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What does a changing climate mean for Canadian agriculture?

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Introduction

Confirmation came from U.S. climate scientists on January 8, 2013: 2012 was the hottest year on record for our neighbors to the South – by a full degree Fahrenheit. A day later officials from the U.S. Department of Agriculture declared a statewide disaster area in Oklahoma and in parts of 13 other states, due to extreme drought conditions. Farmers in the affected areas will be concerned about the upcoming planting season, and with due cause: recent research by a team of academics from Columbia and Stanford Universities determined that a one-degree rise in temperature lowers yields by up to 10% (Mittelstead, 2012).

Incremental warming and increased incidence of extreme weather events are likely here to stay. So, what does this mean for Canada and Canadian agriculture? Does Canada's geography make it exempt from the more damaging effects of climate change? Will Canada in fact gain by being able to extend its agricultural lands further north as temperatures rise? Might Canadian agricultural producers be able to cash in on higher commodity prices as competitors' crops suffer? And will agriculture then increase in importance within the Canadian economy?

After all, according to Lester Brown, President of the Earth Policy Research Centre in Washington D.C., food security and food production are likely to be key concerns in the forthcoming decades:

"Food supplies are tightening everywhere and land is becoming the most sought-after commodity as the world shifts from an age of food abundance to one of scarcity".

This paper will look at the present state of Canadian agriculture, current and future trends in the sector, and its level of preparedness for the challenges, the potential benefits and the uncertainties of climate change.

The state of Canadian agriculture

The 2011 Canadian Census of Agriculture (Statistics Canada, 2012) shows an industry growing in output while consolidating and adapting. The overall number of census farms decreased by 10.3% from 2006 to a total of 205,730, while the country-wide farm area decreased by 4.1%. Gross farm receipts in 2010 amounted to $51.1 billion, up 3.9% in real terms since 2005. Most of this growth occurred on larger farms which have been consolidating and drawing on technological innovation to increase productivity and augment sales. In 2011, Canada had 9,602 farms that reported $1 million or more in gross farm receipts, a 31.2% increase from 2006.

Beef farming and crop production have long been the backbone of Canadian agriculture. However, the former has been losing out to the latter, and between 2006 and 2011 production continued to shift such that the share of oilseed and grain farms had increased to 30.0% of all farms (up from 26.9%), while the share of beef farms had declined to 18.2% (down from 26.6%). Oilseed and grain farms accounted for 35.7% of total receipts in 2010 ($18.2 bn). Beef farms came second with $7.3 billion in gross farm receipts in 2010, 14.3% of the total.

Among field crops, the stories from the 2011 Census include the decline of tame hay and alfalfa crops (linked to the decrease in the numbers of beef cattle) and the rapid rise of canola and soybeans. Canola has now surpassed spring wheat in area planted, up 55.9% from 2006, to 19.4 million acres as exports of various canola products (oil/seed and meal) have risen by a factor of between 3.5 and 6 since 2002. Meanwhile, soybean planting has increased 33.2% since 2006 to 4.0 million acres.

Indicators of future trends

Adaptation and dynamism are critical in agriculture. For decades we have witnessed a process of consolidation and specialization. Essentially farms have been getting larger and more specialized as new technologies have ushered in economies of scale, but also high up-front costs.

Of late we have witnessed greater diversification and a change in farming practices to become less environmentally damaging. The 2011 Census showed that, for the first time, over 50% of the total area prepared for seeding across the country employed no-till methods. No-till and conservation tilling methods are less ecologically disruptive and reduce fuel costs. They are now the dominant method employed in the Prairies where the soil tends to be more prone to erosion. More recently, government incentives in Quebec have led to a 69% increase in the number of farms adopting the practice.

Organics are also on the rise: the number of certified organic operations increased 4.4% from 2006 to 3,713, representing 1.8% of all farms in Canada (compared with 1.5% in 2006 and 0.9% in 2001). In addition, farmers are moving in greater numbers into new niches such as agro-tourism (AAFC, 2012a).

