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# Moving Toward Prairie Agriculture 2050

Editors:
Brian Amiro, Christine Rawluk and Karin Wittenberg

Green Paper presented at the
Annual Conference of the Alberta Institute of Agrologists,
Banff Alberta, April 02, 2014

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# Moving Toward Prairie Agriculture 2050



**Brian Amiro, Christine Rawluk and Karin Wittenberg**

Climate and weather: a common discussion topic in coffee shops across the Prairies. Discussions tend to be driven by our experiences, and these are influenced by recent events, especially extreme or catastrophic ones. Record heat, record cold, record snowfall, record flood, record drought – all invoke some desire to attribute extremes to driving factors. A changing climate, caused by increases in atmospheric greenhouse gases, may be driving some events but attribution of any event is not possible. As Agrologists, we have a responsibility to consider climate and weather effects on our agricultural production systems, irrespective of causes. The best advice we can offer will consider future resilience so that agricultural systems have capacity to cope with the current climate, as well as potential future conditions.

This report addresses the question of ***Climate and Food: Is There a Future?*** through the eyes of 23 experts with thoughts on our Prairie agricultural systems over the next 35 years. Many of the contributors are Professional Agrologists, who discuss the need for us to adapt in response to likely scenarios for our future climate while considering the uncertainty in any future prognosis. The contributors come from all three Prairie Provinces and work in government (federal, provincial), industry and university. As in any discussion of the future, the relative impact of change or of new technology cannot be predicted with accuracy. Consider what has happened in the past 35 years, and that the 1980 reality was no internet, no cell phones, no GPS, and the start of canola!  Our history is one of technological advances arising from adversity. But to charge forward expecting as-yet undiscovered technologies to save us from the potential ills of climate change is a risky approach. Our best strategy for preparedness is ongoing dialogue based on what we know now, evolving as we learn more. The goal for this report is to generate discussion so that we can prepare ourselves to better adapt to an uncertain future.

We choose the year 2050 as our horizon. We summarize the current state of knowledge of future climate and present 14 essays on specific topics. The topics are not fully inclusive because of the diverse nature of climate effects on agriculture; but they provide a diversity of outlooks. We conclude with some aspects of preparedness, whereby we aim to strengthen the capacity of the Prairie agri-food sector to adapt and thrive. Our bottom line is that we are fortunate to be engaged with a fantastic industry; one that has already demonstrated good resilience to adapt to a changing climate. Future resilience will be affected by the many variables that impact agriculture's ability to adapt, with climate perhaps being one of the more predictable variables. It is likely there will be many surprises and we will need to be aggressive in addressing a broad range of coping strategies.

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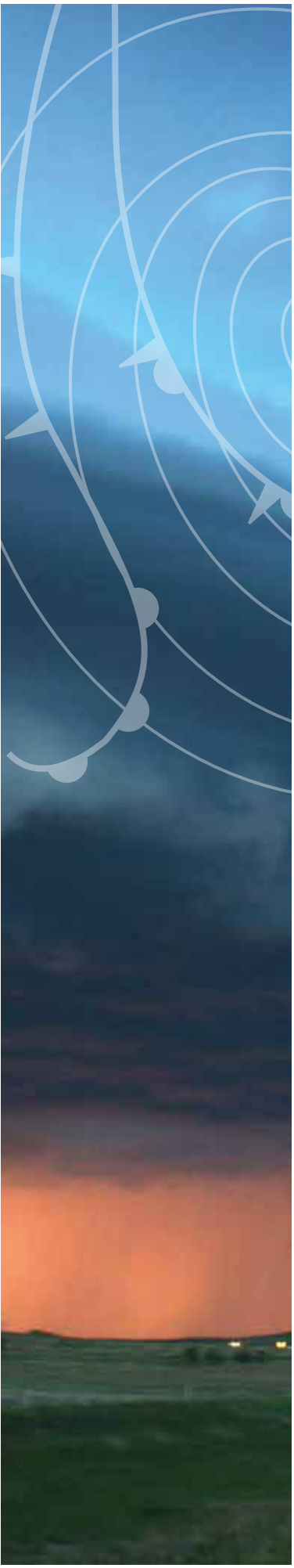

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## Acknowledgements


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# Moving Toward the Year 2050

## Why 2050?

The year 2050 approximates when the atmospheric carbon dioxide concentration is expected to double compared to pre-industrial times. This doubling has been a baseline for many simulations of future climates so that an extensive dataset exists. 2050 is also within the timeframe that today's young generation of agricultural producers will be operating. Finally, 2050 marks just over 200 years of agriculture activity across the Prairies, with the more intensive crop and livestock production practices primarily developed in the last century.

There is extensive literature on the potential impacts of a warming climate on agriculture with some excellent summaries for both Canada[1] and the U.S.[2]. While overall warming trends are statistically significant for Canada[3,4] and globally[5], identifying the impact of climate change on the Prairies is difficult because of substantial climate variability among years. There is also a high degree of uncertainty in predicting the future of drivers beyond climate change that will continue to impact production, processing and distribution systems supporting agriculture in Canada. For example, changes in policy, politics, trade, transportation and technology development are key global drivers of future change to the Canadian agri-food sector. More locally, change with respect to infrastructure support,

*"young farmers will... be the main drivers of our food system over the next 35 years"*

(credit: M. Gaudry)

domestic market demand, land and water demand, and economics are equally important. In fact, it is proposed that climate warming and population growth are better understood and thus present less uncertainty compared to these many other factors. None-the-less, we still **need to plan for change to be competitive and to ensure that Prairie agriculture continues to thrive in 2050 and beyond.**

## Canada's Food System and Today's Climate

The current Canadian food system has developed based on our resources. This includes the influence of climate over the past thousands of years during which our soils developed, and the past few decades during which our production strategies have adapted to the present climate. Currently, primary agriculture occupies only about 7% of Canada's land base, with the Prairie Provinces accounting for 82% of the total[6]. About 55% of this agricultural land base is cropland, 31% is pasture land, with the other 14% classified as woodlands and wetlands (8%), summerfallow (3%) and other (3%; this represents cropland that is temporarily out of production due to excess moisture). **Changes in climate have the potential to increase or decrease this agricultural landbase.** For example, the areas of pasture land and wetlands are usually dictated by soil moisture.

Canada's agriculture and agri-food industry encompasses primary agriculture, farm input and service suppliers, food and beverage processing, food distribution, retail, wholesale and food service. Agriculture has become increasingly internationally focused and makes a significant contribution to the gross domestic product (8% of total) while directly providing one in eight jobs in the Canadian economy. Our relatively high production capacity with the low national demand of our small population is also a function of our climate. This provides export opportunities that are critical to continued growth of agriculture. Canada is the sixth-largest exporter ($40B) of agriculture and agri-food products globally. Canola, non-durum wheat, canola oil, soybeans and frozen pork represented the top five agri-food exports in 2011[6]. Our current climate supports all of these, and is especially conducive to canola and small grain production. We could argue that the development of canola by Canadian scientists was a direct response to an opportunity in our current climate!

Our temperature regime on the Prairies dictates much of our production capability. This sets the stage for our seasonal differences, pests and diseases, grain storage, and heating/cooling requirements for buildings. However, water is equally important. Agricultural activities account for 10% of gross water withdrawals in Canada, well behind thermal power generation and domestic use[7]. However, agriculture is looked on as the largest consumer of water because it is lost through evapotranspiration and infiltration. Water supporting irrigation, livestock production

(credit: D. Flaten)

and food processing competes with drinking water use, urban, industry and hydropower needs, as well as its role in maintaining healthy ecosystems. This is especially true in Alberta, which has the greatest amount of irrigation. Currently, governance and management of Canada`s water resources are complex with limited monitoring or valuation of its use. Even under our current climate, water is critical: either too much or too little. An expert panel on water and Canadian agriculture has highlighted needs to improve water monitoring information and data interpretation, develop more efficient and sustainable methods and technologies for water management, improved governance, and to consider adoption of beneficial management practices that employ conservation agriculture and ecosystems services[8]. This is urgent in the present climate, with the urgency likely increasing in a changing climate.

On the socio-economic side, our tenure system has evolved in the present climate. Owned land as a proportion of total farm area has been decreasing steadily every census since 1976, with 62% owned by those who farm it in 2011. Other tenure arrangements include rentals, leasing of crownlands and crop sharing arrangements. The 2011 Census reported 205,730 farms in Canada, down 10% from 2006[6]. This also marked the first time the 55-and-over age category represented the highest percentage (48%) of total operators. Of equal interest was the observation that young farmer enterprises, managed solely by operators between the ages of 18 and 39 years, accounted for 7.5% of Canadian farms, but earned more from both farm and non-farm sources as compared with older farm enterprises. These young farmers will likely still be producers by the year 2050, or at least be the main drivers of our food system over the next 35 years. We may also expect that they will be large users of developing technologies, maintain an entrepreneural focus, and be in touch with global market drivers.

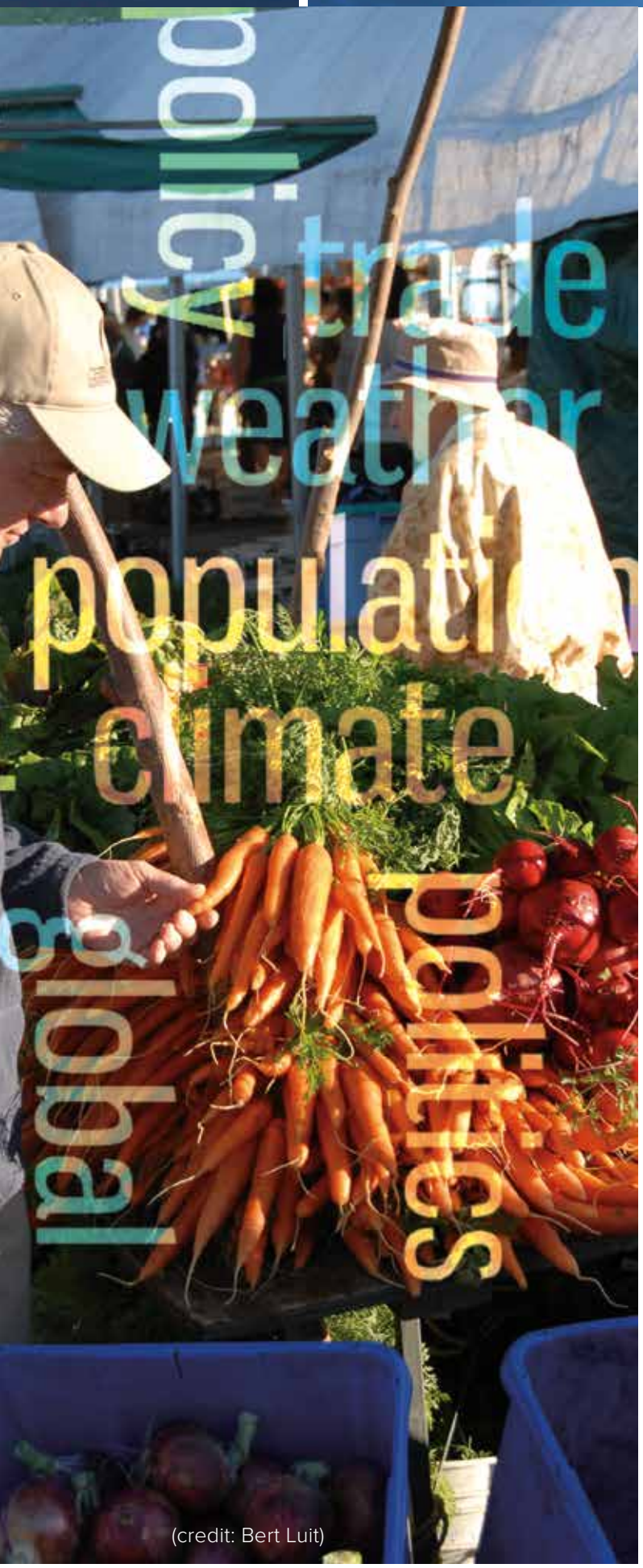
The food distribution, retail, wholesale and food service industries interact most directly with consumers. As such they have become increasingly important in conveying consumer trends and demands with respect to food ethics, and food safety, quality, value and convenience to the rest of the food value chain. Public awareness of climate change and environmental health is reflected in the retail industry`s interests in carbon footprint or ecological footprint labeling. While the complexity of monitoring and reporting environmental impact has slowed adoption of labeling policies in Canada`s food and beverage sectors to date, further development of accountability labelling is anticipated if consumer pressures continue. The impact of social media has also increased in importance conveying messages about sustainable food production, a feature that will likely increase in impact. The interaction between known climate drivers, such as emissions of greenhouse gases, and the potential to change production methods to reduce climate impacts (mitigation) will also likely increase in importance as consumers are more actively involved in food choices.

## The Science of Climate Change

"Greenhouse gas" is a term for atmospheric gases that have radiative effects, resulting in the capture of long-wave (thermal) radiation that is emitted by the Earth. For simplicity, we will keep our discussion to those gases that have increased in our atmosphere as a result of human activities. Evidence for increases in these gases is clear from decades of measurements of atmospheric concentrations, as well as measurements in long-term storage media such as ice cores. The sources of these gases are also known, with the combustion of fossil fuels being the largest new contributor. The radiative forcing caused by these gases has been calculated as an average global energy addition, expressed in radiative units of W $m^{-2}$. The Intergovernmental Panel on Climate Change (IPCC) periodically reports on the science associated with climate change and has recently updated the information in their 5$^{th}$ assessment report[5]. They estimate future radiative forcing based on potential scenarios for global emissions of greenhouse gases. Here we use a scenario that has a representative concentration pathway that assumes a medium growth rate of greenhouse gas emissions resulting in a radiative forcing of about 4.5 W $m^{-2}$ in the year 2100[9]. This assumes that greenhouse gas emissions will start declining at about 2050 when mitigation becomes more effective. While this scenario may be optimistic, it is important to note that most scenarios have similar outcomes by the year 2050, with larger differences thereafter because different levels of continuing emissions drive different endpoints over the last part of this century.

Figure 1 illustrates the radiative forcing estimates relative to the pre-industrial period (about 1765). Estimates up to 2010 are based on current measurements and the future is based on climate model projections. For this scenario, today's radiative forcing caused by humans is slightly less than halfway to the peak. However, the climate effect is more complicated and temperature changes do not scale linearly with radiative forcing for a given year or scenario. The global temperature increase by 2050 for this scenario is estimated to be about 1.4°C (likely range of 0.9 to 2°C) compared to the 1986 to 2005 period. This is in addition to the estimated 0.6°C increase in global temperature that has already occurred from about 1850 to the 1986-2006 period. Scenarios with higher emissions project global temperature increases of about 2°C by 2050. Differences among scenarios become greater at about 2100; for example, a different scenario projects 3.7°C warming by 2100.

So what does this mean for agriculture in the Prairies and globally? IPCC uses the radiative forcing information to project the climate in 2050[5]. For the Canadian prairies, we can extract estimates of the change based on the coarse resolution of the global climate models. Potential changes are compared to one standard deviation of the current 20-year variability. If the projected change is less than one standard deviation, we estimate



(credit: Bert Luit)

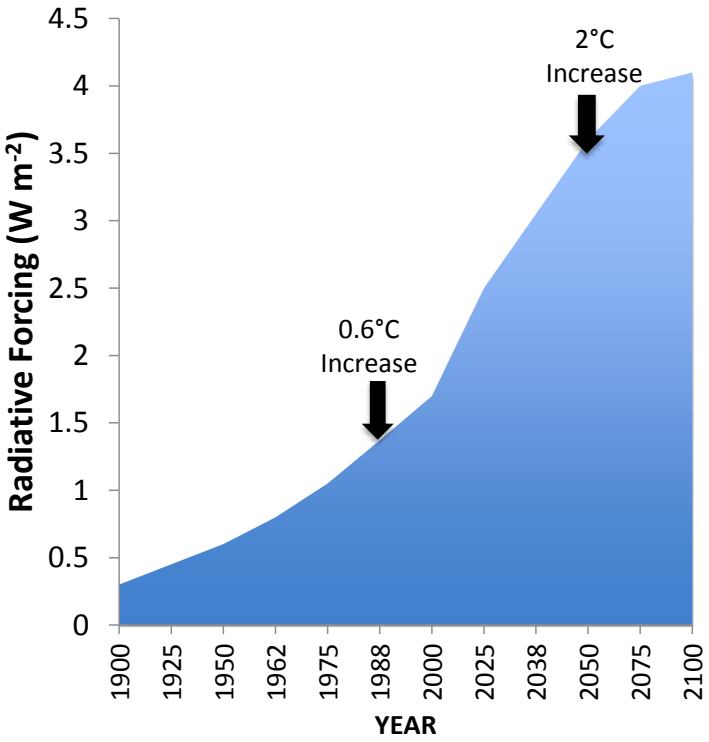



**Figure 1:** *Global radiative forcing from all human-caused sources based on the representative concentration pathway RCP4.5 medium emissions scenario of IPCC relative to 1765[5]. This scenario assumes that emissions will be mitigated and start decreasing after about 2050. Estimated temperature increases are shown.*

that no change will occur. Note that agricultural production currently copes with changes within this variability range. Table 1 indicates that both summer and winter temperatures will increase, with the increase being greatest in winter. To put this in perspective, the year-to-year variability in annual mean temperature across the Prairies typically has a standard deviation of about 1°C based on a 30-year record. However, short-term or year-to-year variability would distribute around a higher average temperature. Precipitation is projected to have little change, with likely no change in summer and perhaps a slight increase in winter. Yet precipitation can vary widely among and within years under our current climate.

