IACC

INSTITUTIONAL ADAPTATIONS TO CLIMATE CHANGE PROJECT

FINAL REPORT
DECEMBER 2009

COMPARATIVE STUDY OF DRYLAND RIVER BASINS IN CANADA AND CHILE

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For more information about the project see our web site at: www.parc.ca/mcri or call toll-free: 1.866.874.2257

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PROJECT DESCRIPTION

The Institutional Adaptations to Climate Change (IACC) project is an international, multidisciplinary five-year research initiative funded under the Major Collaborative Research Initiatives (MCRI) program of the Social Sciences and Humanities Research Council of Canada (SSHRC). The goal of the IACC project is to develop a systematic, integrated and comprehensive understanding of the capacities of governmental institutions to formulate and implement strategies of adaptation to climate change risks and the forecasted impacts of climate change on the supply and management of water resources in dryland environments. This goal is addressed through a comparative study of two regions: the South Saskatchewan River Basin (SSRB) in western Canada and the Elqui River Basin (ERB) in north-central Chile. Both regions have a dry climate adjacent to a major mountain system and landscapes at risk of desertification as well as an agricultural economy dependent on water derived from mountain snow and glaciers. As a result of drier conditions and increased climatic uncertainty, they will be similarly affected by climate change. The specific objectives of the project are:

1. to identify the current social and physical vulnerabilities related to water resource scarcity in the two dryland regions;
2. to examine the effects of climate change risks on the identified vulnerabilities; and
3. to assess the technical and social adaptive capacities of the regional institutions to address the vulnerabilities to current water scarcity and climate change risks.

The project focuses on the vulnerabilities of rural communities to climate and water stress as well as the organizational capacities of governance institutions to address those vulnerabilities. These foci are based on the idea that

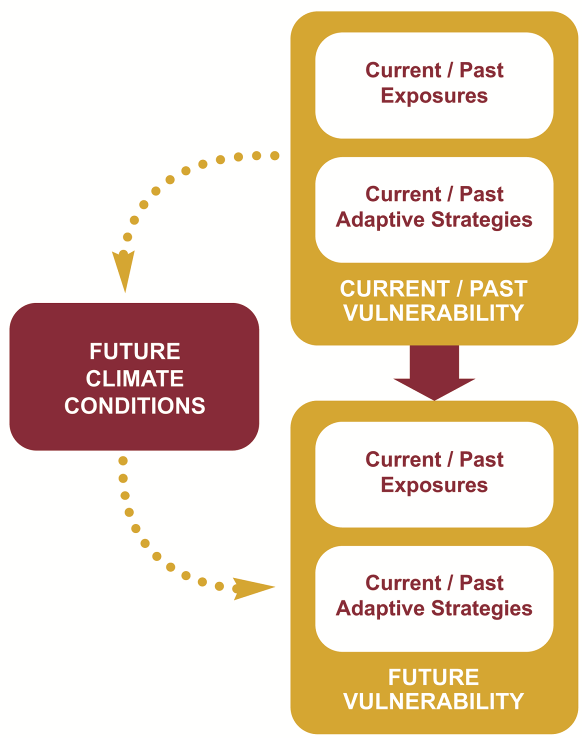

Figure 1. The Vulnerability Approach Model

the capacity to adapt—or reduce—vulnerability is determined not only by local assets (e.g., economic capital and available technologies) but also by broader governance networks that define the use and distribution of vital natural resources, as is the case with water.

This document is the final report for the IACC project. It begins with an introduction to the project and a description of the conceptual model and approach that was adopted. This is followed by a discussion of the project's research activities, which were organized into three clusters. It concludes with an integrative summary of the key findings from both study basins as well as a comparison of these findings. This report contains an appendix that identifies the research team and lists (in alphabetical order by author) the working papers, theses, presentations and media releases, workshops and publications, and reports produced by the research team in relation to the project.

CONCEPTUAL MODEL AND APPROACH

The project adopted a vulnerability model (Figure 1), which guided the research process and analysis, and also facilitated the integration of research activities. For the purposes of this research, vulnerability is conceptualized as a function of *exposure-sensitivity* and *adaptive capacity*. *Exposure-sensitivities* are properties of a system (community, sector, region, basin, etc.) and refer to the interaction of both the characteristics of the system and a stimulus. They reflect the manner in which a system experiences conditions to which it is sensitive (Smit and Wandel, 2006). The actions taken to ameliorate risks and capitalize on opportunities are considered *adaptive strategies*. The system's ability to employ adaptive strategies reflects its *adaptive capacity*.

The vulnerability model emphasizes the need to analyze not only the future vulnerability of a system to climate change, but also its vulnerability in the context of past and current climate conditions. This approach acknowledges that resource use decisions are rarely made independently of other stresses and opportunities. The analysis begins with the identification of how climate-related factors influence individuals, communities or economic sectors, and what ability exists to manage changes in these. The empirical application of the approach requires: (1) the development of a systematic understanding of both the current exposure of a system to climatic and other stresses as well as its adaptive capacity; (2) the construction of future climate scenarios for the study area; and (3) an assessment of future vulnerabilities based on (1) and (2). This involves an analysis of how existing vulnerabilities may be affected by future climatic conditions.

RESEARCH ACTIVITIES

Since the vulnerability approach consists of three stages, the project's research activities are organized into three clusters (Figure 2). Cluster 1 accomplishes Objective 1 and involves the analysis of current rural community vulnerabilities. There are several research projects within Cluster 1:

(a) an assessment of the current vulnerabilities of a group of rural communities in the two basins (Unit 1A);

(b) an analysis of the role of institutions in the resolution of a group of recent conflicts related to water scarcity (Unit 1B);

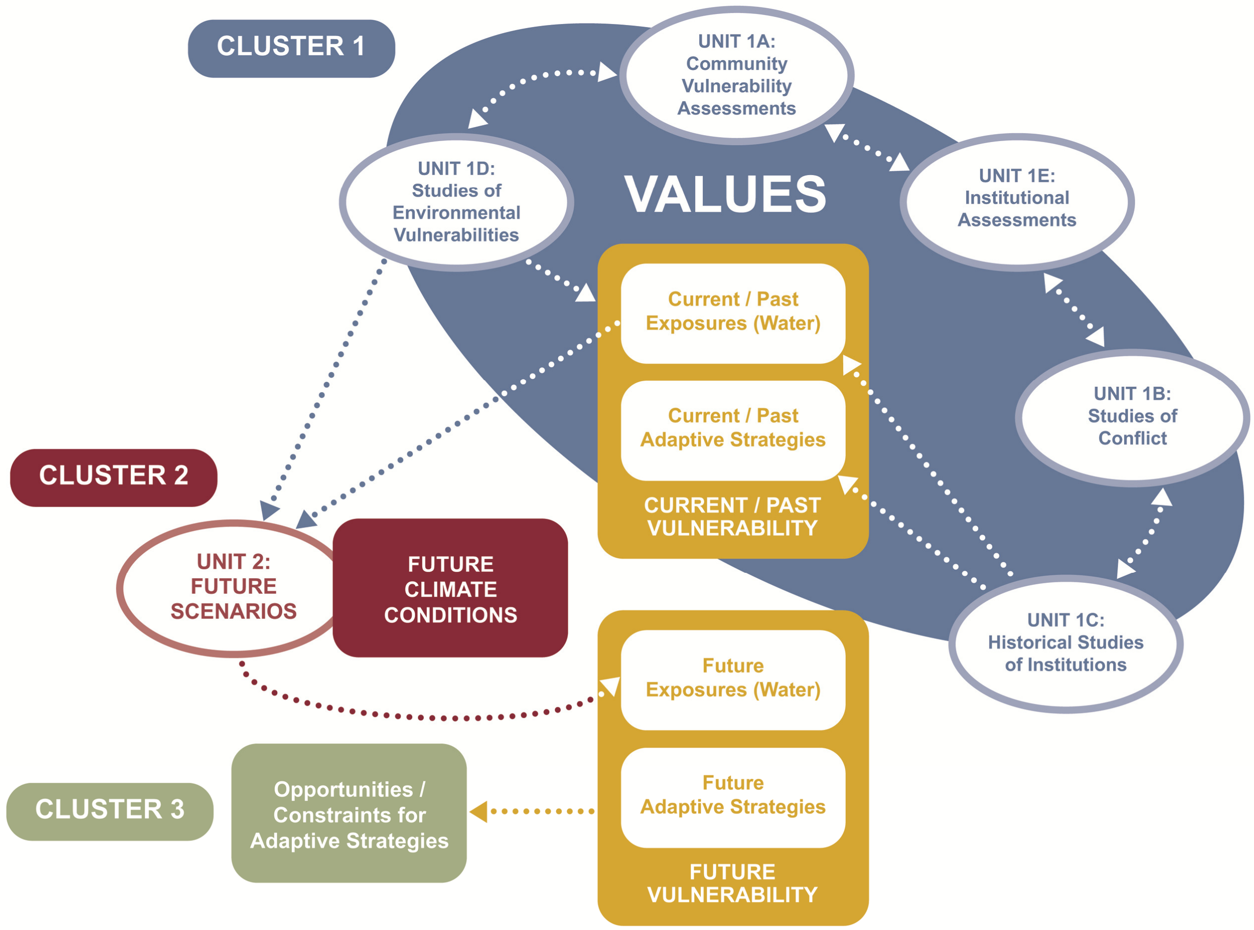

Figure 2. Project Organization

(c) a historical study of institutional adaptation in periods characterized by water scarcities (Unit 1C);

(d) an analysis of environmental vulnerabilities identified by stakeholders (Unit 1D); and

(e) an assessment of the capacities of governance institutions to reduce the vulnerabilities of rural communities (Unit 1E)

Cluster 2 accomplishes Objective 2 and involves an assessment of the future climate scenarios for the two basins and their potential impacts. Cluster 3 accomplishes Objective 3 and involves an assessment of the capacities of governance institutions to deal with the future vulnerabilities of rural communities. The project's website (www.parc.ca/mcri) contains all the documents produced by the three clusters.

RESEARCH INTEGRATION:
THE CASE OF THE TWO BASINS

This section integrates the main findings from the three clusters into a single comprehensive report for each of the two study basins. Following the vulnerability approach, each case study discussion begins with a summary of past and present vulnerabilities, followed by a description of future climate conditions, a synthesis of future vulnerabilities, and a detailed outline of the project's recommendations. This section concludes with a comparative discussion of the two basins.

THE CASE OF THE SOUTH SASKATCHEWAN RIVER BASIN (SSRB), CANADA

Past and Present Vulnerabilities

PAST/PRESENT DROUGHT AND OTHER CLIMATE-RELATED EXPOSURES

The SSRB covers approximately 166,000 square kilometres, encompassing three provinces, with four major rivers; the SSRB is one of Canada's larger watersheds, experiencing a wide variability of climate, geography and hydrology (Toth et al., 2009). Its climate is determined by its location. The Rocky Mountains to the west impede easy access of moisture-bearing winds from the Pacific Ocean. As a consequence, most of the basin has a continental climate, subhumid to semiarid with short hot summers (mean temperatures from 14°C to 16°C), long cold winters (mean temperatures from -12.5°C to -8°C), low levels of precipitation (with mean annual precipitation extremely variable but generally increasing northwards from less than 300 mm to 600 mm per year, and also increasing towards the eastern and western margins of the basin), and high summer evaporation. A water deficit is a characteristic of this area—this is Canada's largest dryland watershed—with the high winds accelerating evaporation. While average precipitation values are as low as 282 mm per annum in the central part of the SSRB, the Montane Cordillera receives well over 600 mm. Consequently, the SSRB is highly dependent on snowmelt runoff from the eastern slopes of the Rocky Mountains, which feeds the rivers and streams of the SSRB. The Palliser Triangle—the driest part of the Canadian Prairies—is characterized by large annual average water deficits. Precipitation is less than potential evapotranspiration (PET), with values well below 0.5 P/PET in the eastern portion of the basin south of Saskatoon.

The six rural communities selected for the community vulnerability assessment—Kainai Blood Indian Reserve, Taber, and Hanna in Alberta; Cabri, Stewart Valley, and Outlook in Saskatchewan—are within the Palliser Triangle (Figure 3). Although there is great diversity among the study communities, one commonality is that they are all heavily engaged in agriculture. Taber and Outlook are heavily reliant on irrigation, while Cabri and Stewart Valley are surrounded by agricultural dryland, which is dependent on the right amount of precipitation at the right time of the year. Hanna is also in a dryland area, with a predominant ranching mode, while the Blood Reserve faces many of the challenges experienced by First Nations communities. Despite these differing situations, the communities have had, and are expected to have, similar exposure and sensitivities to climate and other stresses (Marchildon et al., 2008; Marchildon et al., 2009; Matlock, 2007; Magzul and Rojas, 2006; Pittman, 2008; Prado, 2008; Young and Wandel, 2007; Wandel et al., 2009).

Rural communities and agricultural producers are exposed and sensitive to a variety of climate variability-related events. Changes in temperature (e.g., heat waves, temperature fluctuations, and late and early frosts), and other climate-related events (e.g., hail, high winds, wind erosion and grasshopper infestation) sometimes severely impact rural livelihoods and economic activities.

The western portion of the SSRB is frequently exposed to Chinook winds, which can drastically raise temperatures over the course of just a few hours. These winds can be problematic

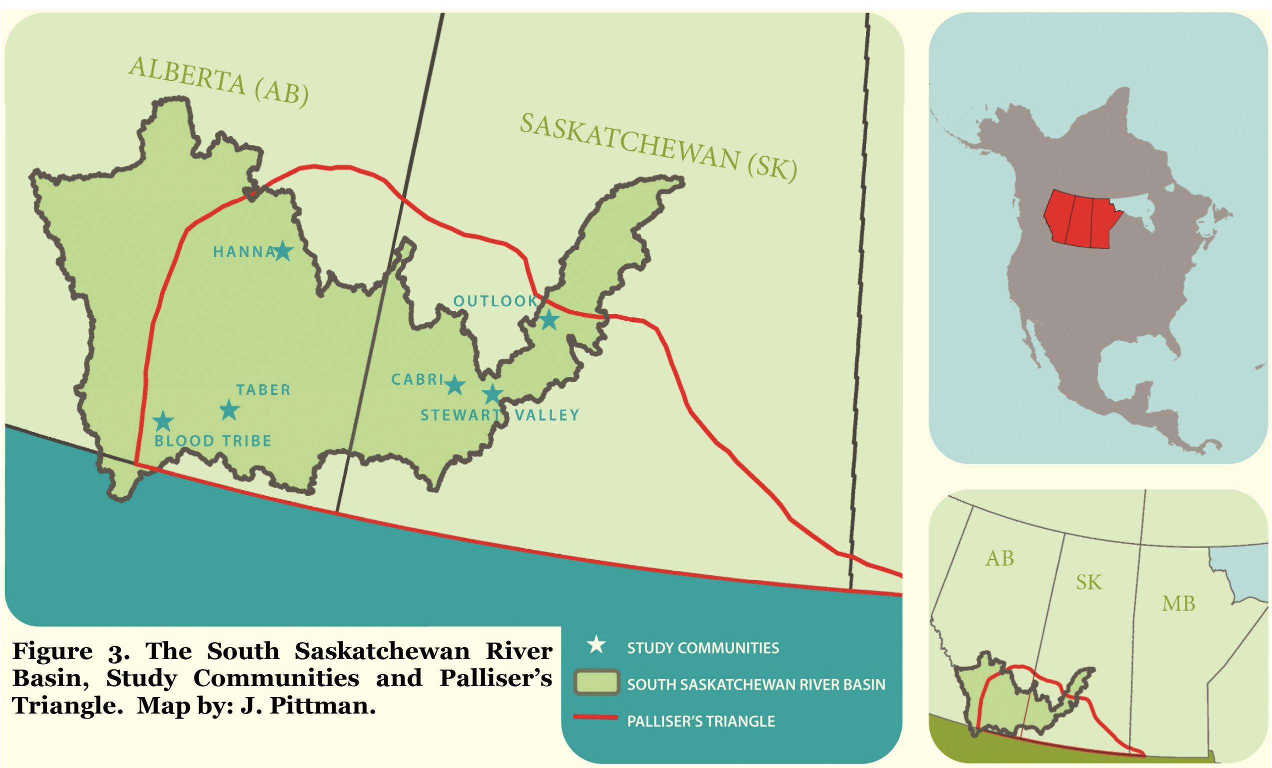

Figure 3. The South Saskatchewan River Basin, Study Communities and Palliser's Triangle. Map by: J. Pittman.

for cattle producers as thaw cycles can melt snow in the middle of winter, which subsequently refreezes as ice, causing problems for cattle health. Vegetable producers in Taber report that crops in long-term storage are sensitive to Chinook-related temperature fluctuations, as they cause decreases in the sugar content of crops that are not stored in a climate-controlled environment. The Chinooks present particular problems for moisture management in both crop and livestock farming. Complete snow cover throughout the winter months means that the soil is protected from the drying effect of wind. However, warm winds can melt enough snow that the ground is now bare, and thus stored soil moisture is lost through evaporation. Furthermore, if the Chinook melts accumulated snow in moisture-stressed areas, the snow's contribution to soil moisture is generally inferior to what it could achieve during a slow, gradual spring melt. During rapid warming such as during a Chinook, the soil does not warm up enough to thaw and thus runoff does not infiltrate and the accumulated precipitation is lost as it runs off fields, save for what can be captured in surface storage facilities such as dugouts, reservoirs or lakes.

In addition to this alternating freeze-thaw, low temperatures in winter are an important exposure-sensitivity. The southern Prairies have, historically, frequently experienced extreme cold snaps during the winter, and crop farmers count on these to control insects from year to year. A lack of periods with extreme cold temperatures (e.g., -25°C) can result in the year-to-year survival of pests, which ultimately results in lower crop yields. In contrast, warmer winters may result in some economic savings for cattle producers, who face an increase of 30% to 50% in feed requirements if temperatures are below -20˚C.

In late winter and early spring, rancher operations are particularly sensitive to extreme cold, because this is their calving season (e.g., January to May). Such cold temperatures can affect the health of the cow and her calf and contribute to an increase in pneumonia among newborn calves. Temperatures during snow melt also present exposure-sensitivities for farmers and ranchers: if the snow melt is slow and gradual, soil moisture increases and contributes to better crop and grass growth throughout the growing season. However, a slow and gradual snow melt coupled with low snow accumulation, either through low precipitation or as a result of repeated "Chinooking off," may mean that ranchers' dugouts, which are reliant on snowmelt runoff, may not fill and thus there may be insufficient stock water throughout the year.

Later in the spring, all producers need adequate heat for crop germination and growth. However, the need for sufficient warmth is closely tied to adequate moisture, as both are required. Ideally, farmers need rain and mild temperatures after seeding. If it is both cold and dry, the seed lies dormant until such conditions are reached. However, if conditions are both cold and wet, seeds may become unviable. Similarly, if the plants germinate and they do not receive adequate moisture thereafter, they will fail. This is an issue for both field crops and tame pastures, as native pastures are more resilient to these conditions.

Crop farmers' operations are particularly sensitive to late frosts if they occur during post-emergence of the plant. Too much heat during summer can be a problem. Dryland farmers are sensitive to extreme heat (30˚C and above) as it dramatically increases the moisture requirements for crops; thus, extreme heat coupled with dry conditions poses substantial problems. Even those who rely on irrigation to meet crop moisture requirements have difficulty with extreme heat as this hastens crop ripening. If crops mature early, yields decrease.

Crops and pastures require moisture throughout the growing season, though the crucial times vary by enterprise type. Ranchers need moisture early in the season for hay germination, establishment and growth. After haying in mid-summer, they are far less sensitive to low moisture than field crop producers, whose crops develop throughout the growing season. Even among ranchers, those relying on native grasses are less sensitive to low moisture than those who seed tame grasses. Both native and tame grasses, as well as field crops, are subject to drying winds during hot summers with inadequate moisture, but native grasses will retain their protein value even if they dry on the stalk.

Hot summer days are linked to the formation of thunderstorms. When these are accompanied by hail, all agricultural producers can be affected. Although hail is particularly damaging to pre-harvest field crops, even pastures can be decimated by localized hail events. Similarly, wind, whether accompanying thunderstorms or on its own, can be problematic as it contributes to the drying effect of hot temperatures and, in cases of high winds, can damage crops and buildings. Irrigators are particularly sensitive to high winds as irrigation equipment such as pivots are vulnerable to wind damage. Later in the growing season, early frosts (e.g., prior to September 15th) can be problematic for both dryland and irrigated farmers. A frost event before frost-sensitive crops such as vegetables have been harvested will affect crop quality. Irrigated farmers are particularly exposed and sensitive to early frosts, as their crops tend to ripen later than dryland crops, and thus the pre-harvest window is longer (Wandel et al., forthcoming; Young and Wandel, 2007).

The SSRB is also subject to many extreme weather events. The project's studies highlight that prolonged and severe drought is the single most marked exposure feature of the SSRB. The challenges imposed by water scarcities become more dramatic during periods of drought, a phenomenon that is a natural and recurrent characteristic of the regional climate of the western part of the Prairies (Sauchyn et al., 2002; Toth et al., 2009). Droughts affect not only the supply of water to the regional population but also amplify the negative impacts of aridity on soil erosion. They also contribute to ecosystem degradation. An increasing point of concern is that although severe drought has occurred most often in southwestern Saskatchewan, droughts have more recently migrated farther northward and affected communities less accustomed to dealing with drought impacts (Wheaton et al., 2008). Several studies completed within the project show that the impacts of drought on the Canadian Prairies during the last century have been dramatic, such as the drought of the Great Depression, which affected millions of acres and forced thousands of people to migrate into less affected areas (Marchildon et al., 2008). The most recent significant droughts—2001 and 2002—seriously impacted the Prairies: net farm income was negative in Saskatchewan and zero in Alberta, and agricultural production losses reached over $2 billion in the two provinces (Wittrock et al., 2007; Sauchyn and Kulshreshtha, 2008). The IACC project carried out several studies to analyze the impacts of the 2001 and 2002 droughts on the six communities selected for the vulnerability assessment. Although the extent and severity of low water levels varied from community to community and affected the economic and social activities differently, these droughts had a devastating effect on local economies and water supplies (Wittrock et al., forthcoming; Diaz et al., 2009b; Wandel et al., 2009).