This snapshot of Canadian agriculture paints an agreeable picture – one that shows a dynamic agriculture and agri-food system directly providing one in eight jobs, employing two million people and accounting for 8.1% of total GDP (AAFC, 2012a).

Agriculture and Agri-Food Canada's *Medium Term Outlook for Canadian Agriculture, 2011-2021* (AAFC 2012b) projects a picture of continuity, with prices of grains, oilseeds and special crops remaining well above historic levels (though below recent peaks). This higher price

plateau is a result of strong global demand due to: a still-growing global population, recent crop failures in the U.S. and the Ukraine, increased consumer affluence, and a continued push for biofuels.

A 2011 McKinsey report on future global resource needs underlines the economic boost to exporting countries from higher commodity prices: 'China and India have resource intensive economies… [and] may need to import 5% and 15% of their 2030 cereal demand, respectively, having been modest net exporters of this commodity in 2010.' (Dobbs et al., 2013, p.9).

Government projections see Canada's total harvested area increase by 4% by 2021 (compared to the historical average, 2006-2010). Canola (both production and crushing capacity) is predicted to expand in area in western Canada and corn and soybeans will become more important in eastern Canada. Cattle and hog prices are expected to increase with cattle exports benefiting from an expected revision of the U.S. Country of Origin labeling (COOL) in 2013 (AAFC 2012b).

On the negative side, Canadian farmers face high energy costs and feed prices, as well as strong Canadian dollar which affects their cost structure.

Climate uncertainties

But what of climate change? Despite the increased incidence of extreme weather events over past years, the Government's Medium Term Outlook '….assumes no impact from climate change and from policy to mitigate climate change nor significant animal disease outbreaks or unusual climatic conditions over the period of the outlook.' Given what we know (and what we don't know but expect), this is a very questionable set of assumptions that significantly undermines the usefulness of the projections.

The Intergovernmental Panel on Climate Change's Fourth Assessment report, issued over five years ago, presented climate scenarios which showed mean global temperatures increasing by between 1.4C and 5.8°C this century. A recent climate change report issued by Price Waterhouse Coopers in November 2012 (*Too late for 2 degrees?*) pours cold water on any hope that warming can be limited to 2°C: 'Even doubling our current rate of decarbonisation would still lead to emissions consistent with 6 degrees [C] of warming by the end of the century'.

With changes of this magnitude in store, it is both unreasonable and unwise to ignore climate's effect on Canada's agricultural future.

As a high latitude country, warming in Canada is likely to be pronounced, with certain regions - including the North and the southern and central Prairies - warming more than others (Lemmen and Warren, 2004, p.55). Indeed, the Canadian Prairies (home to more than 80% of Canada's agricultural land) have already experienced warming at a faster rate than the global average (Sauchyn et al., 2013, p.3).

Changes and impacts across the country are not expected to be uniform. In broad terms, however, we should expect all of the following:

- warmer temperatures
- drier or wetter conditions
- increased frequency of extreme climatic events
- enhanced atmospheric CO_2.

Lemmen and Warren (2004, p. 56) summarize the likely impact on agricultural crops in Canada. On the **positive** side they predict:

- increased productivity from warmer temperatures
- the possibility of growing new crops
- accelerated maturation rates
- increased productivity from enhanced CO2
- longer growing seasons
- decreased moisture stress.

On the **negative** side we can expect:

- decreased herbicide and pesticide efficacy
- increased moisture stress and droughts[1]
- increased insect infestations
- crop damage from extreme heat
- planning problems due to less reliable forecasts
- increased weed growth and disease outbreaks
- increased soil erosion.

In the early days of warming the positive effects are likely to outweigh the negative effects, but this is unlikely to last: most expect there to be temperature and $C0_2$ thresholds, beyond which yields will level off or decline.

What will be the overall impact on Canadian agricultural output? Lots of people have been trying to figure that out.

[1] The fact that both increased and decreased moisture stress are predicted illustrates the variability over time and space, but also the uncertainty of predictions.