Based on some older climate projections, the Prairie Adaptation Research Collaborative assessed possible changes in agricultural land capability[1]. They estimated that a changing climate by 2050 would remove many of the heat limitations for agriculture across most of the currently cropped area, but that aridity issues would increase across the Prairies (Table 1). An important aspect is that suitable climates for agriculture will be available northward, although there may be soil limitations.

**Table 1:** *Projected climate changes by 2050 for the Canadian Prairies and globally, compared to the 1985 to 2005 period*[5].

| | Changes by 2050 |
|---|---|
| **The Prairies** | |
| Summer Temperature | Increase by 1 to 4°C; median 2 to 3°C |
| Winter Temperature | Increase 2 to 4°C; median 3°C; warmest in east |
| Summer Precipitation | No change; possible increase by 10% |
| Winter Precipitation | 0 to 10% increase; possible 20% increase |
| Agriculture land capability[1] | Class 1 climate increases from 8% of area to 19% with less heat limitation; aridity increases to affect 80% of currently cropped land. |
| Population[12] | Increase from 5.5 to 7 million |
| | |
| **Global** | |
| Heavy precipitation intensity & frequency | Increase |
| Frequency of warm days & nights | Increase |
| Frequency of cold days & nights | Decrease |
| 1 in 20 year extreme daily temperature | Increase by 1 to 3 °C |
| Heat waves | Increase |
| Drought | Increase in some regions (medium confidence) |
| Population[13] | Increase from 7.2 to 9.6 billion |

Agriculture on the Prairies responds to average conditions, variability around the average, and extreme conditions in any given year. The IPCC projections have higher uncertainty in change related to extremes for a specific region of the Earth, such as the Prairies. However, there will likely be global increases in temperature related impacts such as heat waves, extreme warm temperatures, drought, and perhaps heavy precipitation events. Our expectation is that the Prairies could be affected by these global trends.

## Adaptation for the Prairies

Looking to 2050, let's assume that Prairie agriculture remains an important resource in the global food system, and that international trade has many of the same features that we have witnessed over the past decade. Within this context, how will we adapt to a changing climate? Adaptive management is part of standard operations for Prairie producers, who respond quickly to changes in weather events each year. Slower changes in average conditions are actually easier for producers to adjust to; the extremes present the larger challenges. Currently, local adaptation within cropping systems appears to be occurring: for example, maize crops have regional adaptations to extreme heat in the U.S. that help to mitigate yield losses[10]. This is in addition to breeding developments and management strategies that have agronomists asking questions like: *Is Manitoba the new Iowa?*[11]. Asking such a question is important for climate adaptation, where we have opportunities to look at current production strategies further south. Generally, a warming climate is expected to increase stresses on the U.S. agricultural sector, although the vulnerability will depend on the measures taken by the agricultural industry[2]. In most cases, at least with moderate warming, **we expect that the Prairies will gain opportunities** that presently occur further south. Despite this, there is likely not a direct analogue that we can copy because our industry will be evolving in response to many pressures, only one of which is climate.

Often our immediate concern is how a changing climate will affect our Prairie production and food systems. The global nature of climate change caused by increased greenhouse gases may well have greater effects related to how climates change in other parts of the world, especially where food production is already limited by excess heat. This effect, coupled with an additional 2.4 billion people to feed, could create opportunities for Prairie agriculture. This assumes that other global and local factors, such as disease or social unrest, are not limiting.

In the following sections, we provide some points on a range of topics that affect the agricultural industry on the Prairies. These topics provide a framework for further discussion as we adapt our management to ensure a strong Prairie agriculture industry into the future.

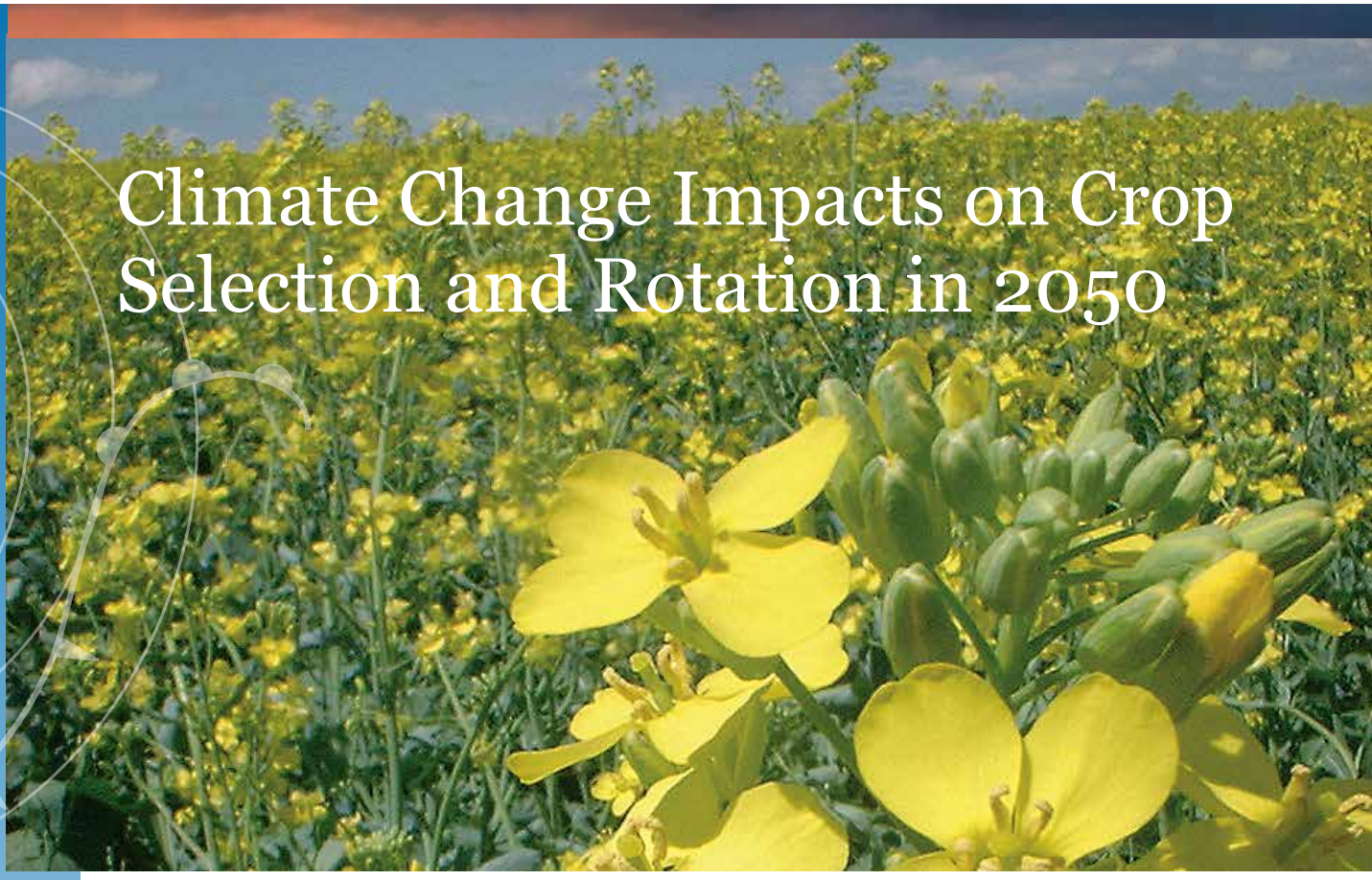
# Essays on Climate Change and Prairie Agriculture

The issue of a changing climate poses an ongoing challenge for planning Prairie agriculture over the next few decades. Past dialogues have made it clear that given identical data or prognosis for the future, individuals will provide a wide array of interpretations. This is especially true for analyses of our recent climate and for concepts on what could be experienced over the next 35 years. When discussing the future, it is unlikely that anyone will be able to anticipate all factors, or even correctly pinpoint all of the governing variables. So there is an advantage to create a dialogue with a diversity of viewpoints to help us prepare for the unknown. Everyone has an opinion on the climate and the weather!

Here, we have asked several agricultural scientists to consider what climate change could mean for Prairie agriculture in 2050, based on their field of expertise. We solicited scientific viewpoints from a wide range of disciplines such as meteorology, crop science, animal science, and economics. The topics are not exhaustive, nor were they chosen to reflect the relative importance of potential impacts. Instead, they form a sample of thoughts. We present the current status; what is likely to be forthcoming; describe the importance; and provide some guidance around what is being done or should be done. The following 14 essays aim to provide a basis for further discussion.

(credit: K. Blair)

# Climate Change Impacts on Crop Selection and Rotation in 2050



(credit: R. Currie)

Bruce Burnett, M.Sc.
Weather and Crop Specialist, CWB Market Research.

## What's going on?

The question of what crops will be grown in the Prairies in 2050 is a deceptively difficult subject to forecast. Decisions made by farmers in determining what crops to grow are complex. They involve not only agronomic factors, but also economic ones. The economic factors are especially difficult to predict over an extended period of time. Adding climate change to this scenario just magnifies complexity of any forecast. It is important to recognize that climate change is only one factor in determining what we will grow on the Prairies in 2050. Climate change will have both positive and negative impacts on the selection of crops that farmers can consider planting, but other factors will determine what crops are actually planted. Economic profitability, technology and government policy are likely to have huge impacts on the eventual result.

To illustrate the impact of all of these factors, one only needs to go back in history to see the changes that have happened to one crop, oats. For the first half of the 20th century, oat area in Western Canada increased rapidly; it was well suited to most growing areas and cropped area peaked at 4.6 million hectares in 1943[1]. This contrasts to the area planted to oats in the 2013 growing season of only 0.45 million hectares[1]. What happened to change the oat area over the course of time? The demand for oats has decreased dramatically since the 1940's due to the mechanization of farms. Oats were the primary feed of horses, which provided most of the power for the farm. As tractors began to replace horses on farms, the demand for oats diminished. This drop

in demand resulted in other crops taking the place of oats in most farm rotations. To summarize the situation, the introduction of new technology resulted in lower demand for a specific crop and resulted in a decrease in planted area of nearly 73%. It is very difficult to predict what transformative technologies may appear between now and 2050 that could alter the acreage mix in western Canada.

Market demand is one of the main drivers in determining what crops we grow on the Prairies. Domestic demand for crops is relatively small due to the small population compared with production. Domestic demand should increase with population growth rates in Canada, which are low at 0.77%[2]. This slow population growth should keep domestic demand for grain and oilseed products at levels that will ensure that Canada will have ample stocks to export. International demand therefore will determine to a large degree what crops are grown on the Prairies in 2050. It is beyond the scope of this document to examine in great detail the various demand changes that will occur in every country that Canada is a trading partner, but one country, China, needs to be examined in more detail.

China is the world's largest importer of agricultural commodities, especially oilseeds. The rise of China's demand for oilseeds and oilseed products is typical of an economy that has moved from a developing economy to an advanced economy. The combination of dietary changes from grains to more processed foods and the ever-increasing population of China results in a large demand for vegetable oils. Increased demand for meat and meat products also increases the need for feed grains and protein meal supplements. This demand increase by China has been felt across the world in the form of rising oilseed demand and prices. In the case of soybeans, China has transformed from being a small soybean importer in the 1990s to a major importer in 2013. USDA forecasts that Chinese soybean imports in 2013 will reach 69 million tonnes (Figure 1). To keep this in perspective, total world wheat trade (imports) in 2013 is expected by USDA[3] to reach only 127 million tonnes.

Similar types of demand increases are seen for vegetable oils and oil meal products. Although the development of the Chinese economy has played a major role in increasing demand for these products, policy changes by the Chinese government have also played a role. China's policy of self-sufficiency in rice and wheat has resulted in only a minor increase in domestic oilseed production. This has forced China to turn to the international market for soybean

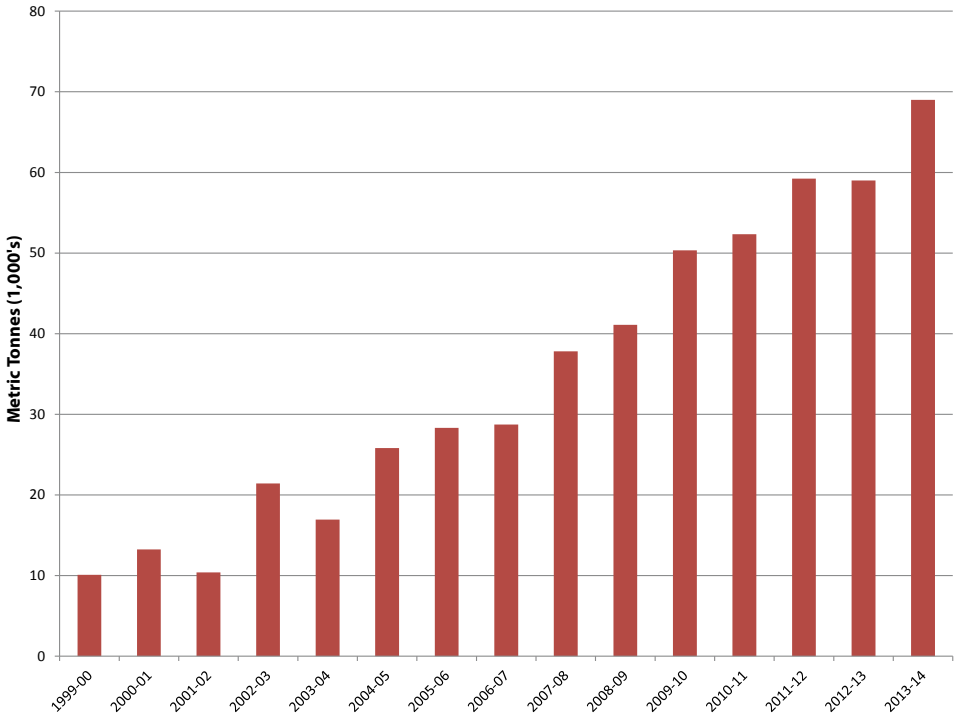



**Figure 1:** *Soybean imports by China[3].*

supplies. This demand from China for oilseeds has boosted the area devoted to oilseeds around the globe. This trend is likely to continue in the future, unless policy changes are made in China. This assumption is supported by the last global outlook published by the Food and Agricultural Research Institute[4] that projected strong oilseed demand into 2022.

