Canadian Agriculture and Water

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Abstract

Canada is a unique country with a large land base and plentiful water resources. In spite of these factors, Canada is experiencing water shortages and issues related to water quality. The majority of Canada's population resides in the south, while most of Canada's water supplies flow northward. Increasing competition is occurring for available water resources. Agriculture is a dominant economic player in most southern regions across the country, and is clearly affected by climate and available water resources. Droughts are of particular concern to dryland and irrigated agricultural production in semi-arid regions. The myth of abundance of Canada's water supplies is being replaced by a realization that existing water supplies are not limitless, especially where the high demands are. Existing water availability is expected to be impacted even more so by climate change. Over the past 25 years, water management in Canada has evolved from a water supply development focus to a sustainable development focus. Integrated water resource management approaches are now being applied in the management of water, land and agricultural resources. The federal Department of Agriculture and Agri-Food Canada established an Agricultural Policy Framework in 2003 in which the environment was identified as one of five key pillars. Agri-environmental programming has been driven from the need to protect air, water, land and biodiversity in Canada. This paper provides an overview of the evolution of federal-provincial agri-environmental programming and associated linkages with water. Agri-environmental programming has proven to be popular with the sector and the Canadian public. Much of the environmental programming undertaken by federal and provincial agricultural departments across Canada has been driven from the perspective of adopting agricultural beneficial management practices (BMPs) to conserve water supplies and safeguard source water quality in the environment, and to better adapt to climatic effects on natural resources. The agricultural sector has contributed significant time and resources to adopting BMPs that protect water resources and the environment. Programs where the agricultural sector and producers learn how to develop their own environmental farm plans have proven to be useful to individual farms and farm groups, making the sector an active participant in integrated water resource management within local watersheds. Continued research is needed to better understand the environ-mental and watershed effects of agricultural BMP adoption, and the associated costs. On-going dialogue is needed between the agricultural sector and the Canadian public to better understand and value the societal benefits of agricultural beneficial management practices.

1 Background

Agriculture is a key driver for the Canadian economy, providing 1 in 7 jobs within the country. The agri-food sector accounts for 8.3% of Canada's Gross Domestic Product. The combined sales of red meats, grains and oil seeds, dairy products, poultry and eggs account for $23 billion (78%) of farm market receipts (Agriculture and Agri-Food Canada 2005a). Canada has 246,923 farms with agriculture practiced on 67.5 million hectares. The total farm population is 727,130 people, roughly 2.4% of Canada's population. The rural (non-urban) population of Canada is about 6 million people, representing about 20% of Canada's population (Statistics Canada 2001a).

Canada is considered to be a water-rich country, but 67% of the water flows northward, while 90% of the population lives in the south where most of the arable land is located (Policy Research Initiative 2005; Fig. 1). Canada has about 20% of the world's fresh water stored in lakes, but a distinction must be made between "stored water" and "renewable water supply". The renewable water supply is that portion of water which replenishes lakes and underground aquifers. Canada has about 6.5% of the world's renewable water supply (Sprague 2007). All of these factors must be considered in water management, in order to balance society's needs and the capacity of the ecosystem to replenish the water that is withdrawn for use. The available water supplies in Canada are particularly challenging to the semi-arid regions such as the Canadian Prairies, where existing water supplies are at, or near, full allocation.

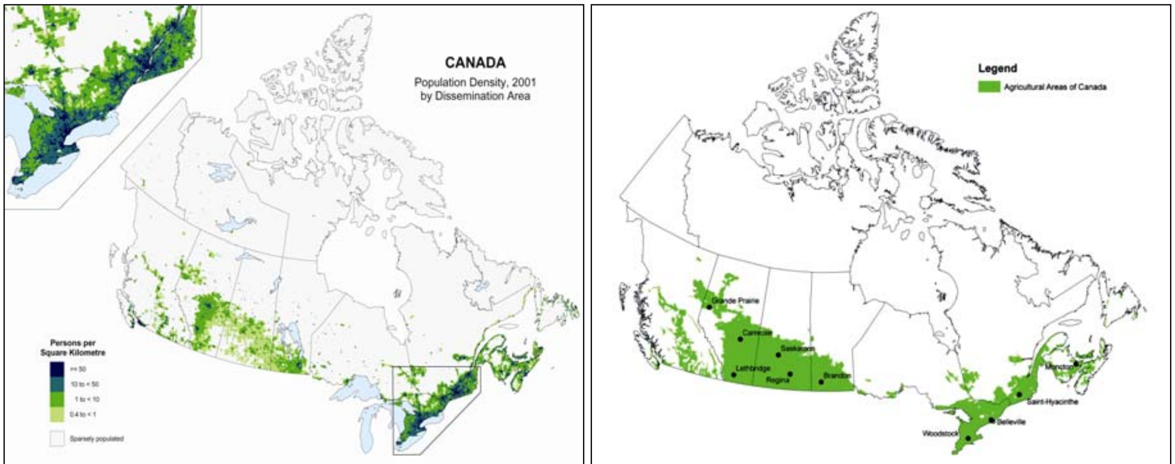

Figure 1. (a) *Population density in Canada (Statistics Canada 2002a) and (b) agricultural land extent in Canada (Statistics Canada et al. 2001).*

Canadian agriculture and rural citizens in Canada rely on having access to sufficient quantities of good quality water for a variety of needs. As an industry, agriculture also has the potential to negatively impact natural water resources. Negative impacts could affect both the environment and human health. Agricultural production must therefore adopt practices that protect, enhance and improve water for its own economic interests, and at the same time, for the diversity of societal and environmental needs.