Canada is generally expected to fare better than many other countries in relation to climate change impacts, and international investors are already acting on that assumption (Tom Eisenhauer, president of Bonnefield Financial, 'when we looked around the world at agricultural investing, we just thought Canada is where you have got to be, and we're seeing more and more people reach that conclusion" quoted in Mittelstaedt, 2012).

Simulations produce a wide range of estimates of future crop yields, for example:

- McGinn et al. (1999) suggest that yields of canola, corn and wheat in Alberta could increase by between 21% and 124%.
- Singh et al. (1998) suggest that yields of corn and sorghum in Quebec could increase by 20%, but that yields of wheat and soybeans could decline by up to 30%.
- Bootsma et al. (2001) suggest that, in the Atlantic Provinces, there could be gains in grain corn and soybean yields (by up to 3.8 and 1.0 tonnes/hectare respectively), whereas barley yields would likely not shift.
- Brklacich et al. (1999) show estimates of climate change on agricultural GDP in the Prairies ranging from -7% to +7%.

(Source: Lemmen and Warren, 2004, p. 55, Weber and Hauer, 2003, p.164)

Overall, Weber and Hauer (2003, p. 164) present an extremely positive outlook for Canada:

'We find Canadian agriculture benefits significantly from climate change, with land values increasing on average by 65% over the next 50 years. This is equivalent to a $5.24 billion or 16% increase in annual agricultural GDP relative to the current $32bn value.'

They do, however acknowledge the power of the unknown: changes 'outside the range of current conditions' and unmodelled factors such as soil chemistry, water constraints or the costs of adaptation are not included in their calculations.

In contrast, Reinsborough (2003, p.36) concludes that there is negligible benefit to Canadian agriculture from climate change. While there may be potential benefits in shifting from temperate to tropical crops, they do not find that this has a significant effect on farmland values or farm revenues. [N.B. Weber and Hauer (2003, p. 164) argue that Reinsborough's model is aggregated at a very coarse spatial resolution, potentially hiding the responsiveness of agricultural productivity to changing climate conditions].

It should be noted, however, that these largely positive studies issued in the late 1990s and early 2000s have recently come in for criticism. Questions over the validity of studies based on temperature averages are raised by Ackerman and Stanton (2013) who point to the new wave of research indicating that crops are often more sensitive to temperature extremes than to averages. The 'threshold' model of recent studies reveals, in certain cases, rapid drops in yields for degree-days beyond the optimum: 'With a better explanatory framework, focused

on temperature extremes rather than averages, judgments about temperature impacts on crop yields have become more ominous.' (Ackerman and Stanton, 2013). In addition to this updated thinking on thresholds, newer experimental studies have also sharply reduced older estimates of carbon fertilization effects.

A closer look at potential benefits

There is clearly a good deal of remaining uncertainty, then, which makes it all the more important that Canada should build on our relative strengths and be quick to adapt to the new reality.

Expanding agricultural land: According to the 2011 Census of Agriculture farmland accounts for just 7.2% of the total land area in Canada, so there should be plenty of opportunity to expand. At present, Newfoundland and Labrador, is ahead of the curve in recognizing this (Government of Canada PRI, 2012, p.2). The province has called for a development strategy focused on potential agricultural opportunities in northern areas of the province. The Yukon government, also looking at deriving benefits from climate change, has charged the Department of Energy, Mines and Resources with increasing agricultural production in the territory in the interests of greater food security.

Brklacich et al. (as quoted in Lemmen and Warren, 2004, p.55) point out, however, that temperature is not always the limiting factor in crop production. Poor soil conditions are likely to be a major constraint on extending northwards.

Introducing new crops: Much has been written about farmers' dynamic adaptive capacity. For example, in the 1970s, a glut of wheat led to the introduction of lentils in Saskatchewan. The province is now Canada's largest producer of pulses, the majority of which are exported to India and China. Pulses (which include lentils, chickpeas, dry beans and dry peas) have the advantage of being adapted to dry climates. They also have nitrogen-fixing properties, making them valuable in rotations and reducing the need for fertilizers containing synthetic nitrogen.

