Agricultural Adaptation to Drought (ADA) in Canada:

The Case of 2001 to 2002

By E. Wheaton, G. Koshida, B. Bonsal, T. Johnston, W. Richards, V. Wittrock

May 2007

Prepared for Government of Canada's
Climate Change Impacts and Adaptation Program

Canada

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SYNTHESIS REPORT

Agricultural Adaptation to Drought (ADA) in Canada: the Case of 2001 to 2002

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Cattle grazing on native rangeland in southwest Saskatchewan. May 30, 2006 (B. Godwin, Saskatchewan Research Council).

Centre pivot irrigation system and blowing dust near Carberry, Manitoba. May 17, 2007 (A. Nadler, Manitoba Agriculture, Food and Rural Initiatives).

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HIGHLIGHTS

The drought of 2001 to 2002 (nick-named Ada) can be considered one of the worst natural disasters in Canada. Consequently, the Ada drought offers a unique and timely opportunity for the purpose of this project which is to improve our understanding of current adaptation processes and options in Canadian agriculture, especially with regard to drought. The study area is the agricultural region of Canada. We use the record to near-record drought of 2001 to 2002 as the basis for improving the understanding of adaptation. We also use that drought as a harbinger of possible future climate change stresses.

This paper summarizes the Agricultural Drought Adaptation (ADA) project, which is the first work to comprehensively assess the severity, area, and duration of past droughts across Canada. It is also the first work to estimate the characteristics of future droughts across the entire country. It is also the first to extensively document and categorize current adaptations and the dynamics of adaptation to drought across Canada. The work is designed to provide many benefits, such as improved information to characterize the nature of droughts, as an aid in the development of actions to reduce vulnerability to droughts, and building more effective adaptation. Highlights include:

- Two types of drought assessment demonstrated that the 2001 to 2002 drought was the **most severe drought for several decades** in southern Canada. However, the spatial extent and severity of droughts during much earlier droughts, that is, those of the 1920s and 1930s, were found to be more extreme. However, at several individual stations, Ada was the worst drought during the period, 1915 to 2002. The majority of these stations were in the Prairie Provinces.

- Ada was also a rare **cross-Canada extreme drought**. An important difference for 2001 when compared with the other severe drought years is that interior British Columbia, the Prairie Provinces, southern Ontario, Quebec and Atlantic Canada all experienced dry conditions simultaneously. In the 105 years analyzed, only the summer of 1914 had coincident droughts of the same magnitude in all areas as did 2001. Furthermore, areas less accustomed to droughts were also affected including the northern agricultural Prairies and Atlantic Canada. Impacts were greater since these recent droughts followed a relatively wet period in the 1990s, thus making the contrast more noticeable. Both these factors of large area coverage and lack of recent experience with drought combined to make adaptation more difficult.

- **Future droughts** were projected to dramatically increase in both spatial extent and severity, if the effect of temperature is considered. Climate change scenarios indicate that the worst droughts on record, including the Ada drought, may be frequently exceeded in the future.

- Drought adaptation dynamics were found to have distinctive time and space patterns. In eastern Canada, the six most **frequently mentioned adaptation options** identified as being used during the Ada drought were: irrigation, crop insurance, water conservation and management, Ontario Low Water Response (OLWR)/Water Response Teams

(WRT), the Net Income Stabilization Account (NISA) and the Canadian Farm Income Program (CFIP). Many other adaptation options were mentioned, including types in the categories of government assistance, finance, research, health, as well as soils, crops, livestock, and pest management. A lack of awareness of programs to decrease vulnerability was indicated and stresses the need to increase awareness.

- In the Prairie Provinces, the **most frequently mentioned adaptation options** were those for crops and livestock, followed by water and economics. The topics of "community support and technology" were second lowest and lowest in frequency. This pattern indicates the areas of the greatest and least adaptation emphasis. The most frequently mentioned topics are not surprises, but it does appear that community support and technology may have much less emphasis than expected. This means that such coping measures may be under-utilized and could address some of the adaptation deficit, or the negative impacts that remain after adaptations are applied. Several negative drought impacts occurred, even with the application of adaptation.

- The total number of articles during 1999 to 2006 for the Prairie Provinces was highest in **August 2002**, reflecting a **peak of concern and effort** regarding the drought and actions to manage impacts. The number of articles increased quickly to this maximum, but the number declined much more slowly after 2002, indicating a sensitivity to the need for continued adaptation. The lowest numbers were for 1999 and 2006, the tail ends of the period. This frequency pattern was consistent when examined for each Prairie Province, except that the numbers did not decrease as rapidly after 2002 for Saskatchewan as compared with the other provinces. A monthly analysis of the numbers of articles shows that spring and late summer to early fall are peak times of adaptation concerns. This pattern likely corresponds to seeding and harvesting times for crops, for example. Adapting to drought was mentioned more frequently for Alberta and Saskatchewan, and least often for Manitoba, likely because impacts were generally less severe and more regional in Manitoba.

- In Eastern Canada, the total number of drought articles peaked dramatically in **August 2001**, a year earlier than for the Prairie Provinces. In Atlantic Canada, most citations of drought adaptations occurred in 2001, and decreased sharply in 2002. In Ontario, the number of articles detailing drought adaptation options was similar for 2001 and 2002.

- Adaptation is most effective if it is implemented properly, facilitated and has few barriers. **Barriers to adaptation** (to drought) in Canada were documented, including lack of knowledge of water supplies and water use. Barriers to dealing with droughts documented for the Prairie Provinces included lack of funds, lack of research, and difficulty in making changes. Provincial and national drought and integrated water management planning could be useful vehicles for reducing vulnerability to water scarcity. In Eastern Canada, different levels of local leadership and capacity, lack of funds to expand water infrastructure, and lengthy bureaucratic processes to obtain water permits were identified most frequently as barriers to implementing adaptations to lessen vulnerability to drought.

