

Report in Focus

WATER AND AGRICULTURE IN CANADA: TOWARDS SUSTAINABLE MANAGEMENT OF WATER RESOURCES

The agricultural sector is an important contributor to Canada's prosperity and well-being. Primary agriculture plays a vital role in the food sector which is linked to nearly \$100 billion per year in economic activity and approximately 1 in 7.5 Canadian jobs, in 2011. As the world's population grows, so does the demand for food. Rising incomes are causing a shift in global patterns of food consumption towards higher-value and more water consumptive forms of agricultural production, such as meat and dairy products. There is also increased demand for non-food agricultural products such as biofuels and natural fibres. Canadian agriculture is faced with great opportunities, but also important water-related risks and uncertainties.

A successful and growing agricultural sector in Canada requires access to sufficient quantities of fresh water. Although it is commonly believed that Canada has an abundance of water,¹ most of it is in regions where agriculture does not take place.² Many agricultural regions, including parts of the Prairies and British Columbia, are already water-stressed, and water quality is a concern in most of Canada's agricultural lands.^{3,4,5} While Canadian agriculture is largely precipitation-fed,⁶ some regions use irrigation to address deficits in the amount of precipitation, increase productivity, and, in some cases, improve product quality. Such uses can compete with other demands for water. Agriculture is the largest consumer of water in Canada, accounting for 66 per cent of total water consumption.⁴

The relationships between agriculture, water, the environment, and human well-being are complex and inter-related. Agriculture has changed much of our land area and can affect the environment in complex ways through irrigation, tillage, drainage, and other land and water management practices. While effects can be negative, important opportunities exist for agriculture to improve environmental quality. Increasing pressures on water quality

include agricultural practices which can lead to contaminated water and impaired ecosystem health, due to pesticides, nutrients from fertilizers and manures, veterinary products, and pathogens from animal waste,⁷ for example. While agriculture can affect water quantity and quality, the reverse is also true. Poor water quality can affect animal health, pesticide effectiveness, and efficiency of cleaning operations.⁷ Finally, agriculture faces challenges from the physical environment due to the uncertain impact of climate variability, including floods and droughts, and climate change. Increasing extremes are expected in a warmer world, and multi-year drought is of major concern.

THE CHARGE TO THE PANEL

To better prepare for the challenges facing Canadian agriculture, and seize the opportunities, Agriculture and Agri-Food Canada asked the Council of Canadian Academies (the Council) to conduct an in-depth assessment to answer the following question:

What additional science is needed to better guide sustainable management of water to meet the needs of agriculture?

The Council assembled a multidisciplinary expert panel (the Panel) of Canadian and international experts with backgrounds in hydrology, agriculture, climate, engineering, economics, and water management and governance. Dr. Howard Wheeler, Canada Excellence Research Chair in Water Security and Professor at the School of Environment and Sustainability at the University of Saskatchewan, chaired the Panel.

The Panel gathered and analyzed evidence on Canada's water resources, water futures for agriculture and other industries, agriculture and the environment, beneficial management practices from Canada and around the world, trends in technology and

innovation, public policy frameworks and economic instruments, and knowledge transfer strategies for land and water management. The Panel then drew on the combined expertise and experience of its members to conduct a comprehensive assessment in response to the charge.

TOWARDS SUSTAINABLE MANAGEMENT OF WATER RESOURCES

The international water community recognizes that our global well-being depends on the extent to which water is used and managed sustainably.⁸ Sustainable water management in agriculture can be defined as meeting “the social, economic, and environmental needs of present and future generations.”⁹ In its definition of sustainable management of water for the needs of agriculture, the Panel incorporated the five elements described in the Council’s report on *Sustainable Management of Groundwater in Canada*:¹⁰ i) protection of water supplies from depletion, ii) protection of water supplies from contamination, iii) protection



of ecosystem viability, iv) achievement of economic and social well-being, and v) application of good governance. The Panel then added a sixth element to its definition: integration of the needs of future generations.

Key Findings

The Panel identified five key areas in which additional science and action could contribute to sustainable management of water in agriculture.

1. **Achieve a better understanding of risks and uncertainties, in areas such as market conditions, competition for land and water resources, and climate change, to inform management decisions leading to more effective management practices and outcomes.**

To better understand future risks and uncertainties, the Panel examined the scientific evidence on trends and future possibilities up to 2050. Changing market conditions would likely result in new export opportunities, which require more water-intensive forms of agricultural production. At the same time, urban and industrial development and climate change would place greater pressures on land and water resources. The resulting intensification in the competition for resources could create social pressures on the agricultural sector to more effectively demonstrate its contributions to economic growth, food security, and environmental protection. Finally, regulatory and

non-regulatory risks could bring about changes to production methods and locations.