International trade is going to be influenced by global warming as well. Two of the world's largest agricultural producing countries, China and India, are also the most populous. China and India rely on irrigation to maintain high

(credit: D. Flaten)

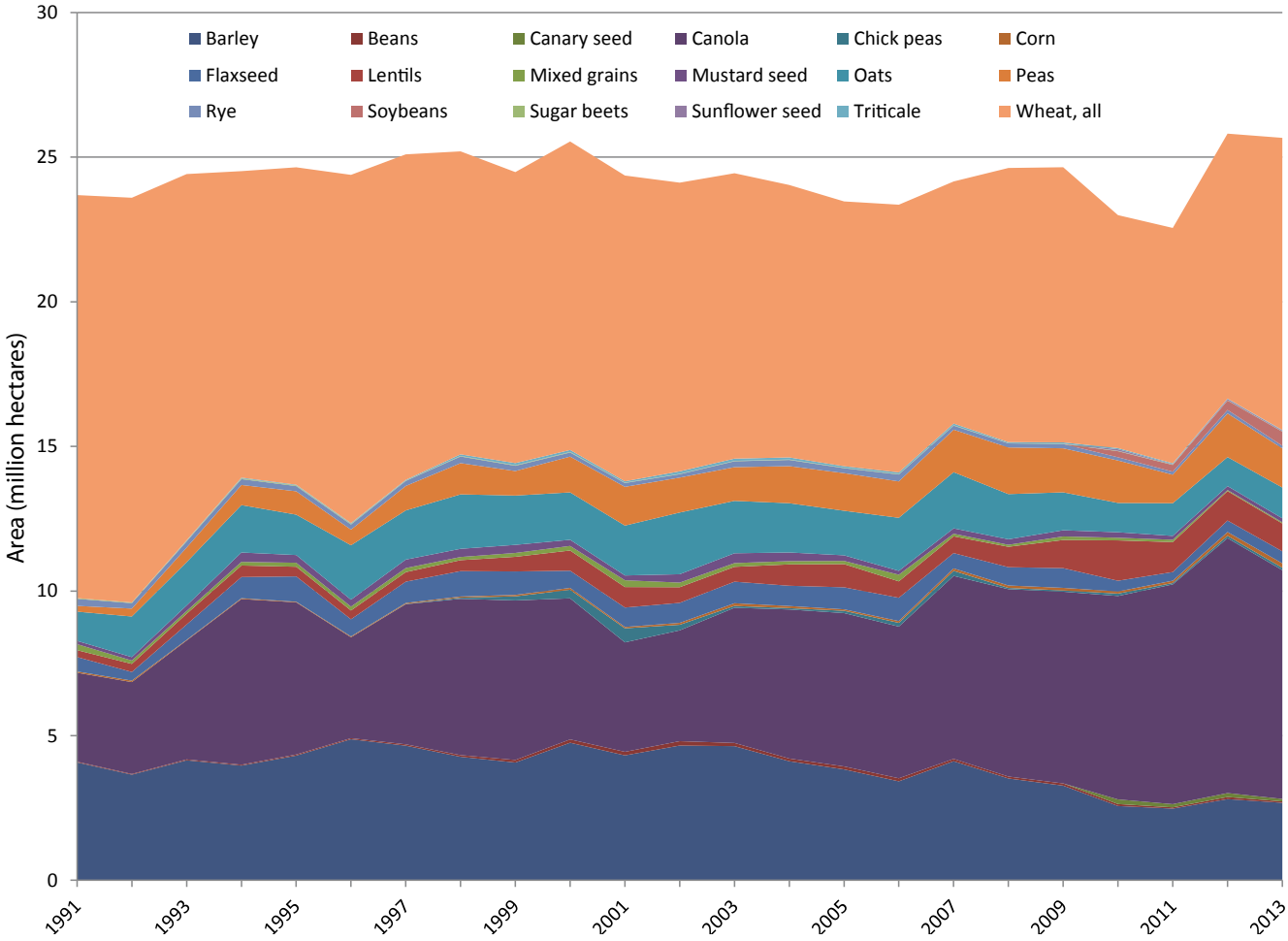



**Figure 2:** *Area of major crops on the Canadian Prairies (read legend from left to right).*

productivity. Any change in the ability of either country to meet the needs of the population will result in increased demand for Canadian (among other countries) imports. India is a major pulse importer and China imports canola, barley and wheat from Canada. These countries are expected to remain key customers of Canadian grain, oilseeds and pulses in 2050. Any climate change in either country that is negative for production will result in larger imports.

The number of crops available for Prairie farmers to grow is quite large. Statistics Canada follows the production of 17 crops, which represent the bulk of the area sown on the Prairies. The total sown area of these crops has ranged between 23 and 26 million hectares over the past decade (Figure 2). There are also a large number of smaller crops from buckwheat to hemp that are climatically suited to the current Prairie climate. Wheat, barley and canola have accounted for 79% of the area over the past five years. This percentage has been relatively constant over the past 20 years with increases in canola being offset by decreases in barley and wheat. Area devoted to these three crops is likely to continue to occupy the bulk of the sown area in 2050. Despite the emergence of some new crops due to a changing climate, it is not expected that the increase in these crops will be enough to dislodge the three largest crops currently grown in the Prairies.

## What is coming up?

The question of what the climate will look like in 2050 has been studied by a number of groups. For the purpose of this paper, the following scenario outlined by Sauchyn et al.[5] will be used. This is generally consistent with the latest IPCC reports[6], but provides more regional detail. The major changes in climate related to crop production are:

- Growing degree days expected to increase by 25 to 50% from 1961-1990 levels
- Hot spells hotter by 1 to 2 $^{0}$C; cold spells colder by 2 to >4$^{0}$C
- Growing season increases from 15 to 50 days
- Precipitation extremes increase (wet and dry)
- Amount of precipitation little or no change, but annual moisture deficits increase due to increased evaporation and transpiration.

These changes should have a significant impact on crops that are grown in the Prairies. The main concern is that although the growing season will lengthen, the amount of available water to grow crops is likely to remain the same or increase slightly at best. The increase in growing season is of interest as it increases the potential for crops grown only in the southern Prairies to move northward. The two crops showing the most potential are corn and soybeans. The one misconception is that the climate change in 2050 will result in the Prairies experiencing a climate that is similar to the U.S. Midwest. Unfortunately, the scenario outlined calls for a climate that would be much more like South Dakota than that of Illinois. It is for this reason that total corn and soybean acreage is unlikely to challenge those of the current three largest crops.

One of the biggest concerns will be the variability of the climate in 2050. Extreme events (floods or droughts) are very difficult for agricultural systems to adapt to. In the past decade, a series of very heavy rainfall events in Saskatchewan and Manitoba during the spring have resulted in large drops in seeded area[1]. These types of events present a threat to all crops grown on the Prairies. Drought during the 2000 to 2003 period caused severe losses of yield and seeded area. These events have a limited impact on the long-term sown acreage choices.

Crop productivity is likely to increase by 2050 due to expected improvements in genetics and management. Yields of all crops have increased dramatically over the past decades. There will be some yield drag caused by the climate conditions experienced in 2050, but these limitations are expected to be overcome by improved genetics and the arrival of new crops more suited to the environment. An example of this expected productivity improvement is the Canola Council's 2025 target for production at 26 million tonnes[7]. This estimate is based on a yield of 52 bushels per acre, which would exceed the current record by 30%. Similar productivity increases are expected in the cereal crops over the same period of time. This productivity improvement makes the expected increases or decreases in acreage less important than the projected productivity increases. This is not to dismiss the impact of climate change on the crops: the ability to maintain the rate of yield increases will be hampered by the changing climate conditions.

*"Wheat, barley and canola will still dominate the landscape"*

## What can we expect?

Crop selection and rotation is the core of our Prairie production system. Here, we provide some thoughts on a potential outlook for selected crops over the next few decades.

**Wheat** – Wheat area likely to remain the largest of any single crop. Winter wheat area likely to increase as winters become milder and crop stress increases in summer months. Market outlook is not compelling large increases in area, but world demand should be steady for the crop.

**Canola** – Canola area likely to increase slightly. Soybeans will cannibalize southern growing areas from canola, but central and northern growing areas will still be predominately canola growing regions. Strong oilseed demand will keep canola as one of the most profitable cropping alternatives.

**Barley** – Area likely to be under pressure as the humid, cooler growing areas are shrinking in the 2050 climate scenario. Barley is in direct competition with canola and wheat, the area likely to shrink. International demand is expected to be constant, but domestic use will be under pressure from increasing corn supplies.

**Pulse crops** – Pulse area likely to increase in the drier, more arid growing environments that are expected in 2050. Strong international demand structure is a positive for pulse crops.

**Soybeans** – The transition to larger soybean area in the Prairies is already underway with former marginal areas in southern Manitoba and Saskatchewan now growing the crop in a regular rotation. Strong international demand is expected to continue to support area growth.

**Corn** – The movement of corn is also underway to parts of southern Manitoba and southern Alberta, but the transition expected to take a longer time period than soybeans. This is primarily due to the fact that the international demand structure for corn is not as strong as that for soybeans. Corn will also be limited by the dryness in parts of the southern Prairies. Corn has large moisture requirements to produce economically attractive yields.

**Sorghum and millet** – Sorghum and millet are two possible crops to move into the drier areas of the Prairies in 2050. These crops represent a possible feed grain for the driest areas, but sensitivity to frost will limit area even with increased growing season. International demand for sorghum and millet is mixed, but domestic use as a feed grain is a possibility.

In conclusion, the cropping patterns on the Prairies in 2050 will be a mixture of new crops and existing old crops. Wheat, barley and canola will still dominate the landscape in the northern growing areas. In southern areas, the regular rotations will be supplemented with a significant amount of soybean and corn crops. Strong oilseed demand should be the primary factor in keeping oilseed area relatively high in relation to the cereal crop area. Pulse crops will also see strong international demand, which should in a drier, warmer climate result in a larger adaptive area.

# What Does a Warmer Winter Mean?

Brian Amiro, Ph.D., P.Ag., and Paul Bullock, Ph.D., P.Ag., are Professors in Soil Science at the University of Manitoba, specializing in agricultural meteorology and climatology.

## What is going on?

Analyses of trends over the past few decades indicate that the warming across Canada has been greatest in winter[1,2]. The winter warming has likely contributed to the date of the last spring frost occurring earlier, resulting in a longer frost-free season across the Prairies[3,4]. For Alberta, the earlier last spring frost, coupled with a later fall frost, has increased the frost-free period[5]. If such changes continue, and are predictable without increased variability, new agricultural opportunities are likely.

## What's coming up?

Projections by climate models indicate that climate warming will be greater in winter, with increases of about 3°C in the average temperature by about 2050[6]. The uncertainty in this estimate ranges from about 2°C to 4°C for the December to February period. Expectations are that the eastern Prairies may warm slightly more than the west.

## Does it matter?

It is instructive to consider if we can learn from current climates as possible analogues. For example, what would be the implications if Edmonton became more like Medicine Hat, or perhaps Grande Prairie became like Edmonton? Such analogues are not perfect because of important differences in daylength, precipitation and soil types. However, we have decades of experience with these temperature regimes and how they relate to agriculture. Let's investigate the dynamics of January temperatures as an indicator of the impact of a warmer winter. Figure 1 shows 40 years of mean January temperatures for the three locations. These locations represent a range of 5°C in mean January temperature with differences of about 2 and 3°C between individual stations, similar to the predicted change by 2050. The mean monthly temperature varies by more than 20°C among years at each location over this period. Potential mean temperature increases by 2050 of about 3°C seem relatively small given this current large inter-annual variability. Despite the large variability, the last decade appears warmer than the first decade of this series.

*"winter warming of about 3°C by 2050 is small compared to the current range of extreme temperatures at any given location: Prairie agriculture will still need to address a wide range of conditions"*

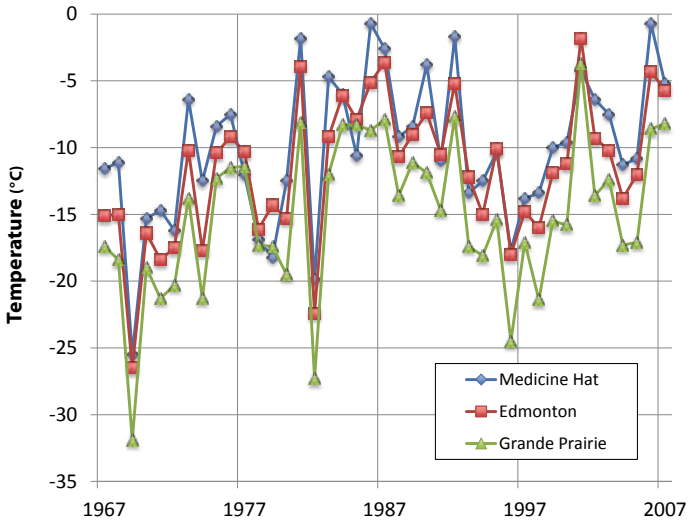



**Figure 1:** *Mean January air temperature at Medicine Hat, Edmonton (Stony Plain), and Grande Prairie, Alberta, for the 1967-2007 period[7]. The 40-year average is -10.1°C for Medicine Hat, -11.7°C for Edmonton, and -15.1°C for Grande Prairie.*

However, mean temperature is often not the best indicator of the driving forces that affect agriculture. For example, extreme cold temperatures create heating challenges for cattle or can kill off overwintering pests. Extreme warm temperatures can remove snow cover or create icy conditions that affect both crops and cattle. Figure 2 shows the frequency of the January extreme minimum temperatures, an indicator that can be limiting for some organisms. For this time period, January temperatures below -35°C were experienced about 30% of the years in Edmonton and Medicine Hat, and 75% of the years in Grande Prairie. Further, the year-to-year variability exceeds 20°C at any location. Temperatures of -20°C are of similar frequencies at all sites, about 90%. The year-to-year variability in maximum January temperature is less, but still greater than 10°C at any location. For the 40-year period, all three locations experienced thawing events and the frequency of exceeding 10°C was 40% for Medicine Hat, 22% for Edmonton and 7% for Grande Prairie. We can argue that the frequency of "climatological significant" events will change with a warming climate, but that we currently experience such events and have developed mechanisms to cope with these, although they stress our agricultural production system.

## What is being done?

Our current range of winter temperatures on the Prairies is extraordinary, exceeding 50°C from minimum to maximum January temperatures. This range reflects "weather" whereas the overall mean and the projections are more about "climate". Projections for mean temperature increases of about 3°C by 2050 are relatively small compared to the range of extremes. It is difficult to project whether the warming climate will increase the variability beyond which we currently experience. It is more likely that we will need to adapt to a new frequency of events, even if the agricultural impact of each event (cold or warm) is not a new experience.

It is likely that warmer winters may create some competitive advantages in other parts of the world. For example, winter cropping could be more sustainable in more parts of North America, which could offset some losses caused by summer heat stress. Such a change could affect the competitiveness of Prairie agriculture, since it is unlikely that our climate will allow much winter cropping by 2050.

The bottom line is that warmer winters by 2050 will likely not change our current experience and Prairie agriculture will still need to address a wide range of conditions. However, the change in frequency of events will likely alter the way we undertake some practices. If warmer winters contribute to longer growing seasons, there could be reduced risk of growing a wider variety of crops, providing that water is not limiting.

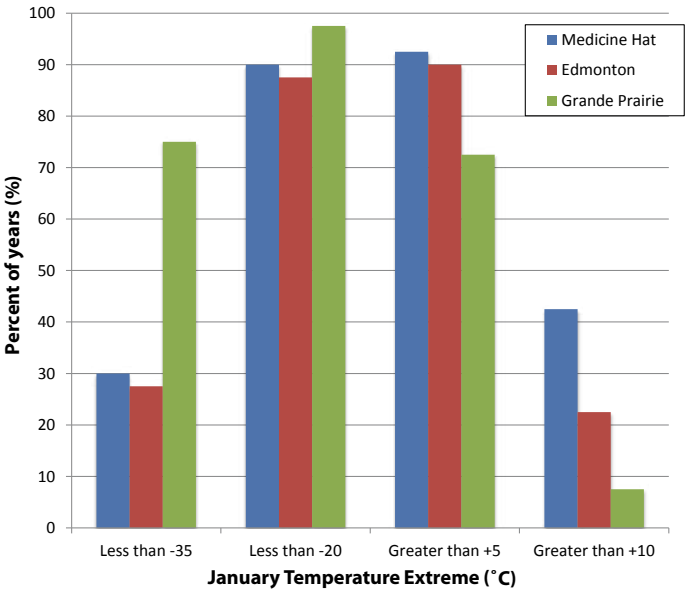



**Figure 2:** *Percentage of years exceeding a January extreme minimum or maximum air temperature at Medicine Hat, Edmonton (Stony Plain), and Grande Prairie, Alberta during the period 1967-2007[7]. Note that all locations had a thaw period (greater than 0°C) every year.*

# Severe Weather and Crop-Atmosphere Interactions

**Figure 1**: *An approaching severe storm with a defined shelf cloud and extreme downburst winds.*
(credit: J. Hanesiak)

John Hanesiak, Ph.D., is a Professor of Atmospheric Science at the University of Manitoba. His research focuses on surface-atmosphere interactions, extreme weather/ storms, and convection initiation processes.

