BLUE ECONOMY INITIATIVE

Better by the Drop:

Revealing the value of water in Canadian agriculture

This is the third in a series of reports prepared for the Blue Economy Initiative

Prepared by Hanspeter Schreier and Chris Wood

JUNE 2013

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Introductory Letter

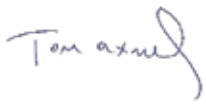
Canada is one of five countries capable of expanding its agri-food exports in order to ease increasing global demand for food. As such, we have a tremendous opportunity to develop a dynamic, innovative agri-food sector that will benefit our economy and the world.

However, because fresh water is a critical input in agriculture and agri-food production, Canada must also work to ensure food production does not come at the expense of sustainable water management practices. Better understanding the value of our fresh water resources will us help make informed decisions that increase water use efficiency, maximize productivity and mitigate environmental impacts.

The Blue Economy Initiative (BEI) invited Hanspeter Schreier and Chris Wood to outline opportunities for Canada to employ strategic approaches and tools to leverage existing water resources. This will ensure a thriving agri-food industry that is dependent on a sustainable water management model. The report offers a set of recommendations and actions for the public sector, in working together with relevant stakeholders, to enable the productive and sustainable use of water.

On behalf of BEI's founding members, I invite policy-makers, agri-food producers and other agricultural leaders to read and comment on this report, and join us in capitalizing on our strategic advantages while sustaining our fresh water resources.

Sincerely,



Dr. Tom Axworthy
Chair of the Blue Economy Initiative
President and CEO of the Walter and Duncan Gordon Foundation

Preface

The Blue Economy Initiative (BEI) is a national project founded by the Canadian Water Network, the Royal Bank of Canada, and the Walter and Duncan Gordon Foundation.

Our long-term vision is for Canada to have a prosperous future as a global leader in water sustainability. We advocate for a national and global "blue economy" that recognizes all economic development should be pursued within a water sustainability framework.

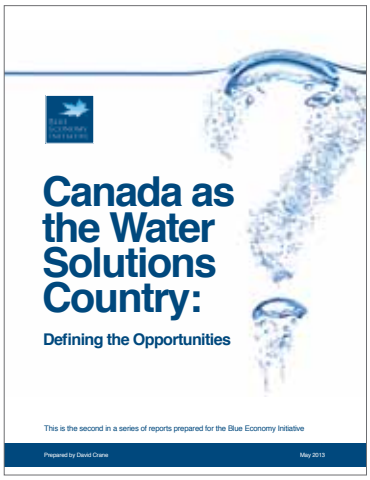
Our mission is to catalyze well-informed water management decisions, policies and practices that ensure maximum social, environmental and economic benefits, and our overall goal is to build the case for water sustainability.

By producing discussion papers and convening events, we intend to catalyze discussion and action that will strengthen our national understanding of the value of water, create broader awareness of the risks of failing to make sustainable decisions, and illustrate the opportunities and benefits of sustainable water management on a watershed, national and global scale.

Two feature reports have been prepared to date as part of a four-part series developed on behalf of BEI. These include:

1. A report by Steven Renzetti, Diane Dupont, and Chris Wood entitled **"Running Through Our Fingers"** looked at Canada's ability to adequately measure and account for the value that water contributes to our economy.

2. A paper by David Crane entitled **"Canada as the Water Solutions Country: Defining the Opportunities"** helped frame a national conversation around Canada's water-related strengths as well as emerging opportunities to become a global leader in water sustainability and innovation.



This third report in the series takes a deeper look at Canada's opportunity to increase its agricultural output in order to meet global demand for food, but also speaks to the responsibility we have to ensure the long-term sustainability of our precious fresh water resources. Virtual water and water footprint analysis are part of a suite of tools designed to better understand water use and impacts in agriculture, and help manage virtual water trade in support of strategic objectives.

The authors recognize the critical role of farmers, agri-businesses and food processors in managing water, and the need to look at the entire supply chain. However, this paper focuses on the agricultural production portion of the supply chain and makes recommendations for ways in which senior levels of government can help enable innovative management approaches at a watershed scale.

The paper also draws an important distinction between irrigated and rainfed agriculture. While virtual water analysis can be applied to both, the data and experience with virtual water approaches in Canada are considerably more prevalent for irrigated agriculture. As a result, the paper draws from examples in arid regions such as the Okanagan and southern Alberta that rely primarily on irrigation.

This work is based on research and analysis conducted by Hanspeter (Hans) Schreier and Les Lavkulich. Additional research can be found within the Virtual Water and Global Food Security Web-Application developed by Hans Schreier and Garwood Pang of the University of British Columbia.

Acknowledgements

The Blue Economy Initiative would like to acknowledge Hans Schreier and Les Lavkulich in conducting research and analysis that led to this report, and thank Hans Schreier and Chris Wood for writing this report on behalf of the Blue Economy Initiative. We are also grateful to Tim Morris, Korice Moir and Lynn Patterson for their significant contributions to this piece.

We would like to extend sincere appreciation to the following individuals for providing feedback, content and suggested improvements. These include Tony Allan, Shari Austin, Tom Axworthy, Bernadette Conant, Simon Glauser, David Hill, Eric Mysak, Sandra Odendahl, Brent Paterson, Jenn Willoughby and Anna Warwick-Sears.

Thank you also to University of Waterloo Creative Services for graphic design and layout.

Note on Authors

Hanspeter (Hans) Schreier is a professor in the Faculty of Land and Food Systems at the University of British Columbia. His research focuses on watershed management, land-water interactions, soil and water pollution, and geographic information systems. He has worked extensively on watershed studies in many mountain regions of the world. He developed a web-based Certificate Program in Watershed Management for graduate students and professionals, and was co-leader of the Watershed Program of the Canadian Water Network National Centre of Excellence. In 2008, he received the King Albert International Mountain Award for scientific accomplishment of lasting value to the world's mountains. Hans has also received numerous awards for his contribution to improving water resources management, including from the International Development Research Centre; Landcare Research in New Zealand; and United Nations International Year of Fresh Water, Science and Education Program. **http://wmc.landfood.ubc.ca/Schreier**

Chris Wood is a journalist, author and editorial consultant with four decades of experience in print, on radio and the Internet. For 16 years he held positions at Maclean's Magazine including senior writer and national editor. For the past decade, his work has concentrated on the future survivability of Canadian society in an era of climate change and environmental overdraft. He holds nearly a score of national and regional awards for journalism and his books have been nominated for the Donner, Shaughnessy Cohen and B.C. Book/Hubert Evans prize. Chris is also the coordinating editor for the Tyee Solutions Society, an investigative journalism non-profit associated with Vancouver-based news outlet, **www.TheTyee.ca.** His most recent book, "Down the Drain: How We Are Failing to Protect Our Water Resources," written with Ralph Pentland, appeared in June, 2013, from Greystone Books.

A copy of this report is available at **www.blue-economy.ca**.
For more information, or to share comments, please e-mail us at **info@blue-economy.ca**.

Executive Summary

The world faces unprecedented food shortages as global demand for nutrition is set to double by 2050. Canada is one of very few countries that can expand its agricultural exports in a significant way. This presents our nation with a major economic opportunity and a significant responsibility.

To capitalize on this opportunity and help feed the world, we must invest in our agri-food sector in an intentional, responsible and effective way, recognizing fresh water as an essential input in agricultural production. Without water, there are no crops, no livestock, and no agri-food industry.

This means Canada must implement strategies typically associated with the world of finance – **leverage** (maximizing the productivity of limited fresh water) and **arbitrage** (allocating water to a preferred mix of agricultural production and processing) to ensure water is used strategically and sustainably. Governments and water managing bodies must support and enable farmers and ag-producers so they can appropriately adjust and innovate around water use.

When it comes to water, we have a comparative advantage over much of the rest of the world. Many countries, including some other large agricultural producers, are experiencing severe competition for fresh water resources, as well as declines and/or interruptions in the availability of fresh water during droughts, floods and other disturbances. Water scarcity is reducing their capacity to produce food and threatening to destabilize their economies.

However, Canada's fresh water endowment is not immune to limits and constraints. Our most productive food growing regions happen to be our driest, and are at risk of becoming drier. If we do not adequately consider the fresh water requirements and impact of agricultural expansion, we may not only jeopardize this advantage, but also put Canadian farmers and the agri-business sector at greater risk.

Other countries, such as Australia, Saudi Arabia and China, face severe water shortages and closely monitor their fresh water resources and balance of virtual water trade – the water used to produce imported or exported food or other goods. They are making strategic determinations as to the type and quantity of agricultural products they want to grow based on the availability of fresh water and competing economic uses. As a result, there is great potential to maximize the productivity (i.e. crop yield per unit of water) of existing water supplies, and balance domestic agricultural production and security with food imports, particularly where greater value can be derived from using water for other purposes.

For Canada to reach its potential to become a long-term competitive player leading the global agri-food market, we must be equally strategic — making use of a suite of approaches and tools including virtual water and water footprint analysis to help guide decisions that maximize the value of our fresh water resources, and allow us to make cropping and water use decisions and practices best suited for different watersheds.

> Of this we may be sure: Man must eat to live, and the problem of food will always be inextricably associated with water." – Thompson King, Water, Miracle of Nature

Water, land, climate and talent are necessary advantages in Canada's agri-food opportunity. But they are not sufficient. To reach our economic potential and meet global obligations, Canada must also field the full suite of emerging tools and innovative technologies and practices to ensure we produce and export food that is water efficient, of high value and quality, and has minimal environmental impact.

An appropriate strategic approach will generate jobs, strengthen the national economy, and ensure the health of our precious rivers, lakes and groundwater. We have a tremendous opportunity to create a dynamic, innovative and world-leading agri-food sector, one that makes informed choices, is highly productive, demonstrates resilience and ability to adapt to changing conditions, and supports a healthy environment.

This report aims to inspire dialogue around ways to develop and operationalize a more strategic approach to water use and management in agricultural production. A multitude of actors will need to be involved in this strategic approach, from the local farm level to the multinational food processor. Many of the key actions should take place at a regional watershed or basin-wide scale. However, the primary focus of our recommendations is on the role that the public sector—the federal and provincial governments—can play in enabling and supporting these other actors in applying virtual water approaches and innovative management practices.

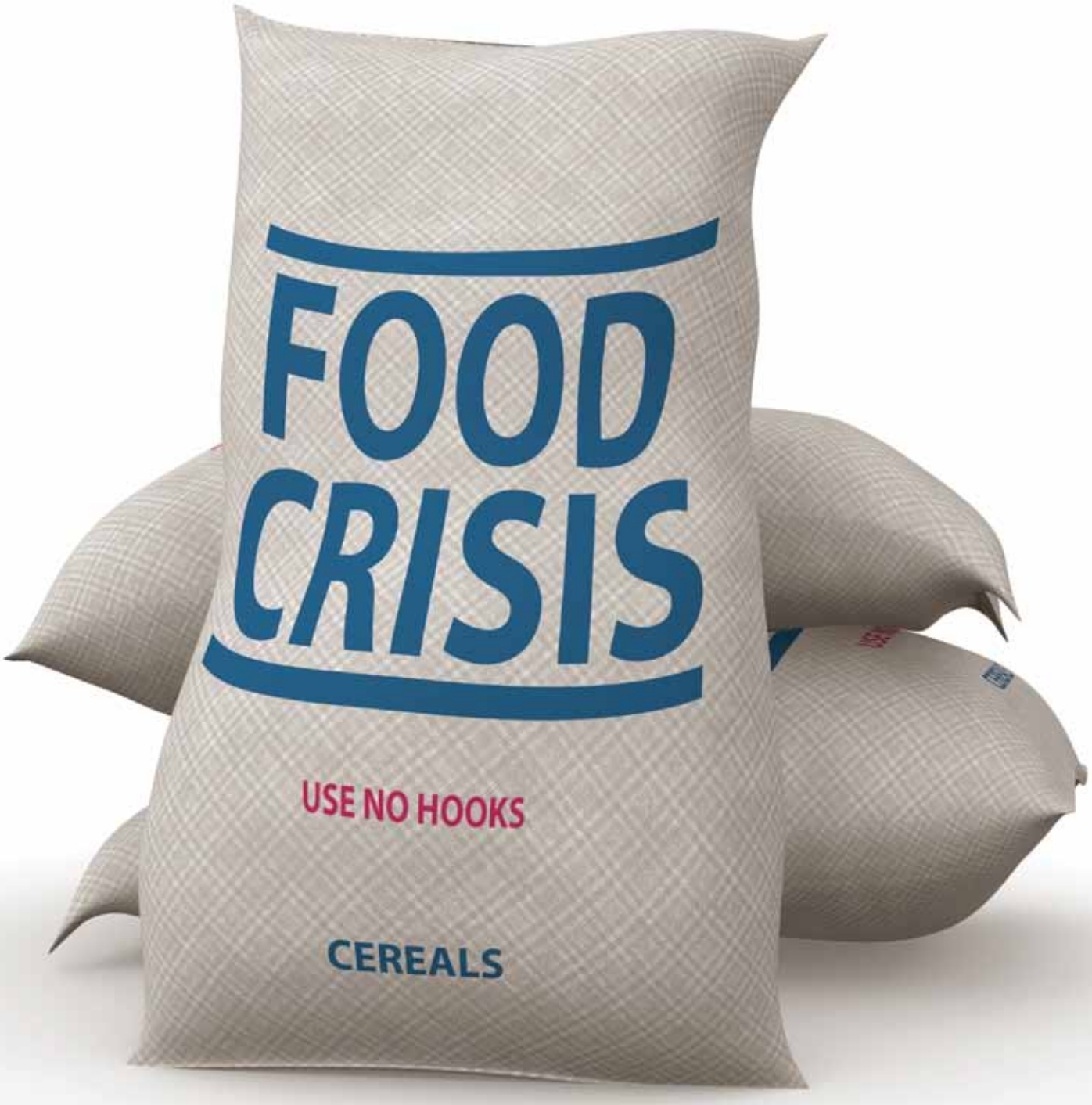
Recommendations

The following recommendations outline practical action areas where governments can lay the groundwork for a more strategic approach to water use in Canadian agri-food production.