- Even if adaptation is applied, it may not be effective. **Effectiveness of adaptation** is difficult to measure so we described effectiveness using criteria including residual negative impacts, positive impacts, opportunities and barriers, mal-adaptations, efficiencies and innovations. Aspects of effectiveness were described using a literature review and examples from the media survey. For example, innovations were discussed and examples provided in the areas of research regarding drought causes, monitoring of drought, community support, communication, diversification, and livestock management. We concluded with a listing of the stages of an effective process of adaptation.

- **Recommended adaptation options** were compared with the **actual** options. Many actual adaptations were recommended and implemented, but the opposite also was found. Innovative options were considered to include those that were used, but did not appear as recommendations in the survey. For example, innovative water sharing arrangements were made and carried out, and farming equipment was modified to suit the shorter and sparser crops. This comparison is another indicator of the potential for improvement of the actual adaptation processes.

In conclusion, much new and extremely useful information was documented. An improved understanding of both past and future possible droughts was gained. Many characteristics of adaptation and the processes of adaptation were determined, including most frequently used options, their effectiveness, and space and time characteristics of the adaptation processes. Canada has relatively abundant water, food, trained people, money, technology, and other resources to lessen its vulnerability to climate change, including extremes. Despite this capacity, the recent drought of 2001 and 2002 had severe and extensive negative impacts that should lead us to reconsider our understanding of droughts and adaptive capacity to deal with climate extremes, especially severe, multi-year droughts. Findings of this study indicate not only that most regions of Canada experienced the Ada drought, but coping ranges appear to have been exceeded in several cases. A threshold of adaptive capacity appears to have been reached for this type of drought and this capacity has considerable room for improvement. This means that much more attention needs to be paid to adaptation research, planning, capacity building and implementation processes.

Drought Naming Tradition Begins

We wish to begin the tradition of naming major droughts. Large and intense droughts may be the most costly natural hazards in the world. Considering hurricanes are immortalized by the tradition of naming, droughts should also be named. A US drought expert, Dr. Don Wilhite, often mentions that droughts need more respect. One way to gain respect for droughts, and to give them more recognition is to name major droughts. We call the 2001 and 2002 drought "Ada" in recognition of the acronym for this project, Agricultural Drought Adaptations (ADA). Also it uses the first letter of the alphabet for the first major drought in the 21st century.

Deliverables

Main deliverables consist of this synthesis report, 14 supporting technical reports, journal articles, a brochure, website, two sets of project workshop presentations, newsletter articles, an on-line survey instrument, and conference papers, poster and presentations. The project supported six Principal Investigators and 12 Co-investigators. A listing of deliverables organized in categories is in Appendix A.

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1. INTRODUCTION AND OBJECTIVES

The record to near record drought of 2001 to 2002 (nick-named "Ada") was devastating for many people and sectors, and posed considerable adaptation challenges. This drought was likely one of Canada's worst natural disasters. The first drought assessment of a national scale in Canada (Wheaton, Kulshreshtha and Wittrock 2005) addressed the possible drought causes, climatology and biophysical and economic impacts of the 2001 to 2002 drought in Canada. However, we only began to explore adaptation, including options, processes and vulnerability. Understanding of current adaptation and vulnerability to climate is a large research gap. This Agricultural Drought Adaptation (ADA) work advanced that understanding, especially with respect to an important hazard, drought.

This paper summarizes the ADA project detailed in the numerous technical reports and other deliverables listed in Appendix A. Note that the 2001 to 2002 drought is given a name, "Ada", as discussed earlier, to give the event more respect and make it more memorable. It uses the first letter of the alphabet for the first major drought in the 21st century, and is also named after the acronym of this project ADA, in recognition of that work.

Climate change impact and adaptation work appears to assume limited or no adaptation to unlimited or perfect adaptation. Actual adaptation would usually fall between these two extremes. Research regarding current adaptation processes is scarce and is recommended (e.g. Smit and Skinner 2002, Johnston and Chiotti 2000). Burton and Lim (2005) suggest that actual adaptation measures in place and vulnerability should be assessed at the local and community level. Attaining knowledge of these adaptations is a necessary step to determine the capacity to adapt, which is a factor in the level of vulnerability. A realistic assessment of climate impacts, such as those caused by drought, depends on a good knowledge of adaptation, including the process and the implementation. This work is a contribution to the knowledge of current adaptation at the local, regional, and national scales. The impacts of drought are serious and recurring problems, and adaptation is necessary.

Canada has relatively abundant water, food, trained people, money, technology, and other resources to lessen its vulnerability to climate change, including extremes. Despite this capacity, however, the recent Ada drought should lead us to reconsider our understanding of adaptive capacity to climate extremes, especially severe, multi-year droughts. Most regions of Canada have experienced drought, but impacts from this drought appeared to have exceeded coping capacities because of the severe impacts that were not dealt with. The drought brought devastating impacts to many sectors of the economy (especially in Alberta and Saskatchewan), posed considerable adaptation challenges, and made history. This rare coast-to-coast drought struck areas less accustomed to droughts, and in some regions, brought drought intensities not recorded for at least a hundred years (Wheaton, Kulshreshtha and Wittrock 2005).

The purpose of this project is to improve our understanding of current adaptation processes and options in Canadian agriculture, particularly with regard to drought. The study area is the agricultural region of Canada. We use the record to near-record drought of 2001 to 2002 as the basis for improving the understanding of adaptation. We also use that drought as a harbinger of possible future climate change stresses. Climate change is expected to bring more intense and more frequent droughts and floods. The 2001 to 2002 drought is a valuable indicator of the coping ranges of key sectors such as agriculture and water management.

The project was designed to provide an estimate of current adaptive capacity and processes, and to help decrease vulnerability to future droughts. The project objectives are linked with regional to national approaches and include (Wheaton et al. 2004):

- Comparing the 2001 to 2002 drought with those in the instrumental past and those expected in the future to indicate possible differences for future impacts and adaptations
- Increasing the understanding of the adaptation process for drought in Canada
- Determining the effectiveness of current adaptation options in reducing the vulnerability of agriculture to the 2001 to 2002 drought
- Using regional studies set in southern Alberta and western Saskatchewan and southern Ontario, Nova Scotia and Prince Edward Island to enhance the understanding of the vulnerability of agriculture producers to drought

The project has five main components, corresponding to the five main objectives. The first section briefly describes some of the characteristics of the Ada drought in Canada, followed by summaries from the Prairie Provinces' and eastern Canada studies. Conclusions and recommendations follow. Data and methods are referred to within each of the sections.