## What is going on?

Severe convective storms can have profound impacts on society, mainly due to loss of life and infrastructure/property damage, including agriculture impacts from hail, strong winds, tornadoes and heavy precipitation. For example, Figure 1 depicts a well-defined shelf cloud and strong downburst winds of a supercell storm that also generated large hail. On average, 221 severe events are reported in the Prairies each summer[1]. Since 1980, Public Safety Canada estimates 51 significant events have taken place, costing more than $2 billion in damage within the Prairies[2]. For instance, Alberta sees the most hail storms in Canada and has experienced many damaging events to agriculture and property. Assessing long-term trends in severe events and attributing them to global climate variability is problematic due to reporting/population biases[3,4] and similar issues arise when attempting to use insurance losses. Canadian severe-event data suffer from these same biases and our temporal database is shorter. Various methods are being considered to overcome such biases[5] with some focusing on how severe storm *ingredients* may change in a future climate[6].

There are four basic ingredients for *severe* summer convective storms: (1) enhanced low level moisture; energy (fuel) for storms, (2) atmospheric instability; air near the surface, when sufficiently lifted, remains upwardly buoyant throughout the troposphere, (3) a trigger to initiate storms; a front or other boundary that will lift air upwards in the lower atmosphere, and (4) wind shear; strong wind speed

and direction changes with height. The wind shear primarily determines the *mode* of convection (i.e. type of convective system) that ensues. It has been shown that slight increases in low-level moisture, and thus greater potential storm energy, have taken place in many parts of the world, including Canada, mainly due to increases in temperature[6,7]. Trapp et al.[6] showed that these increases will only be further enhanced in a future U.S. climate, including enhanced atmospheric instability.

## What is coming up?

Future North American changes in storm triggers can partially be linked to changes in the occurrence/intensity of low pressure systems in summer. Most studies show either no change[6] or slight decreases in both occurrence/intensity[8], hence, storm trigger mechanisms may not change or slightly decrease in the future. There is good evidence and theory to suggest that there will likely be a future decline in wind shear in summer primarily due to a weakening of the upper jet stream/pole-equator temperature contrast[6,9], however, increased intensity of the low-level jet in the future may enhance low level wind shear[10], which can be important for tornadoes. There is some early evidence of the northern hemisphere upper jet already slowing down, affecting the upper level wave pattern and progression[11]. In summary, recent (future) increases in moisture and instability have occurred (are likely) in North America, however, the lack of any historic trends (and future uncertainties) in triggers and wind shear suggest that we are currently unable to determine whether severe convective weather has changed, or will change in the future[9,12].

## Does this matter?

Agriculture plays an important role in weather and climate. Agricultural land, such as crops and forage land, can *primarily* influence severe convective storms through evapotranspiration that adds moisture to the lower atmosphere as well as affecting instability. For example, the phenological development of crops has been linked to the seasonal timing peak of tornadoes[13]. Spatial variations in evapotranspiration (and its associated magnitudes) due to water-stressed crops versus non-stressed crops can determine the timing of and where deep convective cloud forms, and how severe the storms may become[14-17]. Figure 2 shows an example of how lightning occurrence (and hence deep convective clouds) (blue dots) can decrease over severely water stressed regions (i.e. low root-zone soil moisture) (orange and red) compared to other areas that are not water-stressed (green colors). An analysis of tornado/hail days over the Prairies shows a reduced number of days during drought periods[18]. In addition, Betts et al.[19] have shown that Canadian Prairie land use changes (fallow to annual crops) may have contributed to changes in the diurnal cycle climate and increased humidity over the region since the early 1950s. Hence, any future changes to Prairie agricultural practices and/or long-term soil moisture regimes could have profound effects on summer severe storms via the influence they have on low-level moisture supply. Clearly, this is a possible feedback situation, and demonstrates that our weather and surface conditions are tightly linked. Understanding the coupling of the atmosphere and agricultural surfaces is an important area of research, especially for the Prairies.

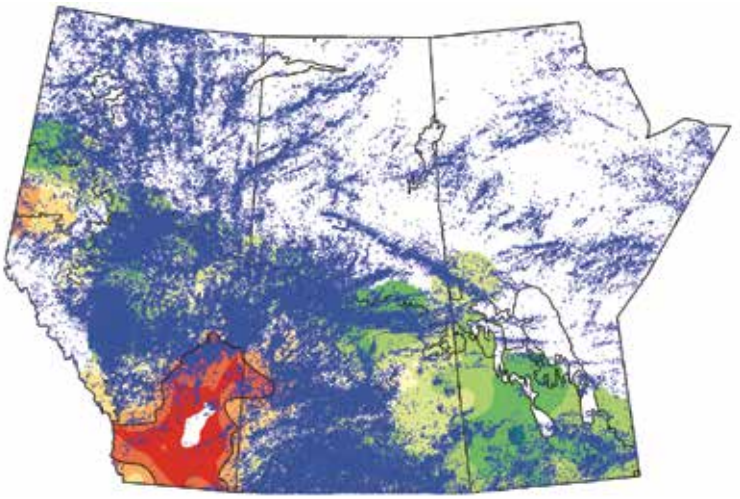


**Figure 2:** *July 2000 lightning strikes (blue dots) and root-zone soil moisture (dark orange/red < 30%; dark green > 75%) via the PAM-II crop model.*

*"slight increases in low-level moisture, and thus greater potential storm energy, have taken place in many parts of the world, including Canada, mainly due to increases in temperature"*

# Demand for Water - Water Retention and Storage in the Eastern Prairies

**Figure 1**: *Retention pond experiment in Manitoba to control water release rates on the landscape.*
(credit: D. Lobb)

Selena Randall, Ph.D., is the Research Development Coordinator for the Watershed Systems Research Program at the University of Manitoba, focusing on agricultural best management practices for the protection of water quality.

## What's going on?

In many parts of the eastern Prairies, agriculture has been dominated by draining land to flush away snow melt-water in spring, so that the land is dry enough to seed as early as possible for a good crop using the available soil moisture. By summer, a landscape covered by water is just a memory, as the ground surface starts to crack, and production depends on a few steady rainfall events for a good yield.

Post harvest, producers may reinstall shallow surface drainage channels to be ready to drain the land in spring to ditches at the field margins, which drain to creeks, streams or man-made drains. Alongside roads, broad ditches take large volumes of water from fields through large culverts to protect property and infrastructure downstream.

The system is dependent on how wet the soil is in autumn; how much snow falls; how quickly it melts; how much the melting snow evaporates; whether the downstream drainage channels can cope with the volume of melt-water; how dry the summer is; how many heavy rainfall events occur. Water is vital for agriculture, but drainage is also a costly inconvenience.

## What's coming up?

Predictions of no overall change to precipitation, but more frequent and heavier rainfall as well as increased aridity across agricultural areas, means that water management will become an even more complex balance of managing flood water but having enough for the dry periods.

With growing pressures on groundwater resources for high-value agricultural production as well as increasing population demand, the need for surface water management has never been greater.

## How does it matter?

Management of floodwaters from fields downstream is important for protecting property and infrastructure, but it is also important to the health of Canada's fifth largest lake - Lake Winnipeg. Run-off, particularly from the Red River watershed is high in nutrients from the land, which cause algal blooms and trophic changes in the lake. Nutrient pulses have been linked to flood events in major tributaries[1]. Clearly, the importance of both water quantity and quality will increase in the future for our Prairie agricultural systems.

## What's being done?

Integrated Watershed Management Planning has become the chosen way to address water issues in watersheds in the Prairies. The process is driven by local communities coming together to set out their concerns and to agree to priorities for action. Provincial staff from Conservation Districts and grants from federal and provincial funds support a limited number of schemes selected from a wide range of beneficial management practices each year. These schemes are usually delivered at the farm scale or sub-catchment scale rather than the basin/watershed scale, which gives individual producers and communities better resilience and management of risk. A common theme amongst the schemes is the reduction of flood risk, and the improvement of water quality. Concepts such as 'keeping water on the land' have become a common theme for a wide range of interested groups including researchers, NGOs, government and community groups.

*"Concepts such as 'keeping water on the land' have become a common theme"*

An example of a successful scheme to keep water on the land is found in Pembina Valley at Lizard Lake, Manitoba (Figure 2). The Conservation District brought together a group of producers and NGO partners and secured a long-term agreement to manage a wetland differently. Rather than drain the existing wetland in an attempt to improve the land enough for crop production, they agreed to extend the flooded area to create a wet pasture. A berm around 630 ha surrounding 200 ha of existing wetland is flooded each spring. A rich diversity of grasses, sedges and cattails has resulted creating valuable habitat. Drainage is managed to allow the wetland to soak up nutrients like a sponge, and the vegetation is cut for forage. Even the cattails have value as part of Manitoba's growing bioeconomy being spearheaded by the International Institute for Sustainable Development.

Systems such as that at Lizard Lake are being adopted where there is marginal land, and where there is a good likelihood of some sort of conservation easement being granted for waterfowl and other wildlife. But with research underway to develop flood tolerant crops, their application could be extended to cropping systems.


**Figure 2:** *Landscape modifications at Lizard Lake, Manitoba, to enhance water.*
(credit: B. Amiro)

Another option is to use the water stored more directly for agriculture. Retention ponds dug into a low spot, with the spoil creating a berm to contain water above grade are starting to be adopted (Figure 1). Most producers are keen to avoid the need for federal permits, so they limit the size to something large enough to drain a section of land (260 ha), which does not provide enough water to irrigate the land drained. But in the right place, say close to a greenhouse, or to high value crops such as potatoes, or forage seeds that need a well-prepared seed bed, it has potential. Such systems also work well with tile-drainage systems, where weeping tile underground drains the snow-melt and rainfall to a pond for recirculation. The full benefits of these systems for water and nutrient management have yet to be established, but research is underway.

One of the major challenges already seen is the multitude of players involved in water management, which makes leadership unclear: from the federal agriculture advisors, to the provincial agriculture extension staff; from the provincial flood engineers to the rural municipalities; from the provincial permitting teams, to the watershed planners, conservation district staff and NGOs. However, the concept of having more local control by producers is a key part of future strategies. It is also evident that a single solution cannot be developed for the wide range of landscapes across the Prairies. However, as we develop test cases, we will improve our knowledge of successful initiatives that are relevant to different regions. Such initiatives need to be developed over the coming decades to address a different climate in 2050.

# Will Crop Breeding Keep Up With the Requirement for Change?



*Examples of durum wheat genotypes sensitive to heat shock compared to a less sensitive type in the centre (2a). An example of a breeding nursery to identify experimental lines that differ in their response to heat stress with a sensitive type in the center foreground (2b).*

(credit: R.M. DePauw)

Ron Depauw, Ph.D., P.Ag., Senior Principal Wheat Breeder, SPARC AAFC, Swift Current, SK.

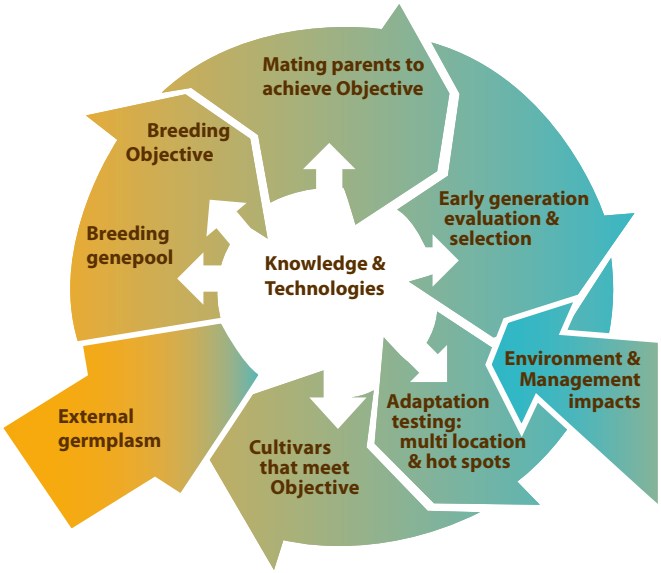
## What's coming up?

The projected climate change for Alberta to 2050 offers some opportunities and challenges for Canadian crops, with warmer summers, milder winters, limited growing season moisture change from April to September, and wetter autumns and winters (October to March). The killing frost-free period is expected to increase sufficiently to enable arable annual crops to be grown over a larger area of the Peace River Region, Parkland, and foothills of the Canadian Rockies. However, increases in the frequency and intensity of severe weather could cause major local damage, such as during heat waves and intense precipitation. The primary abiotic stresses will be heat, drought, waterlogging, salinity, elevated carbon dioxide, and acidic soils developed under coniferous forests. Abiotic stresses under dryland farming scenarios may be both persistent stresses such as dryness and/or above-average temperature, but also a period of heat shock coupled with very high evaporative demand. These shocks are considered to be extremely damaging and have been under-estimated by previous crop models. Consequently, "plasticity" will be a key feature of wheat cultivars to be responsive to variable weather conditions. Biotic stresses are expected to result in shifts of biotrophic and necrotrophic pathogens, insects and weeds.

## How does it matter?

Producers want reliable profitable top performers, such as high grain yield that can be sold at a profitable price. Achieving high, consistent, grain yield in a cultivar will entail selection for traits that result in consistency of performance. In crops, genetic enhancement through breeding is an appropriate adaptation response where it complements management changes, or when management changes are too expensive or too impractical. Prioritization of traits to breed for will be essential to allocate investments. For many Canadian crops, the following gaps need to be addressed: the effectiveness of genetic response to the abiotic and biotic stresses, the magnitude of genetic variation for these traits, and a value-capture mechanism to return an investment to off-set research and development costs.

Genetic enhancement takes time and resources. In the case of wheat it takes about 8 to 10 years from designing and making a new genetic combination through to releasing a new cultivar to seed companies. Breeding is predicated on clear targets, genetic variation, and genetic tools and nurseries to incorporate the traits. Targets that move in one direction, such as warmer weather, may be easier for breeding than those that need to consider more variability, such as increased extremes.




*Components of a breeding program. Solid curved arrows show germplasm flow as it is introduced, hybridized, selected for traits during inbreeding, and delivered as field-ready cultivars. White arrows show knowledge and technology points of impact in the breeding cycle (phenotyping methods, DNA analysis, statistical prediction, crop prediction models). Environment and cultural practices impact phenotyping and selection.*

## What can we do about it?

Breeding new cultivars with adaptation to the climate of 2050 will require:

i) Assessing the potential incidence and intensity of new environmental challenges,

ii) Identifying traits and the physiological basis of the trait for adaptation to the new environmental challenge,

iii) Locating genetic variation for the traits,

iv) Understanding the genetic control, genetic expression and heritability of the traits,

v) Selecting for these new genes to develop cultivars through conventional, molecular or genetic engineering technologies,

vi) Evaluating success in target environments and releasing the cultivar for adoption by growers.

> *"For wheat it takes about 8 to 10 years from designing and making a new genetic combination through to releasing a new cultivar to seed companies"*

Selection for a trait can be either direct or indirect. The physiological traits associated with adaptive responses to abiotic stresses are examples of "indirect" selection for grain yield. To be effective, indirect selection requires the trait to be highly heritable, easily measured, and have a high genetic correlation with the trait of interest: grain yield. Under these circumstances, molecular breeding could be valuable, especially, if "perfect" markers, become available.

Breeding and selecting highly "plastic" cultivars adapted to future climate change will require locations that:

i) reflect overall trends of climate change for the region,

ii) provide high association between parameters at the breeding site and the target region yield variation, and

iii) have a relationship with abiotic stresses at the breeding site that reflect the dominating abiotic stresses in the target region.

The opportunities to respond to climate change using a multi-disciplinary approach with plant breeding at the core, using the combined potential of conventional, molecular and genetically modified technologies, could be capitalized in the provision of cultivars with greatly enhanced nutrient and water-use efficiency, enhanced tolerance to heat and drought, resistance to diseases and insects, appropriate end-use and nutritional quality, and, possibly most important, increased ability to cope with the increasing extremes in temperature and precipitation occurring at one location over years.

# Pollinating Insects- Native and Managed Pollinators

**Figure 1:** *Reproduction of the devastating honey bee parasite, the verrora mite, is limited to times when developing bees are present in the hive. Climate-induced changes in forage availability will affect timing and duration of brood rearing and will affect the management of this parasite.*
(credit: R. Currie)

Rob Currie, Ph.D., is a Professor in the Department of Entomology at the University of Manitoba.

## What is going on?

Insects are among the first organisms to show dramatic responses to variation in climate because they have short generation times and temperature-dependant developmental rates. Under a warming climate insect pests will undergo more generations per year, will have increased winter survival and will have earlier and more frequent migration into Canada from areas south of our borders. Invasive species and pathogens vectored by insects will initially thrive as they expand their wintering zones and enter into areas in which there may currently be no natural enemies. With bees and other pollinating insects our predictions are less clear, but there are some predictions that can be made, particularly with respect to managed species in agroecosystems.