	ACTION
01 **Develop Drought/Flood Contingency Plans**	• Enable development of watershed-specific drought (and flood) contingency plans to identify (in advance of drought conditions or flooding) which crops can be substituted during short and long term periods of water scarcity or excess, when to reduce crops grown for export to support domestic supply, and/or when to reduce irrigated acreage.
02 **Provide Incentives for Innovation in Water Efficiency**	• Provide financial incentives to trial innovation in agricultural technologies and practices for water efficiency. • Provide financing that supports and encourages widespread adoption of innovative technologies and practices. • Identify perverse subsidies that encourage the production of low value, water intensive crops in water scarce areas, and reduce or remove these subsidies.
03 **Establish Virtual Water and Water Footprint Analysis Pilot Projects**	• Designate at least two regions as pilot projects that would receive funding and support to operationalize virtual water and water footprint analysis in specific river basins.
04 **Create a National Virtual Water Inventory and Risk Assessment Tool**	• Develop a national inventory at the river basin scale for virtual water and water footprint requirements of the Canadian agri-food sector, beginning with 20 key crops, calculating amount of water required, percentage of irrigated crops, etc. • Prioritize economic and trade research to track origin, destination, and volume of international virtual water exports. • Conduct water footprint analysis of all exported commodities to show where efficiency gains are possible. • Identify areas where food exports are placed at considerable risk. • Ensure virtual water evaluations are made within a watershed or river basin context, and consider blue, green and grey water components.

ACTION

05 **Support Farm Level Research, Education and Access to Information**	• Revitalize Agricultural Extension Services and provide capacity for farm level research, education and access to information through government staff and agricultural universities. • Work with stakeholders to ensure educational programs are instituted to research and transfer knowledge of virtual water and water footprint analysis tools at the farm level, and provide information and education on water stewardship, conservation and efficiency in an easily accessible format.
06 **Implement True Cost Accounting to Capture Externalities**	• Work with agricultural industry to determine most effective and equitable way to capture externalities and ensure that agricultural practices reflect the full costs of food production, including environmental costs.
07 **Evolve Toward Full Water Footprint/Life Cycle Assessment**	• Prioritize funding for research and demonstration projects that undertake full life cycle assessments of the production and processing of specific food items, and identify ways to reduce water use and evaluate responses throughout the supply chain.


FOOD
CRISIS
USE NO HOOKS
CEREALS

1. Introduction

No global challenge of the 21st century is greater than the exhaustion of the essential resources that support the basic human requirements for food and water. Converging trends in climate, population and economic growth all point to a looming crisis in humanity's capacity to feed itself. These conditions present Canada's agriculture and agri-food producers with unprecedented opportunity—and risks.

Although varied conditions exist across the country, Canada's geography and climate provide our nation with significant comparative advantages. We are among the world's agri-food exporting giants. However, current practices in the most productive regions have already utilized—or in some cases over-utilized—the available supply of the most critical input to agricultural output after land: fresh water. In fact, our fresh water resources are strained and fragile.

So, while Canada is one of a handful of nations in a position to expand its agri-food output significantly, decisions to expand agricultural production must carefully consider competing demands for water to ensure additional water use does not diminish or contaminate current fresh water supplies. We can only remain and grow as an agri-food giant by using our water more strategically, and by supporting and enabling sustainable decisions. We simply cannot do it by using water more voraciously.

Chapter 2 considers the key trends affecting global food availability, including ever-increasing demand for food, declining availability of land, and growing scarcity of fresh water.

Chapter 3 highlights some of Canada's agri-food opportunities, competitive advantages, and areas needing attention.

Chapter 4 outlines the risks and impacts of agricultural production if we ignore the limits of our water supply, with particular attention paid to geographic differences across the country.

Chapter 5 describes virtual water analysis as a framework for understanding and maximizing Canada's economic and strategic fresh water advantage. It highlights how other countries, as well as select regions of Canada, are applying leverage and arbitrage techniques to help reveal the value of water in agriculture.

Chapter 6 we close out the report by offering a set of recommendations and specific actions for discussion to help develop and operationalize this strategic framework.

2. A Hungry, Hot & Thirsty New World

In this chapter, we consider the key trends affecting global food availability. The combination of these trends—including demographics, economics, and climate—points to an increasing imbalance between global food supply and demand.

The world's grain stock buffer against large-scale starvation has plummeted since 2000—down by half in the case of corn, by 40 per cent in that of rice, and a third for wheat.[1] "Even in a good year," the World Banks' senior agronomist, Marc Sadler, told the BBC in October 2012, "we just about produce enough food to meet consumption needs."[2]

Food Demand Climbing

Three main factors contribute to the growth in food demand: rising populations, changing diets, and urbanization.

Population Growth

The United Nations forecasts the addition of another two billion people to humanity by 2050—increasing the number of mouths to feed from a finite planet by more than 28 per cent.[3] Another 900 million people are currently underfed, and their needs must also be met.[4]

Changing Diets

Hundreds of millions of people in Asia and Latin America are entering the middle class and demanding diets richer in meat, which take more resources to produce than grains or vegetables. A kilogram of beef, for example, requires on average five to eight times as much water to bring to market as a kilogram of rice or soybeans.[5]

Urbanization

Residents of the world's growing cities lead those who are demanding more protein-heavy meals. Unlike many rural populations, city-dwellers rely on others to provide their food. An estimated additional three billion people will live in cities between now and 2050 and the current push for urban food production is unlikely to provide enough to meet urban food demand.[6]

To meet these demands, the output of global agriculture will need to increase between 50 to 100 per cent by 2050.[7] That is the equivalent of every farmer in every country as much as doubling their harvest or livestock production over the next four decades.

This would be challenging enough, even if the critical inputs of food supply—land available for farming, growing conditions, water supply, and climate —remained stable. But all of these are changing, and that compounds our challenge.

Of course, growing more food is not the only solution to feeding the world. It is estimated one-third of food produced for global human consumption is wasted or lost.[8] The global food supply could be increased significantly if we addressed issues of waste and spoilage. Further refinements in irrigation technology, plant cultivation, plant strains and animal breeds, along with reducing meat consumption could also help balance food demand with supply.

Available Cropland Declining

Four key threats are encroaching on cropland throughout the world: urban expansion, rising oceans, soil degradation, and the repurposing of acreage for bio-energy production. These factors are combining to sharply reduce the land area available for food production in many regions.

Urban expansion

Cities around the world are expanding—with the fastest growing cities located in developing countries. Historically, many such cities are also located in prime farmland. Every year, an estimated 65,000 km^2 of agricultural land—an area larger than Prince Edward Island—disappears under highways and building sites.[9] Over the next two decades a further 300,000-600,000 km^2 of cropland is forecast to be lost from food production.[10]

Rising Oceans

As sea levels rise, saline groundwater intrudes into fresh water aquifers, rendering them unsuitable for irrigation and sometimes contaminating surface soils as well. Eventually, coastlines retreat, reducing absolute farm acreage. Vietnam and Thailand, near neighbours in the low-lying Mekong River delta and suppliers of most of the world's rice stocks, are especially vulnerable. Rice-growing areas of Texas and Louisiana along the Gulf of Mexico are confronted with the same outlook.

Soil Degradation

Currently, one billion people who are adequately fed are in danger of losing their subsistence as a quarter of the world's arable soils degrade.[11] Short-sighted land management choices such as stripping foliage cover, salinization from excessive irrigation using groundwater, and poor tillage practices, compounded by erosion

from increasingly violent rainstorms, are reducing the fertility of formerly productive farmland.[12] The WorldWatch Institute has estimated that because of these and other factors, an area equivalent to twice Canada's entire inventory of arable land has been taken out of food production since 1945.[13]

Bio-Energy

More than a tenth of the growing land in developed countries has been diverted from food to fuel in an effort to shift industrial economies to "green" bio-energy.[14] Similar trends are at work in developing countries, where large-scale agricultural land concessions have been granted for biofuel production. In one case, the Saudi Arabian Eastern Renewable Fuels Corporation acquired 2.2 million hectares (ha) of farmland in the Philippines for biofuel production.[15] A study by the World Bank predicted "significant" negative impacts for food harvests from the conversion of cropland to biofuel production in sub-Saharan Africa, India and Latin America.[16]

Fresh Water Scarcity Increase

Without water, nothing can grow. Unfortunately, there are a trio of factors curtailing fresh water availability in many of the world's traditional 'breadbaskets': climate change, water pollution, and groundwater overdraft.

Climate Change

As average global temperatures rise, many food-producing regions are experiencing a 'double whammy' of declining precipitation, compounded by sharp increases in evapotranspiration, especially during summer growing seasons.

For example, Australia has seen the water supply in its most important farming region—the southeastern Murray-Darling River basin—decline by half from the average of the last century; in one two-year period it dwindled to one-tenth of the 20th century mean.[17] On the other side of the world, the European Environment Agency forecasts that foreseeable climate-induced water shortages will reduce crop yields by 15-25 per cent in Spain and Greece, and by 5-15 per cent throughout Italy, southern France and the Balkan region, by 2050.[18]

It is also worth noting that some crops are highly sensitive to temperature change irrespective of soil moisture. Certain crops require a cold dormant period to trigger their reproductive biology. The production of these crops will likely decline in areas where temperatures are rising. For example, nut and fruit trees in California's vastly productive Central and Coachilla Valleys are in this category,[19] as are the wheat fields of India's main grain-growing region in the Punjab.[20] This is particularly problematic for rainfed agriculture.

The concept of climate stationarity was never a relevant concept for agriculture, but there is mounting evidence that climatic variability is increasing. It is not just global warming but the emergence of extreme events, such as the frequency and intensity of droughts and floods, that needs to be considered in all future decisions related to food production. Both floods and heat waves can have devastating effects as shown by the recent floods in Manitoba in 2011, and the heat shock from extreme temperatures in Texas and the Mid-West between 2011-2012.

Water Pollution

In many agricultural areas, contamination is rendering fresh water unsuitable for use even where it appears to be available. Two million tonnes of industrial, agricultural and human waste are discharged into the world's rivers every day.[21] According to the United Nations, the amount of contaminated wastewater entering the environment annually is estimated at 1,500 cubic kilometres.[22] In Asia and Europe, inadvertent releases of industrial wastes have contaminated major stretches of important rivers for weeks at a time. In developing countries, it is estimated 70 per cent of industrial wastes are disposed of untreated into surface water supplies.[23] Of all the land use activities, agriculture is now considered the largest contributor of non-point sources of pollution.[24]

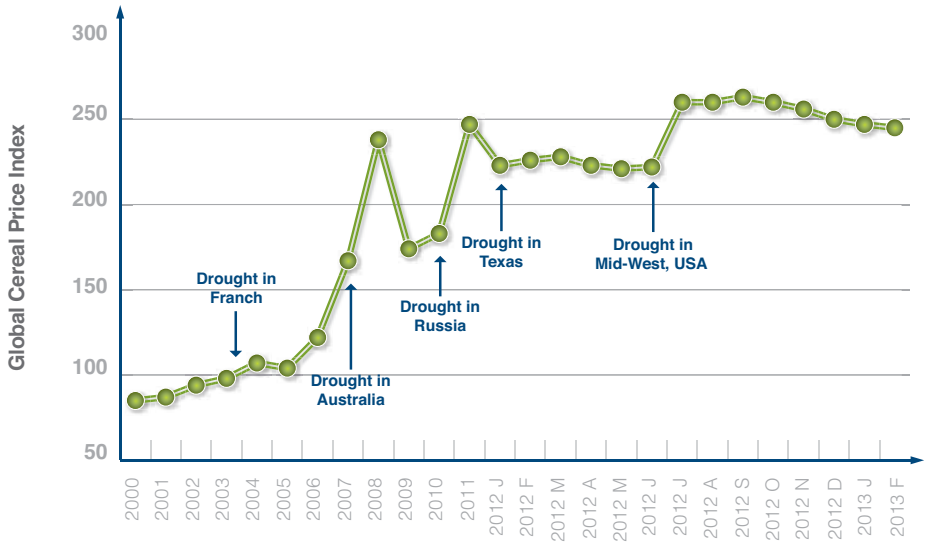
Groundwater Overdraft

A final threat to global food production is the overdraft of groundwater to support staple agriculture, particularly in China, India and the United States. As aquifers decline, more energy is required to pump the vast volumes of water needed to irrigate crops. At a certain point this becomes uneconomical. In India, so many irrigation wells have been abandoned that unattended bore-holes have become a serious rural safety hazard.[25] Unabated over-extraction means that most, if not all, farm regions that now rely on groundwater will eventually find it is no longer economical to do so. As a result, even less land will be available for food production.