Although the SSRB is particularly exposed and sensitive to drought, too much precipitation can and does pose significant problems for rural people. For both dryland and irrigated farmers, an excess of rain means crop losses and much other damage. Ranchers, on the other hand, are far less vulnerable to excess moisture at any stage of the growing season, as grass is generally more resilient to these events. Flooding is also a major natural hazard in the upper reaches of the SSRB (southern Alberta), mainly due to rapid rainfall events, rapid snowmelt, or a combination of these factors. In contrast with the case of droughts, floods can have very rapid and different severe impacts on communities, ranging from housing, agricultural and infrastructure damage, and can place significant strain on emergency services. Producers in Taber, Kainai Blood Indian Reserve and Outlook have reported flooding during extreme rain events in the growing season. Since the early 1990s, the three communities have experienced severe floods. The floods of 1995, 2002 and 2005, for example, resulted in significant costs for residents and the local infrastructure (Magzul and Rojas, 2006; Pittman, 2008; Prado, 2008).

Rural people are also exposed to a range of threats relating to surface and groundwater quality and quantity. Nutrient contamination resulting from agricultural and industrial activities, as well as sewage effluent, storm water runoff, and biological contamination affect the aquatic ecosystems and water resources, with potential negative impacts for the local population. Increasing water demand is another problem in the basin. Potential demand from irrigated and non-irrigated agricultural areas, limited supply for additional water allocation, and the expected increase in population compound water supply issues.

The SSRB has a sophisticated and diverse economy that provided over one million jobs in 2001, and contributes about $69 billion to Gross Domestic Product (Bruneau et al., 2009). However, most rural communities in the SSRB are heavily dependent on agriculture and face all the economic difficulties common to this sector (e.g., high input costs, low commodity prices, market fluctuations, etc.). These economic difficulties have contributed to economic instability, financial hardships, radical changes in family agriculture, high family stress, rural out-migration, and significant changes to rural infrastructure, health care and education. These conditions, which are the product, to a large extent, of the transformations in the global agricultural market and changes in agricultural policies, are identified as an important source of stress by rural people (see Epp and Whitson, 2001; Jones and Schmeiser, 2005; Knuttila, 2004; Stirling, 2004).

These non-climate sources of stress, in conjunction with harsh climate conditions such as drought, have created multiple exposure/sensitivities for all communities. It is this juxtaposition of multiple stressors that has been identified by rural people as being at the central core of their vulnerability. These external stressors interact with regional and local conditions, generating a number of additional issues that result from this interaction (Patiño and Gauthier, 2009).

Past and Present Institutional Adaptations

The rural history of the SSRB has been one of continuous adaptation to multiple sources of risk, climate being one of them. A variety of practices, processes, systems, and infrastructure have been tried and adopted by communities and households to reduce risk and facilitate new opportunities. Accumulating assets, relocating human resources, diversifying income and crops, redefining land use, producing new crop varieties, harvesting water, adopting new technologies, building irrigation and flood control infrastructure, and using kinship and community social networks are among the myriad of strategies that the community vulnerability assessments as well as other IACC studies have illustrated that rural people employ in times of stress.

Agricultural producers have adopted a range of management strategies to deal with climate-related exposure-sensitivities. They rely on changing the timing of their operations based on microclimatic conditions, diversifying their operations to include fewer moisture-sensitive crops as well as livestock or, in the case of several producers in the SSRB, replacing annual crop production with livestock. Cattle producers also rely on a suite of management strategies, including the construction of more or larger dugouts, fencing off existing ones and using on-demand pumps to maintain water quality as supplies run low. In some areas, producers have started digging shallow pipelines for dugout recharge from secure sources (such as pipeline tap-offs or good wells) and, in extreme situations, ranchers have resorted to hauling water using bulk tankers to bring their cattle through extreme dry periods. Both farmers and ranchers have diversified their sources of income in order to deal with the economic risks created by global economic processes; off-farm work has become increasingly common in the basin. Adaptation to insecure farm economics is particularly facilitated in the SSRB by the presence of the oil and gas industries. Producers are compensated for oil industry access to both owned and leased land. As well, these industries are a source of high-paying employment, which in turn can supplement farm income (Wandel et al., forthcoming).

These examples demonstrate adaptive capacity at the local level, or the ability of rural people to deal with climate variability and other forms of risk. Adaptive capacity, however, is unevenly distributed within the SSRB and among social sectors. As the community vulnerability assessments have demonstrated, rural communities differ in terms of their access to resources, types of agriculture, institutional capacities and so on; the Blood Tribe is perhaps the most vulnerable community due to its lack of resources.

The adaptive capacity that exists at the local level has been shaped considerably by larger decision-making frameworks, especially by different levels of government and governance networks. Since the early 1900s the adaptive management process has been continuous and characterized by the steady improvement of management policies and practices, which have to a large extent defined the degree of exposure-sensitivity as well as the adaptive capacities of rural people. This adaptive management process has evolved since settlement, and has usually been reactive in times of crisis (e.g., responses to drought). Over time the accumulated benefits of this process have facilitated (and constrained) the development of capacities to deal with expected climate variability. Examples include improvements in cropping, water management and land use, and improved institutional adaptations (Marchildon et al., 2008; Bruneau et al., 2009). The project's studies demonstrate the outcomes of this process, its strengths and weaknesses, and its contribution to building capacity to deal with climate risks and opportunities, particularly drought.

The study of water-related conflicts and the role of institutions in their resolution provided an opportunity to identify and understand how the impacts of conflicts can increase the exposure and vulnerability of affected groups *vis-à-vis* access to water in the context of climatic change. When these lessons are acted upon in effective and meaningful ways, the adaptive capacity of communities and water governance institutions can be enhanced (Rojas et al., 2009a).

The historical studies illustrate one key lesson: that crises reveal vulnerabilities and expose institutional weaknesses while at the same time forcing institutional innovations that address, at least in part, those same weaknesses. In the early 20th century, two principal water scarcity crises in the SSRB illustrate this lesson: 1) the prolonged drought in southeastern Alberta that preceded the Great Depression; and 2) the prolonged drought after 1927 that covered almost all of the Palliser Triangle.

Beginning in 1917, the Dry Belt (see Figure 3 – Palliser's Triangle) within the SSRB suffered through ten years of successive drought, most adversely impacting the large, specialized wheat growers. This first crisis revealed the weaknesses of the settlement pattern in the Prairie Provinces, including the federal government's encouragement of grain farming in the driest part of the SSRB after 1909, and the weak and divided structure of local government that separated towns or urban municipalities from the farms organized in rural municipalities. The major institutional innovation in the face of this first crisis was the establishment of the Special Areas Boards by the Government of Alberta and its active efforts to shift to a system of land tenure more suitable to the arid conditions of the Dry Belt and more capable of taking on the risk associated with periodic cycles of severe and multi-year drought, providing local people with an institutional adaptive mechanism to reduce their exposure to drought. This change in land tenure was complemented by the establishment of a larger administrative authority, which has significant advantages over small and fragmented rural and urban municipalities in terms of facilitating adjustment to prolonged periods of water scarcity, particularly when a shift in overall land tenure is required. This advantage seems to be well understood by the population living within the Special Areas. Though offered the opportunity to replace the Special Areas Board with democratically elected local rural government, the people of this sub-region have chosen to keep the Board structure intact despite the fact that nothing similar to the almost two-decade-long drought of the interwar years has reoccurred (Marchildon, 2007).

The second water scarcity crisis—the extensive and prolonged drought covering most of the Palliser Triangle from 1928 until 1939—revealed the fatal vulnerability of the small and bifurcated local government structures throughout the SSRB. It also exposed the potential weakness of provincial governments acting in isolation of each other and the federal government. Relief was the most common, and the most expensive, institutional response by governments, charitable organizations and local communities to the disaster of prolonged drought from 1928 until the end of the 1930s. Despite the many difficulties, federal-provincial collaboration in relief distribution likely prevented wholesale starvation in the SSRB (Marchildon et al., 2008). This example emphasizes the value of intergovernmental and inter-agency cooperation.

Because of cattle ranching and irrigated agriculture in western Alberta, and policy interventions to restrict wheat farming and shore up a weak municipal structure in eastern Alberta, Saskatchewan was considerably more vulnerable than Alberta to the effects of the prolonged and severe drought. As a result, Saskatchewan also became the centre of gravity for the Prairie Farm Rehabilitation Administration (PFRA), the major initiative by the Government of Canada to rehabilitate the drought-stricken Palliser Triangle.

The *Prairie Farm Rehabilitation Act* was passed in 1935. The Act set out that the federal Department of Agriculture would administer small earthen dam building to conserve water, and grass and tree planting to prevent further soil-drifting, as well as conduct extensive soil surveys and establish demonstration farms that would address the most pressing needs of farmers in the most drought-stricken parts of the Palliser Triangle. In 1937, these activities were organized under the Prairie Farm Rehabilitation Administration, adding the creation of community pastures out of the worst areas of soil drifting. These federally owned and managed pastures were to be made available, at low cost, to surrounding mixed farmers and ranchers to supplement their own livestock feed. Because of the constitutional distribution of powers, the PFRA—a federal agency—could not operate without receiving a minimum of provincial collaboration. In fact, the federal government received the enthusiastic support of the Saskatchewan government, and this produced a fruitful collaboration that allowed for a remarkable rehabilitation of drought-stricken southern Saskatchewan. While the PFRA received only grudging support from the Alberta government, it was enough to launch most of the PFRA's initiatives with the province, including major irrigation and water diversion projects. The exception was the community pasture program, a limitation on the PFRA that was not fatal because of the Alberta government's pre-existing community pasture program in the Special Areas (Marchildon, 2009).

Since the late 1930s, PFRA has provided technical support and funding for soil and water conservation projects, applied research and demonstration for improved land use and adaptation practices (e.g., use of drought-tolerant crops, conservation tillage, etc.), and on-farm and rural water development projects, including farm dugouts, rural water pipelines, and rural water infrastructure ranging from irrigation works to rural water treatment plants, increasing access to water supplies for the agricultural sector and rural communities. To a large extent PFRA has been responsible for considerable drought resilience on the Prairies. More recently, PFRA[1] has developed climate monitoring and forecasting capabilities designed to facilitate decisions and planning related to climate-induced water stress events like droughts—significantly building adaptive capacity to expected climate changes. As a result of all this experience, PFRA currently appears to be far ahead of other federal and provincial agencies on this front. In recent years, however, some of the PFRA's activities in the region have been curtailed (e.g., reduced water infrastructure programming) while other activities have been enhanced (e.g., national agri-environmental programming).

In an effort to establish sustainable and profitable agricultural practices, significant adaptations were implemented after the severe droughts of the 1920s and 1930s. Reduced or minimum tillage practices were adopted to sustain and conserve soil and soil moisture, marginal lands were converted from cropping to permanent grass cover and community pastures, and increased efforts were made to pre-

[1]In April, 2009, PFRA, once strictly a prairie agency, became the Agri-Environment Services Branch. AESB will remain a branch of Agriculture and Agri-Food Canada, but takes on a national mandate focused on agri-environmental sustainability and innovation to promote a competitive profitable agricultural sector. Water and climate change/adaptation are key priority issues that are currently driving some of AESB's national activities.

serve ecological benefits of natural wetlands (Bruneau et al., 2009).

Several other institutional measures have been developed to ensure secure and reliable access to water, especially in periods of water scarcity. One of them has been a significant investment in irrigation infrastructure and technology. Irrigation has always been perceived as the primary adaptation of agriculture in semiarid and arid regions, such as the SSRB, and the increasing presence of PFRA in the Prairies has contributed to the establishment of a large extension of land in Alberta and Saskatchewan under irrigation. At the present time, Saskatchewan has approximately 11% and Alberta well over 60% of Canada's irrigated land. Access to irrigation provides agricultural producers with not only relatively reliable access to water, but also creates the conditions for crop diversification and the related additional income. The benefits of irrigation are, however, limited only to those farmers and communities located in the irrigated areas.

Another significant institutional contribution to secure water in the Prairies has been the creation of the Prairie Provinces Water Board (PPWB) in 1948. The PPWB, which operates under a formal relationship between Manitoba Environment, Saskatchewan Watershed Authority, Alberta Environment and the federal government represented by Environment Canada and PFRA, oversees the apportionment agreement on river water flow among the three Prairie Provinces. Briefly, this agreement requires that 50% of the waters which rise in Alberta be allowed to pass into Saskatchewan, which then has to pass half of the natural flow into Manitoba—both what it receives from Alberta and what is added in Saskatchewan. The PPWB also monitors the quality of water entering and leaving each of the provinces. This agreement provides some degree of certainty on the quality and availability of surface water, ensuring equitable sharing of the water resource across provincial boundaries, and helping to avoid potential conflicts related to the distribution of water resources.

There has also been increasing institutional support to reduce the risks associated with unpredictable weather conditions. Federal and provincial governments have established safety net programs that reduce the negative impacts of these conditions on farmers and ranchers. By 2002 there were several federal programs to help lessen drought impacts. Alberta and Saskatchewan are partnered with the federal government in several programs. They also maintain their own crop insurance, livestock drought assistance, farm management, and conservation programs (Wittrock and Koshida, 2005). These programs have limitations, however, as was demonstrated in the high costs they incurred during the 2001–2002 drought and the dissatisfaction expressed by many farmers.

Water laws influence institutional capacity to cope with and alleviate the impacts of water stress. Saskatchewan's water law consists predominantly of *The Saskatchewan Watershed Authority Act, 2005,* S.S. 2005, S-35.03. The Act establishes the corporation, the Saskatchewan Watershed Authority, and establishes its powers, mandate, and rules for administration moving from a legislated water rights model to a water rights model managed by a Crown Corporation. Issues formerly dealt with by legislation were then left to be resolved at the discretion of officials of the then Water Corporation (and now Saskatchewan Watershed Authority). It is argued that the licensed water rights established by the statutory scheme prior to 1984 remain in tact; water licenses issued after that time are at the discretion of the Corporation (Percy, 2004). As there is not a statutory scheme of water rights, and there is not a publicly accessible record of water rights, it is unclear what the priority of water rights will be in the event of a conflict.

In Alberta, The Minister of Environment responsible for the *Water Act* designates a "Director" who has responsibilities outlined in the Act for the management of water including issuing licenses, developing water management plans, water conservation objectives and authorizing water works. The *Water Act* establishes four classes of water rights: existing licenses, household users, traditional agricultural users, and new licenses and established a detailed structure of priority amongst these users. Transfer of water rights is allowed if in accordance with an approved water management plan, and in the absence of such a plan, Cabinet order. In the South Saskatchewan River Basin there is a South Saskatchewan Basin Water Management plan which allows the Director to consider applications to transfer water allocations within the basin. This is described as creating a non-regulatory method of reducing wasteful use by creating an incentive to save water and transfer its marginal value for compensation (Percy, 2004).

Significant developments have contributed to this growing capacity over the last decade. The first was the development of a new institutional water governance system aimed at improving the management of water resources. In Saskatchewan the new system was organized around the *Safe Drinking Water Strategy* of 2002, which came to be as a response to drinking water disease outbreaks in Walkerton in 2000 and North Battleford in 2001. The strategy involved a rearrangement of water governance in the province and the development of a wide-ranging water monitoring and regulatory system for municipal drinking water. The system required that municipalities meet standards for water quality and have qualified water treatment technicians. While the institutional approach has its challenges, it provides reliable drinking water to communities and surrounding farm households. In Alberta the new institutional development was organized around the *Water for Life Strategy*, created in 2001. Its goal was to achieve more sustainable management of water resources after Alberta recognized that it was facing significant pressure on its water supplies (e.g., limited availability, water quality impacts, competing demands, etc.).

More recently, the integration of civil society into the governance of water resources was linked with the creation of new institutional systems in Alberta and Saskatchewan. In both provinces local organizations and community members are participating in watershed councils or committees, and engaging in the development of water plans. Integrating local people and communities into watershed decision-making processes is a central theme of integrated water resource management, and is consistent with standards set by the World Water Council. When this approach is fully realized it should contribute to better management of the risks associated with climate change, as well as more sound water management (Hurlbert et al., 2009b).

Finally, there has been a significant increase in institutional research in water resources and climate change areas within the SSRB. Climate change research programs have been developed in regional universities, such as the Prairie Adaptation Research Collaborative (PARC) at the University of Regina, the Water Institute for Semiarid Ecosystems based at the University of Lethbridge, the Alberta and Saskatchewan Research Councils, and other government agencies. This increasing production of knowledge is fundamental to understanding vulnerabilities and impacts and for developing capacities to deal with climate and water stresses, but they still need to be integrated into governance policies, management, programs, and practices.

The aforementioned institutional developments have benefited rural communities, farmers and ranchers by strengthening their adaptive capacity to deal with normal climate variability and, to a certain extent, with extreme variability, although some of the limitations of their adaptive capacity were demonstrated during the 2001–2002 droughts. Several institutional challenges need to be addressed in order to enhance capacity and build resilience to deal with future climate change risks and opportunities. Some of these challenges were identified in the assessment of Alberta and Saskatchewan water governance systems (Diaz et al., 2009a; Wandel, 2009). They are:

- **The distribution of adaptive capacity**. The community vulnerability assessments demonstrate that resources are unevenly distributed. The Kanai Blood Reserve is the most vulnerable due to the particular conditions that characterize First Nation communities, but other communities such as Cabri and Stewart Valley are also highly sensitive to extreme climate events such as drought, due to their lack of access to irrigation and their small and aging populations. Those communities that are most resilient have well-established water infrastructure (storage reservoirs and distribution networks) and utilize irrigation to supplement periods of low precipitation that do not meet crop water requirements. Policy responses targeted at rural communities need to consider climate impacts on several areas, particularly as they relate to water, the environment, and vulnerable economic activities such as agriculture.

- **The scope of most policy analysis and development in these communities**. The community vulnerability assessments reveal a large array of potential harms that climate change and inappropriate institutional actions can produce or perpetuate. These include: harms to communal identities and stability; to people's sense of heritage; to cultural integrity; to informal systems of governance (e.g., First Nation clan systems); and especially to trust-based relationships. The research studies on conflict and values point to the need to protect social capital (the connections between and within social networks) through such activities as allocating resources to augment community-government relations, a practice utilized by the former PFRA. The vulnerability assessments also point to the need for policy and programs to consider different styles of development and ways to relate to ecosystems and preserve the environment (Morito, 2006; Rojas et al., 2007). New methods of program delivery should incorporate future climate scenario planning to anticipate future climate conditions and impacts on regional water supplies, with a balanced view of environmental, social and economic impacts, and ways to build local and rural resilience.

- **Water data availability**. The research identified gaps in water data (water quality, quantity and actual use patterns, groundwater supplies, climate data) required for effective water management and planning. This issue has also been emphasized in much of the relevant scientific and water management literature. Knowledge of water sources and climate impacts on surface and groundwater supplies is critical for effective water management and planning. If the status of available water resources is uncertain, it is increasingly difficult to make projections about future resilience in the face of climate change. For example, at present Saskatchewan lacks a detailed groundwater resource map. There is uncertainty about what data are available, what can be readily accessed and who is responsible for making sure that data are collected and shared. This, in theory, is a manageable problem that can be ameliorated with dedicated resources (time, people and finances).

- **The need for long-term planning**. While much effort has been directed towards climate change mitigation issues, governments are still in the early stages of developing climate change adaptation plans. Many current forms of government activity assist in reducing vulnerabilities or enhancing adaptive capacity; other activities could easily be reoriented to assist with improving adaptive capacity. However, without a more intensive and collaborative effort, it is difficult to achieve the highest returns for climate adaptation work. This is especially important where drought is concerned. While many Saskatchewan agencies involved in water governance mentioned preliminary efforts to plan around drought, nothing of significance currently exists. A number of case-specific responses do not constitute a comprehensive plan. Not only is there a lack of planning related to the negative impacts of drought, there is little planning around the potential opportunities and benefits that drought in other regions might offer Saskatchewan residents. The absence of a drought plan is related to the lack of sufficient data noted above (Hurlbert et al., 2009a). Alberta has a formal "Agriculture Drought Risk Management Plan," which is primarily focused on short-term coping strategies at the producer level. The 2001–2002 drought, however, highlighted the need to address the larger picture of water allocation during times of surface water shortage (Wandel, 2009). Long-term planning also needs to extend beyond provincial boundaries, and should consider regional approaches to achieve effective adaptation.

- **The effectiveness of watershed advisory groups**. Watershed groups play an important role in increasing adaptive capacity in both provinces. They reflect the widely recognized principle that water problems and climate impacts are always local. If impacts are to be dealt with effectively, information must be gathered at the local level and local stakeholders need to be included in the policy development and management process, as well as in the implementation of action plans to build resilience. While the voluntary involvement of stakeholders may be admirable and necessary, the advisory group process is unlikely to be sustainable under the existing model. The endurance of the advisory groups is threatened by their lack of predictable funding. While there is disagreement about whether the groups should be given a regulatory and taxing capacity, their advice-giving role could nonetheless be formalized. Ensuring that local input is given due consideration would assure the watershed advisory groups that their efforts are not wasted—that they constituted something that goes well beyond an “appearance” of local involvement, and achieve a degree of citizen and stakeholder engagement that leads to adopting best adaptation practices (Hurlbert et al., 2009b; Wandel, 2009).

- **Interagency coordination**. Saskatchewan’s water governance and climate monitoring system suffers from duplication and a lack of coordination. Alberta is attempting to address a similar situation with the creation of a Policy Coordination Office, although little evidence of this was seen during the interviews. A lack of coordination often results in failures to identify areas needing attention because it is assumed that other agencies are looking after specific issues. Such complexity often creates confusion among government officials themselves, let alone stakeholders and the general public. The overall need for all orders of government to clearly establish roles and co-ordinate water activities is supported by the IACC research findings through the stakeholder and community interviews; it is also widely supported by a growing body of literature (Pearse et al., 1985, Corkal et al., 2007; Hurlbert et al., 2009a).