The Panel concluded that additional research was needed on changing market conditions, policies, and social perceptions; the implications of heightened competition for land, water, and other resources; and the impacts of climate change and increased climate variability. In particular, adaptive management strategies that could potentially help accommodate uncertainty in water futures should be better understood.

2. **Improve monitoring information targeted at specific areas of concern using a risk-based approach, as well as enhance scientific capacity for the interpretation of these data, to foster a better understanding of Canada’s water resource base and ongoing changes in hydrology, ecology, and climate, and to facilitate adaptive management.**

Most agricultural production depends on natural precipitation (rain or snow), sometimes called “green water.” Concerns about

"By developing forward thinking policies and effective land and water management strategies, adopting strong governance mechanisms, and harnessing technological advancements, Canada will be well placed to be a world leader in sustainably supporting the food demands of an ever growing global population."

– Howard Wheeler, Chair, Expert Panel on Sustainable Management of Water
in the Agricultural Landscapes of Canada

water for precipitation-fed agriculture focus on i) climate suitability for crop production, ii) land management to optimize the water environment for crops, and iii) the impacts of agricultural activities on the quantity and quality of surface water and groundwater systems.

Irrigation and other agricultural uses of water (e.g., intensive livestock production) rely on “blue water” — surface water sources or groundwater aquifers. The use of blue water often competes with other demands for water (e.g., drinking water, urban water use, industry, hydropower, maintenance of healthy ecosystems). Irrigation is essential for agriculture in areas where natural precipitation is low and/or variable, and can also generate increased productivity, diversity (high-value crops), and

product quality. Water stress is a serious threat to the health of the agricultural sector, whether related to the quantity or quality of water used by agriculture or flowing from agricultural lands (see Figure 1). Causes of water stress depend on local conditions. In parts of the Prairies, for example, irrigation is a dominant consumer of blue water in areas where water resources are fully allocated; and the region’s green water supply has been affected by major floods and droughts. In British Columbia, agricultural uses of water in some regions face significant competition from other users and the needs of the ecosystem – e.g., the Okanagan Valley, where agricultural activity depends on irrigation, is already nearing or exceeding the available water supply because of recent population growth.

With stress on water resources projected to increase, the agriculture sector must develop more efficient and sustainable methods for managing water use and consumption. Currently, Canada does not have the data or jurisdictional coordination necessary to fully understand the quantity and quality of its fresh water resources, or to adequately define current and future water needs for agricultural purposes.

The Panel recognizes that a risk-based approach to establishing water-monitoring priorities would allow Canada to maximize existing resources by focusing on activities that are likely to pose the greatest risk to water quantity and quality. However, a risk-based approach centered on historical observations alone will underestimate risks due to non-stationarity from climate change. Additionally, it is not physically possible, and may not be economically desirable, to monitor all possible risks. As such, the Panel concluded that an integrated approach to risk management is needed that combines monitoring, modelling and data analysis, and addresses the associated uncertainties. This can be best achieved within a framework of adaptive management. The Panel also concluded that the development of an integrated water and climate monitoring and forecasting capability could make substantial contributions to Canada’s ability to sustainably manage water for agriculture and mitigate climate-based risk.