System Shocks

The above accumulating hazards ratchet up the odds that a harvest failure severe enough to rattle global markets will occur somewhere in the world in any given year. The results can be read in amplified market volatility, as price chases supply for essential foodstuffs. A series of extreme climate events over the past 10 years in key food exporting countries have had clear impacts on the global market, resulting in significant spikes in the global grain (cereal) price index.[26]

Figure 1: Changes in Global Cereal Price Index



Source: FAO (2013)

Summary

Although there are a number of global trends contributing to the increasing imbalance between global food supply and demand, such as growing and changing demand for food, declining availability of land, and increasing scarcity of fresh water resources, Canada has an opportunity to make strategic decisions to mitigate and adapt to these factors. International trade in food and virtual water trade must play an expanded role to help capitalize on opportunities and resolve both transient and permanent imbalances.

Each year raises the risk that one of the world's 'market-making' agricultural regions will experience extreme weather that reduces its harvest.

Here are some recent examples:[27]

- In **2012**, the worst drought in half-a-century desiccated more than six-tenths of the continental United States, slashing harvest expectations. With 70 per cent of the country's standing corn rated as "poor" or "very poor" in quality in the Mid-West heat,[28] prices for the sharply reduced harvest climbed 55 per cent between mid-June and the end of July.[29]

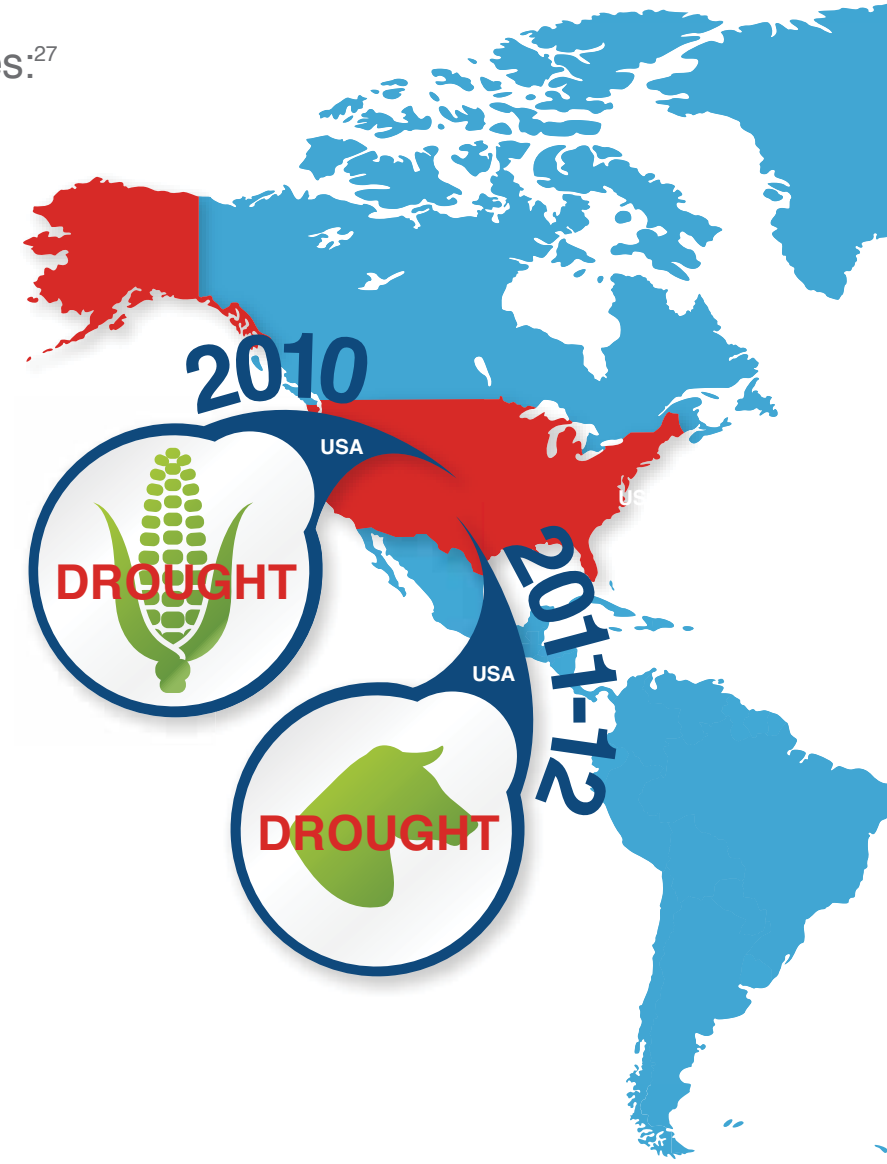
- As drought deepened over **2011-2012**, Texas ranchers slaughtered herds and moved a quarter of a million animals to literally greener pastures in Nebraska. When drought persisted into 2012, US officials predicted that consumers would soon face a knock-on bump of four to five per cent in the price of beef.[30] On international markets, the US drought drove corn prices up 23 per cent in a month. Coincidentally, wheat prices jumped nearly 20 per cent on news of extreme heat in Russia and the Ukraine.[31]

- Over several weeks in **2011**, Thailand experienced twice as much rainfall as normal. Worsened by deforestation and degraded wetlands, incautiously managed dams and impervious surfaces in urban areas, flooding paralyzed 12 per cent of its rice production.

- **2010** was the summer of Russia burning. Temperatures sizzled to heights never before recorded and forest fires shrouded Moscow in smoke. Wheat shriveled on the stalk. In August, the world's number five wheat exporter in 2007 suspended all wheat export shipments—freezing some 10 per cent of global supply. Within a month, the FAO Food Price Index had jumped by 50 per cent.[32]

- Australia's 'Long Dry,' a seven-year drought in the Murray-Darling watershed that lasted until **2009**, reduced its water for agriculture in some years to a tenth of 20th century averages. Wheat and rice production fell by half.[33]

- Europe's **2003** heat wave, which caused an estimated 35,000 human deaths, also reduced the continent's corn, wheat and barley harvests by 10-15 per cent. Production of livestock fodder collapsed by a staggering 60 per cent.[34]




2003
Europe
HEAT WAVE
2010
Russia
HEAT & FIRES
2011
Thailand
FLOODING
2002-09
Australia
DROUGHT

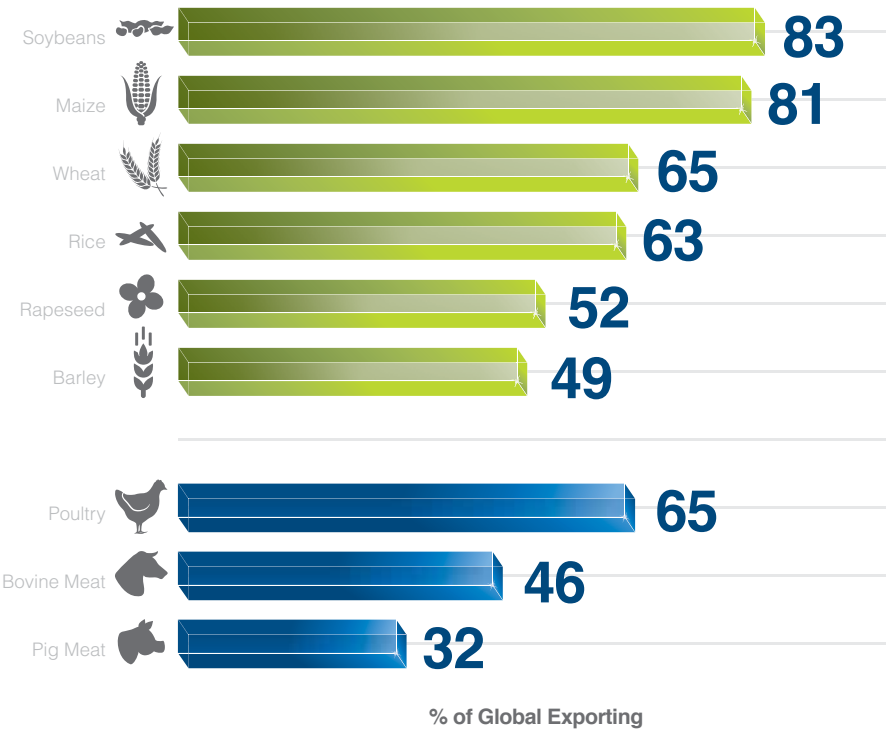
3. Canada's Agri-Food Opportunity

Global food sales are worth roughly $1.3 trillion,[35] and that value is certain to grow in the decades ahead. Canada has the potential to move to the front of the pack in meeting this market opportunity.

Of the 193 countries on Earth, nine supplied two-thirds or more of the most important food commodities traded internationally in 2009.[36] The United States, Brazil, Canada, Argentina, Australia, Russia, France, Thailand and Vietnam supplied most of the world its soybeans, maize (corn), wheat and rice.[37] This list of countries will shrink even more in the years to come.

Figure 2: Percentage of Global Export in 2010 by Nine Countries

Argentina, Australia, Brazil, Canada, France, Russia, Thailand, Vietnam, USA



Source: FAO (2011)

Five Countries to Feed the World

ONLY FIVE COUNTRIES possess the 'Goldilocks' combination of relatively ample precipitation and low ratios of population to arable land, which would allow them to significantly increase food production: Canada, Brazil, Argentina, Russia and the United States. .

There is a relatively simple formula for a country to be a successful food exporter. It needs:

- sufficient fertile land and water;
- suitable climate for the key export commodities;
- reliable infrastructure; and
- efficient commercial and financial services.

National harvests must also exceed domestic demand by margins great enough to provide a surplus for foreign sale. China and India are among the world's top agricultural producers, but between them they have 2.5 billion citizens to feed: nearly a third of humanity.[38] As such, they are unlikely to add materially to international food supplies.

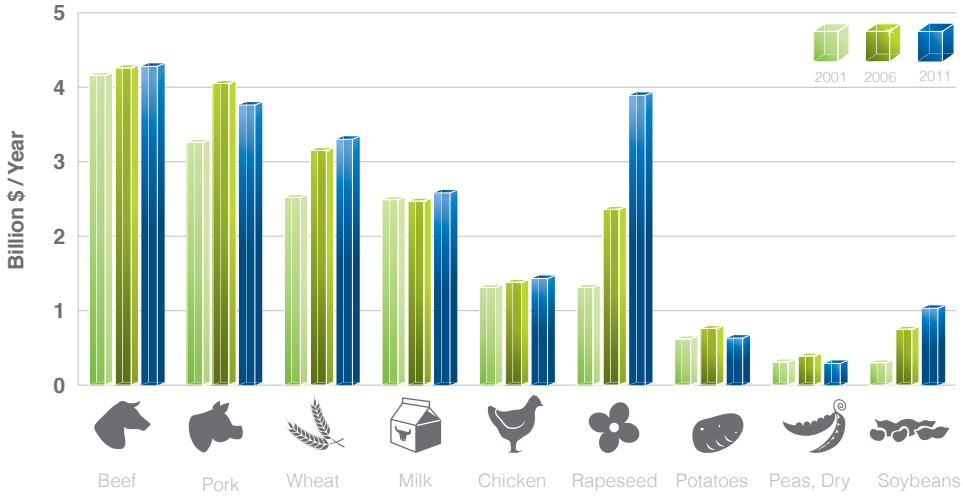
Africa has large land areas that could be brought into more intensive agri-food production. But it lacks irrigation and sophisticated transportation infrastructure, and competitive commercial and financial services, and suffers widely from political instability. Large areas of sub-Saharan and southern Africa may also be on the receiving end of anticipated climate change. While the continent has recently been targeted for large-scale land leases by international investors, the operations being established under those arrangements often feature locked-in commitments to particular markets (e.g. China) and are controversial in their impacts on indigenous residents.[39]

Meanwhile, not all of today's food export superpowers are able to expand agricultural output to meet rising global demand. Australia's most intensively farmed region—the Murray-Darling watershed—faces declining water resources, reflected in a recent shift to less water-intensive agricultural exports (see Section 5). France has adequate water, but its landscape is already intensively farmed. Neither is likely to increase food exports dramatically. The same is true, barring unforeseen breakthroughs in plant science, for the rice-basket nations of Thailand and Vietnam.

Our Top Food Exports and Exporting Regions

Canada is already considered a top food provider. Canada is ranked number one in global production of lentils, peas, linseed, and rapeseed (canola), and second in oats and blueberries by the United Nations.[40] **Agricultural production is estimated to contribute $139 billion annually to Canada's economy.**[41] In 2011, beef was the most valuable commodity in Canada, followed by rapeseed, pork, milk and chicken. Over the past 10 years, the greatest gains in value were made in rapeseeds, wheat and soybeans.