- **Operational challenges**. The effectiveness of water governance in Saskatchewan and Alberta is frustrated by the complexity of the water governance arrangements. Saskatchewan’s rural communities and their residents are often frustrated by the need to deal with a large number of agencies and they are often unsure which agencies are responsible for various aspects of water policy. Although unlikely and possibly impractical, the “one-stop shopping” or “single-desk approach” was identified as a solution by a number of respondents. Water governance and management are also frustrated by the levels of funding available for delivering services to rural communities. Funding is sporadic and availability and eligibility rules often change along with the election cycle. Rural residents and municipalities in Alberta are constrained by the first-in-time licensing arrangements. Large-scale long-term projects (e.g., the construction of further irrigation) are hampered by the need to obtain a water license, which is impossible in the southern part of the basin. Since the license is a necessary prerequisite for all new projects, the only avenue for planning is within existing licenses.

- **Central resources for solving climate change problems**. Most water supply and infrastructure challenges in Saskatchewan are met by municipal governments and individual farm operators. Presently the federal Department of Agriculture’s Agri-Environment Services Branch (AESB, formerly the PFRA) and SaskWater are the only senior government agencies with the experience and capacity to deliver rural water programming solutions to water-stressed communities and farmsteads. However, both face uncertain futures due to potential institutional rearrangements. There are questions being asked in water governance circles about the current mandates and future of these agencies. Were the agencies to disappear, or lose their capacity to provide infrastructure solutions to water problems, there would be no similar bodies in existence that could pick up the slack should a major drought event occur in Saskatchewan. Their loss would represent a major reduction in the province's capacity to deal with climate change (for a more detailed discussion of these items see Hurlbert et al., 2009a and 2009b). In Alberta, the Water Act provides several mechanisms for surface water shortages to be managed at the regional scale. For example, the Water Act includes provisions for temporary water transfers. However, past effective solutions have relied heavily on the abilities and skills of particular Alberta Environment and Alberta Agriculture employees. Alberta's adaptive capacity to water shortages therefore rests in part on the shoulders of particular individuals, without whom the Water Act is unlikely to be used to its full potential.

These institutional challenges are not simply endemic to the SSRB. Rather, many of them are representative of challenges that characterize other Canadian water governance networks, as evidenced by a large number of publications that address the complexities of managing water resources in a diversified political and geographical setting (see Bakker, 2007, and Sproule-Jones et al., 2008).

Climate Change in the SSRB

Scientists have developed sophisticated global climate models (GCMs) to simulate the complex interactions existing between the earth's atmosphere, oceans, ice cover and land surface. Even with these complex models, scientists cannot know the climate of the future but rather only the probable response of the climate system to external forces such as increasing concentrations of greenhouse gases. A high level of confidence of the probable responses can be placed in GCMs because they are: 1) based on physical laws, such as conservation of mass, energy and momentum; 2) able to simulate important aspects of the current climate; and 3) able to reproduce features of past climates and climate changes. GCM experiments reproduce the warming of the past century only when the climate is forced by natural factors plus the observed increases in greenhouse gas concentrations. During repeated runs, minor differences in initial conditions force these simulations of the complex climate system down different paths; therefore GCMs produce a range of plausible future climates or climate change scenarios. Future greenhouse gas concentrations cannot be known but only estimated from assumptions about socio-economic activities that mitigate or accelerate global warming. The Intergovernmental Panel on Climate Change (IPCC) published 40 different emission scenarios that provide a range of future possible greenhouse gas emissions. These socio-economic scenarios, labelled SRES (Special Report on Emission Scenarios), represent different demographic, social, economic, technological, and environmental and policy futures as emission drivers.

Climate change scenarios are typically expressed as a change in mean precipitation and temperature between a baseline of 1961–90 and a future 30-year period, usually the 2020s (2010–39), 2050s (2040–69) and 2080s (2070–99). These changes are converted to future absolute temperatures and amounts of precipitation by applying the differences or ratios to the baseline climate. All climate change scenarios for the mid-21st century suggest increased temperature and variable precipitation for the SSRB, as illustrated in Figure 4. These climate changes actually favour most existing human activities in the basin, but the net result depends on the distribution or timing of the extra heat and water. One of the most certain outcomes of global warming for the SSRB is shorter and wetter winters, and longer and generally drier summers. The surplus water in winter and spring will be lost during more days of evaporation and transpiration by plants during a longer frost-free growing season. The net result is shown in Figure 5 where the difference between precipitation and potential evapotranspiration for May-June-July is mapped for 1961–1990 as well as the three 30-year intervals in this century. The moisture deficit that naturally characterizes the SSRB expands geographically such that there is an annual moisture deficit of 150–200 mm from southern Saskatchewan across the SSRB.

Precipitation and temperature are plotted in Figures 6 and 7 for Lethbridge, Alberta and Swift Current, Saskatchewan by season and time period for a range of five scenarios. These plots clearly show the larger increases in minimum winter temperatures and the much more consistent increase in winter and spring precipitation as compared to the large range of possibilities in summer.

The frost-free growing season is becoming longer and warmer, which could be advantageous to growing diversified, higher value crops. On the other hand, winter is getting shorter and that means that some advantages of a cold winter will be lost. The ability of frigid temperatures to control pests and diseases will be lessened, and snow accumulation, the most abundant, reliable and predictable source of water, will drop off, as most of the extra precipitation expected with the warming climate will fall as rain. Most of the water in the SSRB originates as snowmelt runoff from the Rocky Mountains, and decreased runoff and a shift in timing of the flow from summer to spring will cause lower river flows in summer, which is the season of highest demand. Climate scenarios show flow reductions for the SSRB (Figure 8). This will result in generally drier conditions, bringing also the increased risk for long and severe droughts. Unusually wet years are also expected occasionally. While this seasonal shift to warmer, wetter winters and drier summers is almost certain, the greatest risk posed by climate change is the increase in year-to-year precipitation variability; unusually wet years and drought years will alternate with greater severity and frequency than what occurred in the 20th century.

Predicted future climate variability will be a result of natural climate patterns altered by greenhouse gas-related warming. Historical weather data contain detailed information on climate variability on almost a daily scale; however, these records are relatively short for western Canada. Records that predate the thermometer (paleoclimatologic data) can be gleaned from climate-sensitive artifacts such as trees, stones and sediment. These records suggest that drought was generally more severe prior to widespread European colonization. The perception that the Prairies contain an abundant and fixed supply of water resources has influenced water use and management in the Canadian west for a long time. While this is partly a misconception, reconstructions of past climate show that since the beginning of the last century, Canadians have indeed enjoyed relatively stable and secure water supplies and an absence of drought in relation to centuries past. But this is about to change, if it has not already begun to do so. Communities in the SSRB can expect severe and prolonged drought simply because it is a natural characteristic of the long-term climate variability for the region, and human-induced global warming could make it worse.

Future Vulnerabilities in the SSRB

Expected climate change in the basin involves increasing temperatures, changes in snow and rainfall patterns, reductions in annual river flows, increases in the intensity and severity of extreme climate events such as drought and rainfall, and a geographical expansion of the area with an annual moisture deficit. These changes are outside the range of natural variability that presently characterizes the SSRB, and they provide a range of opportunities and risks to rural communities and agricultural producers.

FUTURE EXPOSURES

The new climate does offer some benefits. A longer, warmer, frost-free growing season, warmer winters, and the possibility to diversify agricultural production by introducing new crops represent some of them. However, the risks are potentially significant and cannot be ignored. Warmer temperatures in the summer may increase the possibility of heavy rainfalls that lead to flooding—an already serious source of risk for rural people. The most significant trend associated with a warmer climate is an increase in water scarcity. A water deficit is already a characteristic of the area and the expected climate changes—higher evapotranspiration, decreased snowmelt runoff and a shift in the timing of the dominant flow from summer to spring—will have significant impacts on surface and groundwater supplies and water quality, especially during the summer months. The deficit becomes even more serious when expected population growth is factored in—the SSRB's population is expected to grow from 1.3 million in 1996 to more than 3 million by 2046 (Sauchyn and Kulshreshtha, 2008; Pietroniro et al., 2006).

Extreme events, however, bring greater risks than a shift in average climate. Drier conditions with droughts of greater length and severity will most likely happen. The likelihood of multi-year drought occurrence is not only inferred from future climate change scenarios but also from paleoclimatologic evidence that shows that multiple-year droughts before 1900 were frequent and that the conditions leading to these extreme droughts could easily reoccur. Droughts are a serious source of risk because they affect not only the quality and the supply of water to the regional population but they also degrade ecosystems, reduce agricultural productivity, increase the risk of fires, affect people's health, negatively impact soil moisture, and create the potential for social conflict resulting from competing water demands.

Water resources in the basin will be seriously constrained in the future, both in terms of quantity and quality. Increasing levels of water stress are expected, which may result in negative consequences for the process of regional development. Although water scarcity will affect everyone in the basin, it is likely that rural people will be the most affected because of their heavy reliance on natural resources and their small population base. Therefore, it is important to understand the degree to which different agricultural sub-sectors—dryland grain farming, irrigated crop agriculture, and ranching—will be exposed and sensitive to reduced water supplies, as well as their capacity to manage expected change.

Dryland farmers will face serious challenges as a consequence of reduced soil moisture caused by less summer precipitation and increased

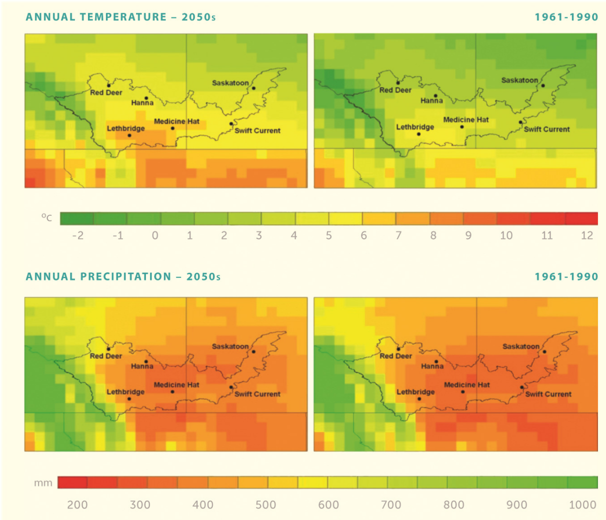

Figure 4. Annual Temperature (Top) and Precipitation (Bottom) for the SSRB. The Baseline (1961–90) Conditions are Mapped on the Right. These Median Scenarios were derived from the Canadian Global Climate Model (CGCM) Version 3.1/T47 and Greenhouse Gas Emission Scenario B1(2).

evapotranspiration. Their agricultural practices are very sensitive to decreased precipitation and increased heat during the growing season because they are dependent on adequate soil moisture to have a successful crop. The expected climate conditions may facilitate an earlier growing season and could perhaps even allow for greater use of winter crops and/or the introduction of new crop varieties. On the other hand, dryland farmers also have to face the possibility of too many hot days in a dry summer, which could stunt crop growth. It is obvious that dryland agriculture is highly sensitive to drought, and a severe, multi-year drought could be disastrous for this sector.

Ranching, similar to dryland farming, needs sufficient precipitation for grass growth and reliable water supplies for livestock. Tame grasses need adequate amounts of rain during the spring and summer, which makes them more sensitive than native grasses, which also need some rain but are not as sensitive to timing. Ranchers also need a secure source of water for their animals. Dugouts that catch snowmelt during the spring currently satisfy this need, but with warmer winters this management strategy could become ineffective, especially during sustained drought periods. The alternatives are either to build extra water storage reservoirs (e.g., dugouts) in order to have a more adequate supply of water (although in a multi-year drought this strategy has limitations) or to install shallow pipelines for dugout recharge, which requires access to more reliable streams or canals and sufficient runoff. Options may also exist to utilize groundwater supplies for livestock water in years where surface water is not adequate, provided the necessary infrastructure (wells) and water treatment are available for utilizing mineralized groundwater.

Irrigated crop farmers, with their access to irrigation, are better equipped to deal with reduced soil moisture. Precipitation is still very important for them during the growing season, although not as much as on dryland. They are also susceptible to the effects of too much heat on their crops. Two big challenges exist for irrigators. During droughts, water scarcity

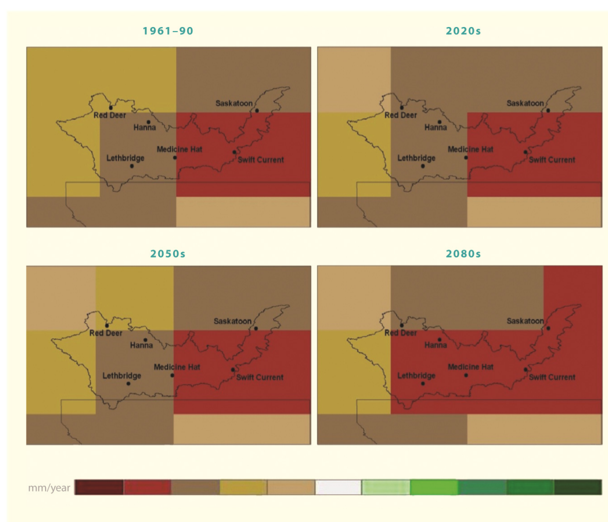

Figure 5. Median Scenarios of May-June-July, Climate Moisture Index (P-PET) for 1961–90, the 2020s, 2050s and 2080s, from CGCM3.1/T47 B1(2).

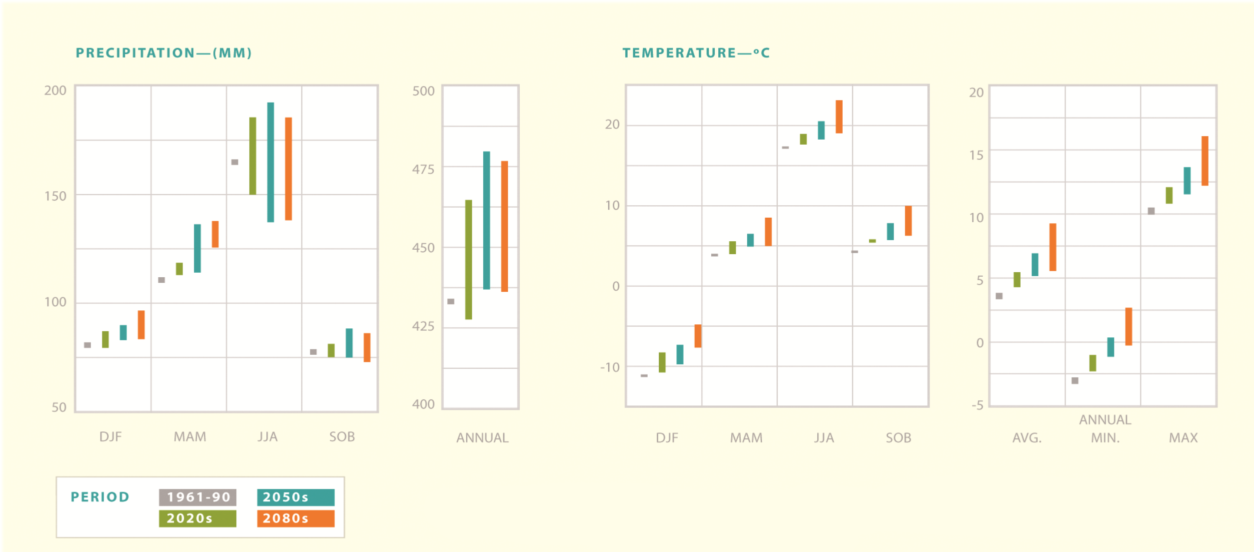

Figure 7. Future Climate Scenarios for Swift Current, Saskatchewan by Season, Period, and for a Range of Five Scenarios, Reflected in the Length of the Vertical Bars.

means that irrigators will not receive full water allocations and will suffer shortages. The second challenge may be water consumption and the increased demand for water from non-irrigation uses, which could double by 2021 (Sauchyn and Kulshreshtha, 2008). There will likely be pressure to expand water infrastructure and distribution networks. This situation could lead to significant conflicts if coupled with periods of drought. As a highly successful adaptation, irrigation expansion will need to be considered where water availability exists. Saskatchewan has significant irrigation expansion potential to help build agricultural resilience. However, such expansion requires significant planning and investment and would require a concerted effort by all stakeholders, citizens and orders of government, in order to

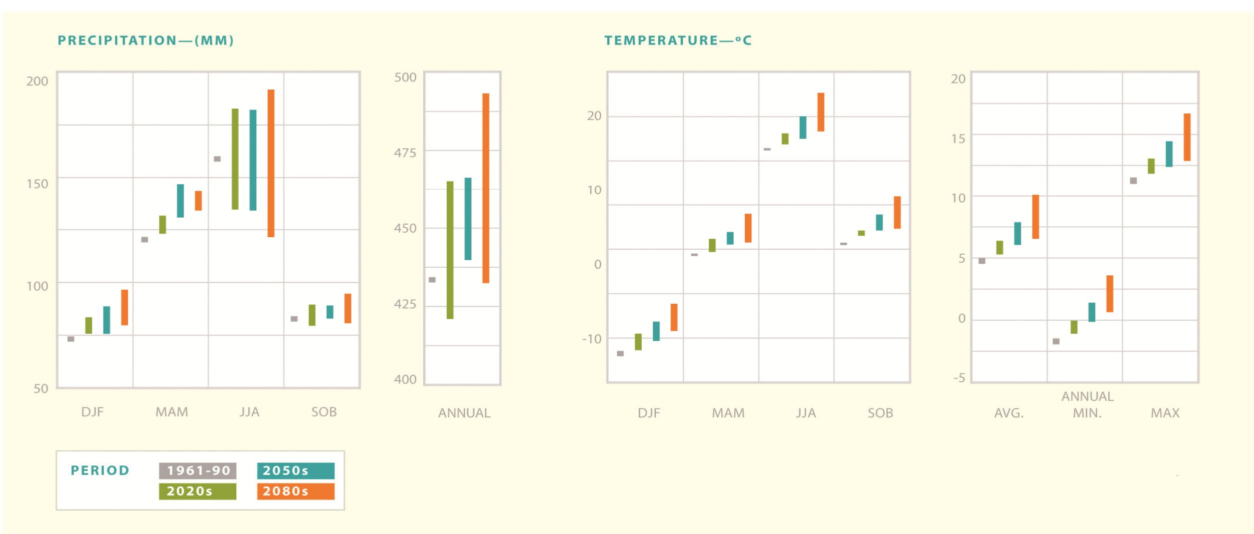

Figure 6. Future Climate Scenarios for Lethbridge, Alberta by Season, Period, and for a Range of Five Scenarios, Reflected in the Length of the Vertical Bars.

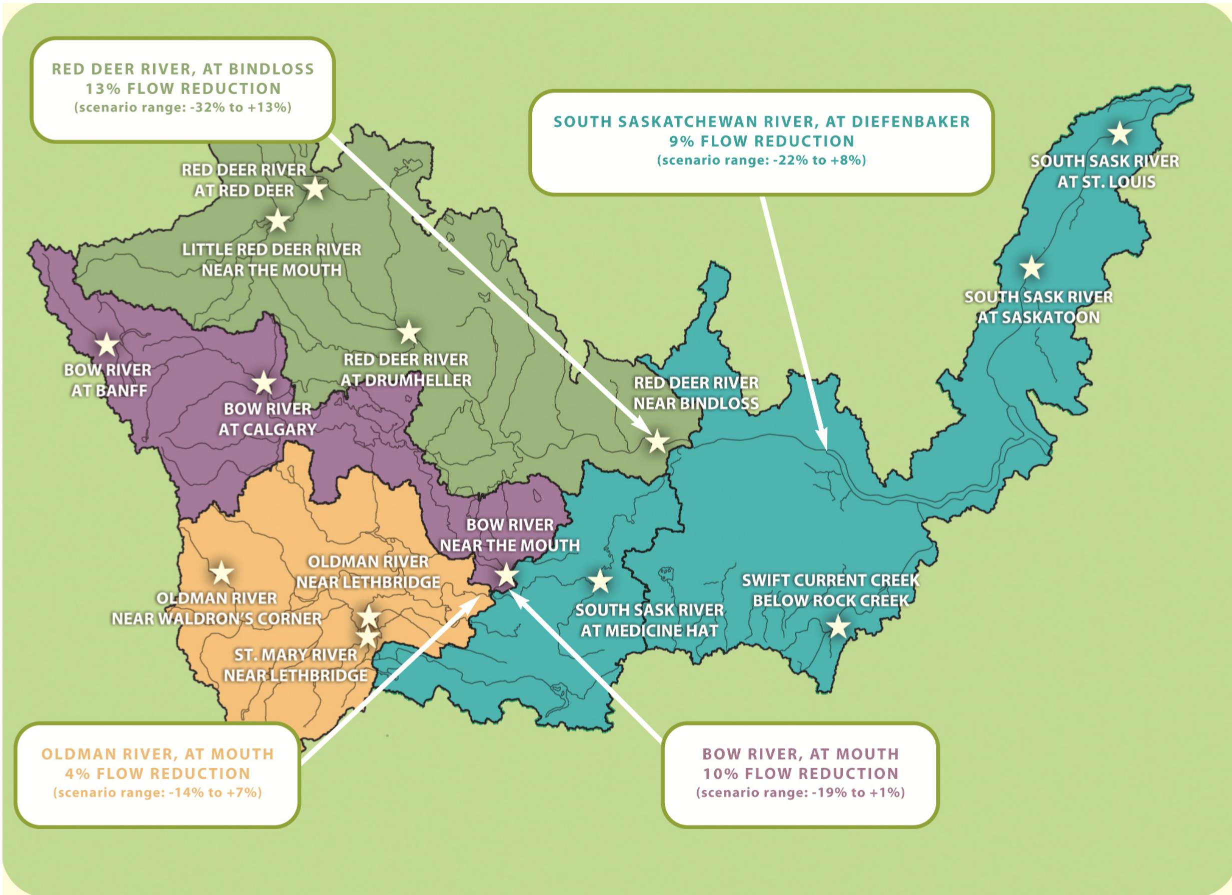

Figure 8. Climate Scenarios, 2039–70, Suggest Average Reductions of 4% to 13% in the SSRB River Flows (Martz et al., 2007). Map by: D. Perrick and D. Campbell.

balance economic, social and environmental benefits and challenges.

Rural communities' sensitivities to the expected climate conditions could be high if their primary economic driver is the agricultural industry. Most community businesses are affected either directly or indirectly by the state of agriculture, so periods of drought are problematic for residents as well. Communities are also sensitive to changes in water quality. They therefore require the financial resources to build modern water treatment plants. Small communities are constrained in their capacity to raise the necessary capital, and unless governments are willing to invest in these communities, they will face problems meeting provincial water quality standards.