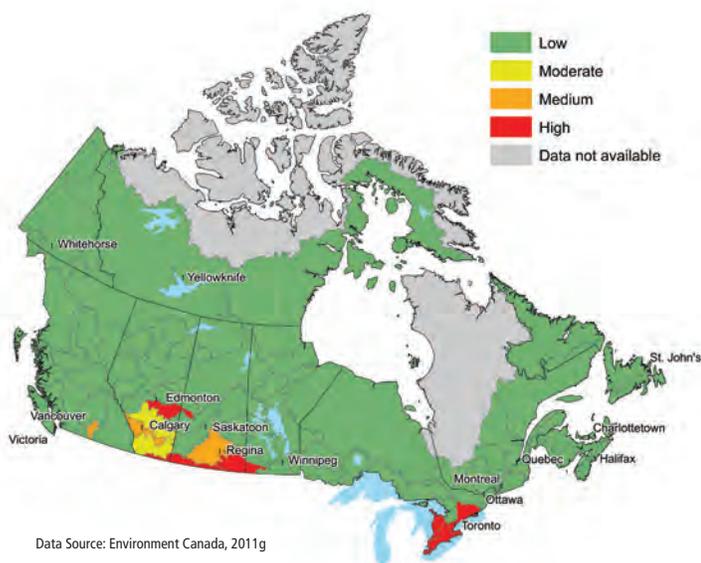


Figure 1. Threats to Water Availability by Sub-Drainage Area in Canada, 2007¹²

This figure illustrates the threat to water availability by sub-drainage area in Canada in 2007. There is a high threat to water availability in areas of south-western Manitoba, southern Saskatchewan, southern Alberta, and southern Ontario. There is also a moderate to medium threat in the Okanagan Valley of British Columbia.

3. Achieve a better understanding of the complex interactions between land management and water resources, including assessment of the economic and environmental efficacy of Beneficial Management Practices and the potential for conservation agriculture and ecosystems services approaches to management of natural resources.

Agriculture can affect the physical environment in complex ways through water management practices such as irrigation, tillage, and drainage. High nutrient loads, particularly nitrogen and phosphorus, are a major issue for water quality. While phosphorus affects surface water quality in the Prairies, in areas such as Prince Edward Island, nitrate concentrations in groundwater and some surface water sources exceed drinking water standards. Pressures like these are seen worldwide. A recent European study estimated that reactive nitrogen effects from agriculture cause between €20 billion and €150 billion of environmental damage per year. In comparison, the benefit of nitrogen fertilizer to farmers was valued at between €10 billion and €100 billion per year.¹¹ Pathogens, pesticides, and veterinary medicines can also have an impact on water quality.

As efforts to increase agricultural production intensify, issues pertaining to the impact of agriculture on water and the environment will become more pressing, exacerbated by population growth, urban expansion, and industrial development.



Beneficial management practices (BMPs), technological innovations, governance strategies, and policy tools provide important opportunities to manage the relationship between agriculture and the water environment so as to increase water use efficiency and enhance environmental protection. BMPs provide the context for two concepts with potential benefits and opportunities: conservation agriculture, which aims to create resilient, productive landscapes in the face of uncertain futures; and an ecosystem services approach, which recognizes the value of non-marketable services, such as flood control, water quality, and ecological diversity.

Quantification of the effects of agricultural land management practices on water quantity and quality and on ecosystem health, and the potential of BMPs to mitigate those effects, are important research priorities. Particular issues for future study and research include the local and regional impacts of changing cropping and tillage practices on runoff processes and water quality; the impacts of agricultural drainage and loss of wetlands on flood risk, drought resilience, water quality, and habitat at local and regional scales; and the potential effects of BMPs on nutrient loads in surface water and groundwater systems.

Addressing these issues would require targeted research in BMP performance and effectiveness, development of methods to encourage uptake of sustainable practices and technologies among stakeholders, and significantly improved data on the relationship between agriculture, habitat, and biodiversity.

4. Improve knowledge of promising farm-scale technologies and research priorities, contributing to better water use efficiency, reduced environmental impacts, and sound investment decisions by governments, industry, and agricultural producers.

Technological developments have had dramatic impacts on the overall productivity of agricultural systems, and experts are optimistic about achieving future improvements in productivity. Canada has a range of technological options relating to irrigation, precision and smart agriculture, pesticide and fertilizer formulation, low-cost water treatment, and many other areas that could contribute to maximizing opportunities and managing risks by improving water use efficiency, mitigating environmental impacts, and enhancing the productivity and resiliency of agriculture. For example, innovation in irrigation technologies

Canada has a range of technological options for irrigation, precision and smart agriculture, pesticide and fertilizer formulation, low-cost water treatment, and many other areas that present opportunities for the sustainable management of water resources for agriculture.

could improve water productivity and reduce runoff from agriculture by way of better controls on the timing and amounts of water dispensed through irrigation systems (see Table 1).

The Panel concluded that additional research was needed to better evaluate the various technological opportunities and understand the most appropriate options and priorities for each agricultural context. Finally, farm-scale demonstration programs designed specifically for stakeholders could effectively

Table 1. Examples of Technological Opportunities and Potential Benefits*

Technological Opportunity	Potential Benefits
Irrigation Technologies	<ul style="list-style-type: none"> Improved water productivity and reduced runoff from agriculture by way of better controls on the timing and amounts of water dispensed through irrigation systems.
Mulching	<ul style="list-style-type: none"> Increased crop water productivity. Reduced herbicide inputs.
Rainwater and Blowing Snow Harvesting	<ul style="list-style-type: none"> Infrastructure or land management techniques to allow for retention of rainwater and snow to enhance water supply and agricultural productivity.
Agricultural Water Treatments	<ul style="list-style-type: none"> Protect downstream water quality and ecosystem services. Enable re-use of irrigation water.
Use of Degraded Water Resources and Biosolids	<ul style="list-style-type: none"> Opportunities to conserve water and nutrients in local environments, reduce waste and environmental impacts, improve fertility of soil and water productivity, and expand geographic range of certain types of agriculture.