2. DROUGHT CHARACTERISTICS

By several standards, 2001 and 2002 can be considered drought years over much of Canada, and in particular, the Canadian Prairie Provinces. Intense dry conditions encompassed most of southern Canada, extending from British Columbia, through the Prairies, into the Great Lakes-St. Lawrence region, and even into the Atlantic Provinces. Over the west-central Prairie Provinces, well below normal precipitation was recorded for a remarkable eight consecutive seasons from autumn 2000 through summer 2002. Although numerous droughts have occurred over various regions of Canada during the 20th century, identification and subsequent comparison of country-wide drought occurrences to those of 2001 to 2002 have not been undertaken. Main objectives of the work by Bonsal and Regier (2006, 2007) and Richards and Burridge (2006) were to conduct a national-scale climatological assessment of the duration, spatial extent and severity of the Ada drought and to compare the drought with other Canadian droughts during the instrumental period of record. More detailed regional assessments were also completed.

Richards and Burridge (2006) used the Standardized Precipitation Index (SPI) to study the Ada drought using a gridded precipitation data set for the agricultural area of Canada. The SPI is becoming a more commonly used meteorological drought index. The seasons considered were June to August (August SPI-03) and March to August (August SPI-06). The 1900 to 2004 period was studied, however, the focus of the analysis was 1950 to 2004. For the agricultural regions of Canada, the SPI-03 indicates that the 2001 and 2002 drought years were the 6th and 8th worst, respectively. The top three worst drought years were early in the record: 1967, 1961 and 1958. For the longer period of SPI-06, the 2001 and 2002 drought years ranked 4th and 13th worst, respectively. The top three droughts for this 6-month period also occurred relatively long ago: 1961, 1958 and 1967. The predominance of a large area of drought in the western agricultural area with the opposite in eastern Canada (or vice versa) is a common climatologic pattern. However, an important difference for 2001 compared with the other severe droughts is that the Prairies, southern Ontario, Quebec and Atlantic Canada all experienced dry conditions simultaneously. For example, in the 105 years analyzed, only the summer of 1914 had

coincident droughts of the same magnitude in all areas as did 2001. The authors also note that these recent droughts followed a relatively wet period thus making the contrast more noticeable.

Bonsal and Regier (2006) used the adjusted historical Canadian climate data set to grid SPI and Palmer Drought Severity Index (PDSI) values for southern Canada. The PDSI, which uses a water balance approach, is also a commonly used drought index, especially for agriculture, hydrology, and other activities sensitive to soil moisture. The authors compared the spatial extent (percent of grids in categories of drought for the summer season, one, two and five year periods) and severity (average PDSI and SPI values for all grids) of the 2001 and 2002 drought years to those that occurred during the entire 1915 to 2002 period. For southern Canada, the severe SPI rankings showed that 2001 and 2002 were the 13th and the 23rd worst drought years on record (for the severe category). The most severe drought years occurred very early in the record: 1929, 1923, and 1924. The PDSI rankings showed 2001 and 2002 to be the 34th and the 11th worst drought years for southern Canada (for the severe category). The worst drought years nationally using the PDSI severe drought category were once again early in the record: 1924, 1923, and 1930. The worst southern Prairie drought years were in 1929, 1919, and 1961. The 2001 and 2002 drought years ranked 6th and 10th worst, respectively. Therefore, the spatial extent and severity of the Ada drought generally ranked well below the early century droughts particularly, over all of southern Canada. However, Ada ranked as one of the top ten worst droughts over the Canadian Prairies. Furthermore, over both southern Canada and the Prairies, the 2001 to 2002 drought tended to be the worst drought on record since the 1930s (Figure 1).

The analyses of historical droughts by Richards and Burridge (2006) and Bonsal and Regier (2006) used different approaches. However, both studies showed that although the Ada drought and drought years were among the worst on record, they were not the most severe in terms of some comparisons. However, the 2001 to 2002 drought was the most severe for several decades, showed unusual spatial coverage from west to east and occurred over consecutive years. Note that for several locations, however, the 2001 and 2002 drought years did rank as the worst or near worst during1915-2002. For example, the one year SPI for 2001 was lowest on record for Prince Albert and Saskatoon, Saskatchewan and second lowest for Edmonton and Lacombe, Alberta (Bonsal and Regier 2006). This confirms the findings of Wheaton et al., (2005), Sauchyn et al. (2003) and AAFC-PFRA (2003) who found that for several climate stations in the prairies, the severity of the 2001 and/or 2002 drought years were unprecedented in the instrumental record from decades to about a century.