Such win-win adaptations will be highly prized in the future. Warmer conditions and longer growing seasons will open up new opportunities but also require new varieties and hybrids with hardier characteristics (e.g. heat and drought tolerance). Research is already being undertaken in this area in Ontario, as part of the OMAFRA-University of Guelph partnership under the federal 'Growing Forward' initiative.

Livestock: The outlook for livestock operations vis-à-vis general warming is largely positive (Lemmen and Warren 2004, p.63), when taking into account adaptations to farm practices (such as: advancing the date when livestock are turned out for pasture, extending the grazing season, introducing new breeds). However, extreme weather events and severe moisture

stress may be a serious challenge (such as the Prairie drought in 2002 when many ranchers were forced to sell off cattle).

A closer look at potential problems

Moisture stress: Drought is no stranger to Canada: 2001-2 saw one of the most intensive and widespread droughts in Canadian history: the economic costs to the agri-food sector for this period of drought are now estimated at $6.14bn (Shabbar (2004) quoted in Wall and Smit, p. 119).

Lapp et al.'s study (quoted in Wall, Smit and Wandel, 2007, p.77) on future snow accumulation and ablation (melting and vaporization) shows that climate warming will likely result in a substantial decrease in snow accumulation in the South Saskatchewan River Basin, with a corresponding decline in critical spring runoff volumes. The area of Canadian plains at risk of desertification has been estimated to have increased by about 50% between recent conditions (1961-90) and those projected for the 2050s (Sauchyn et al., quoted Wall, Smit and Wandel, 2007, p. 78).

Improved land and water management will thus be essential. The irrigation industry is the already largest user of water in Western Canada (Wall, Smit and Wandel 2007, p.77) and as issues of water management come to the fore, the industry will 'likely come under the greatest scrutiny and stress' (Lapp et al quoted in Wall, Smit and Wandel 2007, p.77).

There are, thankfully, some encouraging examples of innovation countering unfavorable conditions: in south west Ontario, tomato growers had their second highest yield ever in one of the driest years in history (2002) after adopting an improved irrigation system from Australia (Wall, Smit and Wandel, 2007, p.9). In southern Alberta there has already been substantial work in upgrading irrigation canals, enhancing water storage capacity and improving irrigation management (Lemmen and Warren 2004 p.62).

Pests, weeds and disease: Again, the story here is mixed**.** Up to a certain threshold, higher concentrations of CO_2 encourage plant growth – sadly, that includes weeds. Research in Saskatchewan (Archambault et al., quoted in Lemmen and Warren 2004, p.76) indicated that the interactive effects of increased CO_2 and temperature caused a decrease in herbicide efficacy (though it has been speculated that these negative effects on herbicide efficacy could be offset by the positive effects on crop yields).

Warmer winters and longer summers may increase the range and severity of insect and disease infestations, such as grasshopper infestations in the Prairies. On the other hand, an enhanced $C0_2$ environment may negatively impact on the success of aphids (Awmack et al, quoted in Lemmen and Warren 2004, p.60).

Pesticide efficacy is also likely to decrease under climate change, with the consequent need for heavier and more frequent applications, leading to increased costs and externalities (potential threats to non-target organisms and increased water pollution).

As with many of the ongoing climate change impact projections, there is still much uncertainty and thus need for further research: 'The complex interactions of the effects of insects, diseases and weeds on agricultural production are still not well enough understood to offer findings on projected impacts' (Sauchyn et al. 2009 p.17)

Responses and the role of policy

Canadian agriculture is already adapting to our changing climate reality. But is enough being done to capitalize on our strengths and increase resilience in the face of an uncertain climate future?

It has been argued that the policy goal in this area should be to increase the flexibility of agricultural systems and introduce 'no regrets' measures that improve efficiency (such as improved well-water management, 'smart' irrigation, nutrient recovery from waste water, land management for soils at risk, and integrated pest management (Wall, Smit and Wandel, 2007, p.8)[2]). Key policy considerations are how to support diversification and innovation and how to secure increases in resource productivity.