Historically, agriculture has always relied on healthy ecosystems. The agricultural sector utilizes practices that have come to be known as agricultural "Beneficial (or Best) Management Practices" (BMPs). By adopting BMPs, agricultural production attempts to safeguard the environment while allowing for a vibrant, competitive and profitable agricultural industry. BMPs support the concept of sustainable development: "meeting the present needs of society without compromising the needs of future generations." This globally understood concept sees society as being comprised of three spheres, including the environment, the economy, and the social (human) aspects.

Water management in rural Canada is particularly challenging. Many rural areas are sparsely populated. The agricultural sector and rural Canadians do not have access to the same types of regional water infrastructure as urban Canadians. Most rural citizens rely on private self-contained supplies. Access to reliable water supplies (sufficient quantity and good quality) can be challenging and costly to rural citizens (Corkal et al. 2004).

2 Uses of Water for Agriculture's Needs

Agriculture needs water for all aspects of agricultural production. Water is needed for:

- *Drinking water and quality of life*: Farm populations, the agricultural sector labour force and rural populations require high quality water for rural households and on-site buildings and facilities. Potable water is required for drinking and high quality non-potable water is required for bathing and cleaning.
- *Crop production*: Dryland farming relies on timely rains and sufficient soil moisture. Crop types and production are limited on the Canadian Prairies, where growing days and precipitation are limited. Annual precipitation in southern Saskatchewan amounts to 300 mm (Environment Canada 2004; Agriculture and Agri-Food Canada 1998; Fig. 2). Irrigated agriculture requires good quality water and sufficient and timely quantities of water; irrigation is usually applied to high-value crops which provide greater economic returns. Horticulture and greenhouse production also rely on access to good quality water for successful operations.
- *Crop health, farm chemicals and fertilization*: Crops are affected by a variety of pests (e.g. weeds, insects). Current practices in safe food production utilize pesticides to grow healthy crops with minimal negative impact from pests. Pesticides are manufactured in concentrated form. To ensure efficacy, pesticide solutions require good quality mix water to be added to the concentrated pesticide before being

applied at a targeted dose to the crop. Irrigated crops, particularly in greenhouse production, may also receive plant nutrients (in the form of fertilizers) added to the irrigation water, known as fertigation.

- *Livestock production*: Animals require good quality drinking water for healthy growth and nutrient uptake in their bodies. Water misting is used to cool livestock in intensive operations during the summer months. The livestock population in Canada (about 15.5 million head of cattle and calves, 14 million head of pigs, and 140 million poultry) require a stable high-quality supply of drinking water (Statistics Canada 2002b; Environment Canada 2004).
- *Food and non-food agricultural processing*: Water is necessary for many aspects of processing and packaging of food and agricultural products (e.g. as an ingredient, a transport mechanism, a cleaning agent, for waste management, etc.).
- *Industrial uses in the agricultural sector*: Water is required for a number of industrial needs, such as water for heating (boilers) and cooling (air conditioning). Ethanol production, as an example, requires about 4 to 6 L of water for each litre of ethanol produced, primarily for cooling and wastewater discharge (Institute for Agriculture and Trade Policy 2006).
- *Cleaning and waste management*: Water is essential for cleaning of livestock barns and agricultural processing facilities. Water may also be required as a transport mechanism for manure management in some livestock operations.

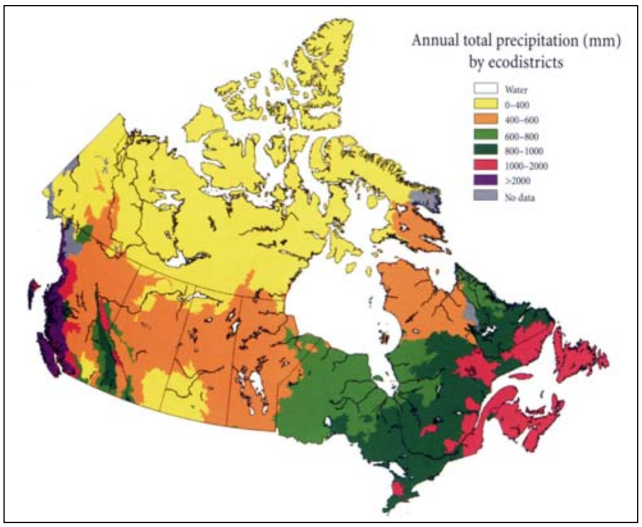

Figure 2. *Annual total precipitation in Canada by ecodistricts.*

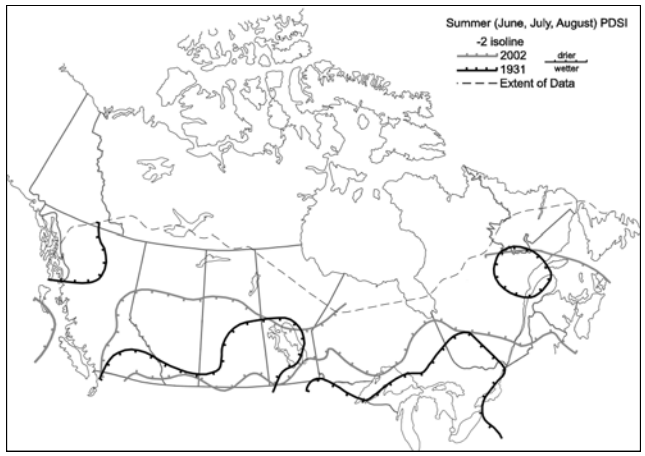

Figure 3. *1931 and 2002 drought extent.*

3 Water Quantity Issues for Agriculture

Agriculture in Canada accounts for 8.3% of Canada's gross domestic product. Agriculture is practiced on approximately 7% (67.5 million ha) of Canada's land base, with 82% of this occurring on the Canadian Prairie Provinces (Statistics Canada 2002b). Agriculture is Canada's largest single sector for water consumption, utilizing about 4.5 billion m^3 of water annually. It is estimated that agriculture consumes 70-80% of the water it diverts (based on 1996 data). About 85% of agricultural water withdrawals are used for irrigation, predominantly in Western Canada, and about 15% of agricultural water withdrawals are utilized for livestock production (Environment Canada 2003, 2004).