Figure 3: Value of Food Commodities Produced in Canada Between 2001-2011

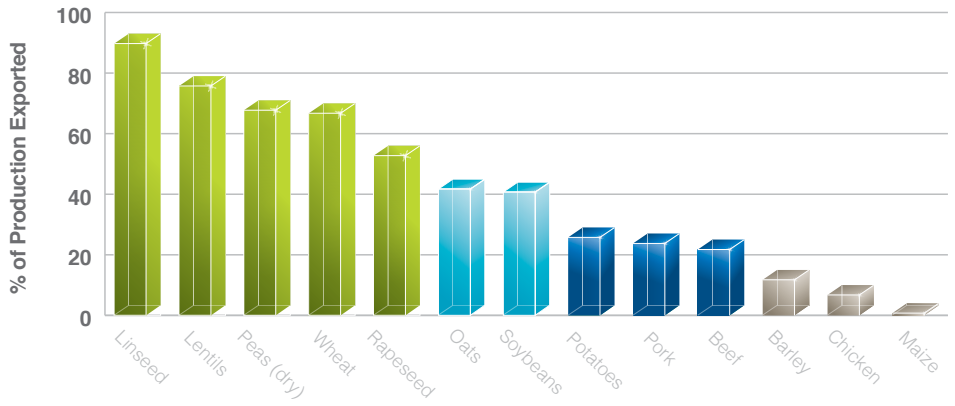


Source: FAO (2011)

In 2011, Canadian meat production (beef, pork, chicken combined) had by far the highest values, reaching $ 9.6 billion. Beef topped the ranking with $4.3 billion, with pork in third place ($3.8 billion), and chicken in sixth place ($1.5 billion). The only crops that reached the top rankings were rapeseed (second with $3.9 billion) and wheat (fourth with $3.3 billion).[42]

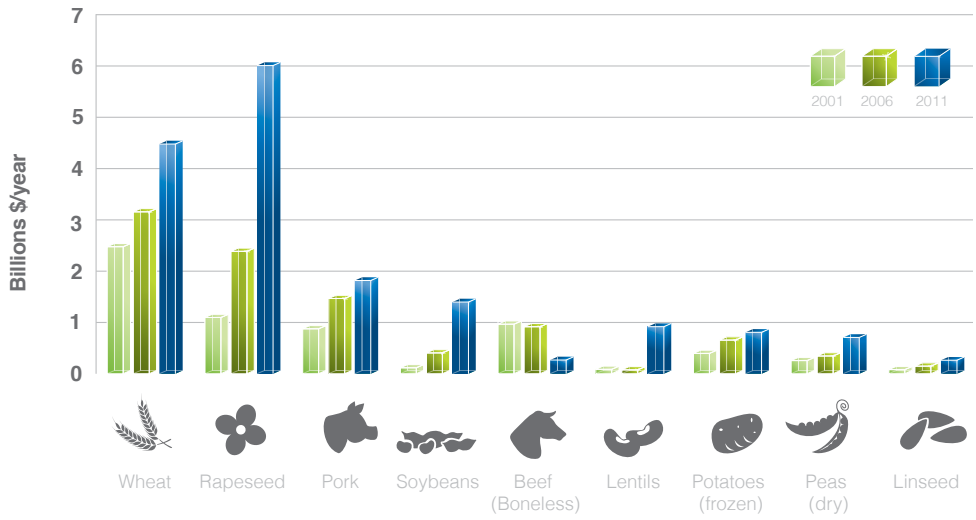
In terms of food exports, Canada leads internationally in a number of commodities. Our country ships more than half the peas, lentils and linseed (flax seed) available to other nations, and roughly a third of the world's canola. Thanks to substantial production increases, in 2010 Canada was the world's second-largest exporter of pork. These, along with nine other top sellers, earn Canadian farmers and shippers some $20 billion every year.[43] Canada exports between 56-93 per cent of its national production of key food commodities.[44]

Figure 4: Percentage of National Production Exported from Canada (Mean Value 2000-2010)



Source: FAO (2011)

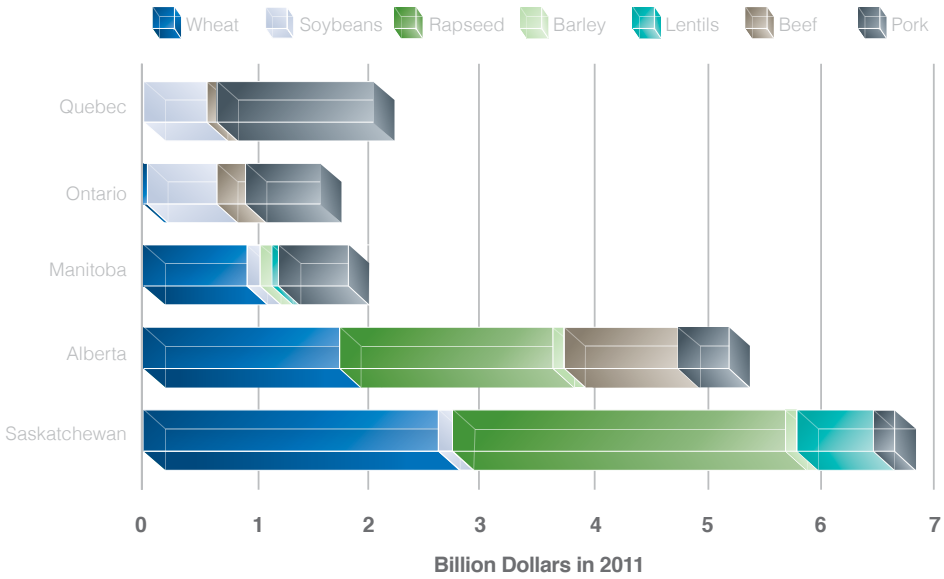
Figure 5: Value of Top Food Commodities Exported from Canada 2001-2010



Source: FAO (2011)

Five provinces grow the lion's share of these commodities. Alberta alone produces 73 per cent of Canada's exported beef. Saskatchewan and Alberta together grow between 83 and 88 per cent of the wheat, canola and barley shipped abroad. And Manitoba, Ontario and Quebec, together, produce 83 per cent of exported Canadian pork and 95 per cent of exported soybeans.[45] This concentration of export production in a few provinces is also of concern as it means a major flood or drought in a single province could greatly disrupt the agricultural export industry.

Figure 6: Value of Exports of Major Food Commodities by Province in Canada (Billion $ in 2011)



Sources: Statistics Canada (2012) and Agriculture and Agri-food Canada (2012).[46]

Canada's Competitive Advantages

Canada's irrigated agriculture takes place primarily in the three western provinces of Saskatchewan, Alberta and British Columbia. Manitoba, Ontario, Quebec and the Maritime provinces primarily rely on rainfed agriculture. Only Alberta and British Columbia have good statistical information on the areas under irrigation, but determining the amount of crops produced nationally from irrigated versus rainfed agriculture is difficult. This is particularly challenging when trying to produce virtual water data for exported food commodities.

1. Water

Canada's comparative advantage is most striking when it comes to water. With some 3,300 km^3 of annually renewable water,[47] we are ranked third in the world on a per capita basis after Brazil and Russia. However, our water is unequally distributed and the bulk of it is not in key food producing areas. While renewable water on a per capita basis looks impressive, we must also be wary of perpetuating a "myth of abundance". As outlined in the next chapter, not all of our water is accessible or in the right places for agricultural production, and increased climatic variability will likely provide new challenges.

2. Land

With fewer people than any of the four other global food super-states, and more land surface than all but Russia, Canada boasts the second highest ratio of arable land per capita within this group of five, bettered only by Australia.[48] Even accounting for anticipated population growth, Canada will still boast nearly 1.2 ha per capita of arable land by 2050—twice that of Argentina and almost three times the United States' ratio.[49] Due to falling population, Russia's per capita land resource may increase by mid-century, but will still be less than Canada's.[50]

3. Growing Seasons

Growing seasons in some parts of the Canadian Prairies have been extended by two weeks or more[51] due to warming in the continental interior and at higher latitudes. That expands the crop choices available to farmers; for the first time, corn is a viable alternative to wheat in southern Manitoba and Saskatchewan. Similarly, warming summers may allow farmers to move into some of the high-value specialty crop niches that competitors in California are being forced to abandon.

4. Infrastructure

Canada's agri-food sector enjoys a well-known and respected national identity, well-established producers and producer associations, and sophisticated intermediary sales, finance and distribution services for agricultural commodities. Some of its commercial brands (such as McCain Foods Inc.) are among the world's largest. Canada's transportation and shipping infrastructure is competitive with any other exporting nation. All these factors equip Canada well to secure a growing share of the expanding global market for agricultural commodities. However, water infrastructure is aging and in significant need of replacement. Water use efficiency is one area where Canada is far behind other nations.

Areas Needing Attention

Geography, climate and infrastructure give Canadian agri-food producers significant advantages. Nonetheless, agricultural productivity has languished in Canada in recent years—especially in contrast to the United States—while our market share has slipped in several commodity categories.

To address these concerns, the Macdonald Laurier Institute has urged that public policy shift from a focus on farm income support and supply management, to productivity enhancement and farm-size rationalization.[52] The Conference Board of Canada, in research informed by some of the country's largest agri-food operators, echoed those recommendations and drew attention to additional issues of food safety and security, as well as lackluster industry innovation.[53]

The Council of Canadian Academies has underscored the pressing need for more "risk-based" scientific research into the role of factors ranging from market dynamics to the connections between land use and water resources.[54] The independent Canadian Agri-Food Policy Institute asserted in 2011 that "a new partnership among industry, government and the health community" focusing on "food systems" rather than sectors could double the value of Canadian farm exports, to $75 billion, by 2025, while also increasing Canadian domestic food security, and powering 75% of agricultural energy requirements from biofuels.[55]

More historic concerns relate to our relatively long winters that make double annual cropping difficult, and restrict the range of crops than can be produced. The transport distances to various markets are also a deterrent.

All these are valid concerns, but Canada has yet to fully address the sector's critical vulnerability to limits on or interruptions in the availability of an essential prerequisite of agri-food production: fresh water.

In the absence of water, all these other factors are moot.

Summary

Fewer than 10 countries supply the world with the bulk of its internationally traded staple food commodities. Of those, only five enjoy sufficient ratios of arable land and fresh water to domestic populations to be able to significantly increase their food exports, and Canada is one of them.

Canada is enviably equipped to expand its share of global food markets based on its world-leading advantages in land and water availability, as well as good commercial and physical infrastructure. Other studies have noted room to improve on productivity, but more fundamental risk factors have remained unexamined: Canada's lack of understanding of the food-water nexus, the emerging risk of increased climatic variability, and the links between water demand for biofuel, urbanization and industrial development. These appear to be the greatest challenges for future agricultural production.

4. Getting Real About our Water Supplies

While it seems like good news that Canada has one of the highest annual supplies of renewable fresh water per capita among the globe's leading agri-food suppliers,[56] this statement overlooks critical distinctions in the geographic location and timing of water flows. It also fails to acknowledge the impact that agricultural practices can have on the quality, sufficiency and reliability of fresh water supply in important food-growing regions.

There is a very real risk that the Canadian agri-food sector will fail to reach its full potential, even degrade its agricultural productivity, if we ignore the limits and vulnerabilities of Canada's water supply, and do not seek out innovations in water use efficiency, improved water infrastructure and full cost accounting.

Canada's Farm Belt is Getting Drier

Most of the water that falls on Canada and runs down our rivers does so in the northern half of the country, where experts say climate change will actually increase Canada's renewable water "income". But, with a very small number of exceptions, that is not where we grow food today.

Almost the entirety of Canada's agriculture—and all of our food production for export—occurs within 450 km of the 49th parallel boundary, or further south still in southern Ontario. Renewable fresh water supplies have been in decline in those latitudes since the early 1970s.[57] According to Statistics Canada, the net effect of ambiguous changes in precipitation and an amplification of evapotranspiration (water lost to the atmosphere as a result of evaporation and transpiration by plants) in recent decades has been a steady decline in annual average water yield across southern Canada. We have lost about 3.5 km^3—enough to supply all of Canada's households—with every passing year.

The availability of fresh water is expected to continue to diminish across Canada's agricultural belt in the decades ahead due to climate change, competition from other economic sectors of the economy, and urban expansion. On the other hand, conservation in industrial and urban water use could also free up water for agricultural production.

The Most Fertile Regions Are Most At Risk

Irrigated acreage is Canada's most productive farmland. More than half of it is located in southwestern Alberta, one of the country's driest regions. And Alberta is getting drier. Until now, producers have been able to offset dry summers partly with irrigation and livestock water drawn from rivers fed from melting snowpack and glaciers in the Rocky Mountains. But those resources are dwindling, and summer flows in some southern Prairie rivers are declining.[58]

At the same time, hotter growing season temperatures are amplifying water loss from soil and lake and river surfaces. Researchers estimate that during the early 21st century, evapotranspiration was drawing off close to 50 per cent more water from farms in southern Alberta than it did a century ago. This is partially compensated by improved efficiencies in irrigation.[59]

As a result of concerns about future over-allocation of limited water supplies, new water allocation requests will not be accepted in most of Alberta's southern rivers. The same region has also initiated improved contingency plans in response to climate change scenarios, significantly improved water use efficiency in irrigation, and moved toward value-added processing. These initiatives should be considered nationally.