Future Institutional Response/Adaptation

The question for the future is whether current adaptive capacity is sufficient to address future challenges. The IACC research findings indicate that the basin currently has sufficient adaptive capacity to deal with the existing range of climate variability. The future conditions outlined by the climate change scenarios fall outside this range, so a greater effort is required to develop a robust, coordinated, more anticipatory approach to reduce future risks and maximize opportunities. People in the communities, too, recognize the need to strengthen adaptive capacity. They recognize the benefits of past and current adaptive strategies but they also indicate that these existing strategies will not be sufficient given future climate scenarios. They argue for long-term planning in terms of conservation, financial management, education and learning, social capital, improved agricultural practices and diversification, and active participation in watershed management decisions, among many others. People say they need to be "more prepared for more extremes," which can be accomplished by understanding the risks involved and by identifying risk-reducers such as more efficient equipment and the ability to change crops, reduce farm expenses and have access to "slush funds" accumulated in good years for use in poor or drought years (Patiño, 2008; Hurlbert et al., 2009a).

Key IACC Recommendations

As in the past, institutional support is fundamental to building adaptive capacity. Without this support, communities and agricultural producers will be unable to access the resources necessary to deal with future climate conditions. Governance networks could help build adaptive capacity through the following (examples are also provided of the published literature supporting these findings):

Develop long-term (10 to 20 year) climate and water plans that build resilience to climate change.

The IACC studies demonstrate the need to develop and strengthen a policy process aimed at building community resilience to climate change. This requires a more comprehensive strategy that combines both mitigation and adaptation activities. Long-term strategies need to adopt an anticipatory approach based on knowledge and scenario planning rather than relying on reactive, ad hoc, or "crisis management" approaches. Strategies also need to integrate (or mainstream) climate policy into several policy fields, especially as they relate to water, the environment and highly vulnerable economic activities such as agriculture. (Planning for climate change and adaptation requires long-term planning. See for example: Environment Canada, 2008; Oliver and Wiebe, 2003: 69–71; and Alberta Environment, 2008.)

Integrate government and community adaptation activities.

Climate interacts with many other stressors, and there is a need for an inclusive policy framework across branches and orders of government that emphasizes the links between adaptation and sustainable economic development priorities, while also specifically targeting communities with low adaptive capacities. The inter-relations between climate change and economic and social vulnerabilities require an approach that is able to strengthen the general sustainability of the community, and this will involve a great deal of coordination among government agencies. We need to plan and act across traditional sectors and issues, and bring together environmental management, disaster reduction and social and economic development measures. (The need for improved integration and co-ordination of all orders of government is a frequent theme in the published literature on water strategies, a theme that is closely linked to climate change adaptation. See for example: Brandes et al., 2005; Banks and Cochrane, 2005; Bakker, 2007; Morris et al., 2007; Hoover et al., 2007; de Loë, 2008; Sproule-Jones et al., 2008).

Use participatory planning and empower stakeholders and citizens in water management decision-making.

Efforts should be made to strengthen civil society organizations that participate in the water governance process (e.g., irrigation associations, watershed groups, and other stakeholders), as they are crucial to fostering adaptive capacity in both Saskatchewan and Alberta. Their participation in water governance widens the range of interest that is included in the adaptive process, helps legitimize decisions, and enhances goal achievement. It is important to support these groups with enough operational and project funding to ensure their ability to function. No less important is to define their role, so that they are more than simply advisory groups to government agencies, and so that they can play a central role in a large range of adaptations to water stresses (especially implementation) as well as in (potential) conflict resolution. (The principle of participatory planning is widely referenced in the published literature on integrated water resource management, established by the 1992 Dublin Principles. See for example: WWCWAU, 2003: 23; Moss, 2008; Global Water Partnership, 2009; World Meteorological Organization, 2009).

Improve the dialogue between government and communities, particularly rural communities, to build local resilience and seek new opportunities.

Managing the risks and opportunities created by climate change requires a governance structure that improves communication between communities and government agencies. Appropriate and locally relevant solutions to address community sustainability problems require a proper understanding of local vulnerabilities. At the same time, mobilizing and coordinating external resources to alleviate local vulnerabilities requires a systematic knowledge of programs available within government. Both are required to develop the knowledge base and build the incentives required to strengthen communities. Drought planning considering future vulnerabilities will be crucial; climate change adaptation will need to be factored into existing programs and policies. (See for example: Oliver and Wiebe, 2003: 69–71. There is also a need to counter the Canadian myth of water abundance, as stated in Sprague, 2007.)

Focus efforts on improving local and regional coping capacities.

A special joint effort between communities and government should be directed toward improving local and regional capacities. Local training and capacity building could enhance the skills and knowledge available in the SSRB, aiding in the management of risks and opportunities. Water conservation and management is one area in which local knowledge and resources could be improved and supported by an institutional framework, particularly one that supports and trains individuals as to how to implement local water conservation strategies and secure water quality. Existing federal institutions such as PFRA need to be reinforced to assist this process. Programs oriented towards developing or strengthening community networking could foster community organization and mobilization to reduce vulnerability. Furthermore, improving intercommunity (and inter-provincial) coordination around common issues, such as watershed planning committees, could help bring communities together to resolve regional problems. All these measures would not only provide rural communities with the instruments to become more sustainable, but they would also contribute to a more effective climate change risk reduction strategy. (As noted in the previous point, climate change adaptation will need to be factored into existing policies and programs; Oliver and Wiebe, 2003: 69–71).

Prepare for water conflicts: resolve issues using adaptive conflict resolution methods.

Water scarcities could easily lead to water conflicts among water users. In order for governments to truly represent the public good, they must be proactive, making sure that their responses include a highly transparent and accountable decision-making process, which will in turn enhance the legitimacy of government action in the eyes of stakeholders. This will also encourage stakeholders and communities to be more accepting of water management strategies undertaken in times of water scarcity. The IACC project recommends that governments make use of the adaptive conflict resolution approach, which can create a stakeholder dynamic that can often transform conflict into a learning opportunity and at the same time uncover possible institutional adaptations that may have been be unimaginable prior to the conflict. Although all stakeholders can contribute to the implementation of this approach, the role of government in creating the conditions for their implementation is essential.

Obtain and share more and better water data.

There is a need to improve the processes of gathering and sharing water data within each province's water governance network and between federal and provincial agencies. The research identified gaps in water data (e.g., the climate and hydrology of the upper part of the basin; groundwater data, water quality, quantity and usage information) required to monitor and predict future water supplies and the impact of climate change on water resources. In addition it is essential to maximize the coordination and use of data (e.g., through an umbrella water data portal that would accommodate effective water management and planning). (The need for more complete water data is frequently referenced in the published literature. See Banks and Cochrane, 2005, Morris et al., 2007, de Loë, 2008).

Seek solutions with interdisciplinary teams using social and physical sciences approaches and coordinating with stakeholders and policy-makers.

Interdisciplinary research that addresses all of the previously mentioned issues is fundamental to reducing rural community vulnerability and improving institutional efforts to increase adaptive capacity. Climate change impacts and vulnerability are issues that cut across several scientific disciplines, from philosophy to climatology, from social sciences to engineering. Therefore, comprehensive and appropriate responses to climate change impacts and challenges will need to be based on solid interdisciplinary teams that are able to collaborate with a variety of stakeholders and policy-makers. A more intensive effort to bring together governments and universities to organize an interdisciplinary research agenda around climate change would be a great step in reducing the vulnerability of prairie people. A further step would be to incorporate industry and target research towards sustainable adaptation practices. (The inclusion of interdisciplinary teams is advocated by the integrated water resources management principles for sustainable development. The approach attempts to balance social, environmental and economic aspects affecting water resources [and by inference, climate-induced water stress] (WWCWAU, 2003: 23; Moss, 2008; Global Water Partnership, 2009; World Meteorological Organization, 2009).

Simplify water governance arrangements for efficient and effective adaptation decisions.

The efficacy of water governance is frustrated by the complexity of water governance arrangements, especially the lack of interagency coordination. Water governance and climate monitoring systems suffer from duplication and a lack of coordination, which creates confusion among government officials and stakeholders. It is important to reduce this inefficiency and lack of coordination between federal and provincial agencies, as well as within provincial networks, to ensure a comprehensive and systematic approach to the development of a more robust adaptive capacity. The initiative taken in May 2008 by the Western Canadian Premiers is a step forward in addressing the needs identified above. The formation of the Western Water Stewardship Council illustrates the need for stronger federal leadership in water and climate change issues and associated vulnerabilities in the SSRB and across Canada. The Premiers' plans to develop a drought preparedness plan for the west and a climate change policy framework are laudable. While natural resource management is a provincial government mandate, this current provincial initiative demonstrates that there is a need for regional approaches. The federal government could play a significant role in supporting such provincial initiatives that enhance regional adaptation. It would be advantageous to develop climate and water strategies that span 10 to 20 years with built-in performance measurement requirements. Such strategies should allow for flexible and incremental improvements as knowledge is improved. If implemented, this type of approach would provide unique adoption opportunities and adaptive resilience for regional and local needs. (See for example: Brandes et al., 2005; Banks and Cochrane, 2005; Bakker, 2007; Morris et al., 2007; Hoover et al., 2007; de Loë, 2008; Sproule-Jones et al., 2008. With respect to the South Saskatchewan River Basin, Banks and Cochrane [2005] suggest that all orders of government need to work together. This wide body of literature identifies a need to clarify water governance arrangements and to integrate water activities.)

The vulnerability of rural communities in the SSRB is not defined solely by the severity of the climatic events they experience, but also by a variety of social and economic conditions that characterize the daily life of rural people. A reduction in vulnerability will require a synchronized institutional effort across all levels of government, an interdisciplinary perspective that integrates both the natural and the social sciences, and strengthened stakeholder and citizen engagement. This collaborative effort will help us manage the risks and explore the opportunities presented by the new climatic conditions.

THE CASE OF THE ELQUI RIVER BASIN (ERB), CHILE

Past and Present Vulnerabilities

Past/Present Drought and Other Climate-Related Exposures

The ERB (Figure 9) is the northernmost basin of the Coquimbo region in northern Chile (29° 40'S to 32°10'S). It spans 9,675 km², from the Pacific coast to the Andes Mountains. Its northern limit is the arid Atacama region; its southern limit is the Limari Basin, the second of three basins within the Coquimbo region; its western limit is the Pacific Ocean; and its eastern limit is the Argentinean border. Its climate is influenced by the desert to the north and the semi-arid Mediterranean climate of the central region to the south (Cepeda et al., 2008). The ERB has four major geographic and physical zones (described from west to east): (1) the lowlands of the coastal fringe's gentle slopes ascend from the sea toward the mountains and transport coastal humidity, which influences the climate regime as far as 25 km from the coast into the valley; (2) the narrow Elqui valley slopes from east to west, at an average altitude of 850m at Rivadavia, broadening up as they reach the gentler slopes of the coastal plateaus; (3) the mid-mountain range with altitudes between 800 to 3,000 meters; and (4) the high Andean mountains range in altitude from 3,000 to peaks up to 6,332 meters. The fourth zone experiences the highest amount of precipitation, with high snow accumulation in winter, and glacier melt feeding the highland tributaries of the Elqui River. The region is heavily engaged in agriculture, with the majority of agricultural production occurring in the second zone.

The climate of the ERB is strongly influenced by the high pressure of the Pacific sub-tropical anti-cyclonic system that moves north during the winter, allowing low pressure systems to bring precipitation one or two months of the year to the valley, where the majority of agriculture takes place and where the majority of communities in the basin are located. Average precipitation is 100 mm per year, although it may double or triple during the wet El Niño phase of the El Niño Southern Oscillation (ENSO), and be half the average or less during the dry La Niña phase of ENSO. Eight to ten months without precipitation is a common feature of Zone 2. Zones 3 and 4 also experience a high degree of inter-annual variability; however, these zones experience a much higher average precipitation than in the valley (Fiebig-Wittmaack et al., 2008).

Temperatures in the basin are mild, with summer temperatures ranging from 13°C to 23°C in Zone 1, and reaching 14°C to 29°C around the middle valley area of San Carlos (Zone 2); whereas in the winter they range from 7.8° C to 16°C on the coast (Zone 1), to 9.5°C to 18.5° C at San Carlos. At 1600 meters of altitude, temperature starts to decrease rapidly (approximately -6.5°C per 1,000m change) (Fiebig-Wittmaack et al., 2008). The relative humidity also decreases from the coast (85%) to the drier, more arid interior (40% at San Carlos).

A shift in precipitation has been recorded at the La Serena airport station—the oldest coastal station in the area. Records show a decrease in precipitation over the past century from between 150 and 180 mm per annum in the early 1900s to the currently experienced 100 mm. In the last 25 years, the decreasing precipitation trend has levelled off, and even shows a slight recovery (Fiebig-Wittmaack et al., 2008). Still, this is among the most pronounced decreases in all of Chile, and it represents a risk that affects both human and natural systems (Cepeda, 2009).

There are diversified agricultural operations within the ERB that are highly dependent on runoff from the Andes—this is the primary source of water for irrigation (Fiebig-Wittmaack et al., 2008; Zavala, 2009). High fluctuations in the precipitation regime, which naturally characterize the region, acts as important exposure for communities, as precipitation can vary drastically from year to year (e.g., from 40 mm to 360 mm). ENSO has a strong influence on precipitation (e.g., years 1982, 1986, 1997, 2002), and can result in over 40 mm of rain in a few hours, which increases the risk of mudslides and floods, particularly given the unstable nature of the denuded and meteoric soils as well as the steep slopes on both sides of the valley (Fiebig-Wittmaack et al., 2008).

There are four conditions that increase community exposure to mudslides: (1) the presence of dendritic and loose material on the steep valley slope; (2) intensive rainfall on poorly developed soils with slopes greater than or equal to 25%; (3) human activities such as the construction of infrastructure (e.g., roads

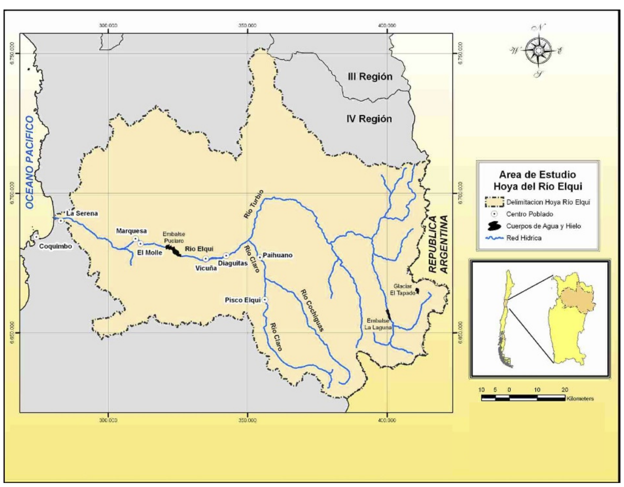

Figure 9. The Elqui River Basin and Study Communities. Map by: Andrés Bodini S.

and irrigation channels), deforestation, overgrazing and unsustainable agricultural practices on unstable soils; and (4) unstable mine tailing sites (Cepeda, 2008: 291).

The rural communities chosen for the community vulnerability assessments are: Pisco Elqui, Diaguitas, Marquesa and El Molle (Figure 9). Community members' livelihoods depend to a large extent on the agricultural sector, which has been rapidly integrated into the global economy in recent years. Marquesa has a significant mining presence, and Pisco Elqui is heavily involved in tourism. El Molle is located below the Puclaro Dam (Figure 9), and thus benefits from regulated water availability. Diaguitas is located between two dams, while Pisco Elqui relies entirely on the Claro River.

Mudslides were often mentioned by community members as the climatic exposure to which the four selected communities of the ERB are most sensitive, particularly in Diaguitas and Marquesa (Salas et al., 2009). This is due to the fact that all too often communities are located on the foothills close to the river and ravines which render them particularly vulnerable to mudslides and floods. The steep hills and narrow valleys of the ERB leave few options for community dwellings. Concentrated rain patterns along with the precarious location of rural housing in hamlets and risk prone areas, the lack of early warning systems and poor contingency and emergency plans highly increase rural people's exposure to mudslides and floods (Cepeda, 2009; Salas et al., 2009).

A devastating mudslide took place on the night of April 22, 2004 in the community of Diaguitas, which received 90 mm of precipitation in twelve hours. The soils in the vineyards located on the hillsides of Quebrada Puyayes became waterlogged and a mudslide rushed down the valley slope via a ravine, collecting large rocks, trees and debris. More than 150 families were affected; over 60 families lost their homes, approximately 800 hectares of agricultural land had its irrigation infrastructure badly damaged, and the school was destroyed. Four years later the community had still to fully recover from the losses it suffered that day (Salas et al., 2009: 292).

Floods are a common characteristic of the ERB. There were 373 flood events documented in the ERB between 1900 and 1981. This figure is almost four times more than what was observed in the other two basins of the Coquimbo region. In 1997, an ENSO year, mudslides and floods killed two people at El Almendral and negatively affected the economy. Low income families and subsistence farmers are more sensitive to high precipitation events because they often settle in areas with higher probabilities of mudslide or floods, as is the case in Marquesa and Diaguitas.

In addition to extreme precipitation events, droughts create risks for rural communities. Between 1915 and 2003 there were 11 years of extreme drought (annual precipitation of less than 30 mm) and 16 years of moderate drought (annual precipitation of between 30 and 60 mm). Some communities are more sensitive to drought than others, and droughts have different effects on different communities. A review of the period 1980–2003 showed that Montegrande suffered extreme drought in 8 of 23 years (35%), while Rivadavia had 9 of 23 years (39%) and Pisco Elqui had 8 of 23 (35%) years with moderate drought (Perez-Valdivia et al., 2009).

Goat herders who rely on natural grasslands and shrubs for fodder are particularly sensitive to droughts. Goat herding is an important component of the poorest communities' subsistence economy (Salas et al., 2009). For over 300 years herders have used common pasture lands for winter and summer grazing, but land use changes and overgrazing have drastically reduced the availability of natural pastures (Jorquera, 2001; Cepeda, 2008). Many herders move their herds to the upper reaches of the ERB where natural grasses thrive (Cepeda et al., 2008). In recent years, the number of herders, as well as the size of herds, has decreased, as fodder is becoming scarce in winter as a result of droughts and limited access to lands due to crop expansion (Salas et al., 2009: 17). Recent studies show a 43% decrease in the number of goat herders in the last 17 years[2]. The number of registered herders in the Elqui province was 1,155, with close to 160,000 goats in 2006 (CEAZA, 2009; Salas et al., 2009)[3]. During severe droughts, herds may be decimated. Farmers themselves claim that "nature is regulating how much cattle we can manage" (Varas et al., 2007 cited by Salas et al., 2009). Still, herding has helped build the adaptive capacity of subsistence farmers by providing income opportunities (e.g., through milk by-products and meat and leather products).

Droughts also affect natural ecosystems. Native species have been subjected to climate variability and they have developed the ability to cope with a certain range of variability. The regional arid and semi-arid biota is expected to be well-adapted to greater aridity induced by future climate change (Arroyo et al., 1988; Huenneke, 2001). Nevertheless, biota will ex-

[2]The information provided by the National Statistic Institute (INE) portrays a 45% increase in the number of goats in the 1997–2005 period with 78,000 heads for the Province of Elqui (Instituto Nacional de Estadísticas, 2006).

[3]Transhumance, the seasonal migration of livestock, is common strategy used by over 25% of the goat farmers moving their animals from lowlands to higher altitude pastures during the summer. Almost 46% of goats are raised in this manner (Instituto Nacional de Estadísticas, 2006).

perience accelerated changes that are 10 to 40 times faster than the changes they have had to adapt to in the past (Peters, 1988 cited by Cepeda, 2008). This rate of change would produce an increase in extinction rates for many species; however, it may favor others, or even promote diversification. Human activities (e.g., the expansion of agriculture) limit opportunities for many species because their environments have been destroyed or modified by overgrazing, deforestation, fires and pesticides/herbicides (Cepeda, 2008).

Occasional cold spells and near-freezing temperatures in winter also affect agricultural producers. The 2007 cold spell that lasted several days had severe impacts on vegetable and fruit crops (Salas et al., 2009) —over 50% of crops in the ERB were lost. This motivated the Ministry of Agriculture to declare an agricultural emergency in order to protect farmers against financial bankruptcy (Portal Coquimbo, 2007).

Water quality is an issue for communities. Mining accounts for much of communities' employment opportunities (e.g., Marquesa and Nueva Talcuna), and community members accept seasonal employment on labour intensive, small-scale mining operations that leave behind unmanaged tailings sites. These tailings are later removed by floods, which results in the contamination of soil and water resources (Salas et al., 2009). Many of the communities believe contamination is a result of the unmanaged tailings and pesticide residue that is applied in surrounding areas. However, there is little institutional regulation and no enforced legislation pertaining to mine tailings. Another factor influencing water quality is the lack of proper sewage infrastructure for the collection and treatment of all rural drinking water systems, which are managed by the communities themselves (Reyes et al., 2009).

Past and Present Institutional Adaptation

Adaptation to climatic and other conditions that create risks and opportunities for rural communities has been a historical process in the ERB. Community adaptations include migrating to northern mining districts to diversify income, diversifying crops and income, building water harvesting and irrigation infrastructure, building flood control infrastructure, adopting new technologies, and changing targeted markets. These are some of the strategies revealed through the community vulnerability assessments.