In dryland farming, crop water requirements are provided by precipitation (rain or snow), recharging soil moisture for plant uptake. Dryland crops can only be successfully grown when plants receive timely and adequate moisture. Producers have always had to cope with vulnerabilities from climate and associated natural environmental influences. The agricultural sector will require increased knowledge of future vulnerabilities caused by global warming. Scientists estimate that future increases in temperatures and precipitation will result in less available plant moisture in summers, due to increasing evaporation and reduced summer precipitation (Sauchyn 2007).

For Canada, global warming may actually present opportunities for agricultural operations that require warmer temperatures (e.g. increased cropping diversity). However, challenges will be posed concerning water availability and infrastructure requirements for new or different agricultural activities. Global warming and climate change are also expected to increase variability in water supplies and weather (e.g. droughts, floods, extreme weather events). Agricultural production is expected to experience increasing vulnerabilities which could have significant economic impacts. As an example, the drought years of 2001 and 2002 were unique in that they affected large areas across Canada, although the effects were most severe in Alberta and Saskatchewan. The drought was estimated to have caused a $3.6 billion drop in Canadian agricultural production, a $5.8 billion drop in Canada's Gross Domestic Product, and 41,000 job losses (Wheaton et al. 2005). The 2001-02 drought actually extended over a larger land base than the 1931 drought, which had followed a number of consecutive drought years occurring in the 1920s (Fig. 3).

Irrigation is an adaptation technique designed to withdraw water from available supplies to secure crop water requirements. Globally, agriculture has relied on irrigation for millennia. Field crops grown under irrigation rely on large quantities of water. Agricultural withdrawals of water total 9% of water withdrawals for all water uses in Canada (consumptive and non-consumptive). Considering consumption only, agriculture consumes a much larger percentage of water. In the Alberta portion of the South Saskatchewan River Basin, irrigated agriculture accounts for 75% of the total volume of all water allocations in the basin (Alberta Environment 2003). This amounts to a water consumption of about 2.2 billion m^3 of water annually, or about 28% of the total annual river flow (Environment Canada 2004). The four western provinces of Canada irrigate approximately 707,000 ha of land (Natural Resources Canada 2004). In the province of Alberta, irrigated agriculture is practiced on 499,241 ha of land, accounting for about 64% of the irrigated cropland in Canada (Fig. 4; Statistics Canada 2001b).

Of Canada's 67.5 million ha of agricultural land, 36.4 million ha is in cropland. In reality, the irrigated land base in Canada is relatively small, just under 1 million ha. It is estimated the country could practice irrigation on about 1.9 million hectares (Agriculture and Agri-Food Canada, 2005b). While there is potential for expansion, limitations exist based on access to suitable water sources combined with significant infrastructure costs. Summer river water flows in the Prairie Provinces are less than they were at the dawn of the 20th century, largely due to societal demands, river system alterations and increased warming (e.g. withdrawals for multiple water uses, dams and reservoirs for water management, increased evaporation) (Schindler and Donahue 2006). The effect of global warming and climate change on dryland farming could increase future vulnerabilities to agricultural production. Adaptation strategies, water infrastructure needs, water conservation, water allocations, increasing competition for water, and potential water conflicts, will undoubtedly create increasing pressures on future water management in Canada.

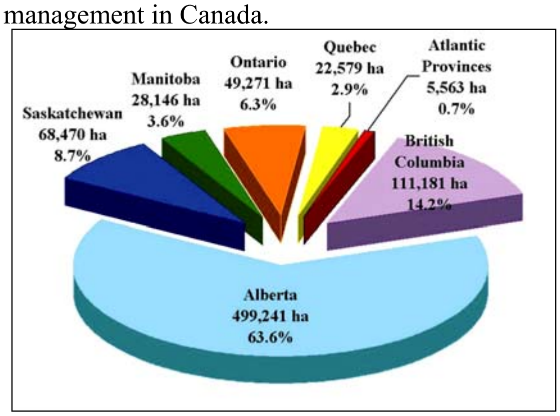

Figure 4. *Distribution of irrigated areas in Canada.*

A summary of agri-food sector water supply issues was conducted in 2002 and 2003, and identifies national rural water supply issues across Canada, listing the issues for each province (Agriculture and Agri-Food Canada 2003). Water supply issues facing the sector include: limited access to water supplies and water allocations, lack of information, seasonal shortages, allocation/regulatory/licensing issues, poor water quality, lack of infrastructure, limited capacity, competition for water, limited water conservation, and lack of technical assistance.

4 Water Quality Issues for Agriculture

As with all sectors of society, water quality needs vary depending on the use of the water. Of course drinking water must be safe for human consumption. Non-potable water must also be safe and aesthetically-pleasing for non-potable human uses such as bathing and cleaning.