Evapotranspiration is also accelerating in southern Ontario's agricultural heartland. While precipitation is increasing in some parts of the lower Great Lakes basin (in part from additional water evaporating from the Lakes—implying no net increase in available fresh water), losses to the atmosphere from reservoirs in the Grand River watershed on some summer days exceed withdrawals by all the domestic and industrial consumers in the area.[60]

British Columbia's Okanagan Valley produces some $85 million worth of high-value tree fruit, wine grapes and other agricultural products a year. However, urban areas compete with agriculture for limited fresh water supplies; landscaping soaks up half of all domestic water. And the region has been warned to expect an additional 70,000 to 90,000 new residents by 2035,[61] equivalent to doubling the population of its largest city, Kelowna. But the confined watershed is receiving no new precipitation, while hotter summers are accelerating losses to evapotranspiration. Modeling suggests the region will experience declining water supply, most acutely during the growing season, because of a reduction in snow accumulation that produces earlier runoff and longer dry seasons.[62]

Degrading the Water We Have

Canada's emergence as a global food superpower has profited agri-food producers and the national economy. But it has also incurred environmental costs far beyond the farm fence line. And these threaten the quality of the very water essential to agricultural productivity.

In Manitoba, for example, ploughing fields for barley produced an average gross return to farmers of $310/ha in 2009. However, sediment and nutrient runoff from that same ploughed hectare of field caused an estimated $143/ha in damage to Manitoba waterways and infrastructure downstream.[63]

Beef, pork and chicken are among Canada's most valuable food exports. But the water requirements of their production are an order of magnitude greater than those of cereals, or of legumes like peas and lentils. Of greater consequence is that animals are… animals. Once fed, they excrete—on enormous scale. In fact, in 2009, livestock of all kinds equivalent to some 18 million mature cattle produced as much animal waste as 126 million people.[64] This is a key problem in intensive livestock operations and feedlots where manure disposal by field application close to farm operations is common, leading to nutrient release into watersheds.

Beef production accounted for roughly four-fifths of the resulting environmental impact (82 per cent of the nitrogen and 78 per cent of the phosphorus).[65] Even so, the concentration of industrial pig farms in Manitoba has raised concern for that province's struggle against eutrophication in Lake Winnipeg, linked to nitrogen and phosphorus overload.

Manure properly applied to soil can reap enormous benefits—improving soil structure, adding organic matter, increasing soil moisture holding capacity, and improving nutrient cycling. However, manure can only be economically transported to fields within a range of about 50 kilometres. Given the scale of many livestock operations, the volume of manure produced creates problems for storage and timing of applications. It also saturates soil in nutrients and poses a higher risk of nutrient and pathogen leaching into waterways during intensive storm events, as experienced in the algal bloom in Lake Erie in 2012. Manure treatment needs to be given more consideration in some of these intensive operations.

As the Blue Economy Initiative authors noted in the 2011 publication **"Running Through Our Fingers"**, the economic costs of such water-born agricultural "externalities" are seldom accounted for. Producers do not pay for the environmental damage caused by sediments and excess nutrients leaching into waterways. The rehabilitation costs from flood damage, eutrophication, and water quality impairments are usually borne by the public.

Limited Opportunity to Grow North

While warmer days and longer frost-free growing seasons may allow a few regions, such as the Peace River basin of northeastern British Columbia, to bring significant additional arable hectares into crop production, hotter summers alone aren't enough to expand Canada's farm production northward. The Canadian boreal region, with its thin soils, offers poor support for agriculture. Converting forest soils into productive agricultural soils will take decades of inputs and effort. Building appropriate infrastructure is a formidable challenge. The barren Canadian Shield that dominates the maps of Quebec and Ontario is unlikely to become fertile in anything less than geological time.

Summary

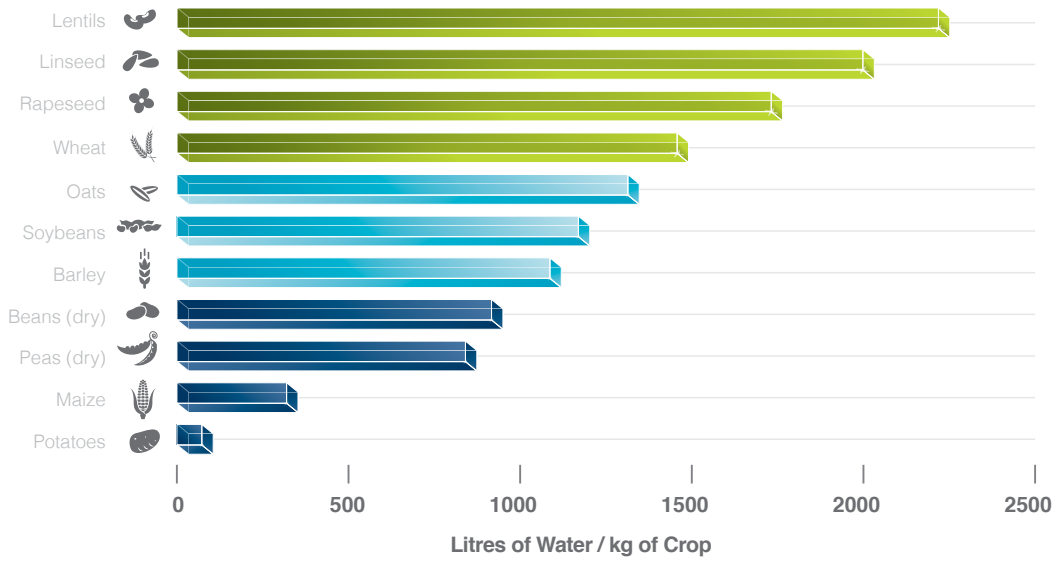
There are significant geographic differences in the supply of fresh water across Canada. In fact, most of that supply flows through northern or mid-latitude regions that are inhospitable to agriculture. In the fertile southern zones where agricultural production for export actually occurs, renewable fresh water supply is already stressed and subject to increased variability. Any expansion of agri-food production will need to be accomplished within existing, or even shrinking, water budgets.

5. Maximizing Water Productivity

'Virtual' water is the volume of water required to produce a quantity of food or any other product[66] (see Appendix for a short primer with more information on virtual water and water footprinting). This amount varies dramatically depending on the type of crop or commodity, the region in which it is produced, the prevailing climate, soil type, and the manner of production.

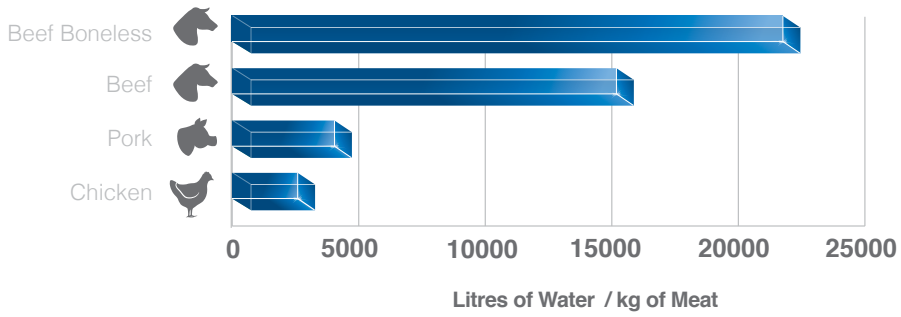
For example, a tonne of rice takes more than three times as much water on average to produce than a tonne of potatoes. Cattle grazed traditionally require twice as much water as cattle raised under industrial conditions (partly because industrial cattle reach market weight sooner and food conversion efficiency is higher).

Figure 7: Annual Virtual Water Requirements for Major Crops Exported From Canada



Sources: Chapagain and Hoekstra (2004), Hoekstra and Chapagain (2008).[67]

Figure 8: Annual Virtual Water Requirements for Meat Exported from Canada



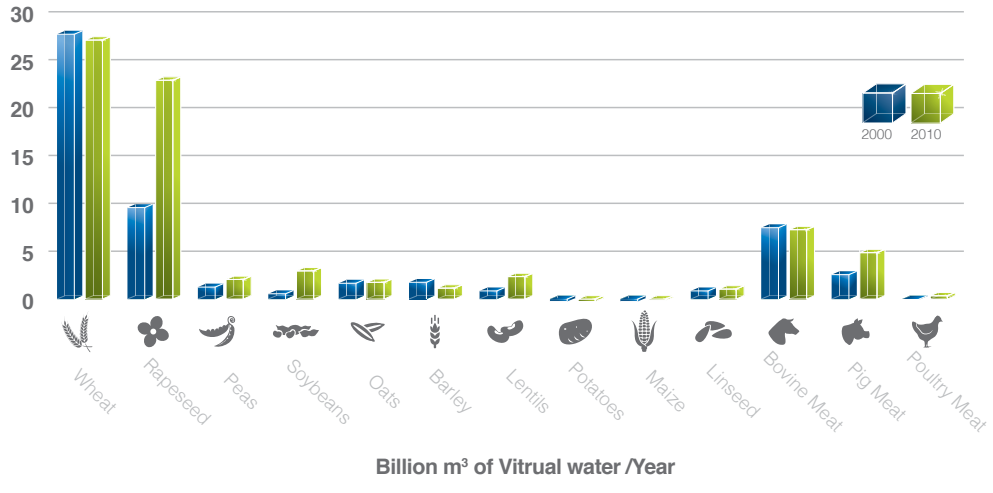
Sources: Chapagain and Hoekstra (2004), Hoekstra and Chapagain (2008).

Other countries, including important food producers and major global customers of Canadian products, are using an awareness of these differences in total production water requirements to leverage limited water resources, crop decisions, and trade choices to maximize domestic economic advantage.

Canada's agri-food sector, equipped with significant competitive advantages but constrained by overlooked threats to fresh water supply, must learn to do the same.

Canada is the world's third largest 'exporter' of water contained in or required to grow food. The volumes are substantial. Although data on the breakdown between irrigated versus rainfed production is limited, the water required to grow our exports of grain, meat, and other foodstuffs was estimated to be 67 billion m^3 per year in 2000, while the imported water at that time was 21 billion m^3.[68] Since that time, food exports have increased significantly for a number of the major exported food commodities. If we consider the 13 major food commodities that dominate Canadian exports, the virtual water exported in 2010 reached 78 billion m^3, which represents a 33 per cent increase over 10 years.[69]

Figure 9: Difference in Virtual Water Export of Major Food Commodities from Canada (2000 versus 2010)



Source: FAO Database (2011).

Different crops, in combination with different soils and local micro-climates, require varying amounts of water to ripen. The same can be said about animals raised for their meat. While arable land area is, for most purposes, inelastic, Canada has the ability to amplify water's effective productivity through the choices we make in crop and husbandry practices.

An Important Distinction: Blue Water vs. Green Water

A clear distinction needs to be made between irrigated water use (blue and grey water) and rainfed production (green water). The water evapotranspired from both types of food production is usually lost from the watershed and will eventually be deposited in the form of rain somewhere else. If we export the crop, then the water used for irrigation is no longer available. The water primarily managed for human uses is 'blue', and if it becomes scarce, then the water used to irrigate crops for export cannot be used for other competing water uses. In contrast, green water is sparingly used for direct human activities; options for alternative uses apart from growing food are somewhat limited.

Accounting for these differences is challenging in Canada: few statistics exist to show the proportion of irrigated versus rainfed crops that are exported.

Based on virtual water analysis by the Water Footprint Network, the crops produced in Canada annually evapotranspire about 30 billion m^3/year of water for domestically consumed crops, but about 52 billion m^3/year for crops exported from Canada. Using the same data source, the total virtual water used for crop export was 48 billion m^3/year, while the imports were estimated at 16 billion m^3/year. In addition, the virtual water trade for livestock exports accounted for 17 billion m^3/year, while livestock imports accounted for five billion m^3 per year.[70]

If and when water resources become scarce, there are a number of options we can take:

- Improve irrigation efficiency
- Reduce the area under irrigation
- Grow crops that are more water efficient

In rainfed agriculture, only option two and three are viable. When taking economics into consideration, we should consider not only water efficiency, but also the value of the food commodity and its environmental impacts.

Virtual water and water footprint analysis are useful tools for informing those choices and making proactive changes with respect to environmental and economic performance.

Virtual Water Indicators

The following indicators illustrate some of these issues:

Total virtual water requirement: this is the amount of water required to grow a product. Every crop has a different water requirement.