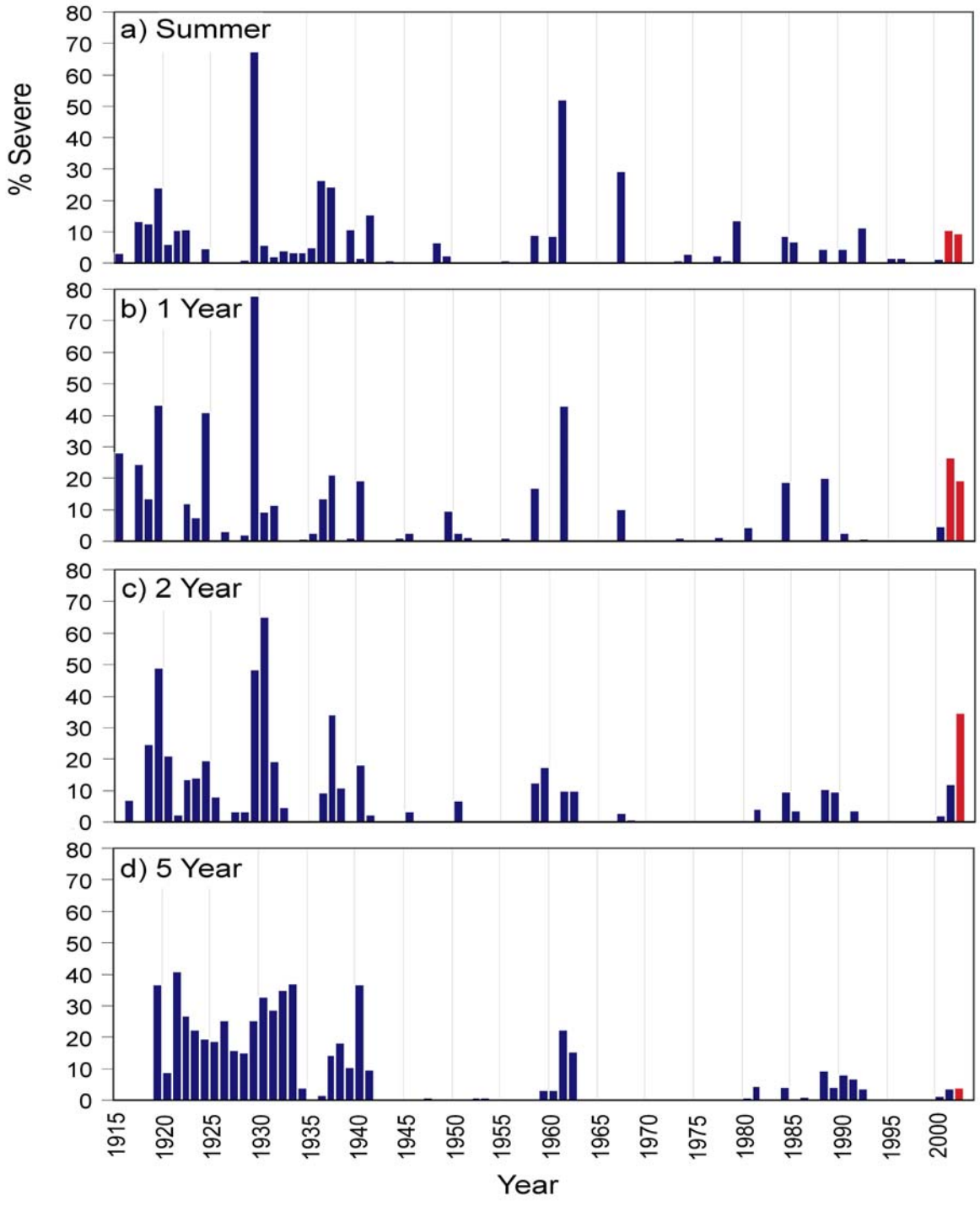

Figure 1 Percentage of grids over the southern Canadian Prairies in severe drought based on values of the SPI (i.e., SPI ≤ -1.5) during the period 1915 to 2002 for a) summer, b) one-year, c) two-year, and d) five-year time intervals. Values associated with the 2001 and 2002 drought are denoted in red (Bonsal and Regier, 2006)

All Global Climate Models (GCMs) are projecting future increases of summer continental interior drying and associated risk of droughts. The increased risk is ascribed to a combination of increased temperature and potential evapotranspiration not being balanced by precipitation (Watson et al., 2001). In fact, the recently released Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) has stated that future increases in the area affected by drought are likely (i.e., 66% probability of occurrence) (IPCC 2007). However, considerable uncertainty exists with respect to future precipitation, particularly on a regional and intra-seasonal basis. Because of this increasing risk, another objective of the work by Bonsal and Regier (2006) was to place the Ada Canadian drought, as well as, other identified severe droughts during the instrumental period into the context of potential future drought occurrence.

Incorporation of GCM-projected temperature and precipitation changes for several climate scenarios showed that on average, the spatial extent and severity of future droughts based on the SPI are not significantly altered over southern Canada or the Prairies. The worst droughts during the instrumental record are rarely exceeded, however, the spatial extent and severity of the 2001 to 2002 drought is projected to be surpassed on numerous occasions. The PDSI findings are substantially different with future droughts projected to dramatically increase in both spatial extent and severity. In addition, the worst droughts on record and the drought of 2001 to 2002 will be frequently exceeded. Results from this study can be considered as an initial step toward the better understanding of both past and future drought occurrence over southern Canada and the Prairies.

3. DROUGHT ADAPTATIONS: PRAIRIE PROVINCES

Wittrock and Wheaton (2007) completed the Prairie Provinces component of the ADA project, and Johnston (2007) led the regional study in Alberta and Saskatchewan. Both studies emphasized producer-level adaptation for consistency, and because producers experience most of the impacts and strive to deal with the impacts.

The regional study led by Johnston (2007) was based on farm-level information collected via a questionnaire survey and a series of case study interviews. The study sets out to document the extent to which recent droughts caused producers to adopt a range of measures called drought-proofing strategies. “Drought-proofing” strategies are measures which have been developed and promoted by various agencies and organizations as means of reducing a production unit’s degree of exposure to drought and hence reduce the various risks associated with drought. The research also attempts to explain, in a theoretically-informed way, the pattern of adoption of drought-proofing measures. Preliminary assessment of the information gathered suggests that the adoption of drought-proofing measures is seen by relatively few producers as a priority. This preliminary finding is consistent with the literature on natural hazards which tells us that an individual’s perception of the risk associated with natural hazards declines with time. Consequently, the more time that elapses since the last drought, the less likely it is that producers will adopt measures to reduce exposure to the negative consequences of drought.

Recognizing that these observations are extremely preliminary and based on a small but growing number of responses, it does seem reasonable to suggest that government agencies, researchers and producer organizations all have roles to play now vis-à-vis enhancing drought preparedness. Rather than waiting for the next drought – and it will come, it is just a question of when – and

then responding with ad-hoc programs such as compensation packages, resources should be allocated now to enhance drought preparedness at the production-unit level by helping producers to better understand the nature and risk of drought and to facilitate the adoption of various drought-proofing measures (Johnston, 2007).