In Canada, it is recognized that well water quality (untreated source water quality) commonly exceeds safe drinking water quality guidelines for about 20-40% of the rural wells across Canada (van der Kamp and Grove 2001). Over 4 million Canadians rely on private water supplies, the majority being a groundwater source. While this accounts for about 13% of Canada's population, it is estimated that more than 20% of Canada's waterborne disease outbreaks occurred on private supplies during the period from 1974-96, and an additional 45% of reported outbreaks occurred on non-municipal systems, in rural or remote areas (Robertson and Neil 2001). In Saskatchewan, 99.6% of private rural wells exceeded one or more aesthetic or health-related guidelines; about 35% of the wells exceeded health-related guidelines (Sketchell and Shaheen 2001; Health Canada 1996). In Alberta, 93% of rural water supplies exceeded one or more aesthetic guidelines; about 32% of wells exceeded health-related guidelines (Fitzgerald et al. 1997). In an Ontario study, 40% of rural wells exceeded one or more maximum acceptable concentrations for targeted drinking water contaminants; about 32-36% exceeded maximum acceptable concentrations for coliform bacteria (Rudolph and Goss 1993; Goss et al. 1998).

Poor quality water not only affects human uses, but also agricultural uses. Impacts of poor quality water can affect operational efficiencies (chemical spraying, cleaning operations), animal health and weight gain, and the production of safe food. Irrigation and horticulture also rely on good quality water (Corkal et al. 2004; Peterson 2000). Water quality impacts on the agri-food sector are often not well-understood by the sector, and additional work is needed to address the nature and extent of the issues. A "Rural Water Quality Survey" conducted in Saskatchewan discovered that many producers and producer organizations were aware of water quality to a minor extent (Mason et al. 2000). Most rural people did not test their water quality and were unaware of specific water quality issues. Essentially, water quality was ignored until an obvious or severe problem was evident. In contrast, experts working in the discipline of water resources (government, academia) stated that commonplace water quality problems were likely impacting agricultural production practices (e.g. impairing pesticide efficacy, affecting livestock weight gain or animal health), and thereby likely affecting the agricultural economy to some degree. This knowledge gap was characterized in a phrase presented at one of the dissemination workshops: "*people are generally not aware of what they do not know*". In spite of this gap, the agri-food sector and producers stated they were [and still are] receptive to more information on water from dependable and trustworthy unbiased sources.

5 Agriculture's Impacts on Water

Water use in agriculture, access to reliable water supplies (sufficient water quantity and quality), ecological issues, economic issues, droughts and floods, and rural growth each have some connection with water in the environment. Irrigation requires large quantities of water (Figs. 5 and 6), and clearly places a significant demand on water resources. Climate change is expected to place additional pressure on dryland cropping. However, limitations exist with respect to irrigation expansion (access to suitable water sources, land suitability, water development and distribution). Even though irrigated land is a comparatively small percentage of all agricultural land in Alberta and Saskatchewan, agriculture uses a large portion of the consumptive water demands for each province.

Figure 5. *Irrigation of field crops from Lake Diefenbaker. (Image of Gardiner Dam and surrounding area used with permission of Google Earth 2007)*

Figure 6. *Centre Pivot low pressure field irrigation system utilizing drop tubes to conserve energy and reduce evaporative water loss. (Gillies et al. 2003).*

As earlier noted, in the South Saskatchewan River Basin of Alberta, 75% of the water allocations are for irrigation (Alberta Environment 2003). In southern Alberta, competing demands and large irrigated agricultural water extractions have now been recognized as reaching a critical limit. Water resources are recognized as fully-allocated in some locations, and this means that existing or new water users cannot access more water. Basin Advisory Committees in southern Alberta, established under Alberta's Water for Life strategy, have recommended closure or reduction of allocations for several rivers including the Bow, Oldman, and Red Deer rivers. Recommendations were also made on maintaining ecological flows to protect the aquatic environment, and for allowances of water transfers for irrigation purposes (Alberta Basin Advisory Committees 2004). The government of Alberta approved these recommendations and will not allow new allocations in the Bow, Oldman and South Saskatchewan River sub-basins. The government has also retained the right to withhold 10% of river flows for ecological needs (Alberta Environment 2006).
Similar concerns are being expressed about water for agriculture in the semi-arid Okanagan Valley of British Columbia. In the Okanagan Basin, irrigation of high value vineyards and fruit crops accounts for 70% of the water licensed for consumptive use. The basin is densely populated and experiencing high population growth. Concerns also exist about the impacts of climate variability and climate change (Okanagan Basin Water Board 2006).

The majority (67%) of Canada's water flows northward, away from the population mass and the arable agricultural land. The possibility of utilizing northern water supplies for southern needs has been considered in the past, such as diverting water from the North Saskatchewan River to the South Saskatchewan Basin (Hoppe 2003). Any consideration of large-scale water diversion projects would require significant long-term planning and commitment by all sectors of Canadian society, and a careful examination of environmental and socio-economic impacts. Diversions would also need to consider the impact on the regime of renewable water resources, and the supply necessary to replenish existing surface and groundwater resources.

The Health of Our Water: Toward Sustainable Agriculture in Canada presents an overview of the inter-dependency between agriculture and water resources in the natural environment (Agriculture and Agri-Food Canada 2000). This publication emphasizes the fact that most agricultural production relies on having access to sufficient quantities of good quality water for its various needs, as earlier described. Concerns also exist about agricultural impacts on water quality and the environment. *The Health of Our Water* report lists a number of water quality issues, and identifies the need to adopt agricultural practices that protect water in the natural environment. Agricultural contaminants are identified as suspended sediments, nutrients, pesticides, pathogens, metals, organic matter, bacteria, etc.