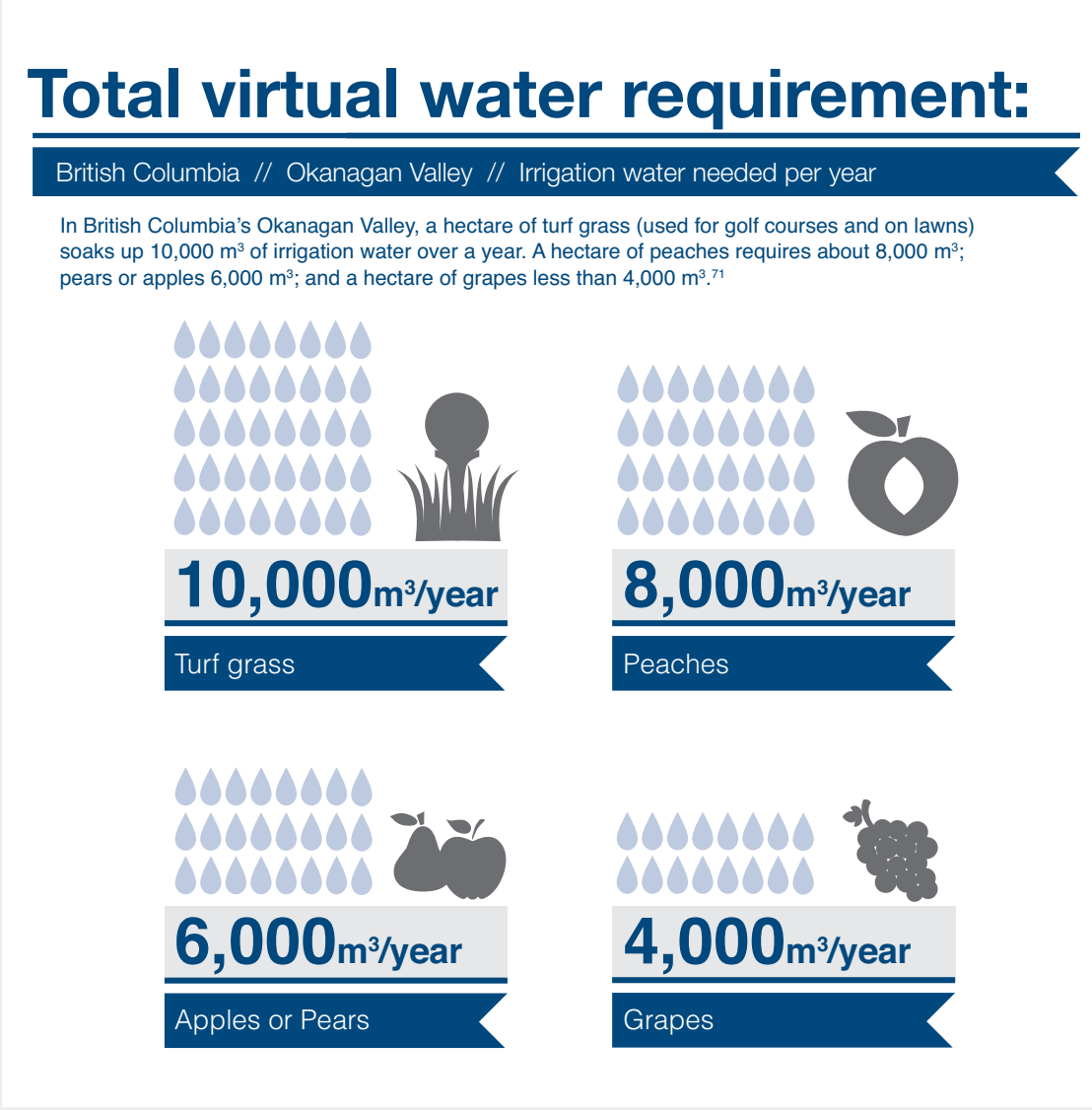
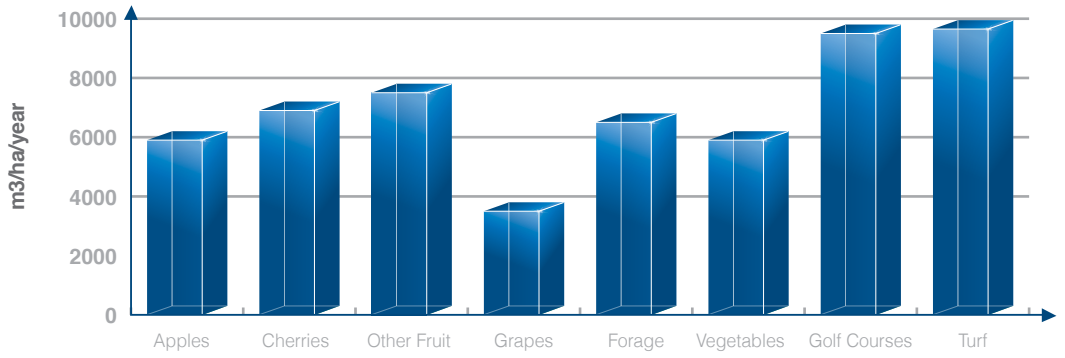


Figure 10: Water Requirement for Different Crops Irrigated in the Okanagan (m^3/ha/y)

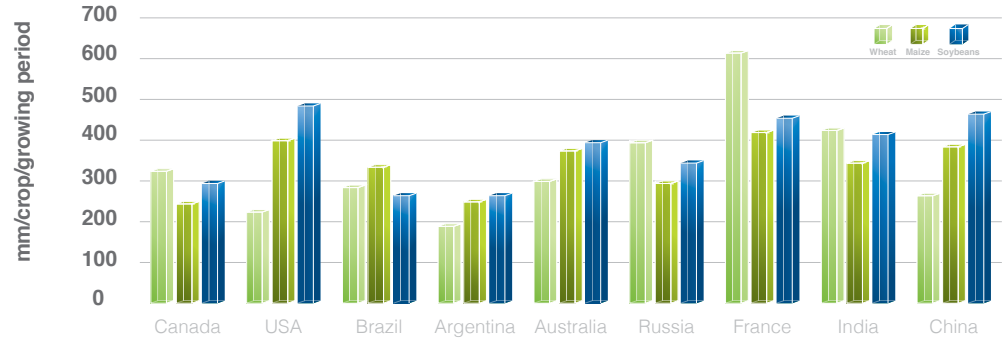


Source: Schreier et al (2008)

Crop-per-drop: this is the ratio of a crop's yield to the water required to produce it. This reveals a farm product's water efficiency under different growing conditions. (The inverse—water required for a given volume of product—is its **water intensity**).

In the Okanagan, growing any crop in soil with high clay content—which retains moisture—requires nearly 40 per cent less water than rooting the same crop in sandy soil. The difference in water intensity for identical crops can be even more dramatic from region to region; in international comparisons, it ranges from two-to-one (for corn) to more than six-to-one (for canola).[72]

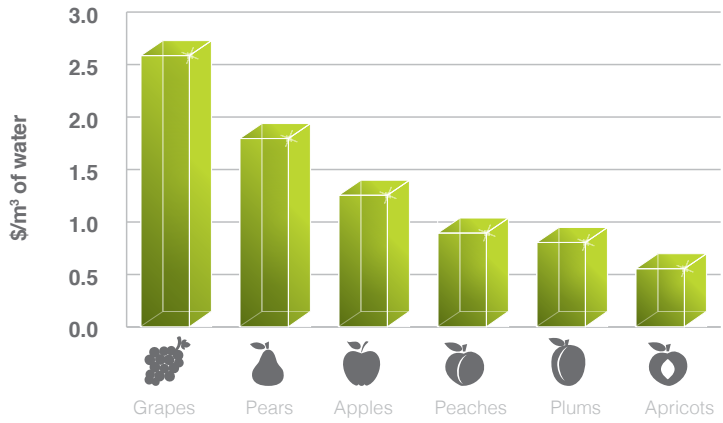
Figure 11: Differences in Crop Water Requirements for Wheat, Maize & Soybeans Between Different Countries



Sources: Chapagain and Hoekstra (2004). Hoekstra and Chapagain (2008).

Dollar-per-drop: this is derived from multiplying the crop-per-drop by the market price for that crop, to reveal the economic value of the virtual water content. Grapes from Okanagan vineyards, for example, use little water in comparison to other fruits, and as such return four times the revenue for their virtual water content than do apricots from its orchards: $2.75/m^3 against just $0.70/m^3. At the extreme, oats grown for export capture barely $0.20 in economic value for every cubic meter of water they require; tomatoes recover $48.57.[73]

Figure 12: The Value of Water ($/m^3) in Producing Different Fruit in the Okanagan (Based on Farmgate Values)



Source: Schreier et al (2008)

This is not to suggest that all of Canada's farmers should grow tomatoes, or that all the Okanagan's apricot orchards should be torn up for grapes. But we cannot overlook differences in return on water invested, whether measured in crop weight or market value (or, indeed, in caloric value, a variable beyond our scope here).

When water is plentiful in a growing region, a rational strategy may be to pursue the highest export dollar value regardless of a crop's water intensity. But as water supplies become more strained, new alternatives can arise when individual farmers, irrigation districts, agri-food producers and government authorities know which farm products deliver the most 'crop-per-drop' under different conditions.

For example, rather than restrict irrigated acreage during a prolonged drought, it may be possible to plant the same area with higher 'crop-per-drop' varieties that require less water to bring to harvest. This of course is only viable if similar equipment can be used for the production. Even when a reduction in irrigated hectares cannot be avoided, selecting crops with a higher 'dollar-per-drop' value can limit the economic impact of a long-term drought.

As an example, about 70 per cent of the water used in the Colorado River Basin is used for agriculture and 90 per cent of the crop and pasture land is irrigated. Fifty per cent of the irrigated land is dedicated to forage production for cattle and horses. With the emerging new climate norms water scarcity is becoming a significant concern. Initiatives attempting to adapt to these new conditions include improving irrigation efficiency, and shifting from water intensive crops like alfalfa to more water-efficient crops.[74]

A similar adaptation strategy for drought is also in place in the Lethbridge Northern Irrigation District in Alberta where irrigators have the option to reduce the area irrigated or shift to less water-intensive crops during periods of short or longer term droughts.

On larger scales and over longer time horizons, agri-food producers and governments can use virtual water analysis to achieve more flexibility and reduce risk. At the regional and global levels, several examples illustrate how virtual water analysis has equipped leaders to make more strategic and sustainable choices.

Global Examples of Leverage and Arbitrage

Greater virtual water awareness has allowed thirsty economies and large populations in other parts of the world to squeeze every ounce of value from their limited physical water assets. These nations selectively target certain crops for domestic production or export, and strategically identify the food commodities they choose to import. The cases of Australia, the Middle East North Africa (MENA) region, and China are particularly instructive.

Australia: How to maintain exports when the water runs out

The Murray-Darling Basin, Australia's most important agricultural basin, appears to have undergone a permanent downward trend in water availability over the last two decades. Over this period, fresh water supply has been as much as 90 per cent below previous 'normals'.[75]

On a national scale, this period also saw a sharp and, it would appear, permanent decline in Australian exports of rice and cottonseed—among the most water-intensive agricultural commodities. Amazingly, even during the peak of the 2007-2008 drought, Australia was able to increase the value of its total agricultural exports, in part due to a shift in horticulture. [76]

This is thanks to a range of responses—from embracing water trading, to curtailing water allocated to farmers, to technological advances in monitoring, to instituting a new program of reservoir building. But at both local and national scales, Australia also engaged in widespread crop substitution practices that reveal a clear consideration of virtual water content. An important contributor to this greater productivity was the shift to less water intensive crops.[77] However, it's not just a question of water intensity, but also a cropping system that is more water appropriate according to time and location.

As water supplies declined, hitting bottom twice in the 2002-2003 and 2007-2008 growing seasons, many individual farmers chose to relinquish their water rights (for compensation) to other producers. In the process, they shifted much of the limited water available from wheat fields (that returned a relatively low dollar-per-drop), to grape vineyards (which required less water to produce a satisfactory crop and brought a high dollar-per-drop return), to support the country's high-value wine industry.[78]

The Middle East and North Africa (MENA): How to Feed a Region That Gets No Rain[79]

While there are other reasons for instability and tension in the Middle East, the region has avoided famine, largely through adroitly leveraging virtual water.

Half a billion people live in the 20 countries of the MENA region. They are overwhelmingly young, and their numbers are growing. Another 321 million new citizens are expected over the next four decades—38 per cent more mouths to feed. The region's water needs already exceed its own water resources. Without imported food, the arid region could not feed the people living there today, let alone tomorrow.

Sixteen countries, including Iran, Egypt and Algeria, depend on large imports of virtual water in food—especially wheat, the region's staple grain. By one calculation, if Jordan did not have access to the virtual water connected to imported food, it would need five to seven times more water than is available in its own rivers and aquifers.[80]

The region now consumes a quarter of all the wheat brought to market internationally—effectively 'buying in' some 47 km^3 of virtual water.

Further population growth is not the only reason why Middle East food imports are destined to grow. The Intergovernmental Panel on Climate Change forecasts that precipitation in the Mediterranean-Persian Gulf basin will fall by as much as 20 per cent over this century. Declining rainfall will reduce regional crop yields, so the MENA region will have to import more food to free declining domestic supplies of natural fresh water for energy production and essential domestic uses.

Saudi Arabia's story is especially telling. Starting in 1985, Saudi Arabia cultivated wheat irrigated from groundwater for regional export, supplying much of the region's needs for the next quarter-century. But Saudi exports have declined in this decade, and its central government has announced that it will abandon wheat cultivation entirely by 2014. This is due to the deterioration of its groundwater supplies as a result of the pressures caused by irrigation. Desalinating seawater was considered as a replacement source for watering crops but this would have consumed up to a quarter of the output of Saudi Arabia's oil and gas fields.[81]

Supply, demand and market pricing may explain most of the region's reliance on virtual water imported as food. However, the Saudi government's decision to exit wheat production sacrificed both its domestic self-sufficiency and the goodwill it gleaned from providing grain to neighboring states. This decision suggests a more conscious weighing of the relative value of the kingdom's limited physical water and its virtual equivalent imported from France or Canada.