The construction of water and irrigation infrastructure started early in the 19th century in the ERB (Jorquera, 2001), but it was not until the mid-20th century that the construction of large water reservoirs became a central element of government policies aiming to regulate river flows and water storage. Adaptations to secure reliable water resources during periods of scarcity have been primarily achieved through the construction of dams and irrigation systems, and more recently, by introducing more efficient forms of irrigation, such as drip irrigation systems. The early construction of the La Laguna Dam in 1941 in the upper reaches of the ERB was the first major attempt to regulate river flow and store water for irrigation[4]. This small dam and the management of the irrigation system assisted in the early development of social adaptations to cope with water scarcity. The creation of an Irrigation Association at Estero Derecho helped secure water resources as well as more secure crop yields in the upper and lower reaches of the Valley. It took another 57 years before another

[4]The Laguna dam has a capacity to hold 40 million m^3 of water.

dam—the Puclaro Dam—was built in the lower mid-reach of the Elqui River in the late 1990s[5]. Together, these two dams secure irrigation for approximately 25,000 hectares (62,000 acres) of crops. There are three Irrigation Associations managing an irrigation system that consists of 126 channels. This reflects the high degree of social learning in the valley. The Department of Hydraulic Works (DOH) of the Ministry of Public Works provided the technical training and initial managerial support to the Irrigation Associations, which are now autonomous, well-structured organizations that satisfy other social roles in the communities (Salas et al., 2009; Reyes et al., 2009). The dams, the irrigations systems, and the Irrigation Associations managing them are considered proactive adaptations that increase water security and reduce the effects of drought on agriculture. The Puclaro Dam, for example, secures a two-year water supply for irrigation. However, conflicts have arisen as a result of the construction and management of the dam. The construction of the Puclaro Dam required the relocation of the town of Gualliguaica and three nearby hamlets, sparking several years of conflict and controversy in the area (Rojas et al., 2009b). Without proper environmental and social assessment studies for this major project, the institutional response to the demands of local communities was controversial; they undermined social capital, and created serious social conflicts among the communities and the project's developers[6]. The major issues in the conflicts were both the loss of access to water for irrigation and agricultural lands flooded by the dam. The compensation packages could not replace the social capital lost nor their traditional orchards and river habitats.

The communities were relocated next to the dam but are unable to extract water for irrigation or use it to develop income generating activities (e.g., tourism) (ibid). Villa Puclaro, the result of an amalgamation of three communities located in the southern portion of the dam's reservoir, has a seriously undermined social capital, as many of the community members now suffer from depression. The better-compensated inhabitants of New Gualliguaica, located in the northern portion of the reservoir, feel they were adequately compensated for their relocation; however, they lost their ability to engage in agriculture, and the social relations within the community have been forever changed. The two relocated communities highlight the positive and negative consequences of an irrigation project in the ERB. Their new location is probably safer in terms of flood risk, but they are now more exposed to mudslides and drought and are lacking land and water for subsistence farming and other activities (Rojas et al., 2009b).

Another adaptation relates to more efficient forms of irrigation. The introduction of water-saving technologies has been closely associated with the recent expansion of vineyards and avocado plantations for sale in export markets. Drip irrigation in the Elqui Valley is an advanced adaptation that eases the growing demand for diminishing water resources. Vineyards and avocado plantations on hillsides are adopting this technology, with powerful pumping systems, which allows agricultural producers to plant more crops while using the same amount of water as they used previously. Vineyards are the one crop that grows in extreme conditions. Harsh winter conditions and the strong summer sun tend to result in high quality vintages. These

[5]The Puclaro dam is located at an elevation of 432 meters, with a reservoir 7 km long, 2 km wide and a 200 million m^3 holding capacity.

[6]The relocated communities complained of poor and unequal access to information, housing arrangements, social infrastructure and information, all of which favored those with greater negotiating capacity.

highly efficient irrigation systems have facilitated the expansion of agriculture to the steep valley slopes; commercial fruit plantations (including vineyards) and production have more than doubled in the area in the last ten years (Instituto Nacional de Estadísticas, 2007)[7].

The adoption of more efficient irrigation and other water-saving technologies is not enjoyed by all producers of the ERB. Access to water and improved technologies, as is demonstrated by the IACC's community vulnerability assessment, is unevenly distributed. Most agro-industrial operations have the financial resources and know-how to secure the latest technologies to reduce the risks associated with water stress. These operations may even acquire water rights through the water market. Small producers and traditional farmers, on the other hand, have little access to water resources and tend to mainly use traditional irrigation systems that are not as efficient (e.g., flood irrigation). Government agencies' financial support for water infrastructure has reinforced the trends towards high productivity goals and the export-led agricultural model, which marginalizes small subsistence farmers, sparking conflicts and leading to exclusion (Rojas et al., 2009b).

High-tech drip irrigation systems and other technological innovations associated with modern agriculture are not always embraced in communities; they are often accepted with hesitation, as many community members expressed concerns regarding the future impacts of these technologies on the environment. One area of concern is related to the availability of water for irrigation downstream. In traditional irrigation systems, water usually feeds back into the system, which ensures that all users' water rights are generally satisfied and that the lower reaches of the river receive the full water allocation. After the water is used for irrigation, the infiltrated water re-enters the river system. Drip irrigation systems, on the other hand, ensure effective water use but limit aquifer recharge in the lower zones of the valley. More area can be irrigated and less water is "lost" compared to traditional systems. However, producers are concerned that there may not be sufficient recharge, causing allocations in the lower reaches to not be satisfied. They are also concerned that drip irrigation could cause conflicts among farmers in the lower reaches (Lira, 2003), which may be compounded by droughts and aquifer exhaustion, something already experienced in the Copiapo Basin north of the ERB. Water governance institutions have not yet addressed the pressing issue associated with the over-exploitation and depletion of aquifers. Small farmers with limited access to water rights fear their rights will be compromised by their technologically advanced neighbors.

Salinization of soils is another important concern associated with drip irrigation technology that has yet to be properly addressed in the ERB. The intensive use of pesticides in the expanding plantations is also a cause of concern for communities in the valley (Salas et al., 2009). Community members expressed concerns about the potential risks of mudslides in the hillsides that have been drastically changed by the new terracing and cropping patterns that have arisen after the adoption of these new irrigation technologies. Extreme precipitation events have already devastated communities in the basin and their members fear that the recent land use changes will increase the risk of mudslides (Salas et al., 2009).

[7]The region of Coquimbo has shown one the largest increases in cultivated area in the last agricultural census of 1997–2007 with more than 26,000 hectares (65,000 acres), doubling the cultivated area in one decade (Instituto Nacional de Estadísticas, 2007).

The National Irrigation Plan acknowledges that the construction of reservoirs and dams does not always take into account long-term agricultural plans or include integrated basin management plans or adaptation policies. Dams and reservoirs are often constructed because of the political and social commitments made during elections, rather than being based on integrated water and basin management approaches that take a holistic perspective on water management.

Existing Chilean water laws are embodied in a water code that has undergone significant historical changes since 1855 (see Mentor, 2001). The current water code was enacted by the military regime in 1981. It replaced the 1967 water code, which gave the state significant authority over water rights and supported the massive redistribution of agricultural land. The 1981 water code was oriented to promote private agricultural development and economic efficiency through a water market. This code has sought to increase the legal security of private water rights, separating them from land ownership. Water resources are still defined as public property, but the state can grant private rights to use. Once water rights are granted, they are fully protected as private property rights under the Chilean constitution and they can be freely sold, bought, transferred, or inherited as any tradable commodity (see Bauer, 2004a; Mentor, 2001). The fact that water rights have constitutional protection means that they cannot be appropriated by the state without specific legislation and compensation. Under this legal framework for water resource allocation private rights are extensive and state authority and control are constrained. Those who own water rights are not required to indicate how they will use their water resources, nor can they be lost as a result of non-use. Moreover, owners of water rights do not have to pay taxes or fees to the government. This unconditional nature of water rights allows for unregulated speculation in water rights and, in some other cases, for hoarding of these rights (Bauer, 1988). It is also important to mention that most of the water rights are not formally registered. They predate 1981 and they are recognized as traditional rights, with the same constitutional protection as the rights awarded after that year.

As Bauer (2004b) argues, the 1981 water code was oriented mainly to ensure irrigation rights and it does not deal specifically with water uses and how to coordinate them. The law does not establish any priorities in terms of the use of the resources because this function competes with the market. This means that disagreements about water use and coordination are left to the market, where private bargaining among owners of water rights plays a central role. When this bargaining fails the only alternative left to resolve existing conflicts and differences are the civil courts. This alternative, however, is not viable for small agricultural producers who have had their water rights violated due to the costly and slow judicial process (Galaz, 2003; Sabatini and Sepulveda, 1997).

A comprehensive assessment of ground and surface water is incomplete for the basin, and hence water right allocations as well as irrigation infrastructure follow the logic established by the 1981 Water Code—first come, first served; no priority use or performance demands are incorporated into the water rights system. The net result has been an active water market and a large mobilization of technical and financial resources to manage water as a private good and commodity (Hearne and Easter, 1997). Current policies are aimed at privatizing dams and giving users full control of the related infrastructure.

The State is also shifting its public investment policies, creating new protocols that permit private investment in irrigation infrastructure and that demand financial investment from water users before an irrigation project is approved. Thus, this requirement for users to pay the State for the construction of water infrastructure such as dams and irrigation systems ensures that water is used efficiently and that water users have a more market-oriented perspective regarding water resources. As a result, water associations and regional governance institutions need to reach agreements, and hence, new rules and administrative capacities emerge.

The Irrigation Association of Rio Elqui has made an agreement to pay the construction costs of the Puclaro Dam. It will take ownership of the dam's operations and be responsible for its maintenance costs; neither will be carried out by government agencies any longer. Private ownership of dams has sparked new institutional arrangements that integrate energy generation as a cost-recovery and income-generating alternative. The ERB showcases the first regional case of the integration of irrigation and energy generation schemes[8]. This win-win situation provides opportunities for dam shareholders to diversify income, and is an important step towards renewable and low-impact energy production that could also be extended to other dams in the region. This adaptation strategy is also linked with emission reduction strategies[9]. Institutional capacities to manage climate, water and other stresses are emerging through the management, diversification and administration of the Irrigation Association of the Elqui River.

The benefits of this strategy are not equally shared among water rights holders, which is one major drawback of this strategy. The strong and powerful become even stronger and more powerful, and there is no mechanism to bring those without access to irrigation water on board, unless they can pay market price for water rights, which most cannot.

Sufficient quality water plays an important role in rural community members' health. An important goal of government in the 1960s was to improve access to potable water in rural areas. The potable drinking water systems were built by government and are community-operated. Later, Rural Potable Water Committees (CAPRs) were established and now serve as administrators. There are more than 1500 CAPRs that serve over one million people in Chile's rural areas. The construction of the drinking water systems and the autonomous management and administration of the CAPRs have helped build social capital in communities. This is an important adaptation strategy that seeks to collectively secure a basic necessity of rural communities.

Although there are institutional and legal gaps with respect to the rural services offered by CAPRs[10], they have managed to remain autonomous and self sustaining, fighting attempts to privatize their services, as what happened with all major water facilities in the 1990s in the entire country (Reyes et al., 2009). Even though CAPRs exist and help provide rural communities with drinking water and sewage collection services, the more isolated and dispersed communities

[8]This arrangement is in stark contrast with growing conflicts among farmers and energy companies over the priorities for water resources in large dams in south-central Chile (Reyes et al., 2009).

[9]The National Energy Commission hopes that its assessment of over 290 irrigation opportunities with potential to generate 890 MW (Reyes et al., 2009) will be fulfilled with similar agreements in the future.

[10]Regular and frequent water quality control and sewage re-collection systems are two of the major weaknesses of the rural drinking water systems.

(representing close to half a million people) still rely on water trucked in by rural municipalities, their own wells, or makeshift systems. Poor coordination among government agencies and a lack of resources has seriously affected water quality management. Sewage collection and water treatment will require major government funding in order to meet the needs of the rural population and to avoid health risks. So far no major diseases or contamination situations have seriously affected communities, but poor management is gambling with community health. Mining, sewage and pesticides are among the major threats to drinking water sources. Currently there are no comprehensive regulations, programs or policies to address these activities, which could turn into major water quality risks for rural communities.

The return of a democratic government to Chile in the early 1990s saw an increase in public investments to establish several large irrigation infrastructure projects and to upgrade existing ones. The initial focus was on arid and semi-arid regions (Huasco, Elqui, Limarí and Choapa Basins), followed by the Mediterranean basins of La Ligua and the Aconcagua rivers[11]. Between 1990 and 2000 almost 275,000 hectares (700,000 acres) of agricultural land in Chile were converted to irrigation (Lira, 2003). In the ERB, over 20,000 hectares (50,000 acres) of agricultural land is irrigated (Reyes et al., 2009).

The National Irrigation Commission (CNR) also increased its efforts and resources to attain ambitious irrigation targets set by the current government[12]. Irrigation is considered a key component to agricultural expansion, to achieving the goal of Chile being among the top ten agricultural exporting countries in the world, and to strengthening Chile's current position as the largest fruit exporting nation in the Southern Hemisphere.

Irrigation programs within agricultural policies have become increasingly important for agricultural producers in terms of enhancing economic activity and reducing the risks associated with unpredictable weather conditions. Currently, close to 330,000 hectares (816,000 acres) are under fruit production in the country, three times the area in 1990. Fruit exports jumped fourfold from US$800 million in 1990 to US$3,500 million in 2007. There are approximately 60 major water reservoirs and 1,180 medium and small dams irrigating over 1,200,000 hectares (3,000,000 acres), being managed by 212,000 users. Presently, irrigated land accounts for 80% of agricultural exports, and hence, CNR's goal is to turn family farms into food exporters. CNR's mandate and policies were strengthened in 2005 when they received a substantial amount of funding for irrigation projects after the Ministry of Agriculture set a mandate to turn Chile into a "Food Exporting Power." Climate change is not yet among the concerns of CNR, as they believe that irrigation has already protected agricultural producers against drought, one of the major climate change risks for the ERB (Reyes et al., 2009). There is no doubt that public investment in irrigation infrastructure has helped secure water resources, and enhanced the adaptive capacity of large and medium farmers, but a major drawback of this strategy is that it lacks an integrated approach to water resource management and does not incorporate social equity.

A major deficit of agricultural and irrigation programs is that family and subsistence agriculture—producing mainly for domestic mar-

[11]The "El Bato" reservoir is currently being built in the Choapa basin in the Coquimbo region.

[12]The goal established by the Ministry of Agriculture is 460,000 hectares (1,140,000 acres) of newly irrigated land by the year 2014.

kets—have not developed technologically, nor have they developed access to water for irrigation. One factor limiting their incorporation into irrigation systems is that surface water rights and most groundwater are fully allocated. Farmers already holding water rights are therefore the only ones who can be the subject of irrigation subsidies, as those without rights do not qualify. Poor farmers without water rights do not have access to water and new technologies, a recurring problem for small farmers in the ERB. Thus, irrigation policies are still strongly biased towards large and medium farmers and companies that hold or have the financial resources to purchase water rights.

Three major factors have enhanced agricultural modernization and diversification in the ERB: (1) The agrarian reform of the late 1960s and early 1970s that broke the traditional land holding system and redistributed land to many peasants and farmers; (2) Many indebted farmers lost their lands in the 1980s and early 1990s; a few cooperatives survived the harsh economic and political period, managing to maintain and expand their vineyards and pisco processing plants. Most sold their land to agro -industrial companies and landowners seeking to expand into export-oriented farms. This initiated the process of agricultural modernization in the valley. Cereals, pasture land and orchard production gave way to vineyards, citrus and avocado plantations that have higher input costs associated with them and a need for sophisticated irrigation systems (Jorquera, 2001). Soil quality stopped being a barrier as they conquered the hillside with drip irrigation and fertilization. Former farmers turned to migration, and many have become seasonal labourers for large agricultural operations, while others have maintained their traditional migrations to mining areas to secure and supplement farm income; (3) Public investments and incentives to support exports and new market opportunities associated with free trade have been the essential ingredient in the drive to modernize agriculture in the Elqui valley. In the coastal areas, however, some family farms and orchards have continued producing traditional crops (e.g., vegetables) to sell in regional and metropolitan areas (e.g., La Serena and Santiago).

In the rural communities of the ERB social capital is being rapidly lost due to migration and land transformation, with the exception of Irrigation Associations, rural drinking water committees, and a few neighbourhood associations (Salas et al., 2009). Small- and medium-sized producers have trouble organizing and are poorly represented in decision- making structures. This limits their capacities to negotiate with government institutions for funding to adopt new innovations, to adapt their operations to changing market demands, to purchase crop insurance, and to be able to bear the financial burdens when extreme climate events result in crop losses. However at the regional level there is renewed interest in understanding and responding to social and economic challenges posed by expanding aridity and desertification processes[13].

Institutional research capacity has increased in the region. A research cluster on arid zones and water governance is being created in the region. The Center for Advanced Studies in Arid Zones (CEAZA) created in 2003 integrates two regional universities (Universidad de la Serena and Universidad del Norte) and the National Institute for Agricultural Research (INIA) of the Ministry of Agriculture. Also, in 2006, the United Nations Educational, Scientific and Cultural Organization

[13]The recently established “Regional Water Dialogue” is a multi stakeholder approach to integrate different social actors in a broader regional water strategy and the “Caminar” Project focuses on the ERB. See www.cazalac.org/caminar

(UNESCO) and the Chilean chapter of the International Hydrological Program (IHP) created the Centre for Water in Arid Zones for Latin America and the Caribbean (CAZALAC). Its objective is to strengthen the development of technical, social and educational capacities of the region to manage water in arid and semiarid zones and to enhance the role of communities in the development of a new water culture (Reyes et al., 2009).

Water governance institutions are also seeking ways to face the challenges of integrated water resource management through new initiatives, as in the case of the recent public discussion in the emerging Regional Water Dialogue established in 2008. This dialogue brings together the water concerns of public, private and social organizations in order to provide leadership and water policy direction. The influence of this emerging initiative on decision-making is still unclear. A similar, smaller scale initiative for the ERB and other basins are non-existent[14]. In fact, multi-agency coordination is weak and aside from the emerging policy on integrated basin management, there are no major concerted efforts to strengthen adaptive capacities and no multi-agency planning initiatives to anticipate more severe drought and flooding events associated with future climate change. Public agencies are focusing their efforts on expanding agricultural production and improving irrigation and water regulation infrastructure (Reyes et al., 2009)

Data on surface water availability and flow patterns in the ERB is fairly complete, but there is insufficient knowledge on groundwater withdrawals and the recharge capacity of aquifers in the ERB. There are important gaps in water data collection and integration, especially when it comes to water quality, quantity, and climatic data for higher altitudes of the Elqui Valley. The information needed to model the ways in which subsurface water and glaciers will respond to future climate change scenarios is incomplete, and the data sets that do exist have high levels of uncertainty associated with them (Fiebig-Wittmaack et al., 2008). This uncertainty reduces the capacity of water governance institutions to plan in the medium and long term, both regionally and nationally. Locally, most stakeholders complain that they do not have access to the data they need to fully understand the challenges that climate change may bring (Reyes et al., 2009).

One institutional adaptation strategy developed to help producers manage the risks associated with extreme climatic events is crop insurance. Almost all crop insurance programs are geared towards medium and large producers. However, the Ministry of Agriculture via the Instituto de Desarrollo Agropecuario (INDAP) recently created a program that seeks to integrate small producers into crop insurance programs. For now, just a small group of these producers can afford it, even though 50% of the costs are covered by INDAP. Crop insurance could compliment other government aid programs (e.g., drought bonuses) that do not cover the economic effect of droughts on producers; those that attempt to do so do not provide pay-outs in a timely manner (Salas et al., 2009). No plans in the near future exist to develop an income guarantee system for producers during extreme events, and the capacity of small producer groups is not strong enough to convert this into a political priority.

The recurrence of mudslides and floods in the ERB tests the capacity of the National Emergency Office to coordinate responses in light of these natural hazards. Community members

[14]The exception is the “Caminar Project” recently initiated by CAZALAC which focus on the ERB in Chile and two basins in Peru and Bolivia. See www.cazalac.org/caminar

of Diaguitas and others feel that institutional responses during mudslides and floods are inadequate, and that there is insufficient communication and coordination among public regional institutions, municipalities and the affected communities (Salas et al., 2009: 19). Effective disaster relief capacities require close coordination and preparedness among public institutions and local governments. Yet, communities have difficulties identifying which public institutions are responsible for what, and how the institutions go about completing their tasks. Thus, poor planning, enforcement and communication limits the capacity of state institutions to take preventive action and build adaptive capacity. The fact that schools and housing are located in risk prone areas with no plan to relocate them to safer areas in times of crisis is commonly cited as an example of the challenges faced by institutions that negatively affect rural communities (Salas et al., 2009: 19).

Although local governments have the most direct links with local community organizations, they do not have clear legal mandates regarding water issues[15]. However, during droughts, mudslides and other disasters, drinking water systems are often damaged or stop working altogether, and local government is the first to organize relief operations and truck water in for human and animal consumption. But in the case of water contamination or other water management issues, they have no capacity to either respond or provide direction to water users. It is unclear if the emerging integrated basin management approach, which is still in the pilot phase, will be effective in enhancing the capacities of local governments in water management areas, which would improve coordination, planning and communication, and improve institutional learning.

Centralization is a common complaint among regional water governance institutions, as regional agencies have limited power to change water policies and resources (Reyes et al., 2009). The 1981 Water Law is perceived as a major obstacle in the adoption of a regionalized perspective on integrated water management. Multi-agency coordination and planning that integrates regional and national agencies is inadequate. These agencies have limited capacities to undertake anticipatory or preventive measures to effectively deal with drought and other climatic stresses. Water policies are defined at the central level and regional approaches for integrated water management are still in their early stages (Reyes et al., 2009). There are new institutional efforts to establish an integrated approach to water management at the basin level under the leadership of the National Commission on the Environment (CONAMA). The National Strategy and Pilot Plans for Integrated Basin Management were approved in 2007[16] and three pilot basins have been selected. If these results are relevant and applicable, they may help to secure political support for implementation in all regions of Chile and ensure the meaningful participation of different stakeholders in the planning process. However, without clearly established institutional roles, this integrated management approach may not work. The recently created Water Table could be the basis for social learning that strengthens integrated water management at the basin level, although it is not clear whether this initiative would permit a positive change in regional water governance institutions.

Limited access to information is perceived as an important factor that is negatively affecting institutional adaptive capacity. Local stake-

[15]An exception could be the development of municipal by-laws, but these are not developed in the ERB.

[16]See http://www.conama.cl/portal/1301/article-42435.html for more information.

holders state that they do not have the information necessary to fully understand the risks of climate change. The managers of the Elqui River Neighborhood Watch, for example, recognize that climate change could be a threat, but they cannot understand what it means for them. Information regarding climate change is scarce and is not appropriately communicated to those stakeholders and institutions that would benefit from having it (Salas et al., 2009).