In a separate report, Environment Canada identifies threats to water quality and natural ecosystems in Canada (Environment Canada 2001). While a diverse number of non-agricultural influences exist, agricultural production may play a role and/or may have a vested interest in many of the potential threats, including:

- waterborne pathogens (animal waste products, manure runoff and handling)
- algal toxins and taste and odour (nutrient loadings from sediment and runoff)
- pesticides (agricultural pest control products)
- endocrine disrupting substances (natural and synthetic chemicals and pharmaceuticals in livestock waste)
- nutrients – nitrogen and phosphorus (risks associated with fertilizer runoff)
- ecosystem effects of genetically-modified organisms (environmental effects)
- agricultural impacts (quantity and quality, land use, farming practices)
- dams, diversions and climate change (availability and distribution)

The most common approach to addressing agricultural impacts on water is to incorporate agricultural practices that protect water in the environment. Protection practices include BMPs associated with land management and production practices (Agriculture and Agri-Food Canada 2000). Examples include:

- chemical and nutrient inputs that ensure correct dosing and uptake, and minimal environmental exposure (fate and mobility)
- the use of waste management techniques (manure, animal burial, oil and gas, etc.)
- using buffer zones and shelterbelts (trees and shrubs) to minimize erosion, and loss of organic matter

- maintaining healthy riparian zones
- conservation tillage to minimize the loss of organic matter and to conserve water
- adopting specific agricultural codes of practice
- environmental farm planning
- peer advisory groups to guide agricultural BMP implementation
- establishing community and governance roles that facilitate BMP adoption (e.g. with agriculture as an active participant in watershed management)

6 Canadian Agricultural Programs and Water: From Development to Sustainable Development

In Canada, provincial and territorial governments have the jurisdiction over natural resources. Accordingly, the provinces have the primary responsibility for water management. Federal roles in water management relate largely to fisheries, navigation, transboundary (inter-provincial and international) waters and environmental research. However, due to the cross-cutting nature of water resources, water management in Canada relies on shared provincial, local and federal jurisdictions; this fragmentation of roles may lead to associated governance issues (Corkal et al. 2007).

Canadian provinces also have the primary responsibility for agriculture. The federal Department of Agriculture and Agri-Food Canada (AAFC) shares responsibility with the provinces for improving the economic performance of the agri-food sector in Canada and for food/livestock inspection. Historically, AAFC has always placed significant emphasis in agricultural production research, assisting the agri-food sector with innovations that would result in increased profits and production efficiencies, and maximizing production outputs. While environmental considerations were factored, they were not the focus of most agricultural research projects in the past. The concept of environmental research in agricultural production is now gaining more attention (as described later in this section).

One branch of AAFC, the *Prairie Farm Rehabilitation Administration* (PFRA), does have a water management mandate (this is rather unique for a federal agency as water management is a provincial government jurisdiction in Canada). PFRA was created in 1935 as a federal response to the severe droughts experienced on the Prairies during the 1920s and the 1930s, and was mandated by the Government of Canada to "*secure the rehabilitation of the drought and soil drifting areas in the Provinces of Manitoba, Saskatchewan, and Alberta, and to develop and promote within those areas systems of farm practice, tree culture, water supply, land utilization and land settlement that will afford greater economic security*" (Justice Canada, R.S. 1985). Throughout most of the history of PFRA, its projects have ranged from human resettlement in severely-affected drought areas, to extensive infrastructure development (dams, diversions, irrigation projects), to land use improvements (promoting soil conservation, expanding tree cultures, applied research for land and water resource issues) (Agriculture and Agri-Food Canada 2005c).

Canada was established as a nation in 1867, and for approximately 110 years, Canada viewed water as a critical resource for nation-building. Water development projects largely related to infrastructure for Canadian society: water supplies and diversions for communities and industry; transportation canals; water as a source of steam power; hydro-electricity and thermal power; industrial water and wastewater; manufacturing; and even recreation. The history of PFRA's involvement in water projects closely followed the history of water development as a principal economic driver for the settlement of the country. Technical and regional planning was targeted to secure water resources for the settlement of Western Canada. PFRA provided federal funding, technical resources and programs to assist in securing more dependable water sources, enhanced and more sustainable agriculture, improved protection from drought, and greater economic security (Figs. 7 and 8).

By the 1980s, Canadians and global society began to realize that economic drivers had to be balanced with other impacts on social life and the environment. Society began to recognize that there were potential negative consequences if environmental damages resulted from development. Society realized that protective actions undertaken with development could protect and safeguard the environment. The concepts of *sustainable development* began to take shape around the globe, and were reported in the Brundtland Report (World Commission on Environment and Development 1987). Sustainable development emphasizes meeting the present needs of society without compromising the needs of future generations.

Figure 7. *Gardiner Dam, the world's 17th largest dam was constructed by PFRA in 1968. It supplies drinking water to about 50% of Saskatchewan, enhances aquatic biodiversity, and is used for irrigation, hydroelectricity, and recreation.*

Figure 8. *Trenching of rural water pipelines. Small diameter polyethylene pipeline trenching was adapted to prairie clay soils to supply farmsteads with water.*

Canada's 1985 *Inquiry on Federal Water Policy* emphasized the need for sustainable water management, and culminated in Canada's 1987 *Federal Water Policy* (Pearse et al. 1985; Environment Canada 1987). The Canadian policy called for greater integration of water management to meet the economic, social and environmental needs of society. In 1992, Canada along with countries around the world, embraced this approach under the Dublin Principles, now known as "integrated water resource management" or "IWRM" (Dublin Principles 1992). Canada increased its commitment to the principles of sustainable development (Johannesberg Summit 2002). Water management principles were evolving, and these new approaches would have an effect on the agri-food sector.