Egypt is another good example of the rapid changes that are happening in the region. Between 2005 and 2010, the annual wheat import has grown from 4.3 million tonnes to 10.5 million tonnes, and these imports now account for 60 per cent of the wheat consumed annually.[82]

China: How to become the world's factory on 'new' water[83]

Within memory, China was almost synonymous with hunger, but this is no longer the case. The country has not only succeeded in feeding a fifth of the world's population, but within the last 15 years its industrial boom has moved a third of a billion of those people from a subsistence existence to the middle class.

Its size and success, however, mean that China faces many of the globe's compounding problems of water and food supply within its own borders, including crop-destroying floods, cyclones and droughts. In many regions, municipalities and industry compete with agriculture for water. Much of the water returned to the environment is severely degraded; large-scale toxic spills into lakes and rivers are common. At the same time, the growing wealth and influence of its middle class fuel aspirations for diets with less rice and more meat. Should all Chinese develop the same ambition, the country's agricultural water footprint would double.

One response by state-owned enterprises has been to secure long-term leases on farmland in other countries to produce food for its home market. While there are considerable tradeoffs and implications in taking such an approach, it is evident, from an analysis of the different virtual water content in China's imported and domestically produced food supply, that China is pursuing a strategy informed by virtual water analysis.

China's imports of meat—especially chicken, and more recently pork—have soared since 2004, as much as tripling in the case of chicken. Meat requires two to 10 times more water to produce than grains, tubers or legumes. Soybeans and cotton (grown for its seed oil as well as fibre) are among the most water intensive crops to grow. China's cotton imports tripled between 2000 and 2008; imports of soybeans increased by a factor of six. By contrast, China imports little wheat, corn or sugar cane—all comparatively water-efficient commodities to produce.

In buying foodstuffs that devour water to grow, while growing crops that merely sip, China is employing the tactics of financial arbitrage (allocating water to a preferred production mix) to free its own limited physical water resource for other purposes in its burgeoning economy. The liberated volume is substantial.

China's imports of virtual water in food exceed the water requirements of all of its manufactured good exports.

The virtual water China that imports, and hence doesn't use to feed its 1.3 billion people increasingly upscale meals, has allowed more domestic natural fresh water to be used for manufacturing.[84] While no doubt a result of complex drivers, this appears to be a deliberate if unacknowledged national policy. China's increasing differentiation between high 'crop-per-drop' (low water intensity) domestic agricultural production, and the much lower 'crop-per-drop' (highly water intensive) meat and other products that it imports, suggest that its leaders are employing virtual water arbitrage as a strategic tool.

China shows that a policy of importing water intensive food will save large quantities of the relatively scarce local water supplies. The saved water can then be used for key domestic uses and for producing higher value products.

Canadian Case Examples

Virtual water analysis can raise water efficiency and productivity in both irrigated and rainfed agriculture. While Canada has yet to implement strategic virtual water and water footprint analysis at either the national or provincial policy level, some regions facing imminent water challenges are beginning to do so. The following Canadian case examples focus on the concentrations of irrigated crops in the Okanagan Basin in southern British Columbia, and the South Saskatchewan River Basin in southern Alberta. Both regions have taken steps to develop water footprinting analysis for improved water use efficiency.

The Okanagan Basin, British Columbia

The Okanagan Basin Water Board has embarked on a water accounting project for Canada's driest watershed. Agriculture uses 70 per cent of water in the region. Meanwhile, urban and industrial water demand is growing, and climate change is predicted to cause significant variability in water supply in coming years.[85]

Virtual water analysis will need to be included in the development of water use scenarios for long-term planning and to achieve the Board's goals of improving water use efficiency in both urban and agricultural areas.

In 2008, the University of British Columbia, along with the provincial Agriculture Ministry and federal Agriculture and Agri-Food Canada, undertook a study of irrigation requirements in the Okanagan. Its report outlined the virtual water requirements of different crops and livestock in different climatic scenarios in the Okanagan Basin.[86] It revealed that the largest volumes of irrigation water being used in this dry watershed were going to forage crops, which are highly water intensive and have some of the lowest farm gate values—a 'dollar-per-drop' value near the bottom of the scale.

The 2008 study informed the development of an Okanagan Agricultural Irrigation Model,[87] itself the core of a broader Okanagan Water Demand Model which also includes irrigation for domestic and municipal landscaping and for golf courses. This model has the potential to be an invaluable decision support tool.

The Okanagan's Water Demand Model provides reliable, virtually real-time validated information to illuminate some of the key tradeoffs that will need to be made in the region to ensure a sustainable agricultural sector. It can preview water demand for individual crops on a particular parcel of land, or for entire sub-basins or local government areas within the Okanagan.[88] This information can be updated weekly or even daily to inform irrigation scheduling, provincial water allocations, regional land use planning, water conservation strategies, and drought response planning.

The 2008 report also identified three potential initiatives to translate this knowledge into policy:[89]

- An analysis of current water policies in the Okanagan, and how they are suited to respond to water shortages, with recommendations for changes as needed;
- Community consultation to inform the development of a process to link water management and community planning; and
- A strategy to facilitate equitable water distribution during shortages, such as a Basin-wide drought plan or water management plan.90

The South Saskatchewan River Basin, Alberta[91]

Alberta holds the majority of Canada's irrigated land. With almost two million acres under irrigation, almost all of it in the South Saskatchewan River Basin (SSRB), agriculture is the largest consumptive user of water in Alberta. While less than four per cent of Alberta's arable lands are irrigated, they account for as much as 20 per cent of the agricultural GDP of the province.

Water supplies in the SSRB are highly variable and likely to become more so due to ongoing climate change. Add to this uncertainty the pressures of continued population growth, economic development, and the need to restore overdrawn ecological water flows, and it is evident how critical decisions about water management are to the province.

During the past 15 years, irrigation districts, farm producers and the Alberta government have explored a suite of options for improving water efficiency and productivity, while also looking for new economic opportunities in irrigated agriculture.

The irrigation sector undertook a comprehensive five-year field research program to evaluate crop water requirements. The Alberta Irrigation Projects Association (AIPA), again with provincial and federal agency support, developed leading-edge models and analytical tools to represent crop irrigation requirements at the level of each irrigated parcel. Concurrently, highly detailed models of the irrigation infrastructure were also developed. Together, these made it possible to test alternate water management policies across changes in infrastructure and on-farm practices.

Ongoing infrastructure rehabilitation, cost-shared between Alberta and the irrigation districts, has widely improved water delivery efficiencies. These gains, combined with changes in farm water management, have enabled an expansion of irrigated acreage with less water than was previously used, while improving security of supply.

On average, Alberta's irrigators today need a third less water per acre than 15 years ago. The irrigation sector has also taken a lead role in developing sector-based Conservation, Efficiency and Productivity Plans. Such plans, mandated by Water for Life: Alberta's Strategy for Sustainability and coordinated by the Alberta Water Council, set short, medium and long-term targets for ongoing gains in water efficiency and productivity.

Alberta is also pioneering analytical tools and processes to enhance integrated river basin water management. Research pilots funded by Alberta Innovates-Energy and Environment Solutions (AI-EES) and the Climate Change Emissions Management Corporation (CCEMC) during the past three years have advanced new system approaches that highlight the potential for win-win-win outcomes that deliver better ecological health in critical reaches of the SSRB, improve supply security for cities and municipalities, and still allow for modest growth of irrigated land.

Key to seizing these new opportunities is that most can be implemented under existing legislative and policy frameworks. The irrigation sector has also played a key role, developing processes for sharing water allocated to them with other licensees in the basin, to co-ordinate on and off-stream storage operations, and to secure water for critical human uses during times of extended drought.

Summary

Virtual water and water footprint analysis recognizes and accounts for significant differences in the fresh water required to bring various commodities to market in different soil and climate conditions, or under different farm practices, and therefore capitalize on opportunities. These differences in crop-per-drop and dollar-per-drop returns on water may be as much as multiple orders of magnitude.

Other countries, including Australia, the MENA region and China, are demonstrating an awareness of how these differences may be leveraged and arbitraged to extend domestic natural water supplies for strategic objectives. These may include: maintaining export revenues from agricultural products in the face of acute drought; feeding populations several times larger than domestic natural water supplies could support; and effectively stretching static water supply to meet rising lifestyle expectations while greatly expanding industry.

Canada is currently the world's third-largest exporter of virtual water. If our agri-food sector is to expand its output significantly to meet growing market opportunities and global obligations in the decades ahead, it must build on current examples of regions that are using virtual water analysis as a strategic framework to make our water go further.

6. Recommendations and Conclusions

Other countries are already actively employing virtual water and water footprinting techniques. They are either leveraging their own water supplies for greater productivity, as in the case of Australia, or are supplementing limited water supplies by importing food from others, as in the cases of Saudi Arabia and China. A few regions in Canada are also analyzing water use to improve decision-making.

To be at the forefront of the global agri-food opportunity, Canada must explore these techniques (as tested in the Okanagan Basin, southern Alberta, and beyond), and invest in a more deliberate and co-ordinated framework for the use of fresh water resources in food production. Senior levels of government, regional organizations (such as watershed agencies and irrigation districts), agricultural groups, and individual ag-businesses and producers must work together to design and implement this framework.

The goal of such a strategic approach should be to leverage Canada's existing water supplies for maximum productivity while maintaining the long-term sustainability of both the water systems and the agri-food industry that depends on them, as well as improving environmental performance.

Benefits of a Strategic Approach

In addition to supporting solutions to help combat the emerging global food crisis, the implementation of a more strategic approach to water use by the Canadian agricultural sector would bring with it a number of domestic benefits. These include:

- Enabling the agri-food sector to capitalize more fully on a major global market opportunity;
- Growing an economic sector that can produce stable returns and employment over time;
- Strengthening the competitiveness of the agri-food industry in relation to other global food producers;
- Stimulating economic opportunities in innovative technologies and practices related to agri-food production; and
- Supporting a truly sustainable agricultural sector (both environmentally and economically).

Recommendations

In the section that follows, seven recommendations are put forward for leveraging water use in the Canadian agricultural sector. These recommendations are not intended to be exhaustive. There are many factors that can influence water practices adopted by agricultural producers, including market conditions, climate patterns, and competition for water resources. These recommendations focus on

the role of the public sector—our federal and provincial governments—in supporting the application of virtual water approaches at the regional and watershed scales. They provide a framework whereby senior governments can help enable, incentivize, and support innovative water management practices by water managers and agricultural producers at the basin, irrigation district and farm level.

The recommendations are informed by the following four core objectives:

Make Informed Choices: Understanding the total water requirement, crop-per-drop, and dollar-per-drop involved in food production are essential intelligence for informing choices made through national policy frameworks (such as the federal government's Growing Forward strategy), through provincial decisions (such as water allocation policies), at the irrigation district and regional planning levels, and for individual farm businesses. It should also be noted that global food and beverage processing companies (see text box below), which sit further up the supply chain, are increasingly analyzing their exposure to water risk and examining the water use practices of their suppliers.

Increase Productivity: Water scarcity is a constraint to food production in the regions where Canada grows most of its food, such as southern Alberta, southern Saskatchewan and the Okanagan in British Columbia. To improve competitiveness with the global agri-food industry, Canada's agricultural producers will need to increase food production and economic activity without using more water. Irrigation management, improved timing and technology are some of the most effective solutions. Stretching existing water supplies will help free up additional food production for domestic needs, export to the global market, and other economically and environmentally beneficial uses. During drought and under warmer climatic conditions, rainfed agriculture also needs to be prepared to consider the differences between water efficient and water intensive crops.

Build Resiliency: With climate change and increasing demands from urban and other industrial water uses, water shortages will become increasingly common for many of Canada's food growing regions. A critical objective is the ability to effectively plan and respond to drought and flooding. Being able to plan for water scarcity will enable Canada's food producers to be more capable of withstanding climate shocks, extreme droughts and moisture, improving economic resilience, and minimizing disruption in food exports.

Achieve Environmental Sustainability: A short-term increase in food productivity will be counter-productive if it comes at the cost of the long-term health of our fresh water systems – the rivers, lakes, and groundwater – that are necessary for food production as well as our drinking water and myriad benefits they bring to society. For the long-term benefit of the agricultural industry, our environment, society as a whole, and our international reputation, it is essential that the environmental sustainability of our water resources is paramount.

Based on these overarching objectives, the following recommendations outline seven practical areas where governments can lay the groundwork for a more strategic approach to water use in Canadian agri-food production.

1) Develop Drought/Flood Contingency Plans

Our most significant food growing regions are already prone to water scarcity. The instances of drought are predicted to become more severe and long lasting in a changing climate. As described in Chapter 5, Australia increased agricultural exports despite a major decline in water availability due in part to a shift to less water-intensive crops with a higher dollar-per-drop value. Similarly, the Lethbridge Northern Irrigation District has developed a contingency plan for times of drought that presents a choice to farmers: reduce acreage, or switch to less water demanding crops. In light of climate change scenarios, contingency plans and associated cropping decisions can become instrumental in supporting resilience.