Climate change is anticipated to affect native plant-pollinator relationships, especially along the northern ranges where assemblages of pollinators may be incapable of "tracking" climate change quickly enough to adapt and form stable relationships with host plants[1-5]. However, broad scale effects on pollination of native plants have not been identified (yet?): apparently, shifts in pollinator emergence have kept pace with shifts in growth of most plant species[1]. For managed pollinators like honey bees, measurements of honey flows using "scale" colonies show similar phenological shifts[6]. A 1°C increase in the U.S. resulted in a 7 day advance in peak colony weights in a 15-year period from 1992 to 2007[6]. Such shifts could affect bee management (Figure 2).

Honey bees in Canada have been suffering major winter colony losses from combinations of parasites, diseases and a variety of other stresses including extreme weather events and unusual patterns of forage availability[7]. Although honey bees are adapted to a broad range of climate conditions, increases in environmental variability and changes in annual patterns could pose problems for honey bees in the future[8]. Under some

scenarios, pollination by managed honey bees is predicted to decline by about 15% (without management intervention) but increases by native pollinators could buffer some of these effects[9].

## What is coming up?

Warmer winters and springs could benefit winter survival and spring "build up" of honey bee colonies – but climate change is not likely to be all "good news". Shifts in plant species and timing could affect bee nutrition. A shift from forages and oilseeds towards other crops that are less desirable or unsuitable for bee forage (e.g. corn and soybean) would increase nutritional stresses on bees. Shifts in plants that support bees when crops are not in bloom would make it more difficult to synchronize colony population size with peak periods of crop bloom needed to maximize honey production and pollination (Figure 2). Shifts in fall patterns of bloom for native plants could negatively affect production of young bees in the fall that are required for successful wintering. These nutritional shifts compounded with increased variability and unpredictability of weather patterns would pose increased challenges for management of colonies.

Management of leafcutting bees would also be affected by climate change. As a result of warmer spring temperatures, leafcutter bee producers could expect that a higher proportion of their bees would attempt to enter a second generation, which in both Canada and the U.S. results in lower levels of bee reproduction[10]. Both honey bee and leafcutting bee producers could anticipate more severe problems with parasites and disease. For honey bees, longer brood-rearing periods associated with expanded seasons would result in more generations of parasitic varroa mites being produced each year (Figure 1). This in turn would result in either longer exposure times or application frequencies for pesticides and thus greater chances for the development of pesticide resistance. Reduced ability to control mites and their associated pathogens going into winter would impact winter mortality. Leafcutter bee producers might expect to see an increase in diseases such as chalkbrood and more inviable offspring (pollen balls)[10]. This would lower bee reproduction rates and reduce producer income from bee sales.

> *"climate change that increases the level of stress on bees can contribute to population losses"*

Finally, "invasive species" such as the small hive beetle and africanized ("Killer") honey bee could expand their ranges and become significant pests in Canada[8]. Increased diversity and numbers of invasive crop-pest insect problems and the associated increase in the use of pesticides required to control them would also likely increase sublethal colony-level stresses on honey bees and result in reductions in survival rates of leafcutting bees.

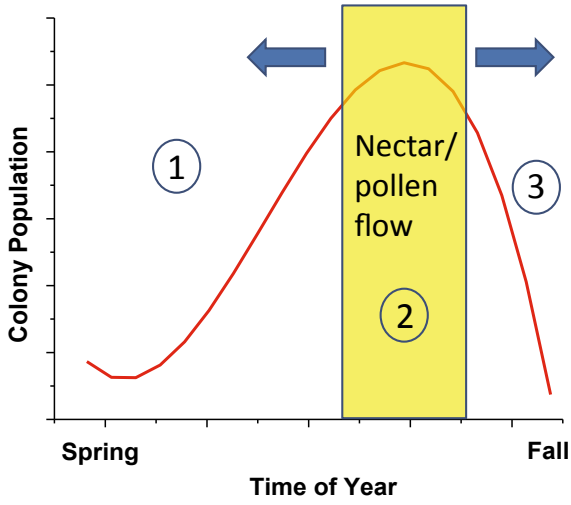



**Figure 2:** *Climate change could (1) influence conditions for honeybee colony growth and development in spring; (2) shift periods of the main nectar flow so that it would not coincide with peak populations of bees; or (3) influence forage availability during the sensitive period when the bees that will form the overwintering population are produced. Beekeepers will have to adopt new management paradigms to mitigate these effects.*

## Does it matter?

In addition to the production of honey and other hive products valued at over $75 million per year, honey bees, leafcutting bees and other insect pollinators contribute to the yield of many fruit, forage and oilseed crops[11]. On the prairies, pollination by bees (primarily honey bees and leafcutting bees) is essential to the production of alfalfa and hybrid canola seed. The total value attributed to the contributions of bee-pollination to crops in Canada is estimated to be over 2 billion dollars[11]. Any climate change that directly or indirectly increases the level of stress on bees can contribute to population losses of managed pollinators having significant economic impact.

## What is being done?

Research into pollinator declines and the impact of such declines on native and managed ecosystems is underway[4] but we still need a better understanding of how climate change will interact with other stressors affecting the health of managed and native pollinators. New strategies to better manage parasites, diseases, beekeeper-applied pesticides, environmentally-applied pesticides and other stresses will have to be developed. Finally, coordinated technology transfer efforts are needed to ensure uptake of research solutions by beekeepers and growers.

# What Will Happen to the Weeds?

(credit: C. Rawluk)

Rob Gulden, Ph.D., is a Professor in Plant Science at the University of Manitoba specializing in weed ecology and management.

## What is going on?

The dominant weeds in a region are a reflection of the crops[1] and the weed management systems[2,3,4] in that region. Physical, ecological and/or biochemical mimicry of the predominant crops allows these weeds to escape control and become the dominant weeds in the weed community. In western Canada, the predominance of summer annual cereal cropping systems over the past century has led to the selection for summer annual grassy weeds (Table 1).

## What is coming up?

Climate change and, in particular a warming climate with longer growing seasons and milder winters is expected to affect annual cropping systems by an increase in both winter annual crops and longer-season crops such as corn and soybean. Winter annual crops are planted in the fall, survive the winter and are harvested earlier in the next cropping season than summer annual crops. They compete very effectively with obligate summer annual weeds (such as wild oat and green foxtail), but support a habitat that favours winter annual weeds (e.g., Downy (*Bromus tectorum* L.) and Japanese *(B. japonicus* L.) brome grass). Warmer winters in the future will also enable weeds such as cleavers, volunteer canola, chickweed and others that

**Table 1:** *Top 10 residual weeds (post- in-crop weed control) based on relative abundance among all crops in 2005 in western Canada*[1].

| Rank | Species |
|---|---|
| 1 | Green Foxtail (*Setaria viridis* L.) |
| 2 | Wild Oat (*Avena fatua* L.) |
| 3 | Wild Buckwheat (*Convolvulus arvensis* L.) |
| 4 | Canada Thistle (*Cirsium arvense* L.) |
| 5 | Lambsquarters (*Chenopodium album* L.) |
| 6 | Chickweed (*Stellaria media* L.) |
| 7 | Stinkweed (*Thlaspi arvense* L.) |
| 8 | Redroot pigweed (*Amaranthus retroflexus* L.) |
| 9 | Cleavers (*Galium aparine* L., *G. spurium* L.) |
| 10 | Kochia (*Kochia scoparia* L.) |

are currently predominantly summer annuals in the cooler regions of the Prairies to assume a winter annual growth habit. During the particularly mild winter of 2005-2006, for example, volunteer canola assumed a winter annual life cycle in Manitoba (Figure 1).

## How does this matter?

Managing winter annual weeds presents challenges as fall-applied herbicides can be less active and in the spring, cold-hardened winter annual weeds may be more difficult to control and can quickly grow out of stage where herbicide efficacy is reduced substantially[5]. Timing and methods of weed management are critical in driving the structure of the weed community[2,3,4].

> *"northward range expansion will result in the introduction of new weeds many of which are already resistant to one or more herbicides"*

The increasing temperatures and longer growing seasons associated with climate change are expected to result in range expansion of many crops and weeds to higher latitudes. Using kochia (*Kochia scoparia* L.) as an example, several models predicted a substantial northward range expansion for this species over the coming century, particularly in the western Prairies where the range for kochia is expected to reach up to or beyond the northern edge of the prairie provinces[6,7]. In kochia, reduced control due to herbicide-resistance is expected to enhance the rate of expansion northward as climate permits.

Northward expansion is also expected for many other weeds including some that currently are not present in western Canada. Northward movement of waterhemp (*Amaranthus rudis* L.) along the Red River basin is soon expected to reach the eastern Canadian prairies while glyphosate-resistant Palmer amaranth (*A. palmeri* L.), which currently is a serious challenge to crop production in the southern U.S., has recently been introduced inadvertently to the north-central states where it appears to be thriving. Soybean and corn production is increasing in the eastern Prairies and is expanding westward and these cropping systems are associated with a different residual weed community than wheat systems[3,4].

**Figure 1:** *Volunteer canola behaving as a winter annual in Manitoba.*
(credit: A. Lawson, May 30, 2006)

## What is being done?

Future changes to the type and species of predominant crops grown in western Canada will result in changes in the predominant weeds in these cropping systems. In addition, northward range expansion will result in the introduction of new weeds many of which are already resistant to one or more herbicides. Both are expected to contribute to changes in the weed spectrum and present new challenges to weed management in the future. Using an integrated weed management approach that includes a diverse set of management tools and is less reliant on herbicides alone will be required to effectively manage weeds in the future. The addition of new crops with different life cycles and management requirements can contribute to the diversity in weed management tools so long as more traditional crops are not abandoned in these rotations.

# Effect of Climate Change on Mycotoxins Produced by Plant Pathogens Affecting Our Field Crops

*Wheat heads infected by the Fusarium pathogen. The infected seed will contain mycotoxins.*
(credit: D. Fernando)

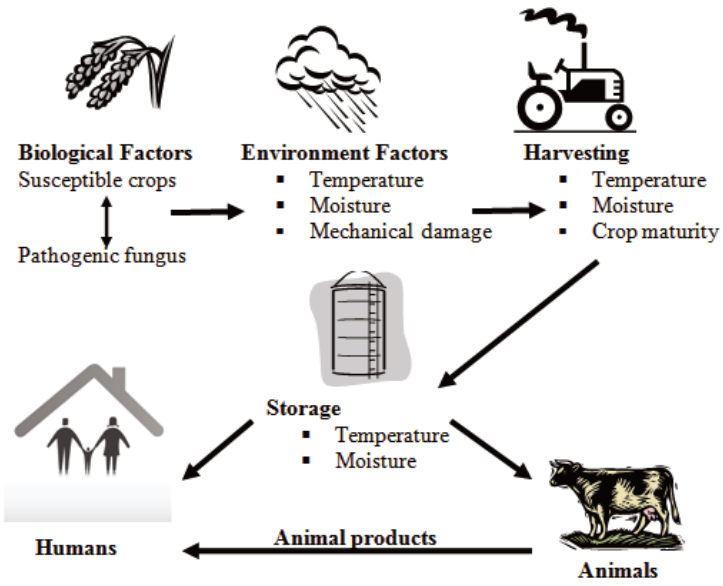
Dilantha Fernando, Ph.D., P.Ag., is a Professor in Plant Science at the University of Manitoba specializing in canola and wheat pathology.

## What's going on?

Mycotoxins are low molecular weight toxic compounds produced by filamentous fungi, which contaminate food and feeds. The mycotoxins of greatest concern in North America are deoxynivalenol (DON), aflatoxins, and fumonisins. These mycotoxins cause adverse effects to human and animal health. Severe health problems and deaths have been reported due to mycotoxin consumption, so government regulations have been set to control the maximum limits of mycotoxins in food and feed[1]. Production of mycotoxins on crops depends on climatic factors such as temperature and relative humidity so a changing climate has a direct impact on mycotoxin production.

## What's coming up?

Although it is predicted that a warmer climate can increase global food production in currently cooler regions, this will affect the biological environment of crops such as the abundance of pests and plant pathogens[2]. This may have a greater impact on plant–pathogen interactions because most plant pathogens have optimum temperatures for their growth and mycotoxin production. Mycotoxins are among the major foodborne risks that are most susceptible to




*Factors affecting the mycotoxin production in the food chain (Adapted from CAST[10]).*

**Table 1:** *Optimal temperature (°C) for mycotoxin production and in vitro growth of important plant pathogens (Adapted from Paterson & Lima[8]).*

| Fungus species | Type of mycotoxins | Optimum temperature for mycotoxin production | Optimum temperature for *in vitro* growth |
|---|---|---|---|
| *Alternaria alternata* | Alternaria toxins | 25 | 23 |
| *Aspergillus flavus* | Aflatoxins | 33 | 35 |
| *Fusarium verticilliodes* | Fumonisins | 15-30 | 30 |
| *Fusarium graminearum* | Deoxynivalenol | 30 | 20-22 |
| *Fusarium culmorum* | Deoxynivalenol | 26 | 20-25 |
| *Penicillium verrucosum* | Ochratoxin A | 25 | 26 |
| *Claviceps sp.* | Ergot alkaloids | 23-26 | 30 |

climatic change. The ability of fungi to produce mycotoxins is largely influenced by temperature, relative humidity, insect attack, and stress conditions in the plants[3]. Additionally, Miller[4] has reported that more extreme rainfall and drought events would favour formation of DON and fumonisin, respectively. Therefore changes in global temperature would directly affect their growth and mycotoxin production capacity. Table 1 shows the optimal temperatures for mycotoxin production and growth *in vitro* for some important plant pathogenic fungi.

Global warming will not only act on pathosystems already present in certain regions, but will facilitate the emergence of new diseases and new pathogens because the changes in climatic factors can modify the present behaviour of pathogens and enhance the development of new mechanisms to fit into the new environment. This would ultimately result in emergence of new strains with (possibly) mycotoxins with novel characteristics.

## Why does it matter?

Fusarium head blight (FHB), caused mainly by *Fusarium graminearum*, is one of the most destructive global diseases of small cereal grains worldwide. Severe epidemic outbreaks of FHB have been reported in North America, South America, Asia and Europe. While Manitoba is the 'hot bed' for FHB disease in Canada, climate change could cause all prairie provinces to be affected heavily with the disease and mycotoxin spread. The most devastating effect of this disease is the deposition of mycotoxins in the grain. Deoxynivalenol (DON) and its analogs 3-ADON, 15-ADON and NIV are the major mycotoxins produced by the fungus. Studies have been conducted on the effects of weather, crop and pathogen-related factors on the accumulation of DON in wheat grain. Results from these studies have been effectively used in developing DON–prediction models such as DONcast. Temperature plays an important role in the entire disease cycle of FHB, from infection of wheat heads to production and dispersal of inoculum, so a slight change in temperature may influence FHB disease incidence and severity. The role of climate change in a population shift of chemotypes has been observed in North America. The chemotype distribution across Canada showed an interesting longitudinal cline in which the frequency of 3-ADON producers gradually increased in each province when moving from East to West[5]. In western Canada, the percentage of 3-ADON is highest in Manitoba, where nearly half of the isolates studied were 3-ADON. Studies of FHB pathogen diversity revealed that 3-ADON producing *F. graminearum* are now widely prevalent in North America and there has been a significant population shift in FHB pathogen composition towards 3-ADON producers[5,6]. Between 1998 and 2004 the frequency of 3-ADON producers in western Canada has increased more than 14-fold, suggesting that they have a selective advantage over the native 15-ADON chemotypes.

> *"Mycotoxins are among the major foodborne risks that are most susceptible to climatic change"*

High temperatures and drought stress can increase the risk of aflatoxin contamination in the Maize-*Aspergillus flavus* pathosystem. High temperatures and dry conditions favour growth, conidiation, and dispersal of *A. flavus* and reduce growth and development of maize. Crops grown in warm climates have greater likelihood of infection by aflatoxin producers compared to other regions due to the thermotolerant capability of *A. flavus*[7,8]. Aflatoxin-producing fungi are native to tropical, warm, arid, and semi-arid regions: changes in climate result in large alterations in the quantity of aflatoxin producing fungi and could possibly spread to other regions growing maize[9].