* A more complete list can be found in the full report.

demonstrate the benefits and practical application of these emerging technologies while helping to ensure successful deployment and increased uptake.

5. Build a foundation for sustainability by adopting appropriate governance structures, valuation techniques, economic incentives, and knowledge transfer strategies to facilitate better management decisions, improve uptake of sustainable practices, and enable the agricultural community to build strong working relationships with other sectors and stakeholders to resolve cross-sector issues.

Water governance in Canada is highly fragmented, with multiple levels of government holding or sharing responsibility. The increased and changing roles of non-government actors, indigenous peoples, civil society groups, and businesses have led to the emergence of new challenges relating to effectiveness, capacity, legitimacy, and accountability.

Due to differences in legal regimes, institutional settings, and socio-economic contexts across the country, no single framework for sustainable water management would be effective in all jurisdictions. Therefore, the Panel focused on principles and promising practices shown to be effective in supporting sustainable management of water resources, including:

- Ensuring governance operates at the appropriate scale to help facilitate coordination of management efforts across relevant jurisdictions and stakeholders;
- Integrating land-use planning with water management decisions to assist in incorporating the needs of multiple users while ensuring sustainable water management in the long term; and
- Incorporating knowledge and transdisciplinary research on the decision-making process to facilitate development of robust solutions that account for the complex and interconnected nature of current water management and governance challenges.

Agricultural policy strongly influences stakeholder decisions that affect water use in agriculture. Policies often strive to ensure the sector is economically competitive, while, at the same time, balancing and addressing environmental and social concerns. Experiences from across Canada and around the world demonstrate that economic instruments — when designed properly and implemented appropriately — can support the goal of sustainable water management. The Panel considered the potential contributions of economic valuation techniques, economic incentives, pricing, and water markets to sustainable water management for agriculture. Further investigation of how these tools can be used effectively in the Canadian context is needed, as are mechanisms to measure their success.

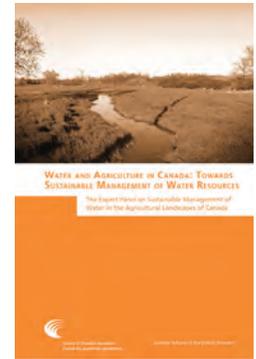
Incorporating the views and opinions of stakeholders in water governance decisions can strengthen governance mechanisms and decisions. Stakeholder engagement should both disseminate information to the public and encourage a sense of responsibility for the sustainable management of water. Consequently, the Panel concluded that research on knowledge transfer strategies, as they relate to agriculture and water use, could improve communication between decision-makers and relevant stakeholder groups. This would be critical for addressing the cross-sectoral issues that affect sustainable management of water for agriculture.

CONCLUDING THOUGHTS

The Expert Panel's report articulates the opportunities, risks, and challenges that exist at the intersection of agriculture and water and land management. The report focuses on critical issues for Canada and lays out five practical areas where additional science and action can contribute to better sustainable management of water in agriculture. The Expert Panel believes their assessment provides the evidence-based information and insights needed to support policy- and decision-makers as they consider how best to move forward to ensure a robust agricultural sector that is sustainably managed.

Inside the Full Report

- An overview of the global and Canadian contexts for water of agricultural use
- An assessment of the evidence on the quantity and quality of Canada's water resources
- An overview of the opportunities for better sustainable management of Canada's water resources, including BMPs, adaptive management strategies, conservation agriculture, and an ecosystem services approach
- A discussion of promising farm-scale technologies for improving water productivity and mitigating environmental impacts
- A review of economic tools to foster sustainable management of water, and the knowledge transfer strategies to enhance adoption of new policies, technologies, and BMPs
- An overview of the challenges in governance and management of water resources in Canada



Endnotes

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This Report in Focus was prepared by the Council based on the Report of the Expert Panel on Sustainable Management of Water in the Agricultural Landscapes of Canada.

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This assessment was made possible with the support of the Government of Canada