be neatly mapped onto social categories of difference like gender. This study showed that gender is indeed a key dimension that shapes vulnerability and adaptation to extreme climate events; however, vulnerability should not be uncritically attached to women. In the case of Saskatchewan farmers, gender roles and ideologies made men more vulnerable to the psychological consequences of drought, challenging conventional discourses that feminize vulnerability. Women “pick up the pieces” (Fletcher 2013: Interview 1) as caregivers, farm workers, or off-farm wage earners. They play a critical role in coping and adaptation. At the same time, however, environmental crises tended to further entrench historical gender roles. Material and ideological factors position women as the “caregivers” and “nurturers” for the family during times of environmental crisis while giving them less agency over concrete adaptation strategies.

Policy Implications

Beyond strategies at the farm level, there is a need for government intervention to reduce vulnerability and facilitate adaptation over the long term (Marchildon et al. 2008). Indeed, Marchildon et al. (2008) showed that government disaster programs were a crucial coping mechanism used by farm families dealing with climate extremes. At the same time, such programs must be appropriately and accessibly designed in order to be useful. Programs must be attentive to both the macro- and micro-level political, economic, and social conditions affecting the community they serve. Disaster assistance and insurance coverage, for example, must keep up with the cost of production as farms grow larger and more industrialized.

Attention must also be paid to financial vulnerability caused by high levels of farm debt. The findings of the current study challenge the idea that small farming operations are necessarily more vulnerable than large farming operations; in fact, debt levels are a key determinant of vulnerability. Agricultural policies and programs must not uncritically promote farm growth—which is often premised on high debt levels—as a positive step for long-term farm sustainability.

Mental health and psychological stress emerged as key forms of vulnerability in the study. Rural residents often lack access to mental health support services due to geographical constraints and the urbanization of health services (Kubik and Moore 2005; Jaffe and Blakley 1999). Further, the stigma associated with use of these services can be a barrier in small and tightly knit communities (Fraser et al. 2005). Until 2012, Saskatchewan had a publicly funded, peer-based telephone helpline, the Farm Stress Line, which was well known among farmers as a source of mental and emotional support. In July 2012, the operation of the helpline was transferred to an urban-based community organization to save government expenditures of $100,000 per year (Government of Saskatchewan 2012b). Mental health services will become more important as climate extremes become more frequent and severe. These services must be provided with attention to appropriateness; that is, they should be provided by individuals with knowledge of, and experience in, agriculture. Further, support services should be designed with attention to gendered dimensions that create different experiences for farm men and women.

Government programs must also extend beyond just coping and disaster assistance to facilitate adaptive capacity over the long term. A dual focus on coping *and* adaptive capacity will help reduce future public expenditure in the event of an environmental disaster. Recent changes to federal infrastructure such as the erosion of the Prairie Farm Rehabilitation Administration, which was established as an institutional adaptation to the extreme droughts of the 1930s, suggest a decreased governmental emphasis on long-term adaptation.

Conclusion

A recent non-governmental organization handbook on climate adaptation stated that "one of the challenges of working at the local level on climate change adaptation is the lack of scaled-down information on impacts" (Dazé et al. 2009: 2). In this chapter, we have presented a scaled-down analysis of gendered impacts of drought in the Canadian Prairies. The analysis reveals the gender dynamics of vulnerability and adaptation—dynamics that are often invisible from a macro-level perspective and thus give the (mistaken) impression that climate change is a gender-neutral phenomenon that affects everyone equally. It is through a gendered lens that important social factors, such as psychological stress and the importance of social support networks, become visible.

At the same time, we emphasize the importance of situating micro-level understandings of climate vulnerability and adaptation within larger political and economic conditions. The current emphasis on industrialization and rapid farm expansion through debt has resulted in particular vulnerabilities for Prairie farm families; these vulnerabilities can be exacerbated by climate events and threaten the future sustainability of food production. Policies aimed at enhancing adaptive capacity must consider these broader economic challenges while simultaneously attending to differences within and between farm families. Such multi-scale, gendered analyses can inform more effective adaptation policies that are relevant and aligned with the realities of everyday life on the Canadian Prairies.

NOTE

1 A recent study (in which the authors are currently involved) found that unanticipated fluctuations between flood and drought, as well as dramatic departures from the "expected" extremes, can be particularly difficult for agricultural producers. For example, among producers in the drought-prone Palliser Triangle region of southern Saskatchewan and Alberta (see Chapter 8 by Marchildon in this volume), drought is generally expected and prepared for; therefore, the occurrence of an extremely wet year in 2010–11, which followed immediately after the drought of 2009, challenged producers' abilities to cope and adapt (VACEA Forthcoming).

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