Diversification

Uncertainty makes diversification a sensible strategy. It helps spread risk at a farm level as well as at a market level and offers the potential for entering new markets with higher value-added possibilities.

A fine example of this comes from Saskatchewan where value-added processing within the pulse business has taken off in the last 10 years: Alliance Grain Traders (AGT) is now the largest value-added supplier of pulse products in the world. As part of its expansion strategy, the pulse industry is working to promote the health attributes of its crop and to encourage renewable fuel/biofuel uptake.

Crop diversification is not, however, without difficulties in implementation. Diversification can require up-front investment for farmers, putting it out of reach for many small operations that struggle to make a profit (in the absence of direct support). Government support is needed, but it has to be smart *and* sustainable. 'Policy and programs encouraging producers to diversify their farm operations need to take into account other factors (such as the

[2] see also the UN's Food and Agriculture Organization's recent 'Climate Smart Agriculture' (CSA) initiative.

established trend towards specialization) that can work against such actions.' (Wall, Smit and Wandel. p.9).

Government programs and policies can both help and hinder. The reform of the Western Grain Transportation Act has contributed to increased crop diversification on the Prairies (Campbell et al., quoted in Lemmen and Warren 2004, p. 64). On the other hand, research suggests that crop insurance may tend to decrease the propensity of farmers to adapt (Smithers and Smit quoted in Lemmen and Warren 2004, p.64).

Ontario has the most diversified agriculture in the country and the recent expansion of soybean production in the province, according to Reinsborough (2003), is related to a complex mix of factors: 'changes in plant breeding, production technologies, crop prices, enterprise compatibility, public programs, and a recognition of climatic risks.'

So where lies the winning formula in fostering diversification? According to Wall et al. (2007) we need research support, and effective mechanisms for ensuring information and technology transfer. The available research needs to be better integrated into decision making at all levels – at the farm, in business and within government.

Innovation

Diversification is one type of innovation. Other areas in which innovation is critical are water management and crop husbandry. Examples of progress in both already exist.

In 2009 the BC Ministry of Agriculture and Lands introduced an Irrigation Scheduling Calculator as part of the government's commitment to improving irrigation efficiency under its *Living Water Smart* plan. The calculator provides users with an irrigation schedule using real-time climate data from Farmwest (part of the Pacific Field Corn Association).

More recently, faculty at the University of Georgia have simplified their earlier GPS-based technology, Variable Rate Irrigation, to allow farmers to more accurately target irrigation needs (and hence improve the efficiency of commonly-used center-pivot systems)(Gies, 2011).

Variable rate technology is fundamental to the implementation of Precision Agriculture management practices (which have been widely adopted over the past 15 years). Precision agriculture responds to intra-field variations and can significantly reduce the amount of nutrient and other crop inputs used while boosting yields. By using the right amount of inputs in the right areas at the right time, farmers save money and maximize potential benefits. There are also environmental benefits.

'The thread that ties all innovations is greater access to research, information and extension' says Keith Wheeler who, as chairman of a company in the agricultural information technology

business (ZedX Inc), introduced a new tool at the most recent round of climate talks (COP 18) in Doha, Qatar. The *Fieldprint Calculator* is an online tool that helps farmers to build scenarios about decisions that affect their current land use, energy use, water use, GHG emissions and soil loss, as compared with state/provincial and national averages. The tool is designed to facilitate the achievement of goals of 'both productivity and sustainability' (Wheeler).

Investment in agricultural research and development is fundamental to continuing innovation in the field. A Canadian Agri-Food Policy Institute (CAPI) study (Clark and Thompson 2011) states unequivocally that the highest returns on investment in the sector come from research and development expenditure programs (with rates of return reaching 20% or more).