Sustainable development and IWRM principles are now clearly supported by all Canadian provinces. Two key examples of how provincial water management has evolved to incorporate IWRM principles include:

- Alberta's *Water for Life* strategy, which promotes comprehensive water management strategies affecting all of society. A key focus is management of water by considering the "watershed approach", participatory planning that is respectful of all stakeholders and the environment, and the recognition that water has economic value (Alberta 2006).
- Québec's *Water. Our Life. Our Future* water policy, which recognizes a need for strategic governance reform, integrated watershed-based management, protection of water quality and aquatic ecosystems, continued clean-up and improved management (including agricultural, industrial and municipal clean-up efforts), and promotion of water-related recreation and tourism. (Québec 2002).

Watershed management and water governance in Canada has been dramatically affected by waterborne disease outbreaks that occurred in Canada between the years 2000 to 2005 in Walkerton, Ontario, North Battleford, Saskatchewan and Kashechewan First Nation, Ontario (Corkal et al. 2007). The most influential of these cases was Walkerton, Ontario, where the drinking water was contaminated by *E. Coli*. Seven people died and 2,300 became ill (of a total population of 5,000). Some people affected by the contamination are expected to endure lasting health effects (O'Connor 2002). The source of the contamination was livestock manure that had been applied on farmland. Heavy rain occurred during a 4-day period, carrying the manure into one of the community's wells. The report noted that this contamination was preventable had the community followed better practices (maintaining continuous chlorine residuals, using turbidity monitoring, improving source water protection practices and water treatment, and improving monitoring of the water system and processes, etc.). The inquiry also investigated the farm operations, and reported that the farm was following proper practices and was deemed not to be at fault for the contamination. [The farm had been following proper manure management BMPs and had an environmental farm plan.]

These serious drinking water outbreaks have had a profound effect on water management approaches across Canada. Increasingly, government agencies and water stakeholders are realizing that water must be managed on a watershed basis from "source to tap" by adopting a number of protection, treatment and monitoring practices to protect water resources and water users. In the Walkerton case, it is clear that contamination can occur even when a farm is following proper practices. What is also clear is that when farm operations practice protective and proper BMPs, the sector is recognized as a good steward of water and land resources, rather than being faulted as the cause of contamination. Furthermore, the example of Walkerton demonstrates the importance of engaging multiple stakeholders for proper water resource management.

In Canada, agriculture and associated water programming has now evolved to consider environmental issues, such as source water protection. Supported by all Canadian provinces, Canada adopted an Agricultural Policy Framework in 2003, establishing five key pillars (areas of focus):

- business risk management (to deal with economic challenges in the global agri-business marketplace)
- food safety and quality in agricultural production and food-processing
- science and innovation in agricultural production
- environment (to enhance soil, water, air and biodiversity in the natural environment)
- renewal (access to new business opportunities)

By including the environment as one of the five pillars, provincial and federal departments of agriculture and the agricultural industry were stating that governments and industry "*are looking to accelerate efforts to reduce agricultural risks and explore environmental opportunities*" (Agriculture and Agri-Food Canada 2007a). The increased emphasis on environmental performance was a natural evolution towards a profitable agri-food sector in concert with sustainable development – economic drivers would not be the sole drivers for the sector.

Accordingly, federal programming was established in partnership arrangements with provincial governments and local stakeholders. AAFC and its PFRA Branch assumed national roles for environmental and water management programming (Agriculture and Agri-Food Canada 2006). Some of the key federal agricultural environmental programming relating to water include:

- *Environmental Farm Planning*: Designed for individuals and farm groups, this program offers training for voluntary assessment of potential environmental risks of farm operations. Risk identification is considered the first step in environmental awareness.
- *National Farm Stewardship Program*: Having completed an Environmental Farm Plan, individual producers or farm groups are eligible to design corrective measures to address practices that could impair the environment. Technical and financial support is available for adopting beneficial practices to safeguard against environmental risks (Fig. 9).
- *National Water Supply Expansion Program*: This program is an expanded national version of the former "Rural Water Development Program" which, administered by PFRA since 1935, had previously been available only to the Prairie Provinces. The current program offers technical and financial assistance to help producers and agricultural communities address water development, enhancement and protection needs, with funding and technical resources for rural water infrastructure and rural water studies.
- *Pesticide Risk Reduction and Minor Use Programs*: The Minor Use Program helps producers access more environmentally-friendly and efficient pest management technologies.
- *Information Gaps in Water Quality and Nutrients*: Research is being conducted to develop improved beneficial management practices for manure and nutrients.
- *National Agri-Environmental Standards Initiative*: Agri-environmental standards are being invest-igated (both "ideal" and "achievable") for specific water sources. These standards include the concept of minimum in-stream flows required for sustaining ecological health. The work is being conducted by Environment Canada under contract to Agriculture and Agri-Food Canada.
- *National Land and Water Information Service*: A new internet-based service for land and water information is being developed to help land owners and land managers with agri-environmental land-use decisions.
- *Integrated Pest Management Research*: Research is being conducted to reduce the use of chemical pesticides and to develop natural products and processes to control pests.
- *Prairie Shelterbelt Program*: To promote conservation and land reclamation, producers are eligible to receive trees and shrubs suitable for the semi-arid prairie environment (Fig. 10).
- *Greencover Canada Program*: This program promotes improved grassland management practices, water quality protection and enhanced biodiversity and wildlife habitat.