Climate Change in the ERB

Future climate scenarios required the application of downscaling techniques in order to provide relevant information for decision-making and to produce plausible future climate change impact scenarios for the basin (Fiebig-Wittmaack et al., 2008). Vicuña, a small city in the middle of the basin, was selected as being representative of agricultural productivity in the ERB. Statistical downscaling techniques were carried out on the Vicuña site data using the Long Ashton Research Station Weather Generator (LARS-WG) (Semenov and Barrow, 2002). The study shows the results from the Canadian CGCM3 with the T47 and T63 resolutions (CCCma 2005) and the emission scenarios SRES A2 and B2 (Semenov and Barrow, 2002).

The period of observed meteorological data for Vicuña (baseline) was 1960–1990, and output data were calculated for the periods 2011–2030, 2046–2065 and 2070–2100 for most of the climate indices defined by the ETCCDI (Expert Team on Climate Change Detection and Indices). The first two periods were chosen because these periods are more relevant to Chilean decision-makers and planners.

The following climate indices that are relevant for agriculture and/or represent sensitivities for rural communities in the ERB were the focus of the scenario analysis:

1. monthly average minimum temperature;
2. monthly average maximum temperature;
3. monthly average degree day (monthly sum of hours with temperatures >10°C) (DG10);
4. monthly average number of hot days (maximum temperature >30°C) (SU30);
5. monthly average number of frost days (minimum temperature <0°C) (DO0);
6. annual precipitation; and
7. number of extreme precipitation events (daily precipitation >40 mm).

Future scenarios for the two periods (2011–2030 and 2046–2065), shown in Figures 10 and 11, illustrate a trend towards increased minimum and maximum temperatures, especially in winter (i.e., June and July). The warming is reflected in the increasing degree day index (DG10), where increases of 36% in September, 30% in October, 15% in November, 9% in December, 11% in January, 24% in February and 25% in March can be seen (see Figure 12). The Degree Day Index significantly affects crops, from germination to harvest (September through March). The analysis for the number of hot days also shows a strong increasing trend, mainly during the period October to April (Figure 11); but this result should be taken with caution, given common overestimations in the simulations. In addition, the number of frost days decreases from June to September, and slightly increases in May (Fiebig-Wittmaack et al., 2009).

The downscaling results for precipitation show that annual precipitation will remain close to or be lower than observed precipitation, but interpretations concerning precipitation are also subject to caution, given the high level of uncertainty in its simulation. Even without a clear negative trend for future precipitation amounts, annual precipitation during the last decades has been low enough that the potential continuation of this trend is a great cause of concern. Extreme precipitation from April through to August may decrease slightly in both periods, but a slight increase of these events is shown for the two scenarios in the later part of the year.

The scenarios generated by the models have important consequences for agricultural activities in the basin, particularly vineyards, fruit trees (orchards) and vegetable production. The increase in average minimum temperature will reduce the amount of cold hours (i.e., the number of hours when the temperatures range between 0°C and 7°C) during the dormancy period of plants (May through August), which may result in irregular budburst in grapes and deciduous fruit trees; plant productivity may also decrease. On the other hand, the decrease in frost days may be beneficial for producers with frost-sensitive crops, primarily early harvest vegetable crops (e.g., potatoes, tomatoes, bell peppers) and fruit trees (e.g., papayas, chirimoyas, avocados, citrus).

The increase in days with temperatures greater than 30°C during the spring and summer will have negative effects on the photosynthetic process of all fruit trees cultivated in the ERB (Jackson and Lombard, 1993). Yield and quality will be affected; however, this may reduce the incidence of some common plant diseases in the ERB.

Higher winter temperatures could have positive effects on the productivity of early spring-summer horticultural crops because these could then be cultivated earlier during the year, potentially enabling producers to obtain premium prices in urban markets. However, as a consequence of higher temperatures, evapotranspiration rates will increase, which will increase water demands from agriculture and irrigation. This may result in increased competition and conflicts among water users and between communities and other sectors (e.g., tourism and mining).

The projected increase in the Degree Day Index will result in a shorter growing period for grapes, which will allow an earlier harvest, potentially resulting in higher prices. However, vineyard productivity and fruit quality will likely diminish as a consequence of the shorter growing season, as grapes will not have the necessary time to reach preferred maturity. This warmer weather could stimulate the expansion of insect plagues, resulting in higher input costs for pest control and increasing the risk of insect and plague contamination (Cepeda et al., 2009).

The future shifts in these climate indices not only create risks, but also opportunities. Some new agricultural crops may be introduced in the ERB, and some traditional crops could be relocated to higher elevations in the valley. Maximizing opportunities, however, will require enhanced adaptation in terms of the awareness of various agro-climatic trends, for example, and of their implications for current and future possible agricultural products.

For some communities and farmers living on dryland or rain-fed agriculture, or with limited access to irrigation water, the impacts of the above scenarios will be dramatically different, as water is already a major limiting factor. On the other hand, the slight decrease in frost days may be beneficial by reducing the vulnerability of some frost-sensitive crops, mainly early harvest crops and some fruit trees. Without access to irrigation, many of the crops cultivated by small farmers, from which they draw their income, will experience reduced yields.

Higher winter temperatures may be beneficial for the productivity of some horticultural crops, as they may be cultivated earlier in winter, when precipitation is available in the ERB. Yet, the overall increase in evapotranspiration and subsequent increases in water demand will limit the potential for farms with poor access to water for irrigation.

Goat producers are most sensitive to reduced water availability since this will translate into lower productivity of natural pasture lands and shrubs, on which they depend. The overall decrease in rain will likely further decrease the available fodder, which may negatively affect herd size and quality. Goat herders may have to graze larger areas for their herds to obtain the same amount of food, and this may accelerate the erosion process in the already stressed and highly eroded hillsides.

Community members engaging in subsistence economies may have to migrate to find seasonal and/or permanent employment opportunities in order to supplement their income (Salas et al., 2009). Scenarios show a small decrease in the number of extreme precipitation events during April to August but a slight increase in the latter part of the year. For low income families living in mudslide and flood prone areas, this may mean either a reduction in these risks or a shift in the timing of these events into the early spring.

With increasing temperatures, the isotherm will continue to shift towards higher altitudes, decreasing snow and ice reserves at higher altitudes, resulting in decreased precipitation, higher evapotranspiration, and reduced river flows. Decreased precipitation and higher evapotranspiration rates, along with a higher demand for water, may mean greater risks for wells feeding potable water systems. Reduced river flows and future potential increases of agricultural and urban-industrial effluents may increase the risk of water contamination, as the dilution potential of rivers will be reduced. Overall, communities will experience greater water stress as there will be greater competition for water because there will be less water available to meet growing demands in the future.

In terms of river flow, it is unclear as to whether or not there will there be enough water in rivers to meet future environmental and social needs. The fact that there is sparse high mountain precipitation data and a lack of knowledge concerning the cryosphere in the ERB, stream flow behavior is difficult to understand and predict (Fiebig -Wittmaack et al., 2008).

On the east side of the Andes Mountains, at monitoring sites in Argentina, precipitation has shown an increasing trend in the past century (Minneti et al., 2003). To the west, it is uncertain whether or not precipitation at higher elevations in the Andean zone has decreased, or if permafrost and glaciers have melted or are currently melting. Also uncertain is whether or not these have contributed water to surrounding rivers; if they have, higher stream flows could be temporary. This is alarming because, besides the changes in the temperature-related indices, the loss of valuable water resources stored in the form of snow, permafrost and glaciers can result in environmental and socio-economic stresses in the near future. This emphasizes the critical importance of monitoring of the cryosphere, evaluating current and future trends, and discussing adaptation measures to water scarcity (Fiebig-Wittmaack et al., 2008).

Improving data collection, integrating information and enhancing coordination between public agencies and research institutions may

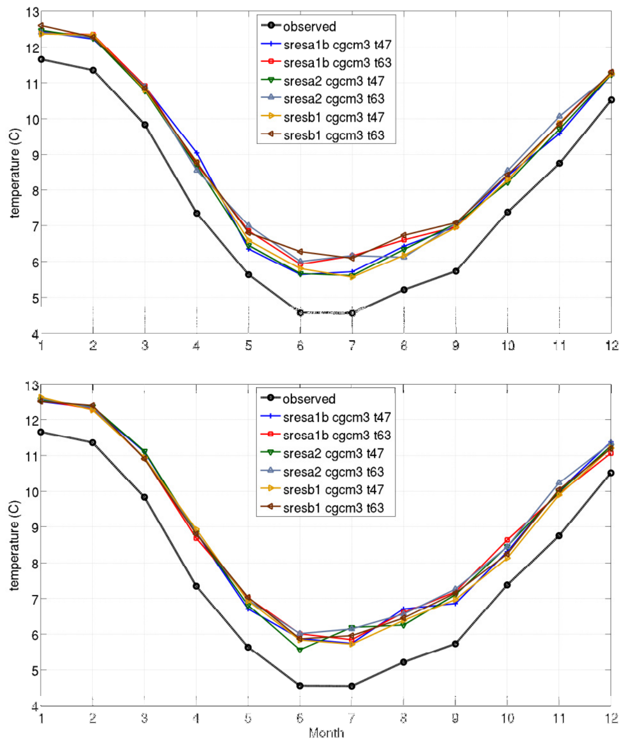

Figure 10. Monthly Average Minimum Temperature for Vicuña. The black line represents the baseline (1960–1990), while the others correspond to results calculated with LARS for different emission scenarios, for the period 2011–2030 (above) and 2046–2065 (below).

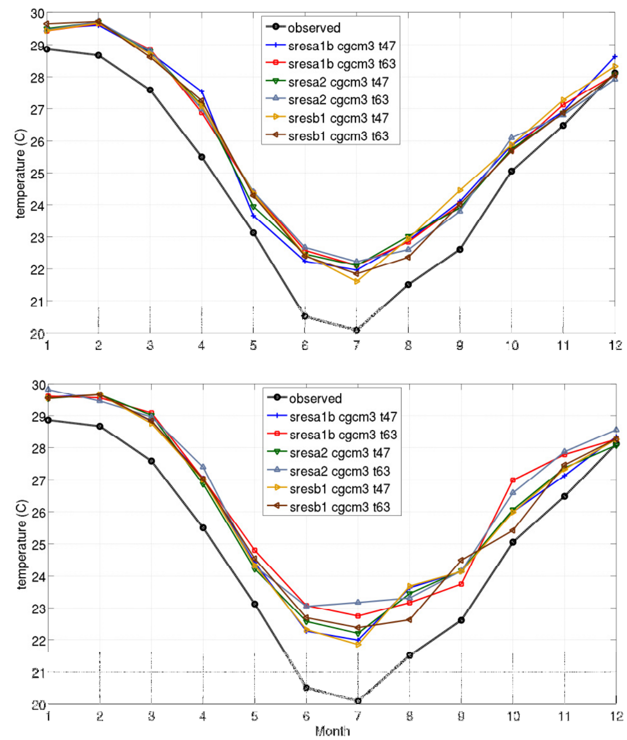

Figure 11. Monthly Average Maximum Temperature for Vicuña. The black line represents the baseline (1960–1990), while the others correspond to results calculated with LARS different emission scenarios, for the period 2011–2030 (above) and 2046–2065 (below).

yield more realistic, reliable climate change models, and contribute to the development of more pertinent adaptation measures.

Future Vulnerabilities in the ERB

Future climate models project decreases in precipitation, increases in temperatures and in the severity of extreme climate events (e.g., droughts and intense precipitation events), decreases in annual river flow, and fewer frost events. These create both risks and opportunities for rural communities as well as agricultural producers.

FUTURE EXPOSURES

Aridity in the basin will be exacerbated by the projected increases in monthly average minimum and maximum temperatures, monthly average degree day (DG10), and monthly average number of hot days. Many of those expected changes will be outside of the climate currently experienced in the ERB and beyond the coping range of rural communities.

Warmer winters and higher maximum summer temperatures will create stress for human activities and natural systems. The increases in temperature will lead to higher evapotranspiration rates, reduced water availability, and increased water demands. Future exposure-sensitivities may include greater competition

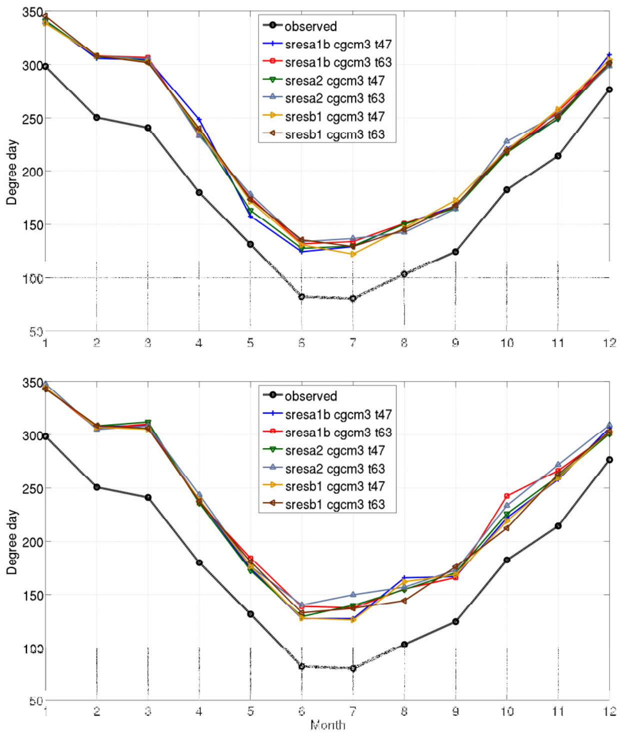

Figure 12. Monthly Average Degree Day Index Temperatures >10°C). The black line represents the baseline (1960–1990), while the others correspond to results calculated with LARS for different emission scenarios, for the periods 2011–2030 (above) and 2046–2065 (below).

for water, which may result in conflicts among water users.

As the climate of the region becomes more arid, snow and ice reserves in the Andes are expected to diminish. This will affect the seasonality and amount of snowmelt and surface runoff, which has implications for annual river flows, groundwater recharge and water ecosystems in lower elevations.

The forecasted increases in temperature will also have an impact on wild species, and it is unclear how they will respond to a warmer climate. It is possible that species with fast biological cycles and high biotic potential (e.g., insects, rodents, rabbits) can benefit from future warming, potentially becoming more abundant, and subsequently becoming plagues (Carey, 2001 cited by Cepeda et al., 2008).

The frequency and magnitude of intense rainfall events associated with ENSO will increase in the future, creating risks for communities, including landslides, avalanches, and flooding. ENSO will also bring more severe droughts (Cepeda et al., 2009). There is evidence that extended, severe and multi-year droughts will seriously amplify aridity trends. An expansion in aridity may result in an increase in water scarcities and have negative implications for agriculture and people's livelihoods.

New exposures will arise in the future in the ERB. A reduction in the amount of cold hours will affect the productivity of some crops, such as grapes, whose dormancy period, for example, is critical for uniform budding, which ultimately influences yields and quality. Irregular budding resulting from an inadequate dormancy period will decrease productivity in fruit trees and reduce the number of temperate fruit species that can potentially be cultivated in the ERB. Similarly, increases in the Degree Day Index will cause decreases in fruit quality and productivity, and affect the financial returns of the fruit plantation operations in the valley, although earlier crops may allow producers to obtain higher prices.

Increasing water demand is likely to drive farmers and enterprises to invest in water-saving technologies (e.g., drip irrigation), the development of new water sources (e.g., purchase new or more water rights, which will result in more active water markets), and/or underground water exploration and technology. As a result, the risk of over-extraction and depletion of aquifers may increase.

There may also be opportunities for production systems in the future if there is better access to information, technology and financial resources to facilitate shifts in current agricultural practices to new, more climate-appropriate crops. The warmer climate will provide an opportunity to introduce new crops that demand fewer cold nights and days, while frost-sensitive crops will benefit from a reduction in frost events.

The forecasted increases in aridity will cause an expansion and intensification in the desertification process, potentially reducing yields and opportunities for subsistence agriculture. This will reduce food production capacity and the income generating potential of subsistence agriculture. Communities reliant on dryland agriculture are already exposed to drought; further droughts will negatively affect cultivated areas, water storage capacities and income opportunities. Animal husbandry, particularly goat herding, which has been an important diversification of farm income, will feel the impacts of water stress in the ERB. With less natural fodder available as result of lost moisture, herd sizes will continue to decrease, and herders will be forced to migrate further distances to highland areas to feed their animals, or they may change their livelihood altogether.

There is a slight decrease in the intensity of rainfall events in the winter, with a shift towards the early spring. However, since torrential rains are often associated with ENSO years, it is unclear if mudslides will be more or less common, while the forecasted decrease in precipitation in the highlands may reduce the risk of flooding. Currently, communities do not have access to early warning systems, nor do they have the institutional support required to anticipate or respond to emergencies arising from sudden climatic changes. This significantly reduces their adaptive capacity to deal with hazardous events such as mudslides.

The CAPRs will experience great difficulties as a result of decreases in the water table and greater competition for water among different economic sectors. Water contamination may also be a more common occurrence, if they continue to lack the tools necessary to prepare for these stressors. Local governments do not have the human and financial resources to support and improve drinking water systems in rural areas, nor do they have the resources to secure water supplies and efficient technologies for rural communities. Unless regional and central governments are prepared to invest in water security in these rural communities, they will experience great risks related to water security (both quality and quantity).

Future Institutional Response/Adaptation

Until recently, the Chilean government had not developed many adaptation strategies or policies to confront climate change. Most of its efforts and commitments within the United Nations Framework Convention on Climate Change (UNFCCC) have been associated with greenhouse gas emissions in different economic sectors, and linking them to reduction processes through the Clean Development Mechanism and carbon credit projects. The National Strategy on Climate Change was approved by the Council of Ministers in 2006 (see CONAMA, 2006a), while the National Action Plan on Climate Change was launched just days before the UNFCCC Conference in Poznan in December, 2008 (CONAMA, 2008). More recently, the Ministry of Agriculture has created a "Climate Change Council for Agriculture," formed by multiple agencies and researchers from different institutions to provide advice and direction regarding adaptation policies. The completion and release of climate change scenarios for Chile, and a recent analysis of climate change vulnerabilities in silviculture, agriculture, water and soil resources have contributed to the incorporation of climate change considerations into public and policy discussions (CONAMA, 2006b; 2008). There is still a long way to go before those discussions are reflected in effective adaptation policies and become well-funded, decentralized programs. A major drawback of future climate projections for 2070–2100 is that they are too far removed for policy actions to take place. The scale of the projections is also too broad to be able to make informed decisions at a regional and basin scale.

Statistical downscaling makes an important contribution for the early development of adaptation programs and policies at regional and basin scales. The assessment of vulnerabilities and institutional capacities at the community, basin and regional levels highlight the local capacity to manage current climatic stressors, but it is unclear if those capacities will be sufficient under future climate change.

Key IACC Recommendations

The following recommendations emerged from the IACC's research activities as ways to increase the adaptive capacity of governance institutions in the ERB in order to alleviate the risks and maximize the opportunities of climate change for rural communities:

- Create an umbrella organization that can effectively monitor and more accurately generate water scenarios (e.g., generate, collect and process climate and hydrological data and integrate climate change scenarios for both highlands and lowlands in the ERB).
- Improve climate monitoring, paying particular attention to improving and integrating highland monitoring and data collection stations, including teledetection in the high Andes where climatic conditions are critical for understanding the hydrology of the ERB.
- Improve inter-institutional coordination and develop new tools to disseminate climate change information and build local and regional institutional capacities.
- Establish and develop a watershed authority that would both effectively manage and coordinate institutional responses to changing climatic conditions and their effects on rural communities, people's livelihoods, household income, agriculture, and other aspects of society.
- Coordinate and develop decentralized tools and programs that improve water use efficiency and water storage and harvesting potential, with particular attention to the most vulnerable (i.e., small and medium size farmers and rural communities).
- Create networks and training programs that sustain an early warning system for droughts, floods, mudslides, and other hazardous climatic events.
- Develop an integrated pest control program. This would reduce the risks as well as the costs associated with the wide use of pesticides on monocropping operations
- Public institutions and basin authorities should develop conflict management and conflict mediation capacities, since future increases in water demand will lead to both increased competition and conflict among sectors.
- Regional water governance institutions would benefit from better surface and

groundwater coordination, monitoring and documentation. This is particularly important for securing adequate, quality drinking water for communities and for avoiding groundwater contamination and aquifer overexploitation.

- Municipal governments are the first to respond to rural community needs, and they therefore need to develop and strengthen their capacities to communicate climate adaptation measures and water management issues to communities.
- Water and development agencies need to develop an institutional framework that enhances municipal, community and other stakeholder involvement in water management (e.g., conservation, protection and restoration).
- Current and future climate change risks and opportunities require programs that strengthen civil society organizations (e.g., capacity building for local, regional and national CAPR associations, Irrigation Associations, research and education teams, etc.). A strong and well-organized civil society will be in a better position to deal with climate change.

The current adaptive capacity of rural communities and of local and regional governments in the ERB reveals some important limitations to confronting the emerging challenges of future climate change and extreme climatic events. Coordination among public institutions, water data availability, and integrated water resources management emerged as some of the major factors influencing adaptive capacity. Policies aimed at reducing resource concentration and improving planning and risk prevention measures are needed to reduce rural community vulnerability to climate and water stresses.

COMPARISON OF THE SSRB AND ERB

The two case studies discussed above provide a brief summary of the key exposure-sensitivities affecting rural communities in two dryland river basins—the SSRB in Canada and the ERB in Chile—and the adaptive strategies rural people use to cope with these. The two basins are characterized by an agricultural sector that is dynamic and highly integrated in global markets, although they differ in terms of their size, population, history, and the social and political conditions that influence the lives of their people. The two also have different water rights systems. In Chile, once water rights are acquired, they are treated as a tradable commodity, which can be bought and sold through an open market, whereas in Canada, no such market for water rights exists. Notwithstanding these differences, they share significant similarities in the context of their vulnerability to climate and other stressors. Communities in both basins experience similar exposure-sensitivities, and they draw on a similar suite of adaptive strategies to manage these stresses. Both cases have a history of adaptation where governance institutions have played a significant role in shaping rural peoples' adaptive capacities. These capacities, however, are not sufficient under future climatic, social, economic, political and environmental change.