The two main objectives of the Wittrock and Wheaton (2007) project were: 1) to increase the understanding of the adaptation process for the 2001 and 2002 drought years, and 2) to explore the effectiveness of adaptation in reducing the vulnerability of agriculture to the 2001 to 2002 drought. The methods included literature reviews, searches of media (e.g. newspapers and newsletters), research framework development, and application of criteria to improve understanding of adaptation effectiveness. We emphasize adaptation at the producer level, as they experience most of the impacts and work to adapt. A chronological description of adaptation strategies and processes was developed. Examples of short term (i.e., during the current crop year) and longer term (more than the crop year) adaptations were presented by topic area.

The framework used to organize the media survey results for the Prairie Provinces has two main parts. The main topics are "crops, livestock and water." These were selected as they are commonly mentioned topic areas in the media and help address the question: what sectors require adaptation and/or are adapting? Each of main topics has sub-topics including: technological developments, government and community programs, farm production practices and farm financial management. These topics address the "how" of the adaptation process. The media survey was demonstrated to be an effective method to examine several characteristics of the adaptation process over several years and several provinces.

The media survey of 1999 to 2006 for the Prairie Provinces resulted in the development of a database of about 853 articles regarding adaptation to drought. A few examples are shown in Figure 2. The total number of articles was highest in August 2002, reflecting a peak of concern regarding the drought and actions to manage impacts (Figure 3). The number of articles increased quickly to this maximum, but the number declined much more slowly after 2002 indicating a continued sensitivity to the need for continued adaptation. The lowest numbers were for 1999 and 2006, the tail ends of the period. This frequency pattern was consistent when examined for each Prairie Province, except that the numbers did not decrease as rapidly after 2002 for Saskatchewan as compared with the other provinces. A monthly analysis of the numbers of articles shows that spring and late summer to early fall are peak times of adaptation concerns. This pattern likely corresponds to seeding and harvesting times for crops, for example. Adapting to drought was mentioned more frequently mentioned for Alberta and Saskatchewan, and least often for Manitoba, likely because impacts were generally less severe and more regional in Manitoba.

Figure 2 **A Collage of Media Articles regarding Adaptation to Drought** (Photo Source: Erin Stratton)

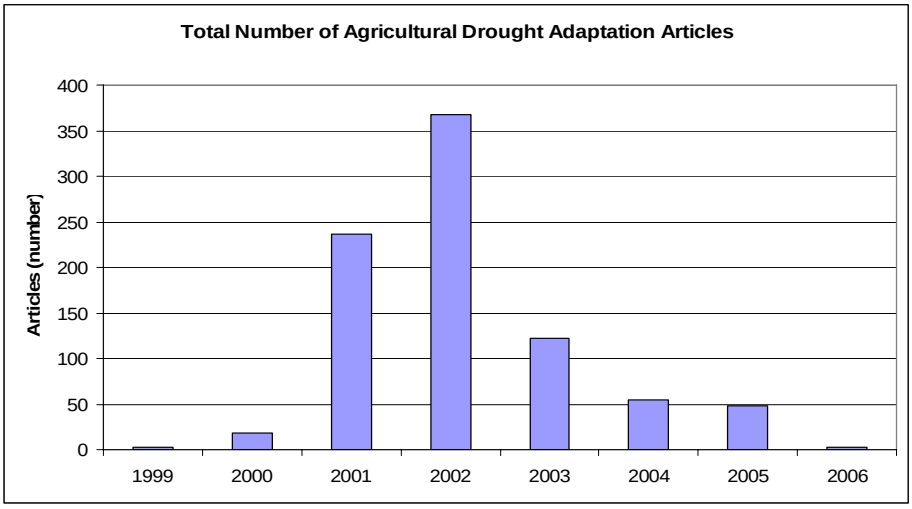

Figure 3 Annual Number of Agricultural Drought Adaptation Media Articles (Prairie Provinces, 1999-2006)

Drought adaptation topics found using the print media survey have distinctive time and space patterns. In the Prairies, the topics with the greatest number of articles were "crops", followed closely by "livestock" (Figure 4). The next most frequently mentioned topics were "water" and "economics" with similar totals. The topics of "community support and technology" were second lowest and lowest in frequency. This pattern indicates the areas of the greatest and least adaptation emphasis. This pattern may also reflect the strengths and weaknesses of adaptation options and processes. The most frequently mentioned topics are not surprises, but it does appear that community support and technology may have much less emphasis than expected. This means that such coping measures may be under-utilized and could address some of the adaptation deficit, or the negative impacts that remain after adaptations are applied.

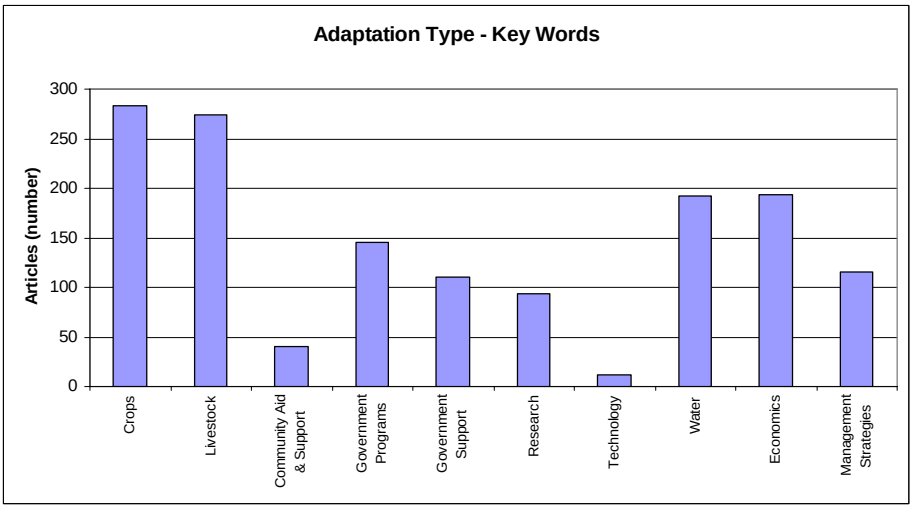

Figure 4 Frequency of Media Articles for Selected Drought Adaptation Topics (Prairie Provinces, 1999-2006)

The pattern of adaptation dynamics for topic area changed somewhat within each year and for each province. For example, 2001 showed a larger emphasis on water, followed by livestock and crops for all three Prairie Provinces, while in 2002, livestock, then crops and economics were the "top" adaptation options. On a provincial basis, the media survey results show that livestock, then crop and water management strategies were most frequent topics for Alberta. Alternatively, the topics of crops, then livestock and economics were the top concerns for Saskatchewan and Manitoba.