Figure 9. *Newly-planted riparian buffer BMP protects the creek from sediment transport by rain or snowmelt runoff.*

Figure 10. *Shelterbelt trees are planted in patterns to shelter from wind, reduce soil erosion, conserve moisture, trap snow, and enhance biodiversity.*

- *Watershed Evaluation of BMPs*: WEBs is a research program to assess the performance and costs of specific BMPs in targeted watersheds across Canada.
- *National Agri-Environmental Health Analysis and Reporting Program*: Environmental Indicators are being developed to gain knowledge on the assessment and tracking of agricultural indicators in the environment. The indicators currently selected for water include nitrogen, phosphorus, pesticides, and water use efficiency.
- *Technical Support for Rural Water Supplies*: PFRA continues to provide a variety of technical support functions for the water needs of the agri-food sector and the rural Canadian population (Fig. 11). Presently, the services have been expanded beyond the Prairie Provinces across Canada, and occasionally on specialized international projects (Fig. 12). Such functions include water resource studies (groundwater hydrogeology and surface water hydrology), irrigation development, assistance following severe events (droughts and floods), applied research into rural water quality issues for protection and use of rural water, support for watershed initiatives, etc.
- *Water and Climate Information Products*: AAFC provides the agri-food sector and the public with diverse water and climate information products. Many of these are posted on the web. Highlights include:
  - *Drought Watch*, which provides climate maps and agro-climate outlooks. Clients employ these for a variety of agricultural uses, particularly related to planning for cropping and associated water needs (Fig. 13).
  - *Clean Water*, which identifies methods for protecting, enhancing and treating water to safeguard and improve water quality for the variety of agricultural and rural water uses (Agriculture and Agri-Food Canada 2007b).

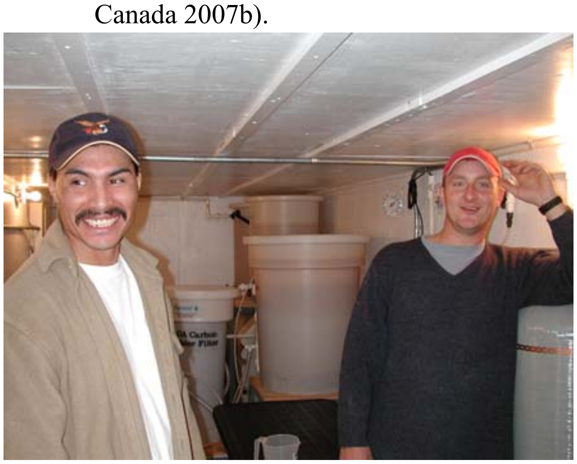

Figure 11. *Applied water quality research helps farmers and First Nations rural communities.*

Figure 12. *Canadian water stakeholders compare climate change impacts and water institutions within the South Saskatchewan River Basin, to those in the Rio Elqui Basin in northern Chile.*

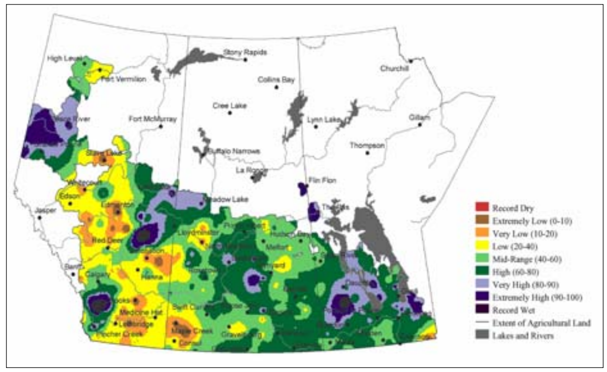

Figure 13. *Internet-based Precipitation maps allow producers to compare historic and current conditions to assist with cropping decisions*

Canadian farms and farm groups have embraced environmental programs. By learning about, and developing their own environmental farm plans, producers are becoming increasingly aware of where their operations can be improved for environmental protection. This type of programming is encouraging the participation of Canadian farmers as respected participants in volunteer watershed committees. The development of group environmental farm plans is contributing to active agricultural sector participation in integrated water resource management. The participation of producers and the agri-food industry, and forecasted estimates of participation to the year 2008, are shown in Fig. 14. Over 22% of farmers across Canada have participated in the Environmental Farm Planning Program as of December 31, 2006.

Uptake for BMP adoption practices has also been strong: about 6,900 producers have utilized $43.8 million of federal cost-sharing to adopt over 11,000 BMPs. Estimates are also provided to the year 2008 (Fig. 15). These BMPs have been jointly funded by producers and the provincial/federal governments. The largest percentage of newly-adopted BMPs relate to protecting natural water sources, by minimizing nutrient, pathogen or pesticide transport into water supplies. Examples include improved manure storage facilities, better methods of manure spreading, and construction of riparian buffer strips and zones.