Flood contingency plans should also be considered, as flooding can have an equally destructive effect on food production and exports.

Action

- Federal and provincial governments should work together with stakeholders, including regional entities such as irrigation districts, conservation authorities, and/or watershed boards, to enable the development of watershed-specific drought (and flood) contingency plans. These plans would identify in advance of drought conditions which crops can be substituted during short and long-term periods of water scarcity, when to reduce crops grown for export to support domestic supply, when to shift to higher value crops, and when to reduce irrigated acreage.

Corporate Water Risk Evaluation in the Food and Beverage Sector

Part of the reason global food and beverage processors, among other sectors, are paying more attention to risk exposure is because producers up the supply chain are encountering greater water-related risks in agricultural production. To help corporations assess risks and make informed, responsible water management decisions, a number of international organizations, including the World Business Council for Sustainable Development, the World Wildlife Fund, and the Alliance for Water Stewardship, among others, have begun to develop water accounting and risk evaluation tools and standards.[92] The Water Footprint Network has produced the "Water Footprint Assessment Manual," that sets the global standard for such evaluations.[93] Companies like Coca-Cola, PepsiCo, and Unilever are among a growing list of food and beverage companies leading the way.

2) Provide Incentives for Innovation in Water Efficiency

Agricultural producers should be encouraged to increase the value derived from water use in agriculture. This may be achieved through a combination of regulatory conditions, incentives, and financial support, and by tackling perverse subsidies.

Action

- The federal and provincial governments should work together, perhaps through the Growing Forward 2 Agri-Innovation Program, to provide financial incentives to trial innovation in agricultural technologies/practices for water efficiency, such as determining the best methods of irrigation depending on the specific crop and the soil conditions.
- Governments and the agricultural sector should work with financial institutions such as Farm Credit Canada and Canadian banks and co-operatives to provide financing that supports and encourages widespread adoption of innovative technologies and practices.
- The federal and provincial governments should identify perverse subsidies that encourage the production of low value, water-intensive crops in water-scarce areas and reduce or remove these subsidies.

3) Establish Virtual Water and Water Footprint Pilot Projects

Chapter 5 outlined promising pilot efforts to account for virtual water use in the Okanagan Basin and southern Alberta. In the case of the Okanagan Water Demand Model, this framework has been expanded to cover most agricultural areas of British Columbia. It would be both practical and cost effective to build on this existing work and expand these efforts to establish benchmarks and best practices for other food producing river basins across the country. As areas become warmer, and water scarcity becomes more apparent due to competing demand by the energy industry and urbanization, the pressure for supplementary irrigation at critical times of the year will increase. Experience gained during the pilot studies will be highly valuable for informed decision-making going forward.

Action

- The federal government should work with the provinces to designate at least two regions as pilot projects that would receive funding and support to operationalize virtual water and water footprinting analysis in their specific river basins.

4) Create a National Virtual Water Inventory and Risk Assessment Tool

At this time, we are reliant on global calculations of virtual water (primarily from the United Nations) to inform analysis of the water requirements of Canadian crops. These calculations are based on generic averages (using the climate conditions of countries' capital cities) and do not account for regional variation across Canada, including the specific climate, soil, and other unique conditions of our food growing regions. The exception to this is in British Columbia's Okanagan Basin and in southern Alberta, where detailed local information has been developed at a watershed or river basin scale.

Canada needs to create its own national virtual water inventory to assist with the crop choice, facilitate more resilient agricultural practices, and allow producers and processers to better identify exposure to water-related risks. This should be on a watershed or river basin scale for a water balance calculation that is credible. Better information also needs to be collected on the amount of exported commodities produced with green water (rainfed production) versus blue water (irrigated production).

While the focus is on virtual water exports, we also need to better understand virtual water imports and identify potential water-related risks and opportunities associated with food imports from different parts of the world.

Action

- The federal government should work with the provinces (possibly through the Council of the Federation) and Canadian agri-business to create a new national inventory, at a river basin scale, of the virtual water and water footprint requirements of the Canadian agri-food sector and its exports.
- This process should begin with a major inventory of Canada's 20 key crops, including specifically calculating the amount of water it takes to grow these key crops by region, and mapping the percentage of crops produced annually that are irrigated (blue water) and those that are rainfed (green water).
- Economic and trade research should be prioritized to better track the origin and destination of food exports and the virtual water destined for exported food.
- Conduct water footprint analysis of all exported commodities to show where efficiency gains are possible.
- This inventory should also identify areas where food exports are placed at considerable risk (such as where a particular crop is grown in a single area that is prone to drought).
- Ensure virtual water evaluations are made within a watershed or river basin context, and consider blue, green and grey water components.

5) Support Farm Level Research, Education and Access to Information

Ultimate responsibility for maximizing water productivity lies at the farm level. In order for any of the previous recommendations to be effective, it is essential that individual producers are provided with the support and information required to make informed choices about the types of crops and livestock they grow, and the methods used for watering them.

Action

- Federal and provincial governments should revitalize Agricultural Extension Services and provide capacity for farm level research, education and access to information through government staff and agricultural universities. Extension service staff would work with irrigation districts, watershed agencies, agricultural associations and other relevant groups to ensure research and education programs are instituted that transfer knowledge of virtual water and water footprint analysis tools at the farm level, and provide information and education on water stewardship, conservation and efficiency in an easily accessible format.

6) Implement True Cost Accounting to Capture Externalities

One of the challenges of implementing virtual water and water footprinting techniques is incorporating the costs associated with the impact of agricultural production on our water resources and the ecosystems that depend on them. As described in Chapter 4, the impacts of meat production can be especially harmful to our rivers, lakes and groundwater. However, global meat consumption is rapidly expanding and tends to produce higher value returns. It is therefore essential that the true cost of this production, including both quantity and quality concerns, be reflected in decisions based on virtual water analysis to prevent the inadvertent degradation of the underlying asset (i.e. water) by pursuing the highest dollar-per-drop.

Action

- Governments need to work with the agricultural industry to determine the most effective and equitable way to capture the externalities and ensure that agricultural practices reflect the full costs of agriculture and agri-food production.

7) Evolve Toward Full Water Footprint/Life Cycle Assessment

Ultimately, Canada needs to evolve its data collection and information systems to the point where a more complete, 'cradle to grave' water footprint or life cycle assessment of different forms of food production, processing, and transportation can be undertaken. For example, to analyze the true water footprint of wine production in the Okanagan, we not only need to understand how water was used to grow the grapevines, but also how much extra water is then used in the wine-making process to turn those grapes into wine.

Action

- Governments should prioritize funding for research and demonstration projects that undertake full life cycle assessments of the production and processing of specific food items and help identify ways to reduce water use and evaluate responses throughout the supply chain.

Conclusions

The global demand for food is rapidly rising. The agricultural capacity of most food-growing nations is diminishing. Population growth, changing diets, and biofuel production are combining with water scarcity, land degradation, urbanization and climate change to dramatically decrease the world's ability to stave off large-scale hunger. These same factors are also increasing the occurrence of disruptive system shocks to the global food market, such as the recent drought in the United States and record breaking heat waves in Russia and Europe.

Canada is one of only five countries that can meaningfully increase its food exports to help feed the world's growing hunger. This presents a major opportunity for Canada's agri-food sector and our national economy at large.

To capitalize on this opportunity, we must recognize the importance of the fresh water resources on which all food production depends. Even though Canada has more water per capita than any other country, the areas where we grow the most food also happen to be the driest, and are getting drier. To meet our market potential while assuring the long-term viability of our agri-food sector, we need to export food that is water efficient, of high value, and minimizes environmental impact, water pollution and greenhouse gas emissions.

A number of other food-producing nations are already grappling with the constraints of limited water supplies and are employing strategic approaches—akin to the concepts of leverage and arbitrage in the world of finance—that maximize the productivity and value of every drop of water. To stay competitive in this increasingly sophisticated global marketplace, Canada will need to adopt its own strategic approach to water use. This approach will enable the effective implementation of a suite of analytical tools, such as virtual water and water footprinting, and also stimulate and support adoption of innovative water management technologies and practices.

Getting the strategic approach right and putting it into practice will generate jobs, strengthen the national economy, and ensure the health of our precious rivers, lakes and groundwater. Getting it wrong, and assuming unlimited water abundance, will harm our competiveness, degrade our water supplies and impact the long-term sustainability of our agri-food sector.

Canada is at a crossroads. As a country, we have a tremendous opportunity to create a dynamic, innovative and world-leading agri-food sector, one that makes informed choices, is highly productive, demonstrates resilience to changing conditions, and supports a healthy environment. The dialogue to create this strategic approach is urgent and necessary. Without water, there is no food, and there is no opportunity.

Appendix

For detailed data on virtual water analysis see Schreier and Pang web-application available at: **http://wmc.landfood.ubc.ca/webapp/VWM**

A Virtual Water Primer

Researchers subdivide water into four figurative types: green water, blue water, grey water and black water.

- Green' water is the rainwater that is captured by vegetation and soil and is recycled through evapotranspiration back into the atmosphere where it becomes rainwater in another location.
- Blue' water is rainwater and snowmelt water that runs over the surface into rivers and lakes, or percolates into underground aquifer; it includes water captured from nature and diverted into irrigation canals.
- Grey' water is water left over from human use that can be reused for some activities without much processing.
- 'Black' water is contaminated water containing sewage or other pollutants, and needs significant treatment before it can be reused.

People have learned to manage the blue water cycle, which accounts for 35 per cent of the water system, and most water accounting until recently has focused entirely on blue water. Relatively little attention has been given to the green water cycle, which accounts for 65 per cent of all the rainwater that moves through the hydrologic cycle. There are significant gains to be made by focusing on water efficiency within the green water cycle.

To this list of water types, Allan added the concept of virtual water.[94] Similar ideas are expressed by Hoekstra in using water footprint analysis to reflect the amount and quality of water involved in producing a good including water along the supply chain. Virtual water refers not just to the actual water content of a product (85 per cent of the weight of ground beef), but to the volume of water required to produce that product (15,000 liters for a kilo of beef on average).[95] If a country is water short, it can save significant amounts of water by importing goods that are water intensive.

The blue water applied to irrigated crops is generally lost from the watershed by evapotranspiration and that water can no longer be used for any domestic or industrial purposes. Some virtual water is recycled within the watershed after being used in food processing, but depending on the rate of pollution, it may not be suitable for use in agriculture. As we move towards greater recycling, this water source needs to be considered.

Here, we are interested in the virtual water required to grow key staple foods: grains, corn (maize), legumes and meat. From the amount of water required to grow a given quantity of these (e.g. volume of virtual water in m^3 per tonne), their respective water intensity can be derived. Water intensity and impact vary widely, depending on where a commodity is grown, how it was produced, and specific crop, especially in the case of those developed for drought resistance.

Comparing the water intensities of different foodstuffs from different origins reveals additional ratios of interest:

- The volume of a foodstuff produced for a volume of water: its water efficiency, or 'crop per drop'.
- By considering the nutritional value of the food produced by a volume of water: its 'calories per drop'.
- By calculating what that volume of food sells for on commodity markets: its gross 'dollar per drop'

In this analysis, we're concerned with the first and last of these, although the second may also become a growing concern in the future.

Setting nutrition aside, variation in virtual water content—in both crop-per-drop and dollar-per-drop terms—is dramatic, across both commodities and geographies.

On average, a tonne of potatoes takes about 755 m^3 of water to bring to market. The same weight of soybeans soaks up two and one half times that much water—1,789 m^3—before it can be harvested. Meats are orders of magnitude more water intensive still. A tonne of chicken meat represents, on average, 3,900 m^3 of virtual water, a tonne of beef, 16,000 m^3.

These are global averages. In fact, local climate conditions such as rainfall and temperature, soils in the case of crops, and animal husbandry or cultivation practices, also influence virtual water requirements, affecting the comparative crop-per-drop water productivity of different geographic regions.

The economic value of virtual water—the dollar-per-drop calculation—is also strongly differentiated. Among non-meat food commodities, water earns its greatest dollar-per-drop return in the United States or Canada by growing corn. In Argentina, by contrast, water is more profitably used to grow soybeans. For Canada, exported tomatoes produce a return on virtual water roughly 150 times higher than barley.

In considering the significance of virtual water, it is useful to bear in mind that water intensity and water efficiency are inversely related. That is, the lower the water intensity of a commodity (volume of virtual water required to produce it), the greater its water efficiency (amount of value in $\$/m^3$ it produces from a given volume of virtual water).

The great usefulness of virtual water as a tool for analysis lies in its ability to help us distinguish between these two, and to reveal water's greatest potential value in a particular setting. Water footprint analysis is a multi-dimensional indicator of the amount of blue, green and grey water used, including the type and volume of polluted water in producing the good. This requires information on the location of water sources, total water requirements, and water used in processing the product. The most water-intensive component of processed food relates to agricultural production (i.e. growing crops). Often, the processing component is relatively small. However, processing can introduce significant contamination, which is accounted for in water footprint analysis.

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