In both basins water scarcities constitute the most important exposure. A lack of precipitation and runoff that leads to water shortages and droughts negatively affects people's livelihoods, particularly agricultural producers (whether irrigated, dryland or rancher) as they are highly dependent on a sufficient amount of water for their crops or livestock to be successful. For rural households, poor water quality is also problematic. Poor water quality is not always the result of natural causes, but is also influenced by human activities (i.e., use of pesticides) and/or institutions (i.e., inadequate training of individuals to operate local water treatment facilities).

Although rural people are highly sensitive to a lack of precipitation, excessive precipitation is also problematic. Precipitation events that lead to floods can significantly damage community infrastructure and contribute to water contamination. The topographic characteristics of the ERB create the conditions for additional problems created by excessive precipitation (e.g., mudslides and avalanches), exposures to which some of the rural communities in the Chilean basin are highly sensitive. People that live in areas affected by mudslides and avalanches have few options but to live in these risk-prone areas (at low elevations surrounded by mountains with denuded soils).

Extreme temperatures also present challenges for rural people in both basins. Low temperatures in winter affect ranchers in Canada, as they facilitate illness in livestock. They also result in increased feed requirements, and subsequently increased input costs. Low temperatures can also affect the quality of vegetables in storage. In the case of Chile, fruit producers—a dynamic sector that has oriented its production toward markets in the northern hemisphere—are sensitive to cold snaps in winter (near or below freezing temperatures), because, although the plants are dormant, they are still sensitive to cold temperatures in winter, which can significantly reduce crop yield as well as quality in the subsequent growing season. In both basins, high temperatures can lead to high evapotranspiration rates, causing reductions in water availability and soil moisture, and affecting agricultural production.

In the two basins, exposures to climate and water overlap with exposures to poor market conditions (e.g., low price and high input costs), an overlap that increases household vulnerability. These climatic and economic conditions largely affect agricultural producers, especially those with reduced capital. In the case of the ERB, there are few sources of permanent employment, which creates a variety of problems, including the inability to ensure enterprise viability and secure household income to support the family. In this context, exposure to droughts and floods compounds the stresses produced by economic conditions.

The strategies that rural people draw from to cope with these stresses include diversifying income and production, as well as securing access to water resources. In both Canada and Chile, many producers have adopted higher value crop varieties to secure income and/or have developed value-added products and services; in Chile goat herders supplement their income by selling cheese and leather, while in Canada some producers sell their mechanical services. For many producers off-farm employment is an important source of additional income; seeking employment in the oil and gas industries in Canada or working for larger farms in the ERB is becoming more and more common. Securing water resources involves mainly access to irrigation in both basins, although in Canada access is restricted to those in close proximity to the irrigation development, while in Chile there are irrigation canals throughout the basin; however access, in the case of Chile, is limited to those with water rights and the technological and financial capital to invest in this technology. Irrigation can provide a significant opportunity to maximize water use and sustain producers through dry periods. Building protective structures to reduce the effects of floods, mudslides and avalanches has also reduced the risks associated with hazardous water-related events, although in many cases they do not effectively reduce risk.

Many of these adaptations have been facilitated and often developed by governance institutions, and many governance institutions themselves have been created as adaptations to climate and water stress. The PFRA in Canada and the CAPRs in Chile were created in response to rural community needs. Zero and minimum tillage was promoted by the PFRA/AESB as a way to conserve soil moisture; the majority of producers in the SSRB now employ zero or minimum tillage management practices. In Chile, the CAPRs have taken on the responsibility of providing rural people with access to clean drinking water; without them, people may not have clean drinking water, which poses health risks and several other problems. Governments in both countries provide funding for water and irrigation projects, and these services are an important institutional adaptation that increases rural peoples' adaptive capacities to deal with climate and water stresses. These institutional adaptations, however, often tend to favour the large agricultural producers that are the most productive, as well as those in powerful positions. This causes an unequal distribution of adaptive capacity and leaves those with low capacities (e.g., First Nations peoples, subsistence farmers, producers without access to water rights, etc.) in a vulnerable situation and more susceptible to risk.

Climate change is expected to have similar effects on both basins. Scenarios for the SSRB and the ERB suggest that the two basins will most likely experience increases in maximum, minimum and average temperatures, as well as decreases in precipitation. These scenarios present both risks and opportunities. Since communities in both basins are heavily engaged in agriculture, which is partly dependent on favorable environmental conditions to be successful, increases in temperature and decreases in precipitation could be problematic (i.e., conditions that currently create risks for communities may be exacerbated in the future), and although institutions have made great contributions to enhancing community capacity to deal with stresses in the past, these efforts have provided communities with a capacity that is not sufficient to cope with climate change. In other words, the future climate conditions will be beyond rural peoples' current coping range. Rural people need to be better prepared to cope with future climate change, and enhancing their adaptive capacity and resilience by adopting anticipatory approaches that include all stakeholders is perhaps one of the best ways of doing this. A significant challenge in both basins is to improve the fair distribution of adaptive capacity in order to ensure the well-being of all rural households.

CONCLUSION

This research identified the climate and water stresses that rural communities in the SSRB and the ERB have experienced in the past, the suite of adaptive strategies they use to cope with stress, and the ways in which governance institutions influence their capacity to cope with stress, particularly those that are climate and water related. These research findings were used to develop recommendations that address community needs. It is important to note that these needs, and therefore the recommendations, are very similar for both basins and are therefore applicable in a variety of contexts.

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APPENDIX A: RESEARCH TEAM

This appendix provides a list of the research team, including researchers, research fellow, research assistants, collaborators, administrative coordinators, and the advisory board.

Researchers

- Dr. Harry Diaz (Sociology, University of Regina, and Director, Canadian Plains Research Center, Canada)
- Dr. Jorge Cepeda-Pizarro (Ecology, Biology, University of La Serena, Chile)
- Dr. Melitta Fiebig-Wittmaack (Mathematics, Universidad de La Serena, Chile)
- Dr. David Gauthier (Geography, Vice-President Research and International, University of Regina, Canada)
- Margot Hurlbert (Sociology/Justice Studies, University of Regina, Canada)
- Dr. Suren Kulshreshtha (Agricultural Economics, University of Saskatchewan, Canada)
- Dr. Gregory P. Marchildon (Economic and Regional Development, Graduate School of Public Policy, University of Regina, Canada)
- Dr. Héctor Luís Morales (Administration/ Tourism, Universidad de La Serena, Chile)
- Dr. Bruce Morito (Philosophy, Athabasca University, Canada)
- Dr. Alejandro Rojas (Faculty of Land and Food Systems, University of British Columbia, Canada)
- Bernardo Reyes (Environment and Sustainability, Universidad ARCIS and Universidad de Chile, Chile)
- Dr. Sonia Salas (Psychology, Universidad de La Serena, Chile)
- Dr. David Sauchyn (Geography, Arts, University of Regina, and Research Coordinator, Prairie Adaptation Research Collaborative, Canada)
- Dr. Barry Smit (Geography, Global Environmental Change, University of Guelph, Canada)
- Elaine Wheaton (Climatology, University of Saskatchewan and Saskatchewan Research Council, Canada)

Collaborators

- Darrell Corkal, P.Eng (Water Quality, AESB/PFRA, Agriculture and Agri-Food Canada)
- Hernan Cortes (History, Universidad de La Serena, Chile)

- Virginia Wittrock (Saskatchewan Research Council, Canada)
- Humberto Zavala (Engineering, Universidad de La Serena, Chile)

Research Fellows

- Monica Hadarits (MSc, Geography, University of Guelph, Canada)
- Elizabeth Jimenez (MA, Center for Latin American Studies, Universidad de La Serena, Chile)
- Suzan Lapp (PhD candidate, Geography, University of Regina, Canada)
- Lorenzo Magzul (PhD candidate, Agricultural Studies, University of British Columbia, Canada)
- Lorena Patino (PhD candidate, Geography, University of Regina, Canada)
- Cesar Perez (MSc, Environmental Engineering, University of Regina, Canada)
- Jeremy Pittman (MSc, Geography, University of Regina, Canada)
- Susana Prado (MA candidate, Social Work, University of Regina, Canada)
- Dr. Johanna Wandel (Associate Professor, Geography and Environmental Management, University of Waterloo, Canada)
- Gwen Young (MSc, Geography, University of Guelph, Canada)

Research Assistants

- Carl Anderson (MA candidate, History, University of Regina, Canada)
- Andrés Bodini (GIS, Universidad de La Serena, Chile)
- Sara Bagg (Law, University of Calgary, Canada)
- James Daschuk (Research Associate, University of Regina, Canada)
- Roxana Espinoza (BSc, Management and Commercial Engineering Sciences, Universidad de La Serena, Chile)
- Brett Matlock (MA candidate, Sociology, University of Regina, Canada)
- Liska Richer (PhD candidate, Agricultural Sciences, University of British Columbia, Canada)
- Jaime A Pizarro (BSc, Biology, Universidad de La Serena, Chile)
- Marcela I Robles (MA, Geography, Universidad de La Serena, Chile)
- Enrique Schwartz (Universidad ARCIS, Chile)
- Jim Warren (PhD candidate, Canadian Plains Studies, Canada)

Organizational members

- Alberta Environment, Canada
- Athabasca University, Canada
- Canadian Plains Research Center (CPRC), Canada
- Centro del Agua para Zonas Áridas y Semiáridas de América Latina y el Caribe, Chile
- Centro de Estudios Regionales, Chile
- Comisión Nacional del Medio Ambiente, Chile
- Instituto de Ecología Política, Chile
- Meteorological Services of Canada, Environment Canada
- National Water Research Institute, Canada

- Prairie Adaptation Research Collaborative (PARC), Canada
- Prairie Farm Rehabilitation Administration (PFRA)/Agri-Environment Service Branch (AESB), Agriculture and Agri-Food Canada
- Saskatchewan Research Council, Canada
- Saskatchewan Watershed Authority, Canada
- University of British Columbia, Canada
- University of Guelph, Canada
- University of La Serena, Chile
- University of Regina, Canada
- University of Saskatchewan, Canada

Administrator Coordinator

- Pat Barrett-Deibert (Project Administrative Assistant, Consortium for Global Change Management, University of Regina, Canada)
- Solange Araya (Project Administrative Assistant, Universidad de La Serena, Chile)
- Carolina Recabarren (Project Administrative Assistant, Universidad de La Serena, Chile)

Advisory Board

- Phil Adkins (Agricultural Water Directorate, AESB/PFRA, Agriculture and Agri-Food Canada, Canada)
- Dr. Fernando Santibanez (Agronomist Engineer, Universidad de Chile, Chile)
- Dr. Martin Mujica (Sociology, Université de Moncton and Research Fellow, Interdisciplinary Research Group on Environmental Management, Université de Québec, Canada)

APPENDIX B: DOCUMENTS AND DISSEMINATION ACTIVITIES

This appendix provides a list of all the working papers, theses and dissemination activities produced by the project. It also includes a list of related projects.

Working Papers

This section lists the working papers produced by the research team. Each entry includes the author(s), year of completion, title, language the document was written in, and the website address where the document can be found.

- Alfaro, S., 2004. "Institutions and Sustainability. An Analytical Report." (English). http://www.parc.ca/mcri/pdfs/papers/iacc001.pdf
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- Cepeda, J., M. Fiebig-Wittmaack, C. Perez-Valdivia, H. Trigos, and H. Zavala, 2005. "Caracterización Bio-Geo-Física de la Cuenca del Río Elqui." (Spanish). www.parc.ca/mcri/elqrb.php
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ada." (English). http://www.parc.ca/mcri/pdfs/papers/iacc035.pdf

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- Daschuk, J., and G. Marchildon, 2005a. "Overview of Climate and Aboriginal Adaptation in the South Saskatchewan River Basin before the Settlement Period." (English). http://www.parc.ca/mcri/pdfs/papers/iacc006.pdf
- Daschuk, J., and G. Marchildon, 2005b. "Climate and Aboriginal Adaptation in the South Saskatchewan River Basin, AD 800–1700." (English). http://www.parc.ca/mcri/pdfs/papers/iacc007.pdf
- Daschuk, J., and G. Marchildon, 2005. "Climate and Aboriginal-Newcomer Adaptation in the South Saskatchewan River Basin, 1700–1800." (English). http://www.parc.ca/mcri/pdfs/papers/iacc008.pdf
- Daschuk, J., and G. Marchildon, 2005d. "Historical Chronology of the Oldman River Dam Conflict." (English). http://www.parc.ca/mcri/pdfs/papers/iacc036.pdf
- Diaz, H., A. Rojas, L. Richer, and S. Jeannes, 2005. "Institutions and Adaptive Capacity to Climate Change." (English). http://www.parc.ca/mcri/pdfs/papers/iacc009a.pdf
- Diaz, H., and A. Rojas, 2006. "Methodological Framework for the Assessment of Governance Institutions." (English). http://www.parc.ca/mcri/pdfs/papers/iacc033.pdf
- Diaz, H., M. Hurlbert, J. Warren, and D. Corkal, 2009. "Saskatchewan Governance Assessment. Final Report." (English). http://www.parc.ca/mcri/pdfs/papers/gov01.pdf
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- Hurlbert, M., 2006a. "Water Law in the South Saskatchewan River Basin (Alberta/Saskatchewan)." (English). http://www.parc.ca/mcri/pdfs/papers/iacc027.pdf
- Hurlbert, M., 2006b. "Inter-jurisdictional Water Law—SSRB." (English). http://www.parc.ca/mcri/pdfs/papers/iacc026.pdf
- Jiménez, E., 2007. "Vulnerabilidad y Adaptación Institucional frente al Cambio Climático: Comunidad de el Mo-

lle." (Spanish). http://www.parc.ca/mcri/pdfs/papers/iacc050.pdf

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- Matlock, B., 2007. "Report on the Community Vulnerability of Cabri and Stewart Valley." (English). http://www.parc.ca/mcri/pdfs/papers/iacc052.pdf
- Morales, H., and R. Espinoza, 2004. "Adaptaciones Institucionales al Cambio Climático. Instituciones Relacionadas con el Agua en Chile y en la Región de Coquimbo." (Spanish). http://www.parc.ca/mcri/pdfs/papers/iacc014.pdf
- Morales, H., and R. Espinoza, 2005a. "Organizaciones de Usuarios de Agua de la Cuenca del Río Elqui." (Spanish). http://www.parc.ca/mcri/pdfs/papers/iacc015.pdf
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- Morito, B., and Thachuk, A, 2006. "Values Analysis of Ethnographic Stakeholder Responses: Report on Cabri-Stewart Valley and the Blood Reserve." (English). http://www.parc.ca/mcri/pdfs/papers/iacc065.pdf
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- Patino, L., and D. Gauthier, 2007a. "South Saskatchewan River Legal and Inter-jurisdictional Institutional Water Map." (English). http://www.parc.ca/mcri/pdfs/papers/iacc054.pdf
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- Pittman, J., 2008. "Report on the Community Vulnerability Assessment of Outlook, Saskatchewan." (English). http://www.parc.ca/mcri/pdfs/papers/iacc063.pdf
- Prado Becerra, S., 2008. "Report on Community Vulnerability Assessment of Taber, Alberta." (English). http://www.parc.ca/mcri/pdfs/papers/iacc066.pdf
- Reyes, B., S. Salas, E. Schwartz, and R. Espinoza, 2009. "Chile Governance Assessment." Unit 1D Report for the IACC Integration Committee. (English).
- Rojas, A., and L. Ritcher, 2005. "Successful Institutional Adaptation to Climate Change Impacts Posed on Water Resources." (English). http://www.parc.ca/mcri/pdfs/papers/iacc018.pdf
- Rojas, A., B. Reyes, L. Magzul, and H. Morales, 2006. "Water Blues in Climate Change: The Role of Institutions in Water Conflicts and the Challenges Presented by Climate Change." (English). http://www.parc.ca/mcri/pdfs/papers/iacc041.pdf
- Rojas, A., B. Reyes, L. Magzul, H. Morales, R. Borquez, and E. Schwartz, 2007. "The Role of Institutions in the Resolution of Water Conflict: Adaptive Conflict Resolution, Vulnerability and Adaptive Capacity." (English). http://www.parc.ca/mcri/pdfs/papers/iacc056.pdf
- Rojas, A., B. Reyes, L. Magzul, H. L. Morales, R. Borquez and E. Schwartz, 2008. "Analysis of the Role of Institutions

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- Smit, B., J. Wandel, and G. Young, 2005. "Vulnerability of Communities to Environmental Change." (English). http://www.parc.ca/mcri/pdfs/papers/iacc021.pdf
- Velez, M., 2004. "Holocene Paleoclimatology in the South Saskatchewan River Basin." (English). http://www.parc.ca/mcri/pdfs/papers/iacc022.pdf
- Wandel, J., Forthcoming. "Alberta Governance Assessment Report." (English). http://www.parc.ca/mcri/pdfs/papers/gov02.pdf
- Wittrock, V., E. Wheaton, and S. Kulshreshtha, 2005. "Climate Change, Ecosystem and Water Resources: Modeling and Impact Scenarios for the South Saskatchewan River Basin, Canada." (Published by the Saskatchewan Research Council—Publication No. 11899-1E05 and 11899-5A06.) (English). http://www.parc.ca/mcri/pdfs/papers/iacc025.pdf
- Wittrock, V., D. Dery, S. Kulshreshtha, and E. Wheaton, 2007a. "Vulnerability of Prairie Communities' Water Supply during the 2001 and 2002 Droughts: A Case Study of Cabri and Stewart Valley, Saskatchewan." (Published by the Saskatchewan Research Council—Publication No. 11899-2E06.) (English). http://www.parc.ca/mcri/pdfs/papers/iacc060.pdf
- Wittrock, V., S. Kulshthreshtha, E. Wheaton, and M. Khakapour, 2007b. "Vulnerability of Prairie Communities during the 2001 and 2002 Droughts: Case Studies of Taber and Hanna, Alberta and Outlook, Saskatchewan." (Published by the Saskatchewan Research Council—Publication No. 11899-8E07.) (English). http://www.parc.ca/mcri/pdfs/papers/iacc059.pdf
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- Young, G., and J. Wandel, 2007. "Community Vulnerability in the South Saskatchewan River Basin: A Case Study of Hanna, Alberta." (English). http://

www.parc.ca/mcri/pdfs/papers/iacc060.pdf

Theses

This section lists the theses that were produced through the research project, as well as those that are in the process of being completed. Each entry includes the author, year of completion, thesis title, degree obtained, university, language thesis was written in, and the website address where the thesis can be found.

- Hadarits, M., 2009. "The Sensitivity and Adaptability of the Grape and Wine Industry in the Maule Region of Chile to Climate Change." (Master of Science Thesis, University of Guelph) (English). http://www.parc.ca/mcri/pdfs/theses/hadarits_thesis.pdf
- Jiménez, E., 2007. "Construyendo Memorias E Identidades Compartidas: Análisis de los Discursos sobre el Pasado de la Comunidad de Diaguitas. Valle de Elqui. IV Region." (Master of Arts Thesis, Universidad de La Serena) (Spanish). http://www.parc.ca/mcri/pdfs/theses/jimenez_teses.pdf
- Lapp, S., Forthcoming. "Climate Moisture Scenarios Using Dendroclimatic, Historical and GCM-based Precipitation Records over Western North America." (Doctor of Philosophy Thesis, University of Regina (English).
- Patino, L., Forthcoming. "Participatory Mapping and the Integration of Knowledge of Community Adaptation to Climate Change: Rural Communities of the South Saskatchewan River Basin." (Doctor of Philosophy Thesis, University of Regina) (English).
- Perez-Valdivia, C., 2009. "Groundwater in the Canadian Prairies: Trends and Long-term Variability." (Master of Environmental Engineering Thesis, University of Regina) (English). http://www.parc.ca/mcri/pdfs/theses/perez_thesis.pdf
- Pittman, J., 2009. "The Vulnerability of the James Smith and Shoal Lake First Nations to Climate Change and Variability." (Master of Science Thesis, University of Regina) (English). http://www.parc.ca/mcri/pdfs/theses/pittman_thesis.pdf
- Young, G., 2007. "Community Vulnerability to Climate Change in the Elqui River Basin, Chile." (Master of Science Thesis, University of Guelph) (English). http://www.parc.ca/mcri/pdfs/theses/YoungThesis.pdf
- Prado Becerra, S., Forthcoming. "Vulnerability of the Taber Community to Climate Change." (Master of Social Work Thesis, University of Regina) (English).

Dissemination Activities

This section provides details on the dissemination activities that were carried out in relation to the project. It includes presentations and media releases, stakeholder workshops, and publications and reports produced by the research team.

Presentations and Media Releases

- Alcayata, O.E., S. Espinoza-Lagos, J. Pizarro-Araya, J. Cepeda-Pizarro, and A. Bodini, "Araneofauna (Arachnida, Araneae) Asociada a Secano y Agroecosistemas del Valle de Elqui (Region de Coquimbo, Chile)." 59th Congreso Agronómico de Chile y 9th Congreso de la Sociedad Chilena de Fruticultura. La Serena, Chile, October 7–10, 2008.