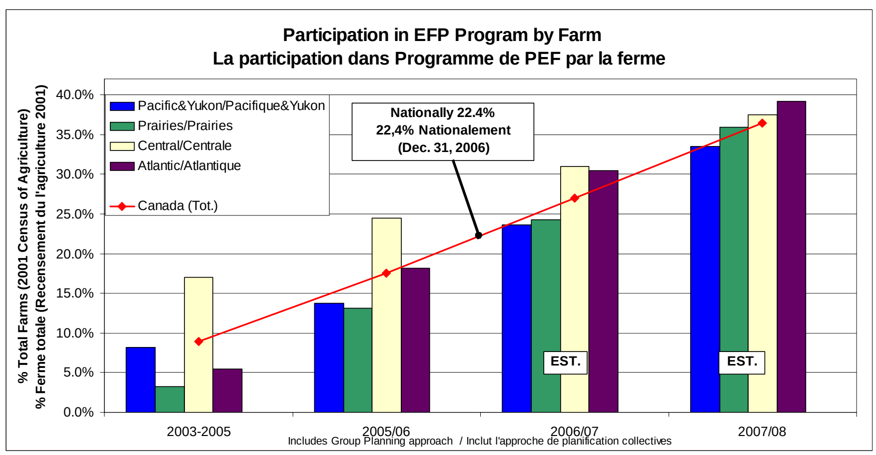

Figure 14. *Farmers participation in the Environmental Farm Planning Program*

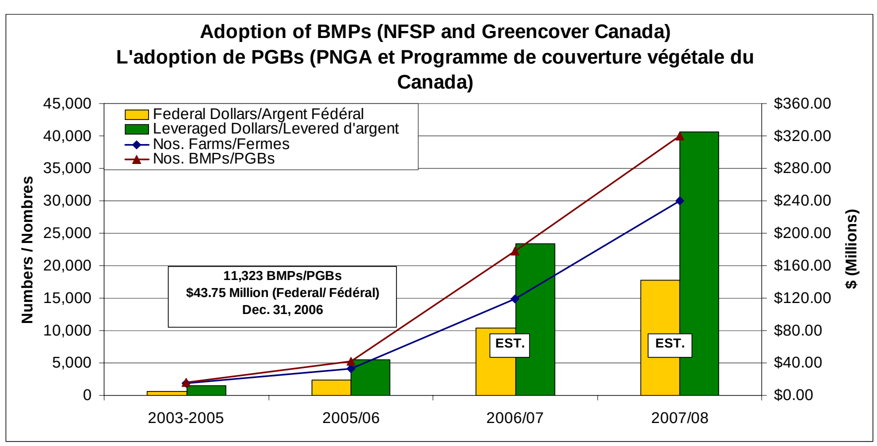

Figure 15. *Farmers spend Significant funds to construct BMPs to protect the environment.*

7 Need for Environmental Programming and Research

As the Canadian Agricultural Policy Framework draws to a close in 2008, the Canadian government is developing the next generation of programs. It is clear that producers, the agri-food industry, and the Canadian public, are very interested in continued agri-environmental programming.

It is also clear that further research and analysis into BMP environmental efficacy and economics are critical factors to investigate. BMP adoption relies on targeted research which clarifies the cost and the effectiveness of BMPs, and assesses whether or not the BMPs are achieving the desired ecosystem effects. The reality is that some understanding exists about specific local effects of BMPs, but very little is known about watershed effects (i.e. the larger scale). Future scientific studies are essential to our understanding of the performance of BMPs at the watershed scale, and of their associated economic costs (Butts and Scott 2007).
Another key gap may be identified as "Agricultural sector - Citizen dialogue or discussion". Oftentimes, the public receives a conflicting message that the agricultural sector is affecting the environment, and yet the sector has, and continues to, adopt practices to safeguard the environment (Harker 1997). Conversely, it is likely that the agricultural sector requires a dialogue with the public to increase its own understanding of the diverse perspectives that exist with respect to environmental issues and potential agricultural influences. There is a need for the sector and the Canadian public to achieve an improved mutual understanding of the human dimension, and how agri-environmental issues affect and are valued by society.

BMP adoption relies, in part, on sociological factors that are not well understood. In a small survey, Kehrig (2002) discovered that:

- producers are concerned about how their practices impact the environment
- BMP effectiveness needs to be proven before adoption
- government roles and jurisdictions are often confusing
- skepticism and negative comments were expressed towards government
- BMP adoption is less likely when economic survival is at stake

More recently, the Alberta Research Council investigated barriers to adoption (Alberta Research Council 2006). Social needs affecting BMP adoption were identified as: c*omplexity, financial issues, worldviews, and uniqueness between conservation and food safety.* To address these needs, extension protocols were suggested to be targeted to: *adjusting extension worldviews to see different perspectives, modifying extension approaches and styles, and entering into a producer-extension discussion to better understand what constitutes BMPs.*

8 Conclusion

The agri-food sector and governments in Canada have evolved from a water development, nation-building focus to implementing sustainable development and integrated water resource management principles over the past 25 years. As water management in Canada engages in participatory approaches with water users, Canadian society is realizing the important role that agriculture has in using and protecting water resources.

Agricultural production requires balancing consumptive water use, competitive economic performance, and environmental protection. Canada is blessed with significant quantities of water and land resources, but the water is not always available when and where needed by agriculture. The country is beginning to experience new stresses and competition for water resources. Global warming, climate change, increased competition for water resources, and societal influences, will affect agriculture in the future. These complex issues are expected to require effective governance structures that include shared decision-making between agricultural players, other water stakeholders and the Canadian public; governance structures will need to facilitate water management decisions that benefit all of Canadian society.

Agri-environmental research and programming has been well-received by the agricultural sector and Canadian citizens. Producers have invested significant time and funds in the adoption of agricultural BMPs. Farmers and the agri-food industry have become active players in integrated water resource management activities in Canada. Should Canada find the means to continue agri-environmental research and programming efforts, the country will improve its capacity to adapt to present and future vulnerabilities, and be well-positioned to achieve sustainable development, environmental protection, and strong future agricultural economic performance.

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