Currently $8-billion is spent annually by federal and provincial governments on agriculture, but just $156-million goes into research programs and only $140-million is spent on trade development. While government spending on crop and livestock research has gone down since the 1990s, direct payments to farmers have tripled (Waldie 2012). The growth of private sector investment in research and development over the years has outpaced that of the government: industrial R&D investment in food manufacturing, for example, has risen from c. $65 million in 1993 to c. $200 in 2011. The Canadian Agri-Food Policy Institute (Sparling and Thompson, 2011) argues that more needs to be done with Canada's processing sector losing ground in efficiency and badly in need of modernization. A strategy is needed to increase both private and public investment in the sector with a particular view to enhancing Canada's advantages vis-à-vis competitors in export markets.

Veeman and Gray (2009) argue that a slowdown on spending in R&D over the past two decades is one of the contributing factors to slower crop productivity growth in the prairie region of Western Canada. According to the AAFC (2012a) R&D spending has been increasing over the past three years and is now 33% higher than it was in 1990-91 though this trend has not been consistent over time: figures put together by Gray (2008) show a drop in AAFC R&D expenditure of just over $40 million in the area of crop research between 1996 and 2004.

Resource productivity

While productivity growth is a concern, analysis by McKinsey (2011) details an abundance of opportunities for increasing resource productivity over the next 20 years. Agriculture features prominently in the report as an area with great potential to improve. Opportunities are ranked ordinally according to their potential impact and include:

- No. 2: increasing yields on large scale farms
- No. 3: reducing food waste
- No. 7: increasing yields on smallholder farms
- No. 10: reducing land degradation

- No. 13 improving irrigation techniques

Investment in reducing food waste and improving yields should be core components of a strategy to build resilience within the agricultural sector. Take as an example the Ontario beet crop of 2004, 17% of which was lost due to rotting in winter storage – an issue currently being investigated by an OMAFRA-supported study.

A continuing focus on reducing land degradation and improving irrigation techniques will see the convergence of sustainability measures with resource productivity goals – the proverbial win-win.

And while Canada focuses on doing more, and doing better, with what it has got, investments in export market development for growth areas (such as India and China) and in the infrastructure to support increased productivity and exports will be vital (Sparling and Thompson 2011, p.14).

Conclusion

Agriculture has an important role to play in the Canadian economy. It has consistently shown its potential for dynamism and adaptation, both essential to increasing productivity and profitability. But is enough being done to secure the best future for an industry facing critical, even existential challenges?

Climate uncertainty and climate extremes are givens for the future of Canadian agriculture, and while there may be some initial benefits from rising temperatures and elevated carbon dioxide levels (and yes, let's take advantage of these), such benefits are unlikely to last: there is a growing body of evidence pointing to temperature and $C0_2$ thresholds, beyond which yields will level off or decline (Ackerman and Stanton, 2013). These risks need to be addressed and policies put in place to reduce them.

There is still work to be done to convince all involved that this is a real issue. In a 2007 study of Ontario farmers (Reid et al. 2007), 62% of respondents viewed climate change as a long-term warming trend, 21% were entirely skeptical, and only 17% of farmers interviewed associated climate change with change in variability and extremes. A USDA report on climate change and US agriculture released 2013 refers to this perception problem: 'Social adaptation barriers represent a significant challenge to climate change adaptation in U.S. agriculture' (Walthall 2012).

This is no time for complacency. Building awareness, resilience and adaptive capacity should be a priority from the farm level up through the industry.

Research-led innovations can ensure that Canada makes more of, and does better with, the agricultural advantages it enjoys. Canada needs to take care of its land and its produce (through innovative, sustainable practices), and to add value to its agricultural product to capture new markets.

Let's make Canadian agriculture better and seek to mitigate climate change while we're at it. There is much to applaud – we are already seeing adaptation measures such as greater diversification and a change in farming practices to become less environmentally damaging.

Adaptive capacity is key for government too. Policy has always played a huge role in agriculture: now is the time to shift to a more long-term strategic view (a view espoused in the Canadian Federation of Agriculture's National Food Strategy) and away from short-termism encouraging non-competitive, inefficient farm management and markets based on predications of the future that are extremely unlikely to hold true.

Appendix

Acknowledgements

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