In conclusion, climate change will add new challenges related to the dynamics of pathosystems and Prairie food production. We will need to continuously monitor the changes in climate and mycotoxin profiles, and to provide solutions to adapt to these changes.

# Global Worming


**Figure 1:** *The root lesion nematode,* Pratylenchus neglectus. *This crop nematode currently limits potato yield in tight rotations but could become a future problem for canola.*

(credit M. Tenuta)

## What's going on?

Nematodes are small round worms that live everywhere, including in soil and plants. Those in soil and parasitizing plants are less than 1/6" long: a palm full contains 1,000 to 6,000 with 20 to 30 species. Most soil nematodes are beneficial to crops, accelerating N and P mineralization and keeping pathogens and pests in check. However, a minority of species specialize to parasitize some crops causing varying degrees of economic damage (from none to severe). Damage goes unnoticed at first. Thus as a crop nematode is establishing and building levels, growers are unaware of the damage to come in subsequent years. Even when damage is visible it is usually misdiagnosed and attributed to other issues.

Fortunately, economically important crop nematodes in the Prairies are few. Generally warmer climates have many more damaging species. In response to the sugar beet nematode (*Heterodera schachtii*), Alberta growers use rotation to keep damage low. Recently the root lesion nematode (*Pratylenchus neglectus*; Figure 1) was identified as part of potato loss in tight rotations. The stem and bulb nematode (*Ditylenchus dipsaci*) has been past observed in alfalfa and can restrict export of high quality product. The Canadian Food Inspection Agency reported an isolated and non-repeatable find of the golden nematode (*Globodera rostochiensis*) in a seed potato field. The U.S. and Canada implemented a certification process to open borders by sampling to declare fields clear.

## What's coming up?

The factors most determining presence of crop nematodes are: a suitable host (crops or weeds), introduction of the nematodes to fields, and suitable soil temperature and moisture. Thus the tighter the rotation, the greater chance of developing crop nematodes. Poor in-season and shoulder season weed

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and volunteer management also can maintain crop nematode populations. Freezing soil temperatures in winter do exclude sub- and tropical[1] and Mediterranean crop nematodes. Temperate crop nematodes are not affected by freezing soil temperatures. They protect themselves from freezing damage by a variety of mechanisms[2,3] and survival life-stages. The stem and bulb nematode can survive at least one month at -80°C because it freeze-dries itself[4]! Winter freezing of soil is expected to still be a Prairie feature by 2050 so there is no concern for sub- and tropical, and Mediterranean species establishing any time soon.

In the presence of suitable hosts, crop nematodes develop faster with increasing soil temperature. Generation time is one life-cycle from egg hatching to adult production of eggs. Temperate nematodes have generation times of 20 to 60 days depending on species, soil temperature and moisture during summer months. Summer soil temperatures at 20 cm have generally increased by 1°C from beginning to the end of the previous century across Canada[5]. Thus, we are experiencing shorter generation times for crop nematodes meaning faster ramping to damaging levels. For example, the change in the generation time for the root lesion nematode is quicker for warming at cooler temperatures (Figure 2). Thus, northern soils experiencing summer warming and greater frost-free periods, such across the Prairies, are more prone to ramping crop nematode populations.

## Does it matter?

It is reasonable to expect oil seeds (canola and soybean), small grains (wheat, barley and corn), pulses and for vegetable, potato, to dominate crop land in the Prairies to 2050.

For the above established crops, crop nematode pressures should increase with cropping frequency, summer

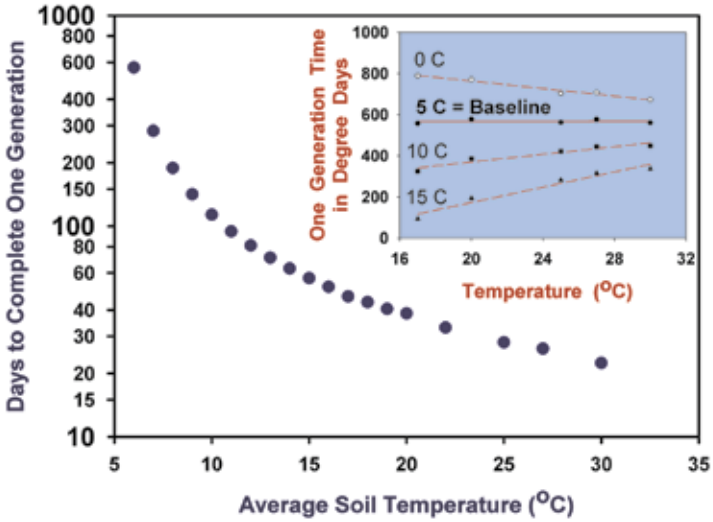



**Figure 2:** *Modelled days to completion of one generation (egg hatching to egg production) of the root lesion nematode* (Pratylenchus penetrans)*; analysis of results by Mizukubo and Adachi[7] (unpublished, Mario Tenuta).*

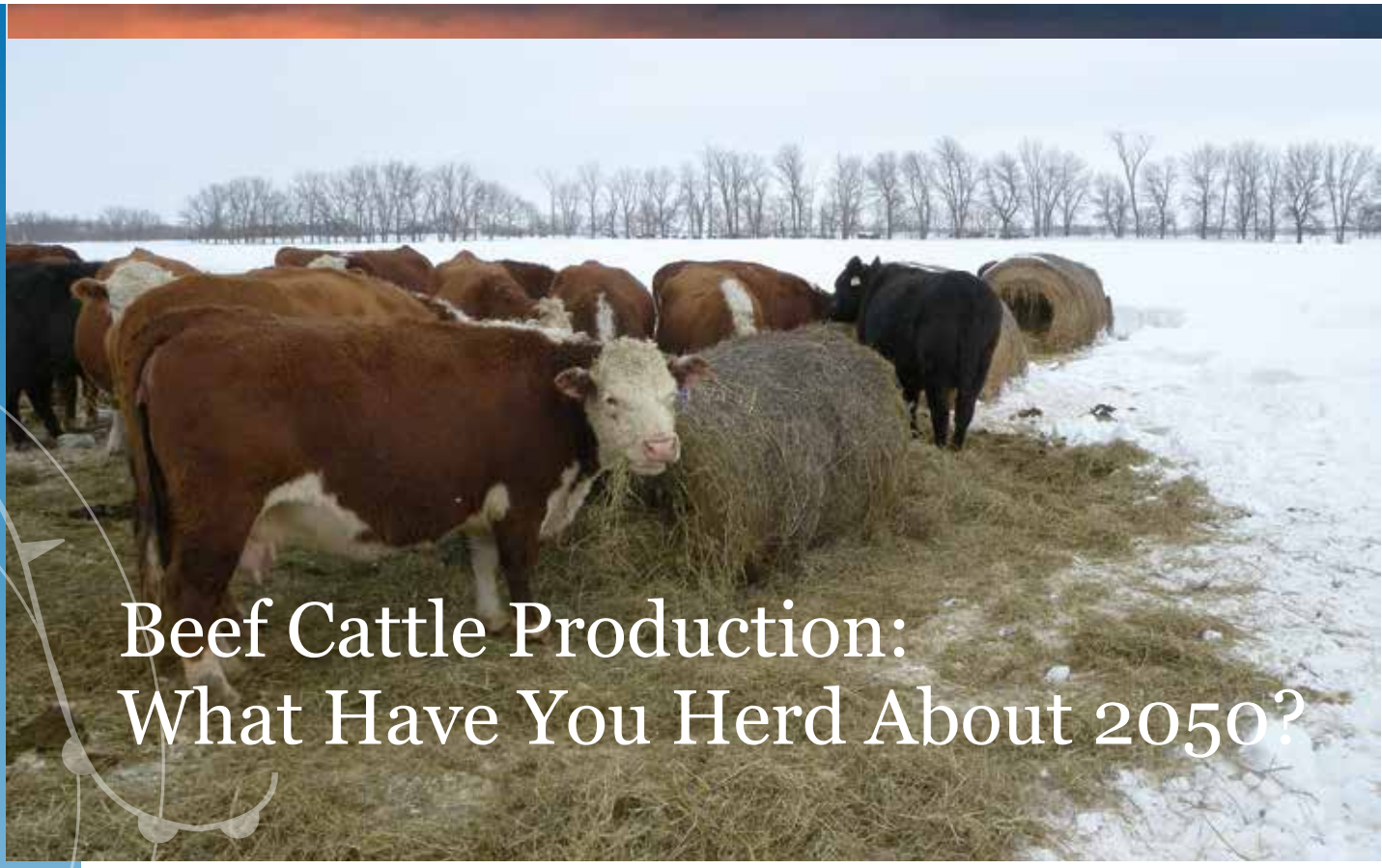
temperatures and shoulder periods. Canola and wheat will be susceptible to the root lesion nematode. This nematode is present in the Prairies[6] and prefers canola and wheat. It currently damages canola in Australia and canola and wheat in the U.S. Pacific Northwest. Canola is an alternative host to the sugar beet nematode. Potato is susceptible to another root lesion nematode, *Pratylenchus penetrans*, that is currently absent but suited to our conditions. The nematode is problematic because it severely aggravates Verticillium wilt of potato present here. Potato cyst nematodes (*Globodera rostochiensis* and *G. palida*) are of great concern because their presence would immediately stop regional export of potato tubers and any commodity with soil tags!

Soybean and corn are currently expanding in the Prairies. Expansion of new crop acreages is surely to be followed by new diseases and pests. For example, the soybean cyst nematode (*Heterodera glycines*) is the most economically important disease or pest of soybean in the U.S. and Canada. It was first reported in North Carolina in 1954, and moved rapidly to all major soybean growing areas of the U.S. and Ontario. In Canada, soybean cyst nematode was first reported in 1987 in Kent County, near the U.S. border. Since then, it spread rapidly northeast and north from New York State into the Kingston area to recently western Quebec. This nematode has expanded northward along the Red River in Minnesota to near the Manitoba border since 1978. In North Dakota, soybean cyst nematode has also quickly spread from the southeast to the Manitoba border in just four years!

## What is being and can be done?

There are things we can do to limit the ramping of crop nematodes:

- Don't import dirty farm equipment and items containing soil and plant material from BC, U.S. and outside Canada,
- Be on the lookout for problem patches in fields that are tough to diagnose,
- Extension agents and crop consultants should be trained in scouting for crop nematodes,
- Rotate wisely and control weeds and volunteers,
- Train students in crop nematology to address emerging needs,
- We are developing rapid molecular diagnostics for determining crop nematodes,
- We are surveying crop nematodes of pulses and soybean, the CFIA conducts surveys of seed potato fields, and surveys for canola and wheat should be initiated,
- Continue to evaluate soybean tolerant varieties to soybean cyst nematode for suitability on the Prairies.



# Beef Cattle Production: What Have You Herd About 2050?

(credit: K. Blair)

Kim Ominski, Ph.D., P.Ag., is a Professor in Animal Science at the University of Manitoba focusing on beef-forage production systems.

## What's going on and coming up?

Beef production contributes over $30 billion to Canada's annual economy[1]. And about 40% of the 4 million Canadian beef cows are in Alberta[1]. Climate change projections are for increases of 3°C in the average winter temperature by 2050[2], as well as an increase in the number of frost free days**.** This increase in winter temperature may provide opportunities as well as challenges for cattle producers. Here we consider some of the possible impacts associated with cattle production if warmer winters prevail on the Prairies.

## The good...

Over the last decade, many producers have moved from confinement feeding to low-cost alternatives for overwintering cattle including grazing of stockpiled forage, standing or swathed corn, swathed cereal grains and hay bales in fields. Recent survey data from Alberta suggests that almost 70% of producers winter their cows in non-confined overwintering areas. The economic advantages of these systems are substantial[3-5]. Performance of cattle in these environments, in general, is comparable to those in confinement. However, in some circumstances, cattle may lose condition. In a three-year study conducted in central Alberta, swath grazing reduced weight gain in cows compared to those fed in confinement[5]. Another Prairie study[4] reported weight loss over a 78-day period in cattle overwintered in a swath (6.4 kg) or straw-chaff (6.5 kg) grazing system, while animals in the dry lot realized gains of 9 kg. Greatest losses (21.6 kg) occurred in cattle that were grazed in the swath-grazed system. However, the following year, cattle in all systems gained weight with the

greatest gains realized by swath-grazed (28.1 kg) and dry lot cows (32.9 kg). Differences in gain in some of these studies may partially be attributed to inaccessibility of the feed due to adverse weather[6] and increased maintenance costs to the animal for thermoregulation during periods of extreme cold[7]. Predicted increases in winter temperatures may lead to improvement in animal performance over the winter grazing period as a consequence of decreased maintenance costs. A warmer climate with longer growing seasons is expected to increase both winter annual crops and longer-season crops such as corn. As these crops are ideal candidates for winter grazing systems, cow-calf producers will have the opportunity to utilize a range of annual crops, as well as varieties with characteristics that are well-suited for winter grazing. Similarly, more crop acres of corn and/or soybeans will offer feedlots a wider range of cost-effective feedstuffs for finishing diets.

## The bad, and the ugly…

Alternatively, increased frequency of extreme weather events in winter may lead to challenges including more frequent freeze-thaw cycles, periods of extreme cold and above-average snow accumulations; all of which may compromise cow-calf performance and well-being, particularly in extensive overwintering environments. Increased frequency of freeze-thaw cycles creating crusted snow, as well as significant accumulations of snow may limit cattle access to stand or swath-grazed forage. Further, many producers have shifted from winter to spring calving to avoid extreme cold which historically occurs in January. Extremes in temperature and or fluctuating temperature at calving can be particularly problematic for calves, leading to increases in calf scours and pneumonia.

*"increases in winter temperatures may lead to improvement in animal performance over the winter grazing period"*

Increased frequency of weather events will result in obvious challenges including water availability for animal and crop production including hay and pasture and other feedstuffs. For example, periods of drought in Manitoba have led to circumstances in which cattle numbers exceed feedstuff availability (Figure 1).

What is less apparent is the potential survival and/or exposure to organisms which persist under extreme condition of either drought or flooding. Anthrax spores, for example, can survive in the soil for decades, coming to the surface during period of flooding or extreme drought. Animals become infected if they ingest the spores while grazing. Potential increases in liver fluke populations may also occur as a consequence of increased precipitation and standing water. This parasite, which impacts animal performance and also leads to condemnation of the liver, is more abundant in wet condition as the eggs require shall water to hatch.

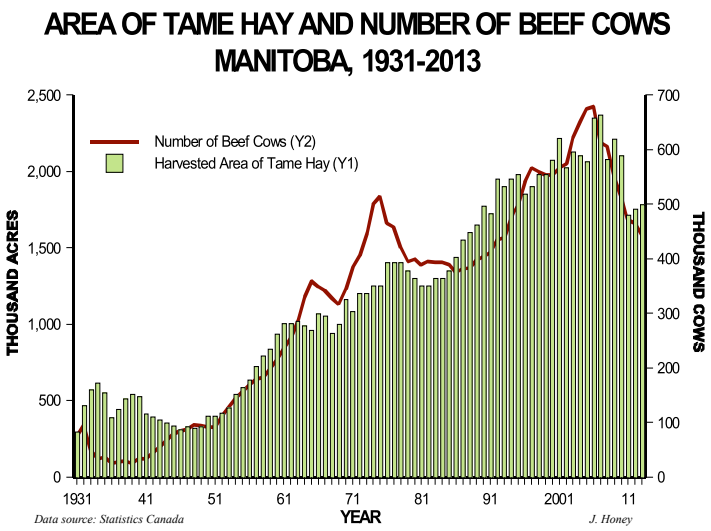



**Figure 1:** *Periods of droughts such as that which occurred in 2002 can result in shortages in available forage required for the cow herd[8].*

## Where to from here?

Changes in climate by 2050 will present both challenges and opportunities for cattle producers. They can expect large inter-annual fluctuations in winter temperatures, as well as a similar magnitude in day-to-day variability that is experienced today. In addition, they will need to consider extreme cold periods, wind protection, and frozen water limitations for cattle, even if the mean conditions are warmer overall. To adapt, not only must they consider new cropping options but potentially new vaccination protocols, which may be regionally specific for organisms such as anthrax and liver flukes. In addition, flexibility in facilities including alternative watering facilities and calving areas should be considered to deal with potential extremes in weather throughout the production cycle.

(credit: D. Timmerman)

# How Will Climate Change Affect My Big Mac Meal®?


(credit: M. Scanlon)

Martin Scanlon, Ph.D., is a Professor in the Department of Food Science at the University of Manitoba. His research focuses on understanding changes in the properties of agricultural materials during the processing operations that convert them into food.