- Alfaro, F.M., J. Pizarro-Araya, J. Cepeda-Pizarro, A. Bodini, and J.E. Barriga, "Ensambles de Orthoptera (Insecta) en Sectores de Secano y Cultivo del Valle de Elqui (Región de Coquimbo, Chile)." 59th Congreso Agronómico de Chile y 9th Congreso de la Sociedad Chilena de Fruticultura. La Serena, Chile, October 7–10, 2008.
- Bórquez R., and E. Schwartz, "El Conflicto Pascua Lama en Chile. Aprendizajes Institucionales a través del Análisis de la Resolución Adaptativa de Conflictos." V Encuentro de Investigadores de Ciencias Sociales de la Región Centro Oeste y II Binacional con la Región de Coquimbo, Chile. Universidad Nacional de San Juan, San Juan, Argentina, October 28, 2009.
- Bórquez R., and E. Schwartz, "El Conflicto Pascua Lama en Chile. Aprendizajes Institucionales a través del Análisis de la Resolución Adaptativa de Conflictos." IV Jornadas de Economía Ecológica. Universidad Nacional General Sarmiento, Buenos Aires, Argentina, November 27–28, 2009.
- Corkal, D., Presentation to federal departmental staff at "Meeting the Millennium Development Goals through Sustainable Agriculture." Ottawa, Canada, November 1–3, 2004.
- Corkal, D., "Agricultura y Clima en el Oeste de Canadá." Adaptación Institucional al Cambio Climático: Oportunidades y Desafíos para Chile, organized by the Comisión Nacional del Medio Ambiente, United Nations Development Programme and the Institutional Adaptations to Climate Change Project. Santiago, Chile, Mayo 29–30, 2006.
- Corkal, D., H. Diaz, and D. Gauthier, "Governance and Adaptation: the cases of Chile and Canada." PFSRB Conference: Climate Change and Water in the Prairies. Saskatchewan, Canada, June 22, 2006.
- Corkal, D.R., H. Diaz, D. Sauchyn, and D. Gauthier, "Institutional Adaptations to Climate Change: The Cases of Canada and Chile." PFRA's Technology and Innovation Symposium. Regina, Canada, February 21–22, 2007.
- Corkal, D.R., H. Diaz, D. Sauchyn, and D. Gauthier, "Water and Governance Institutions in Canada and Chile." 60th Annual Conference of the Canadian Water Resources Association. Saskatoon, Canada, June 25–28, 2007. http://www.parc.ca/mcri/policy.php
- Corkal, D.R, "Water Governance and Government Institutions in Canada's South Saskatchewan River Basin." Adaptation to Climate Change in the Canadian Plains Symposium, presented by the Saskatchewan Institute of Public Policy and the Institutional Adaptations to Climate Change Project. Regina, Canada, April 22, 2008. http://www.parc.ca/mcri/policy.php
- Corkal D., M. Hurlbert, and H. Diaz, "Governance Institutions and Community Vulnerabilities. The Emergence of Civil Society." 61st Annual Conference of the Canadian Water Resources Association. Gimli, Canada, June 17–20, 2008.
- Corkal D., M. Hurlbert, and H. Diaz, "Governance Institutions and Community Vulnerabilities to Climate Induced Water Stress. Case Studies in Canada and Chile." International Perspectives on Governance: Accomplishments, Challenges and Evolving Research Agenda Conference. University of Saskatchewan, Saskatoon, Canada, June, 2008.

- Diaz, H., D. Gauthier, and D. Sauchyn, "Stormy Weather: Climate Change and Sustainability." Coffee House Controversies, Roca Jack's. Regina, Canada, March 4, 2004.
- Diaz, H., Radio Interview, Radio Canada International. June 7, 2004.
- Diaz, H., D. Gauthier, and D. Sauchyn, "Overview of the SSHRC MCRI Project on Institutional Adaptation to Climate Change, South Saskatchewan River Basin (Canada) and ERB (Chile)." Inter-American Organization for Higher Education, Annual Conference of the Institute for University Management and Leadership (IGLU). University of Regina, Regina, Canada, October 6, 2004.
- Diaz, H., D. Gauthier, and D. Sauchyn, "Institutional Adaptations to Climate Change: Comparative Study of Dryland River Basins in Canada and Chile." CWRA-PFSRB 2004 Workshop, Climate Variability: Planning for Floods, Droughts and Change. Saskatoon, Canada, October 7–8, 2004.
- Diaz, H., "The Challenge of Climate Change. Adaptation and Mitigation Policies in Chile." Canadian Association for Latin American and Caribbean Studies. Guelph University, Guelph, Canada, October 28–31, 2004.
- Diaz, H., University of Regina Update Publication. *Leader-Post*, Regina, Canada, February 3, 2005.
- Diaz, H., and D. Gauthier, "Institutional Adaptations to Climate Change: Comparative Study of Dryland River Basins in Canada and Chile." Climate Change Adaptation and Canadian Agriculture Workshop. Edmonton, Canada, February, 2005.
- Diaz, H., D. Gauthier, and D. Sauchyn (Presenter: D. Sauchyn), "Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity." Montréal, Québec, Canada, May 4–7, 2005.
- Diaz, H., Radio Interview—CJTR Community Radio. July 11, 2005.
- Diaz, H., and A. Rojas, "Methodological Framework for the Assessment of Governance Institutions." Workshop on Institutional Adaptations to Climate Change, organized by Prairie Farm Rehabilitation Administration. Regina, Canada, March 17, 2006.
- Diaz, H., and A. Rojas, "Methodological Framework for the Assessment of Governance Institutions." Lethbridge Stakeholder Workshop on Water and Climate, organized by the Prairie Farm Rehabilitation Administration. Lethbridge, Canada, March 25, 2006.
- Diaz, H., "El Desarrollo de la Capacidad Adaptativa al Cambio Climático: el Rol de las Instituciones." Seminario-taller, Adaptación Institucional al Cambio Climático: Oportunidades y Desafíos para Chile, organized by the Comisión Nacional del Medio Ambiente, United Nations Development Programme and the Institutional Adaptations to Climate Change Project. Santiago, Chile, May 29–30, 2006.
- Diaz, H., "Climate Change and Vulnerability in Latin America." Annual Conference of the Canadian Association for Latin American and Caribbean Studies. University Of Calgary, Calgary, Canada, September 28–30, 2006.
- Diaz, H., "La Gestión Social del Agua: Dos Proyectos en Canadá y Chile." II Seminário

Internacional sobre Gestão Social de Bacias Hidrográficas. Universidade Federal de Santa Catarina, Urobici and Florianopis, Brazil, November 21–24, 2006.

- Diaz, H., “Institución y Gobernabilidad.” II Seminário Internacional sobre Gestão Social de Bacias Hidrográficas. Universidade Federal de Santa Catarina, Urobici and Florianopis, Brazil, November 21–24. 2006.
- Diaz, H, “Social Capital and Adaptation to Climate Change.” 8th Prairie Conservation and Endangered Species Conference. Regina, Canada, March 1–3, 2007.
- Diaz, H., “Governance and Adaptation to Climate Change.” Annual Meeting of the Canadian Sociology and Anthropology Association. Saskatoon, Canada, May 28–30. 2007.
- Diaz, H., and S. Prado Becerra, “Local Institutions and Adaptation to Climate-Induced Water Problems.” 60th Annual Conference of the Canadian Water Resources Association. Saskatoon, Canada, June 25–28, 2007. http://www.parc.ca/mcri/policy.php
- Diaz, H., “Adaptación, Capacidad Adaptativa, y Governanza.” Taller on Cambio Climático e Instituciones, organized by the Comisión Nacional del Medio Ambiente. Santiago, Chile, November 22–23. 2007.
- Diaz, H., “Capacidad Adaptativa y Competividad del Sector Vitivinícola Chileno antes los Nuevos Escenarios Climáticos.” Workshop for Research Development and Innovation. Chilean Embassy, Ottawa, Canada, January 14–15, 2008.
- Diaz, H., “IACC Project Overview.” Adaptation to Climate Change in the Canadian Plains Symposium, organized by the Saskatchewan Institute of Public Policy and the Institutional Adaptations to Climate Change Project. Regina, Canada, April 22, 2008. http://www.parc.ca/mcri/policy.php
- Diaz, H., “Community and Adaptive Capacity to Climate Variability in Rural Chile.” Annual Meeting of the Canadian Association for Latin American and Caribbean Studies. Vancouver, Canada, June 5–7, 2008.
- Diaz, H., “Local Institutions and Adaptation to Climate-Induced Water Problems.” 13th World Water Congress, International Water Research Association, Montpellier, France, September, 2008.
- Diaz, H., “Cambio Climático y Recursos Hídricos: Una Perspectiva desde las Ciencias Sociales.” Seminar on Water and Sustainable Development. Academia de Ciencias Sociales de Mendoza, Mendoza, Argentina, November, 2008.
- Diaz, H., M. Hurlbert, and D. Corkal, “Governance and Rural Community Vulnerability to Climate-induced Water Problems.” Presented by Martin Mujica at the International Forum on Integrated Water Management. Sherbrooke, Canada, June, 2009.
- Diaz, H., “Climate Change and Rural Vulnerabilities in Northern Chile.” Centre for Research on Latin America and the Caribbean, York University, Toronto, Canada, October 22. 2009
- Diaz, H., Radio Interview, Radio Canada International. October 22, 2009
- Diaz, H., Newspaper interview, El Diaz. October 26, 2009
- Diaz, H., “The Institutional Adaptations to Climate Change (IACC) Project.” Institu-

tional Adaptations to Climate Change Stakeholder Workshop on Water and Climate in Saskatchewan. Regina, Canada, November 26, 2009.

- Diaz, H., M. Hurlbert, J. Warren, D.R. Corkal, "Governance and Climate Vulnerabilities: The Case of Canada's Southern Saskatchewan River Basin (SSRB)." Institutional Adaptations to Climate Change Stakeholder Workshop on Water and Climate in Saskatchewan. Regina, Canada, November 26, 2009.
- Fiebig-Wittmaack, M., "Catástrofes Naturales y Vulnerabilidad en el Valle de Elqui." Cambio Climatico, Desastres y Adaptación Seminario. Santiago, Chile, December 1–2, 2004.
- Fiebig-Wittmaack, M., Interview at the TVN (Televisión Nacional de Chile) about climate change evidence in the Coquimbo Region, January, 2005.
- Fiebig-Wittmaack, M., "La Influencia del Embalse Puclaro Sobre el Clima Local." Instituto de Investigaciones Agropecuarias. La Serena, Chile, June, 2005.
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Elqui." 59º Congreso Agronómico de Chile. La Serena, Chile, October, 2008.

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- Morito, B., "Value and Ethical Analysis in Vulnerability to Climate Change: Establishing an Analytic Framework for Identifying, Classifying and Evaluating Vulnerability Issue." Environmental Studies Association, Canada, Congress of the Humanities and Social Sciences Meetings. University of Western Ontario, London, Canada, June 4, 2005.
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- Perez-Valdivia, C., and D. Sauchyn, “Trends in Groundwater Levels in the Canadian Prairies.” American Geophysical Union, Joint Assembly. Toronto, Canada, May 24–27, 2009.
- Perez-Valdivia, C., and D. Sauchyn, “Groundwater Reconstructions of Tree-rings in Southern Alberta, Canada.” AmeriDendro, First American Dendrochronology Conference. Vancouver, Canada, June 23 – 27, 2008.
- Pittman, J., “Coming to Know: My Experience with Traditional Knowledge as a wêmistikôsiw in the Land of the nêhiyawak.” University of Guelph, Guelph, Canada, March 20, 2009. Invited.
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- Rojas, A., "Water Conflicts." Stakeholder Workshop on Water and Climate, organized by Prairie Farm Rehabilitation Administration. Outlook, Canada, January 27, 2007.
- Rojas, A., B. Reyes, L. Magzul, R. Borquez, and E. Schwartz, "The Study of the Role of Institutions in the Resolution or Management of (or Failure to Resolve or Manage) Water Conflicts." 60th Annual Conference of the Canadian Water Resources Association. Saskatoon, Canada, June 25–28, 2007. http://www.parc.ca/mcri/policy.php
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- Sauchyn, D., "SSRB Chile Project." Quarterly Educational Forum, Bow River Basin Council. Calgary, Alberta, December 8, 2004.
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- Sauchyn, D., "What's With the Weather? The Controversy of Climate Change." QUEST: North Conference. Winnipeg, Canada, March 4–5, 2005.
- Sauchyn, D., "Reconstructing Alberta's climate from tree-rings for the past 500 years." Alberta Geological Survey, March 14, 2005.
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- Sauchyn, D., P. Diaz, and D. Gauthier, "A Comparative Study of Institutional Adaptive Capacity: South Saskatchewan River Basin, Canada, and Elqui River Basin, Northern Chile." Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity. Montreal, Canada, May 4–7, 2005.
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- Sauchyn, D.J., "Water, Drought and Climate Change: The Long View." International Waters Association, Watershed Conference 2005. Calgary, Canada, September 13–15, 2005. Keynote Speaker.
- Sauchyn, D.J., "What If? ... What Then? ... What Now? The Problem with Climate Change." Annual Meeting of the Canadian Association of Geographers—Prairie Division. Winnipeg, Canada, September 24–25, 2005. Keynote Speaker.
- Sauchyn, D., H. Diaz, J. Cepeda, and M. Fiebig-Wittmaack, "Comparing Human-Climate Interactions between Dryland River Basins in Western Canada and Northern Chile." 2nd Southern Deserts Conference, Human-Environment Interactions in Southern Hemisphere Deserts: Past, Present and Future. Arica, Chile, October 10–14, 2005.
- Sauchyn, D., Contributed to "Fire and Ice" (Extreme Weather documentary), CBC Newsworld, broadcast several times during October, 2005.
- Sauchyn, D., Commentary on climate change impacts on water supplies, CBC Radio International, November 18, 2005.
- Sauchyn, D., The Big Thirst, The National, CBC News Documentary. 2006.
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- Sauchyn, D., "Adapting to the Impacts of Climate Change." Emerging Challenges to Sustainable Water Policy in Canada. Lethbridge, Canada, March 15–16, 2006.
- Sauchyn, D.J., "Climate Change Patterns that Affected and are Affecting the Prairie." Climate Change and Water Management: Science, Impacts, and Adaptation. Edmonton, Canada, April 2–5, 2006. Invited.
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- Sauchyn, D., A. Pietroniro, and M. Demuth, "Upland Watershed Management

Mountains and Western Plains." 5th Biennial Rosenberg International Forum on Water Policy. Banff, Canada, September 6-11, 2006.

- Sauchyn, D.J., "Impacts of Climate Change on Prairie Water Resources." Canadian Water Network National Conference, Connecting Water Resources: Leadership at all Levels. Montreal, Canada, November 20–23, 2006. Invited.
- Sauchyn, D., "Bill C-288 (An Act to Ensure Canada Meets its Global Climate Change Obligations under the Kyoto Protocol)." The House of Commons, Standing Committee on Environment and Sustainable Development. November 21, 2006.
- Sauchyn, D., and S. Lapp, "Water and Climate Scenarios for Alberta's South Saskatchewan River Basin." Institutional Adaptations to Climate Change Project Stakeholder Workshop on Water and Climate. Lethbridge, Canada, December 1, 2006.
- Sauchyn, D., Climate Change: An Uncertain Future, The Nature of Things. 2007.
- Sauchyn, D., Golden West Radio High River Alberta. January 17, 2007.
- Sauchyn, D., "Holding the Reins." Oldman Watershed Council Landowners Summit. Fort Macleod, Canada, January 23, 2007.
- Sauchyn, D., Maclean's magazine. January 23, 2007.
- Sauchyn, D., Wild Rose Country, Alberta CBC Radio. February 2, 2007.
- Sauchyn, D., "Future Climate Conditions in the Prairies." Institutional Adaptations to Climate Change Workshop, Water Management in Alberta's Special Area 2. Hanna, Canada, February 26, 2007.
- Sauchyn, D., "Climate Change and Water: Future Water Scarcity." Alberta Environmentally Sustainable Agriculture Conference. Leduc, Canada. February 27–28, 2007.
- Sauchyn, D., "Climate Change, What is in the Future for Southern Alberta? Getting Started on Adaptation." EVERY DROP COUNTS: Watershed Management Realities, Alberta Irrigation Projects Association Conference. Calgary, Canada, March 4–6, 2007.
- Sauchyn, D., "Energía y Cambio Climático." Cámara de Construcción. La Serena, Chile, April 25, 2007.
- Sauchyn, D., Radio 'W,' La Serena, Chile. April 25, 2007.
- Sauchyn, D., Diario el Día, La Serena, Chile. April 25, 2007.
- Sauchyn, D., "Climate Change—Global, Regional and Local Issues." Communicating Climate Change, Mountain Parks Heritage Interpretation Association. Banff, Canada, May 6, 2007.
- Sauchyn, D., "Climate Change Impacts and Adaptation in Saskatchewan." Premier's Forum on Climate Change. Regina, Canada, June 1, 2007.
- Sauchyn, D., *Western Producer*. June 1, 2007.
- Sauchyn, D., "Prairie Water and Climate Change." National Council of Women of Canada, Annual General meeting. Regina, Canada, June 2, 2007.
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- Sauchyn, D., and S. Lapp, "Expected Impacts of Climate Change in the Cabri Area." Institutional Adaptations to Climate Change Project Stakeholder Workshop. Cabri, Canada, December 7, 2007.
- Sauchyn, D., "Bill C-288." Expert Witness, House of Commons Standing Committee on Environment and Sustainable Development. January 30, 2008. Invited.
- Sauchyn, D., "Climate Change and Challenges." The Fourth Annual Banff Conference on Agriculture, Food and the Environment. Banff, Canada, March 5–6, 2008.
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- Sauchyn, D., *Globe and Mail*, Liquid Asset. March 28, 2008.
- Sauchyn, D., "National and Regional Adaptation Projects: Implications for Alberta" Board of Directors, Climate Change Central. Calgary, Canada, March 28, 2008.
- Sauchyn, D., "Recognizing Climate Variability and Uncertainty for Western Water Management." National Adaptation Summit. Toronto, Canada, March 31, 2008.
- Sauchyn, D., Canadian Farm Business Management Council web site, Successful Adaptation Key to Mitigating Impacts of Climate Change; farmcenter.com; May, 2008.
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- Sauchyn, D.J., and S. Kulthrestha, "Climate Change Impacts and Adaptation in the Canadian Prairies." Canadian Association of Geographers Annual Meeting. Quebec City, Canada, May 21–25, 2008. Invited.
- Sauchyn, D., "Adaptation to Climate Change and Variability: Canada's Western Interior." Pacific Northwest Economic Region Conference. Vancouver, Canada, July 22, 2008.
- Sauchyn, D., "Climate Change Overview." IEA Greenhouse Gas Carbon Capture and Storage Summer School 2008. Parksville, Canada, August 24–29, 2008.
- Sauchyn, D., "Water Scarcity in Alberta – A Case for Leadership in Water Protection." Alberta Lake Management Society Conference. Sherwood Park, Canada, September 19, 2008.
- Sauchyn, D., and S. Lapp, "Future Climate Conditions in the SSRB and Relevance to the Blood Tribe." Chief and Council, Kanai Blood Indian Tribe. Standoff, Canada, October 21, 2008.
- Sauchyn, D., "What Is Climate Change and What Can You Do About It." Kanai Blood Indian Reserve, Grade School. Alberta, Canada, October 22, 2008.

- Sauchyn, D.J., “Climate Change Impacts on Western Watersheds.” North American Lake Management Society 2008 International Symposium. Lake Louise, Canada, November 11–14, 2008. Invited.
- Sauchyn, D., “What Is Climate Change and What Can You Do About It.” Kanai Blood Indian Reserve, Middle School. Alberta, Canada, November 17, 2008.
- Sauchyn, D., “Adapting to A Changing Climate: Past, Recent, Future Hydroclimatic Variability of the North Saskatchewan River.” EPCOR Lunch Talks Series. Edmonton, Canada, December 11, 2008.
- Sauchyn, D., “Climate Change in the Prairies: An Assessment of Impacts and Adaptation.” Shaping the Basin’s Future Together, The Red River Basin Commission. Winnipeg, Canada, January 20–22, 2009.
- Sauchyn, D., J. Axelson, S. Lapp, C. Perez-Valdivia, J-M. St. Jacques, and J. Vanstone, “Prairie Hydroclimate Time Series: Trends and Variability.” Drought Research Initiative Workshop. Regina, Canada, February 26–27, 2009.
- Sauchyn, D., “Climate Change Impacts and Adaptation in Saskatchewan.” Prairie Adaptation Research Collaborative and Johnson-Shoyama Joint Public Presentation. Regina, Canada, March 5, 2009.
- Sauchyn, D., “Implementing Programs within a Climate Change World.” Alberta Chapter, Wildlife Society. Edmonton, Canada, March 6, 2009.
- Sauchyn, D., “Future Scenarios of Climate Change: The Challenges We Face.” Public Seminar. La Serena, Chile, April 22, 2009.
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- Sauchyn, D., The Afternoon Edition, CFRA Radio, Ottawa. July 2, 2009.
- Sauchyn, D., The Link, Radio Canada International. July 2, 2009.
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- Sauchyn, D., The Current, CBC Radio One. July 6, 2009.
- Sauchyn, D., “Responding to Climate Change: Keeping the Marble in the Bowl.” A breakfast briefing for MPs, House of Commons. Ottawa, Canada, September 29, 2009.
- Sauchyn, D., “Introduction to Climate Change.” Institutional Adaptation to Climate Change Project: Stakeholders Discussion and Analysis. Universidad de La Serena, Chile, October 26–27, 2009.
- Sauchyn, D., “Modelamiento Climático y los Escenarios Futuros en la Cuenca del Rio Saskatchewan.” Adaptación Institucional al Cambio Climático: Aprendizajes Institucionales en las Cuencas del Río Elqui y South Saskatchewan. Santiago, Chile, October 29, 2009.
- Sauchyn, D., C. Perez-Valdivia, S. Lapp, E. Wheaton, and V. Wittrock, “Future Climate Conditions in the South Saskatchewan River Basin.” Institutional Adaptations to Climate Change Stakeholder Workshop on Water and Climate in Saskatchewan. Regina, Canada, November 26, 2009.
- Schwartz, E., “Adaptación a Nuevos Escenarios de Escasez de Agua. Embalse Puclaro como Respuesta Institucional.”

Primer Congreso Internacional de Medio Ambiente. Universidad de Cuenca, Ecuador, November 27, 2009.

- Smit, B., "Climate Change Impacts, Vulnerabilities, Adaptations Assessment for Decision-Making." Ouranos–Consortium sur les changements climatique. Montreal, Canada, January 19, 2004.
- Smit, B., "Climate Change and Adaptation." University of Waterloo, Waterloo, Canada, February 23, 2004.
- Smit, B., "Climate Change: So What for Agriculture? The Role of Adaptation." Canadian Federation of Agriculture. Ottawa, Canada, February 24, 2004.
- Smit, B., "Climate Change Adaptation: A Producer Perspective." C-CIARN Agriculture Workshop. Gatineau, Canada, February 25, 2004.
- Smit, B., "Risks and Opportunities for Canadian Agriculture: Approaches and Applications." Climate Change: Its influence on the Canadian Economy. Environment Canada and Natural Resources Canada, Ottawa, Canada, February 26–27, 2004.
- Smit, B., "Science and Practice of Vulnerability and Adaptation to Climate Change and Mainstreaming." C-CIARN Training and Information Session. Vancouver, Canada, March 8, 2004.
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