Adaptation is most effective if it is implemented properly, facilitated and has few barriers. Barriers to adaptation were documented, including lack of funds and research, and difficulty in making changes. Provincial and national drought and integrated water management planning could be useful vehicles for reducing vulnerability to water scarcity. Even if adaptation is applied, it may not be effective. Effectiveness of adaptation is difficult to measure so we described effectiveness using criteria including residual negative impacts, positive impacts, opportunities and barriers, mal-adaptations, efficiencies and innovations. Aspects of effectiveness were investigated using a literature review and examples from the media survey. For example, innovations were discussed and examples provided in the areas of research regarding drought causes, monitoring of drought, community support, communication, diversification, and livestock management. We concluded with a listing of the stages of an effective process of adaptation.

Recommended adaptation options were also compared with action options. Many adaptations were recommended and implemented, but some of the recommended measures were not used. Innovative options were considered to include those that were used, but did not appear as recommendations in the survey. For example, innovative water sharing arrangements were made and carried out, and farming equipment was modified to suit the shorter and sparser crops. Options that were recommended and not used could indicate a weakness in the process. For example, conservation tillage was recommended in order to reduce soil erosion, but more land was left fallow in 2001 to reduce input costs.

4. DROUGHT ADAPTATIONS: EASTERN CANADA

The Eastern Canada part of the ADA project comprised several distinct components and project objectives. The main purpose of the work done by Khairkhahi (2006 a,b), Sweiger and Stranberg (2006), and Truong (2006a,b,c,d,e) was to determine the impacts of the 2001 to 2002 multi-year severe droughts on producer operations (e.g., field, fruit, horticultural crops), livestock and water resources.

To assess the drought impacts on crop yield and livestock, historical fruit, field, horticultural crop data and livestock, data were obtained and analyzed at different spatial scales (i.e, provincial level, Census Agricultural Region (CARs), and Census Division). The availability of long-term historic data varied by crop and by province. Several indices and methods were used to identify variations in crop yield and livestock numbers during the 2001 and 2002 droughts.

Each province has its own unique supply of water resources (i.e., some combination of groundwater, rivers and streams, and lakes and reservoirs). Historical data were obtained from Environment Canada and provincial ministries to conduct a descriptive analysis of water supply

trends, with a focus on conditions in 2001 and 2002. For Ontario, the water impact analysis was augmented with a chronology of adaptations used by Conservation Authorities (CAs) and the implementation of the Ontario Low Water Response Program during the drought conditions in 2001 and 2002.

Another major component of the Eastern Canada work was conducted by Stranberg (2005a,b). One of the overall ADA project objectives was to increase the understanding of the adaptation process for the 2001 and 2002 drought years in Canada, including spatial and temporal characteristics and types of options used. A unique method used in the ADA project was to conduct detailed print media surveys of newspapers, producer newsletters and web sites. The collection and analyses of this information allowed us to identify adaptation options that were actually used during the 2001 to 2002 drought. Drought impacts and adaptations are categorized according to the project research framework. Within each category, keywords are used to identify unique adaptation options.

These identified adaptation options were grouped into the following specific categories or types of measures: 1) to conserve soil moisture and/or water, 2) to modify crop and livestock management practices, 3) specific institutional programs or initiatives, and 4) the application of specific research, monitoring and technological products.

The six most frequently mentioned adaptation options identified as being used in Eastern Canada during the 2001 to 2002 drought were: irrigation, crop insurance, water conservation and management, Ontario Low Water Response (OLWR)/Water Response Teams (WRT), the Net Income Stabilization Account (NISA) and the Canadian Farm Income Program (CFIP). Many other adaptation options were mentioned, including those in the categories of government assistance, finance, water management, research, health, as well as soils, crops, livestock, and pest management.

In Eastern Canada, the total number of drought articles peaked dramatically in August 2001, a year earlier than for the Prairie Provinces (Figure 5). In Atlantic Canada, most citations of drought adaptations occurred in 2001 during the peak drought period and decreased sharply in 2002. In Ontario, the number of articles detailing drought adaptation options was similar for both 2001 and 2002 and highlighted different adaptations used over the two years.