## What is going on?

Regardless of the pros and cons of quick-service restaurant fare, the Big Mac Meal is an unqualified commercial success. It is also the end-point of a significant portion of agricultural products that emanate from the Canadian prairies.

For established food processors, three primary considerations govern business viability. Their manufacturing plant must be efficient, their product must be safe, and it must meet the exacting quality demands laid down by customers such as the quick-service industry. All three considerations will be affected by climate change and extreme weather that impact the producers of potatoes, canola, wheat and beef and their food processor partners who serve that sector. It is therefore highly unlikely that the Big Mac Meal of 2050 will be unaffected by a changing climate

To be assured of high-quality outputs, food processors demand high-quality inputs. Perhaps more importantly, processors demand consistency in the quality or process performance of those agricultural inputs. Variability in properties of agricultural commodities due to climate change poses significant challenges to the food processing industry. To maintain quality uniformity in a global industry, the quick-service cooked frozen French fry should taste the same in Shanghai as it does in Chicago. Potatoes, along with canola oil, make up more than 99% of a quick-service French fry. But, potatoes are particularly susceptible to quality changes brought about by variation in growing conditions.

## What is coming up, and does it matter?

Too hot, too cold, too wet, too dry – potato tubers get stressed very easily. Tubers respond to physiological stresses by producing sugars. Unfortunately, sugars in potato strips diminish the appearance of the finished fry, and the processor can only do so much in the manufacturing plant to get those sugars out. A number of options exist for the quick-service buyer of fries from the climate-challenged processor: lower quality standards and risk losing customers, or lose customers because meals must be higher priced to offset the costs of rejected loads of tubers. A third pro-active option is through potato breeding programs, where cultivars tolerant to abiotic stress will be targeted while maintaining other fry quality traits. The capacity to sort strips based on composition at line speeds is an additional technological response to agriculture's 2050 climate challenges.

Food safety will also be increasingly challenged by the effects of climate change and extreme weather events. The old allies of food safety in meat processing plants - chilled process lines and copious emanations of wash water - will be harder to find as rising prices for refrigeration and potable water force processors into reconfiguring long-held manufacturing practices. Innovative reductions in water usage and the re-use of grey water streams for non-critical process tasks where food safety is not compromised are certainties in all future processing plans. An example is one meat processor who has reduced water usage from 3700 litres per head in 2010 to 2800 litres per head one year later.

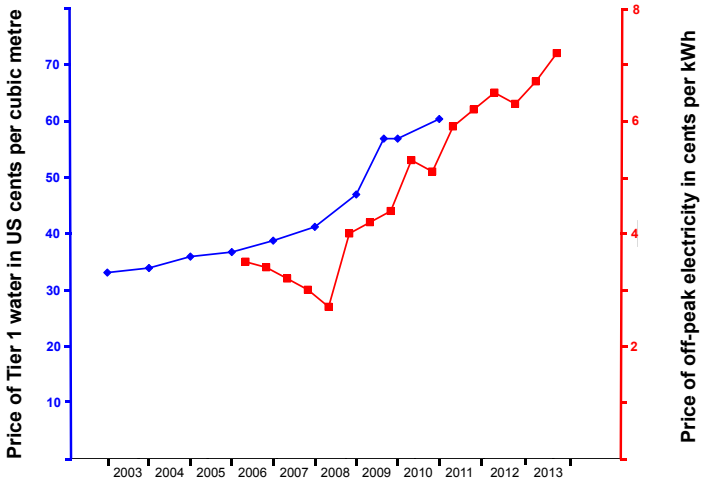
One area where extreme weather can directly affect consumer health is not in the meat patty; this undergoes a rigorous heat treatment at the restaurant before the bun is loaded. Rather, the food safety threat arises from lettuce shreds that enhance the burger's textural contrasts. The intense precipitation of extreme weather events can ballistically launch soil-borne organisms such as *Listeria* and transfer them to the growing lettuce. With no option for heat treatment, these minor components in the meal may pose tomorrow's food safety threat.

> *"processors demand consistency in the quality or process performance of those agricultural inputs"*

Finally, plant efficiency can also be challenged by climate and extreme weather effects. Manufacturing plants that are able to meet the standards of the quick-service industry rely on uninterrupted supplies of potable water and reliable power; they run on large volumes and tight margins. Reducing these inputs is a target for all processors, and some have cited aggressive reductions for 2020 through a variety of innovative strategies and new technology introductions.

In addition, since much of the Big Mac Meal relies on tightly integrated frozen and refrigerated distribution chains, extreme weather events could significantly disrupt the supply and quality of the Meal's components after they have left the process plant. Sensitivity to weather events is exacerbated because these tightly-controlled chains have been purged of the vast majority of previous inefficiencies.

To conclude, one can expect the effects of climate change and extreme weather to affect the viability of food processors meeting the demands of urban customers far from the Prairies. Elevated carbon dioxide levels may change more in the Big Mac Meal than just the carbonation level in the soda.




*Energy and water prices from power-stressed Ontario and water-stressed Southern California[1]. As climate change reduces water supplies and increases energy costs, Canadian food processing facilities will have to cope with increased manufacturing costs. Exacerbating the problem is the high power cost of pumping water to regions that undergo periodic water stress.*

# Climate Change and Transportation

*Vancouver Port*
(credit: Transport Institute)

Paul Earl, Ph.D., is Acting Director of the Transport Institute, and Senior Scholar in the I.H. Asper School of Business, University of Manitoba. Barry Prentice, Ph.D., is a Professor in Supply Chain Management at the I.H. Asper School of Business, University of Manitoba.

## What is going on?

A changing climate will have a direct effect on both transportation infrastructure and operations, but the impacts do not stop there. It will also affect the demand for transportation, particularly in western Canada where grain forms such a large proportion of freight moved. For example, the Canadian Wheat Board predicts that as a result of climate change, more soybeans and corn will be grown in Western Canada as the weather begins to look more like the South Dakota[1]. Yields of current crops are likely to increase because of the lengthening of the growing season. Acreage of wheat and pulse crops will expand, while barley and canola acres likely contract. These changes in production patterns in turn will change the transportation needs of the industry.

## What is coming up?

The impact of these changes on transportation infrastructure and operations could be significant for road, rail and marine – all of which are essential for the movement of agricultural goods in western Canada. Some of the implications, which are mentioned in the literature and attested to by practitioners, are as follows:

- Greater variability in temperature and precipitation could cause more rapid deterioration in road and rail infrastructure. More frequent and wider freeze-thaw cycles could cause road surfaces and bridges to fail, with associated increases in renewal and replacement costs. In the 2013 flooding in Calgary and western Alberta, one bridge was lost, and tracks were flooded through the foothills.
- Greater variability and more frequent extremes also generate more mudslides, snowslides, washouts, tornadoes

and blizzards, any of which can result in short term costly interruptions, and long-term cumulative damage. Extreme heat can cause the buckling of road pavements and both buckling and breakage of rails. Weather disruptions in the winter of 1996/97 were so severe that the Canadian Wheat Board lodged a level of service complaint with the Canadian Transportation Agency – a complaint that was, in part, substantiated by the Agency.

- The 2013 grain crop was a record but the railways have not had the available capacity to move all the grain. This year's experience raises the question of what level of peak movement should be provided for. Moreover, there is insufficient storage on farms and country elevators to accommodate record crops when transportation capacity is constrained.
- The oceans have already risen 30 cm in the past 100 years. It has been estimated that the sea level at Vancouver could rise by 28 to 98 centimeters by 2100. The Port is working on a plan to deal with future increases in the sea levels, but the problems are not confined to Canadian shores. Both long-term rises in ocean levels, and short-term effects of severe storms anywhere can affect our destination ports, and cause delays to shipping of Canadian grain.
- The Port at Churchill, Manitoba, might benefit from a longer season, but higher temperatures that melt the permafrost will threaten the rail line that serves it.
- The Great Lakes have already lost about 30 cm of their navigation depths because of evaporation. This is attributed to milder winters with less ice cover, a long-term trend that reduces the usefulness, and increases the cost, of this route.
- Road infrastructure and operations are also negatively affected by extreme weather. Road access from Winnipeg to the U.S. is regularly interrupted by spring flooding, causing costly detours and deterioration of the road itself due to frequent submersion.

## Why is this important?

Added costs to repair, replace and upgrade infrastructure to accommodate greater climate variability and more severe weather events erode Canada's competitive position, and have a negative effect on farm incomes. These effects ripple through the entire economy of western Canada, and, indeed, in the nation as a whole. This raises the last question:

## What is being, or should be, done about it?

Transportation companies all over the world are taking the effects of climate change seriously, and public pressure continues to grow to address the deterioration of publicly provided infrastructure in roads and bridges. The following are among the many approaches to the issue adopted by industry and government:

- CP Rail claims to have a comprehensive program that entails (1) preparation and planning, (2) detection and prevention, (3) response and resiliency, and (4) restoration and recovery. It engages in continuous monitoring of weather, and works with other members of its various supply chains to deal with contingencies.
- BNSF reports that it is "hardening" its system against weather events with wind fences and snow sheds, and engages in continuous monitoring to deal with weather extremes.
- Omnitrax, which operates Canada's most northerly rail line, is taking steps to deal with melting permafrost, and have two studies underway to determine the effects of weather on its rail line and on sea ice in Hudson's Bay.
- The Province of Manitoba has a long-term plan in place to upgrade its highway link to the U.S. This involves raising sections of the highway to reduce the impact of annual flooding of the Red River. Regulations are also changing to make spring and winter loading restrictions more flexible.
- Port Metro Vancouver is planning for the sea level rises cited above, and for more severe storms. The impacts on the delta and the airport are significant, but the port has already made provision to build higher than anticipated high water levels.

Are current activities sufficient? The current disputes over the movement of the 2013 grain crop are indicative of the extreme difficulty of operating under the conditions of uncertainty that practitioners face in dealing with climate change. Unfortunately the past is no longer a reliable guide to the future and thus there are no data that tell us how climate changes will unfold. Governments and industry are faced with the exceedingly difficulty problem of weighing the risks and associated costs of negative climate change impacts against the costs and benefits of remedial action. If warmer weather makes crops like 2013 more common, what is the maximum production that the handling and transportation system should be designed to handle? To what elevation should highways be raised in order to maintain traffic flows? Too high, and scarce resources are wasted; too low, and shippers and carriers incur extra costs and lose market opportunities. These are the challenges that governments and the transportation industry face an increasingly uncertain future.

*"disputes over the movement of the 2013 grain crop are indicative of the extreme difficulty of operating under the conditions of uncertainty"*

# Regional Trade Agreements Will Shape the Future of International Food and Agricultural Trade

Ryan Cardwell, Ph.D., is an Associate Professor in the Department of Agribusiness and Agricultural Economics at the University of Manitoba. Ryan researches the economics of food policies, international trade agreements and international food aid.

## What's going on?

The most recent round of multilateral trade negotiations, under the auspices of the World Trade Organisation (WTO[1]), failed in establishing a new framework of rules for international trade. WTO negotiations have become increasingly intractable as the large number of member countries (159 members and 25 observers) each push for very different objectives. Negotiations to liberalise trade in food and agricultural industries are particularly difficult because these industries are characterised by high import barriers and high levels of government support in many countries. It is unlikely that we will witness another multilateral trade deal that will discipline these policies and liberalise agricultural trade flows across numerous countries over the next several years. The failure of negotiating countries to agree to a new multilateral trade deal means that the rules agreed to under the 1995 Uruguay Round Agreement on Agriculture will remain in force.

## What's coming up?

The future of international food and agricultural trade in the Prairie Provinces through 2050 will be shaped by two factors. The first is a patchwork of regional trade agreements that will emerge from the rubble of the failed Doha Development Round negotiations of the WTO, and the second is growing demand for protein from emerging markets in Asia.

*"Canada must pursue trade agreements with emerging markets"*

Canada is likely to negotiate regional trade agreements that will reduce barriers with important trading partners, in lieu of a multilateral deal in the tradition of the WTO agreements. Smaller regional trade deals are often simpler to negotiate because each country can focus on a handful of trade policy objectives, without having to satisfy the demands of 150+ WTO member countries in a single undertaking. Canada has recently entered into a trade agreement with the European Union, and is negotiating with South Korea and a group of countries under the banner of the Trans-Pacific Partnership. These types of agreements are becoming much more common (Figure 1), and are likely to proliferate in coming years.

A second important factor in the future growth of Prairie agriculture will be the global demand for meat products as incomes grow and people migrate from rural to urban areas in emerging Asian markets, especially China. China's market for meat products is currently supplied mostly by domestic production, however demand is expected to outstrip supply in coming years, necessitating more imports. Prairie agriculture is well positioned to take advantages of increased demand for swine and bovine meat products on the world market. However growing demand in emerging markets will not increase dairy and

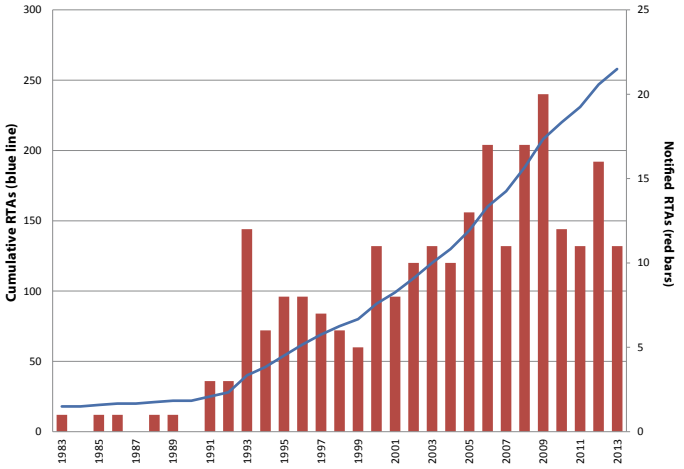



**Figure 1:** *Prevalence of regional trade agreements (RTAs) (Source: WTO (undated), author's calculations).*

poultry exports from the Prairies because production quotas and high production costs keep these off the world market (Figure 2). Increased meat consumption and production in emerging markets will also buoy demand for coarse grains for animal feed.

## Does this matter?

The recent failure of WTO-member countries to conclude a multilateral trade deal bodes badly for future multilateral trade deals between large blocs of countries, and there are several shortcomings of the regional trade agreements that will emerge in the absence of a WTO deal. First, regional trade agreements typically don't include disciplines on domestic government support for agriculture. This means that Canadian exports will have to compete with products that are produced under subsidy in importing countries, most importantly in the U.S. and the European Union. However, this also means that Canada's future agricultural subsidy policies (current examples include AgriStability and AgriInvest)

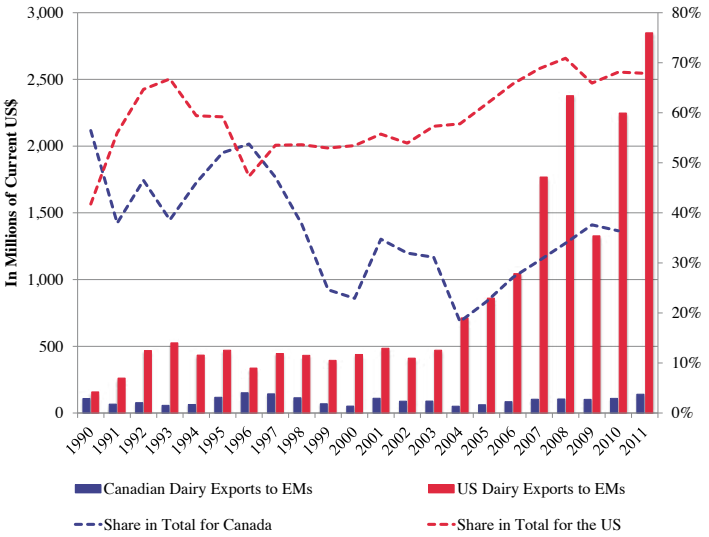



**Figure 2:** *Canadian and US dairy exports to emerging markets (EMs)[2].*

will not be bound by new obligations to WTO countries, as long as they conform to existing rules under the 1995 Uruguay Round WTO agreement.