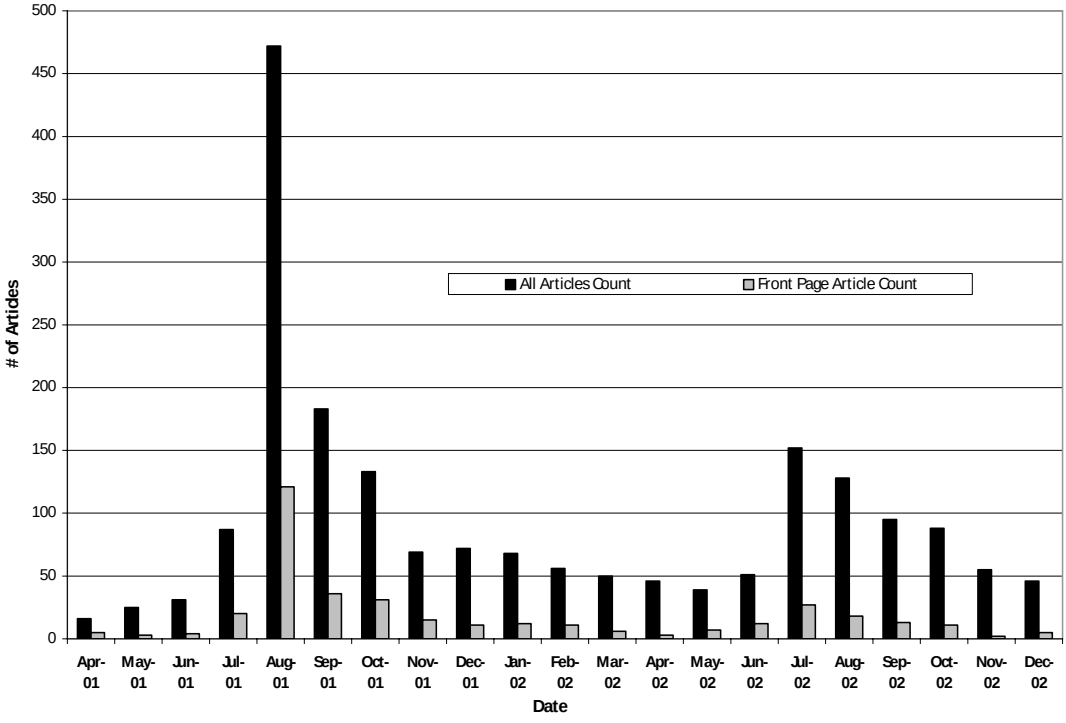

Figure 5 Number of Agricultural Drought Articles (Eastern Canada, 2001-2002)

Khairkhahi and Wahab (2006) and Wahab (2007a & 2007b) led and documented the regional case studies that took place in Ontario and Atlantic Canada. The first component of the regional assessment was to conduct focus group consultations in southern Ontario to obtain more information on the factors and circumstances that helped or prevented the use of these adaptation options at the individual farm or local level. The second component of this project was to interview provincial staff from various departments (e.g. irrigation engineers, agricultural field officers) in order to confirm/validate results from the focus group consultations with farmers in the spring of 2006.

The availability of water supplies in southern Ontario for agricultural and other rural water users are affected by several factors, including increasing water demands among competing users, periodic dry spells and droughts which increase water demands while reducing supplies, and questions about the effectiveness of existing water allocation arrangements. The successes and failures of several programs were documented.

Since the occurrence of several dry spells in the late 1990s, the need for better drought preparedness and response has been recognized by the Ontario provincial government. The Ontario Low Water Response (OLWR) program was developed and implemented in 2000. However, important questions about the ability and effectiveness of the OLWR program to accurately identify key drought thresholds and related water use responses have been raised. The lengthy process and costs involved in obtaining a Permit To Take Water (PTTW) was frequently identified by focus group participants as a barrier to augmenting water supplies and reducing vulnerability to drought.

Another innovative local institutional mechanism developed in southern Ontario after the 2001 to 2002 drought are Irrigation Advisory Committees (IACs). Four IACs were established in different sub-watersheds in southern Ontario. Although recommended as a model for other communities to emulate, the IACs have operated with mixed levels of success with one being disbanded in 2005 due to structural and financial problems. The different levels of local leadership and capacity were other important factors which affected the success and continuation of each IAC.

Agricultural water supply enhancement projects have been jointly funded by federal and provincial governments in several provinces under the Agricultural Policy Framework (APF). These projects provided funds for communities and farmers interested in improving their water supplies. In Ontario, 2006 was the first year that water supply and infrastructure projects were funded, so it is difficult to rigorously evaluate the success of the National Water Supply Expansion Program (NWSEP) in this province with only preliminary data for one year. However, the stakeholders who participated in the focus group sessions indicated the need for such financial support in order to encourage farmers to become less vulnerable to future severe droughts.

Wahab (2007a) conducted a smaller set of focus group consultations in three Atlantic Provinces (New Brunswick, Prince Edward Island and Nova Scotia) in December 2006 and January 2007. Another ADA project objective was to identify adaptive options that would extend the coping range and decrease the vulnerability of crop and livestock systems. Not surprisingly, there were challenges and issues that were unique to each province related to dealing with severe drought conditions.

In New Brunswick, drought has not historically been a major concern for agricultural producers, except for the southeastern portion of the province. Excessive wetness, drainage issues, and soil erosion control were more prominent concerns affecting the agricultural industry. Similar to Ontario, 2006 was the first year that water supply and infrastructure projects were funded under NWSEP, so it is difficult to rigorously evaluate the success of NWSEP with only preliminary data for 9 months. However, unlike other provinces, New Brunswick successfully negotiated with AAFC to include funding for drainage programs under NWSEP (as opposed to water supply augmentation and irrigation) since drought is not normally a major concern there. The main barrier identified by focus group participants to adaptation was regarding the lengthy and complicated process to obtain water permits from the provincial environment ministry. There is also very little monitoring of agricultural water supply and use, and enforcement of permitted water use limits.

By comparison, the 2001 drought had a significant impact on agricultural operations in Prince Edward Island (PEI), with a major decline in potato production (30-50% loss in yields). Focus group participants in PEI indicated that the precipitation patterns have become increasingly sporadic in the last 10 to 15 years. As a result, there has been an increasing desire to invest in irrigation systems as a sound risk management approach to deal with weather extremes such as drought. However, the moratorium imposed in 2001 which banned the approval of applications for new high-capacity wells highlighted the major issue of having access to adequate water supplies at a reasonable cost. The major barrier to allowing agricultural producers access to groundwater is a political one. In 2007 (six years after the 2001 drought), the provincial

government is still opposed to the whole concept of lifting the moratorium and opening up the groundwater resource for large-scale irrigation. Popular opinion on PEI by the non-agricultural water users (municipal) is that agriculture uses too much water, and should not be allowed expand their use. This perception is interesting since the use of irrigation systems in PEI is actually very low (only 6-7% of producers irrigate).

In Nova Scotia, drought has been a big issue in the Annapolis Valley, which is the major growing region. In order to deal with the series of abnormally "dry" summers since 1997 and culminating in the severe 2001 drought, the Nova Scotia government has been providing significant financial support to agricultural producers since the late 1990s to expand their water infrastructure systems. This trend is supported by provincial statistics showing a dramatic increase in the amount of irrigated land from 1995 to 2000. The NWSEP program has also been successfully used for four years to further expand the building of water supply infrastructure and storage systems. Concerns about the adequacy of water supplies to support irrigation were emerging, at the time of writing.

5. CONCLUSIONS

Drought adaptation research and planning strategies are in their early stages, although risk management plans for drought prone regions of the country have been established (e.g. the Agriculture Drought Risk Management Plan for Alberta). Many adaptive strategies have been devised and tested for their effectiveness in reducing drought impacts (Maybank et al., 1995). However, intense, large-area droughts that persist for several years still result in severe hardship to even those regions used to coping with droughts. An improved capability to estimate the numerous impacts associated with drought is required for enhanced adaptation. In addition, future national, provincial, and municipal level coordinated and proactive drought planning is needed since vulnerability to future droughts could be exacerbated by continued global warming and economic development, as mentioned earlier.

The recent severe and extensive Ada drought presented critical opportunities to assess current adaptation, adaptive capacity, resilience and vulnerability. Main benefits of the project include:

- Increased understanding of the status of current adaptation and therefore vulnerability to multi-year, nation-wide, and severe droughts
- Identification of suitable, realistic and practical adaptations to drought
- Provision of information to aid in the planning and actions to address adaptation gaps and limitations and to improve adaptation processes
- Increased awareness of vulnerability and adaptation, using drought examples
- Testing and working towards improving adaptation and vulnerability research methods
- Development of a research model for cooperative, interdisciplinary and multi-institutional research, as required for such complex and vital projects
- Enhanced information for building adaptation scenarios as required for climate impact assessments.

The recent great Ada drought presented unparalleled opportunities to assess characteristics of current adaptation. Much new and extremely useful information was documented. Many characteristics of adaptation and the processes of adaptation were determined, including most

frequently used options, their effectiveness, strengths and weaknesses, and space and time characteristics of the adaptation processes. Project results have applications for several areas including regional-to-national climate adaptation assessments, as well as local-to-national planning and policy regarding drought and water resources. However, this is only the beginning of the required assessments of current adaptation. It is an example of a national agricultural sector assessment of vulnerability to a climate extreme and is useful step in developing vulnerability assessments to climate change.

Canada has relatively abundant water, food, trained people, money, technology, and other resources to lessen its vulnerability to climate change, including extremes. However, even with the adaptation capacity displayed for the Ada drought, several negative impacts occurred and impacts and adaptations were costly. This finding indicates that a threshold of adaptive capacity appears to have been reached for this type of drought. This means that adaptation to drought has considerable room for improvement. Work is needed to enhance current adaptation to drought as well as the understanding of this process and options because of continued global warming and of increased demands for water supplies and stresses on water quality. Much more attention needs to be paid to adaptation research, planning, capacity building and implementation processes.

6. RECOMMENDATIONS

Droughts are certain to recur in the future. As a result, more effective short and long-term adaptation strategies are required to defend against these future droughts including improved technological, monitoring, and predictive capabilities. Despite the critical need demonstrated by the devastating and enormous impacts of drought, a coordinated and integrated drought research program does not exist in Canada. Main research areas are required to support the required improved drought adaptation and examples are provided in this section.

6.1 Monitoring, Modeling, and Prediction

The ability to more accurately predict drought onset, intensity, and termination requires improvements in the modeling and monitoring of current drought conditions, as well as, better short-term (seasonal) and longer term climate forecasts. Drought monitoring, drought early warning systems (DEWS) and data collection systems are the first steps towards better drought preparedness (Wilhite and Buchanan-Smith, 2005). Other steps include:

- More rapid updates of potential drought conditions to activate drought adaptation options.
- New approaches to using Global and Regional Climate Models in the estimation of future drought characteristics are needed. The drought indices used here have several limitations that need to be overcome to improve assessment of future possible droughts. A use of a greater variety of spatial and temporal scales is also required.
- Include an impact/adaptation monitor along with the Canadian drought monitoring system

6.2 Drought Characterization: Understanding the Risk in order to Improve Adaptation

The characterization of drought is a research gap. This work is needed to better understand the risk of droughts. Research areas required to address this gap include:

- As noted above, both the drought indices used in this project have several limitations and improved models for characterization of drought are needed.
- Although the SPI was useful in assessing the nature of past droughts, drought modeling should also consider temperature and other variables.
- Comparison and contrast of droughts and drought impacts across regions, countries, and sectors should be undertaken.

6.3 Increasing the Understanding and Improving the Modeling of Adaptation

As noted previously the understanding of adaptation to drought appears to be in its early stages. Progress is required in the following areas, for example:

- Improved methods to assess adaptation.
- Further research into the understanding and modeling of drought adaptation processes and measures, including their uptake, effectiveness, time lags, geographical patterns, practicality, costs, and benefits.
- Enhanced linkages of science and policy decision making using various methods, including interactive models and workshops.
- Improved knowledge regarding adaptation to prolonged and more severe droughts, including those that may be related to climate change.
- Determine changes in adaptation and thus vulnerability over time and space.
- Better ability to assess the consequences and effectiveness of alternative drought adaptation strategies.

Institutions that undertake drought research and planning must be strengthened and further developed. They can combine and coordinate their efforts and develop a National Drought Adaptation Network capability for example. A possible model exists in the US National Drought Mitigation Center. A critical mass of experts across many disciplines is required for this vital responsibility.

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APPENDIX A: LIST OF PROJECT DELIVERABLES

JOURNAL ARTICLES

2007

Bonsal, B. and M. Regier. 2007. Historical Comparison of the 2001/2002 Drought in the Canadian Prairies. *Climate Research* **33***:*229-242.

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