A second shortcoming is that the disciplines in these agreements are not subject to strong dispute-settlement procedures, as are the agreements of the WTO. The WTO Dispute Settlement Understanding has been an important venue for handling disputes related to exports from the Prairies (e.g., beef hormones, mandatory country of origin labelling). Third, a patchwork of overlapping agreements between Canada and its trading partners complicates (and therefore increases the cost of) exporting to different countries because each export destination may impose different regulatory requirements (e.g., inspection, country-of-origin regulations). This means that producers and exporters from the Prairies must incur the costs of complying with numerous regulations instead of one standard, as would be the case under a comprehensive multilateral trade deal.

Canada's supply management regime, which controls supply and excludes the importation of most dairy and poultry products into Canada, is not likely to be subject to fundamental restructuring because of international trade agreements in the short term. The current supply management regime enjoys broad support across national political parties, so Canada's bargaining positions in future regional agreement negotiations are likely to be built around the maintenance of high import barriers for dairy and poultry. This means continued high producer and consumer prices for dairy and poultry products in the Prairies.

## What is being done about it?

The U.S. remains the primary market for Prairie food and agricultural exports. Canada must pursue trade agreements with emerging markets if exporters hope to access markets where population and income growth will be strongest. Import barriers for food and agricultural products remain relatively high in many of these countries. Some commentators have argued that the Canadian dairy and poultry industries are missing the opportunity to export to emerging markets by limiting production with quotas[2]. However, major changes to the current system of production and import controls do not appear to be on the horizon.

So how might a changing climate influence these trade agreements in the future? The current pattern of comparative advantages in food production across countries may evolve as production costs change in response to weather and climate influences. The incentives to engage in trade agreements with new countries will evolve accordingly, with importing countries looking to acquire low-priced food imports.

# Can Insurance Keep Up With Catastrophic Weather Losses?

Charles Grant, Ph.D., researches and teaches farm management, agribusiness management, and financial risk management at the Department of Agribusiness and Agricultural Economics, University of Manitoba.

## What's going on?

Canada's property and casualty insurers paid record claims of $3.2 billion in 2013. In excess of $2.6 billion of these claims were attributable to catastrophic weather events. Claims of this magnitude are somewhat to be expected since payouts due to severe weather events in Canada have been increasing since the 1980s (Figure 1). Windstorms, snow storms, ice storms, thunderstorms, tornados, hail, heavy rains, flooding, droughts, and forest fires are causing such catastrophic losses. Many insurance underwriters agree that these hazards seem to be occurring with greater regularity and greater severity than in the past.

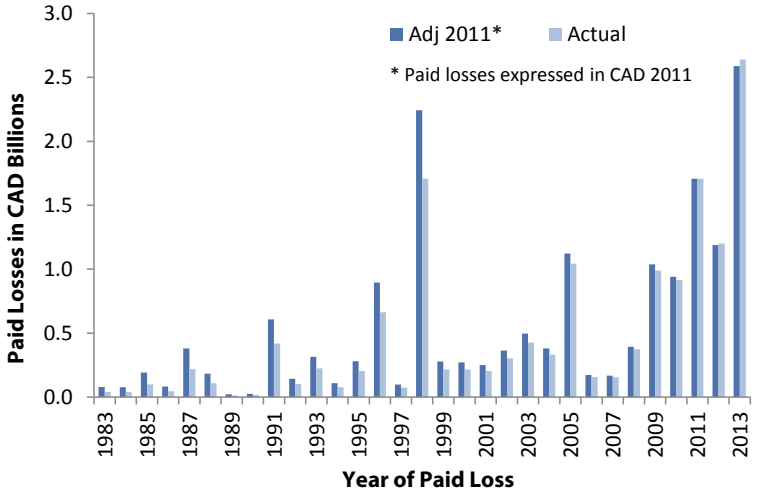



**Figure 1:** *Canadian catastrophic paid losses (in CAD Billions) are showing a general increase over time[1].*

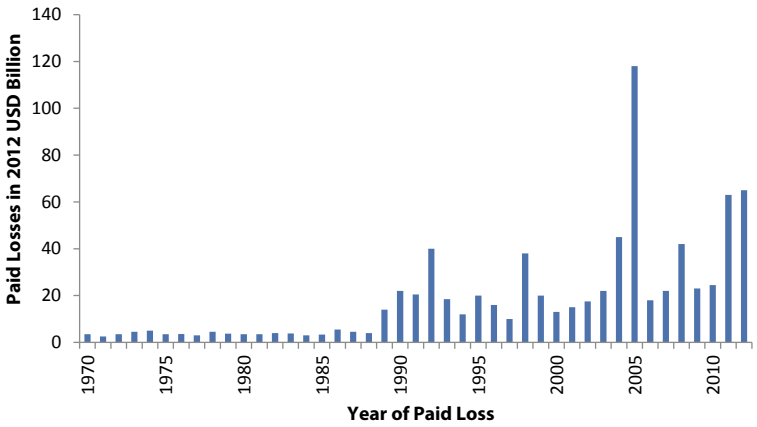



**Figure 2:** *World-wide catastrophic paid losses[2].*

World-wide insurance claims for catastrophic weather events have also been increasing (Figure 2). In 2012, widespread drought in the American mid-west created a claims response of 17 billion USD and Hurricane Sandy on the eastern seaboard created a claims response of 25 billion USD.

In general, insurance claims due to catastrophic weather events have been trending up in both Canada and in the rest of the world. The question is, can insurance keep up with these catastrophic weather losses?

## What's coming up?

Insurers are for-profit entities. Therefore insurers will need to adjust to the increasing claims paid for losses due to catastrophic weather events in order to keep profits intact and maintain business solvency. Insurance profits are determined with the equation:

*"insurers will need to adjust to the increasing claims paid for losses due to catastrophic weather events"*

Insurer Profit = Premium Income + Investment Income - Claims Paid - Operating Expenses.

Since investment income and operating expenses are generally unrelated to weather losses, the places to look for insurer's adjustments are:

1) increasing premiums commensurate with increased claims paid;
2) managing claims exposures by increasing deductibles, reducing coverage limits, introducing exclusions for certain weather-related losses (e.g. exclusion for property damage due to overland water);
3) requiring technological upgrades for policyholders (e.g. improved infrastructure for handling sudden large volumes of water).

## Does this matter?

All of this matters because, in one way or the other, it costs more money to the individuals and firms with exposure to catastrophic weather risk. Premiums become more expensive, individuals and firms are left to self-insure a greater portion of the losses, and costly technological upgrades become necessary to reduce the severity of the losses.

Table 1 shows the catastrophic losses in 2012 and the extent to which they were self-insured. In North America, roughly half the losses were self-insured and the other half was laid off to insurers. In other jurisdictions the self-insurance proportion is higher. If firms and individuals do not have the appetite or capacity to pay higher premiums to cover increased claims for weather events, the self insurance portion of losses will need to rise.

## Can insurance keep up?

Aside from turning back the clock on increasing regularity and severity of catastrophic weather events, insurers can keep up with increasing claims by increasing premiums to policyholders, by requiring greater self-insurance by policyholders, and by requiring policyholders to adopt technological methods of mitigating weather losses. All of these adjustments will cost more money for individuals and firms exposed to catastrophic weather risks because in the end it is these individuals and firms who bear the costs. This will also affect agricultural costs on the Prairies.

**Table 1:** *World-wide catastrophic losses, total and insured (2012)*[2].

| Jurisdiction | Total Loss (Billions USD) | Insured Loss (Billions USD) | Insured Loss as % Total Loss |
|---|---|---|---|
| North America | 118.5 | 64.6 | 54% |
| Latin America & Caribbean | 4.2 | .9 | 21% |
| Europe | 26.8 | 5.5 | 20% |
| Africa | 1.5 | .2 | 13% |
| Asia | 30.5 | 3.4 | 11% |
| Oceania / Australia | 1.1 | .3 | 27% |
| Seas & Space | 3.1 | 2.4 | 77% |
| **TOTAL** | **185.7** | **77.2** | **42%** |

# Preparedness -

## *Strengthening the Agri-Food Sector's Capacity to Adapt and Thrive*

Has the Prairie agri-food sector adapted to the challenges and opportunities of climate, market and input cost changes over the past 40 years? Yes, remarkably well. For example, Prairie agriculture has developed a new crop (canola), a new level of conservation tillage for crop production, and has survived fusarium, wheat midge, as well as Bovine Spongiform Encephalopathy (BSE) outbreaks. Here we address the tools required to ensure that the agri-food industry has capacity to capture opportunities and successfully address challenges in the next 35 years.

There is general recognition that future policy will have to consider not only mitigation strategies but also adaptation and adaptive capacity. Barriers to adaptation are generally linked to uncertainty and lack of understanding causing lack of leadership or inaction by governments, or existing governance and institutional arrangements. Agriculture's capacity to either proactively or reactively respond to future change requires the support and trust of the Canadian public.

### Background

There is tremendous potential for agricultural systems on the Canadian Prairies to expand agri-food exports in response to global demand for food by 2050. Globally, this demand is expected to require farmers to double their production of crops and/or livestock over the next four decades[1]. Achieving such increases in productivity will pose significant challenges since water, land and energy resources are increasingly in demand by other economic sectors and rapidly growing urban areas. As well, response to opportunities and challenges cut across a wide range of interdependent jurisdictions where decisions are made, from local farms to multi-national food processors.

Climate change will influence the conditions under which food is produced, stored and transported more in the future than has been experienced in the past. In addition to population growth and shrinking input resources, stakeholders along the food value chain will be expected to respond to shifts in consumer demand, environmental policy and global trade. While there is recognition that the economic, environmental and social health of Canadians is linked to the health of Canada's agriculture sector; Canadians have less opportunity to interact and, thereby, understand the short- and long-term impacts of current and future practices or technologies on their economic, environmental and social welfare.

Successful adaptation may occur through incremental improvements or may require much more radical change. The advent of the Haber-Bosch process for chemical fixation of nitrogen from air in the 1900s and of Mendelian genetics spurring the green revolution caused radical or system-level changes to food production around the globe. Most improvements to efficiency of resource and labor use, reliability of food delivery, food quality or safety in Canadian animal and crop production systems have been incremental; examples including precision agriculture, continued improvements in crop yield and disease resistance, and animal vaccines. As we look to 2050, we cannot predict the success of technologies such as in vitro meat production which could cause a radical shift in current food production systems. Nor can we predict the relative impacts of a broad range of technologies that will incrementally increase competitiveness, environmental stewardship or food quality in current food production systems across Canada's ecozones.

### What Metrics Should We Use for Successful Adaptation?

**Henry Janzen**, Ph.D., Research Scientist – AAFC

The essence of successful adaptation is coping creatively with unpredictable change; ideally it means not only *surviving* change, but discovering therein new opportunities. Adapting is more than merely conserving what once was; it seeks, rather, to manage our ecosystems – our lands – so that all the many benefits we derive from them are sustained *despite* inevitable changes. But how do we know if these benefits are being sustained? How do we know if our lands are building up or winding down? Clearly, we need some way of gauging the performance of our lands --- metrics to monitor how they are faring during the coming changes.

Establishing the need for metrics is easy enough; actually devising specific measures to use is another matter. Rather than prescribe a list of such metrics (likely a premature exercise, given the state of the science), we describe here what such metrics might look like. If we could develop an ideal set of metrics – of measurements – to monitor how

*"Adapting is more than merely conserving what once was...so that the many benefits we derive (from them) are sustained despite inevitable changes."*
(credit: E. McGeough)

well ecosystems are adapting, what would it look like? The following attributes are proposed; the metric system should be:

**Comprehensive:** To be effective, an ideal set of metrics would consider all the functions expected of our ecosystems – not just conventional ones such as maximizing yield, sustaining economic return, mitigating greenhouse gas emissions, or avoiding nutrient loss (as important as these are), but also others not always immediately apparent: filtering water, fostering rural communities, preserving wildlife, ensuring aesthetic values, enriching human health, and promoting animal welfare, as a few examples. This perspective steers us toward looking at our lands not merely as ecosystems, but as social-ecological systems: humans embedded among the myriad biota, all interwoven and intertwined with each other and their physical habitat. To develop a set of metrics, then, we need first to enumerate the manifold functions derived from land, spanning the boundaries between traditional disciplines.

**Unifying:** None of the functions we ask of the land can be considered alone; all are interactive, creating some synergies but also inevitable trade-offs. For example, the system that best promotes economic return might also minimize nutrient loss, but deplete soil diversity; the system that best preserves aesthetic appeal may also sustain wildlife, but diminish income for rural populations. These interactions all need to be weighed together in arriving at a sound measure of adaptation. One way to move toward such holistic assessment might be to think in ratios of benefits and costs. As an example, consider the case of greenhouse gas mitigation. Reducing the emission of these gases is an urgent aim; but the system with the lowest emissions (e.g., abandoned land with minimal inputs) may not sustain other demands on the land (e.g., producing food). A useful metric, therefore, might be the ratio of services attained per unit of greenhouse gas emitted. In effect, this approach asks: if we 'invest' a tonne of $CO_2$ equivalent (a cost), what is the return in food yield, economic livelihood, biodiversity, and other benefits we deem important?

**Locally applicable:** In the end, lands are always managed locally, farm by farm, field by field; and the stresses of change will be exerted locally, uniquely to each place. A useful scale for applying metrics, therefore, might be the ecosystem: a single farm, perhaps, or a local assemblage of farms, encompassing most of the exchanges of energy, nutrients, and carbon. In a livestock system, for example, the ecosystem might include the land where animals are raised, as well as the surrounding lands that furnish the feed and recycle the manure. Any evaluation of adaptation must explicitly describe the boundaries within which the measurements apply. It is the boundaries, ideally local boundaries that distinguish between a concrete, relevant metric and an abstract, ethereal one.

**Simple and transparent:** To be widely adopted, a metric should be simple enough to be broadly applied and easily understood. An elementary measurement, decipherable by the uninitiated, is usually better than a sophisticated algorithm opaque to all but experts. For example, a measurement of soil carbon is preferred to a model output of carbon dynamics; an estimate of protein produced per unit of greenhouse gas emitted may be better than detailed spreadsheets of farm fluxes and yields. Elegant simplicity, of course, demands much more creativity than mere sophistication; so this attribute is better seen as alluring target than as immediate goal. Particularly challenging are those ecosystem functions that are not easily measured: aesthetic appeal, for example, or biodiversity. A possible approach for these might be a simple numerical index, produced by representative human panel. Better to include a simple index, with admitted flaws, than to ignore a function entirely.

**Timeless:** The underlying variable in adaptation is time; change, by definition, unfolds as each future moment is overtaken by the present, and then slips into the past. A metric to monitor adaptation to change, therefore, must stay true and consistent across time, into an uncertain future. This forces those who design the metrics to envision the range of unfolding possibilities for future lands, and to devise measures that will be robust across long time, even in the event of certain surprises. Ironically, some of the best insights toward this future perspective may be found in the past, by asking: Which metrics have survived the tumultuous changes of the past century or so? Some of these, such as soil carbon, ecosystem nutrient balances, diversity of farming systems (including livestock) might well be melded into future metric systems.

This list of attributes, no doubt, is still incomplete. Even so, it is already daunting, and we are only now taking the first faltering steps toward building a set of metrics that might satisfy these criteria. So what is the way forward? Maybe our quest can be guided by the following questions, asked sequentially:

1. What functions do we ask of the land? And what functions will our successors, some decades hence, ask of it? In pondering this question, of course, we think of the full spectrum of uses, from the biophysical to the social.
2. What stresses may be imposed on our lands? And which lands are most vulnerable? We cannot know exactly how the future unfolds, but many of the coming challenges seem already apparent: demand for food, shrinking land area per capita, energy constraints, dwindling freshwater, for example. Enumerating these coming stresses might steer us to those parameters and places of our systems most vulnerable to adaptive pressures.
3. What, then, do we measure to see how well our lands can continue to furnish into the future all we ask of them in the face of coming stresses?

These questions, of course, are not merely academic and conceptual. They are best asked in parallel to measurements already begun, or needing to be started. It is as we measure performance of our lands, even with our still feeble and fragmentary metrics that we answer the preceding questions, and stumble on new ways of resolving them with better measures. And always we think: "What measures should we start today for those who will be monitoring success of adaptation tomorrow?; just as we have learned so much from the measurements begun by our far-sighted forbearers.

A system of metrics for measuring adaption, as sketched above, may seem ideal, not soon fulfilled, if attainable at all. But the effort toward it still is warranted, for it will likely lead us to better science in understanding our ecosystems, and to more compelling visions about how we should live on our lands in a changing world.

## What Kinds of Government Policies Will Help Us Adapt in 2050?

**Sheilah Nolan**, M.Sc., P.Ag., Climate Change Specialist, Alberta Agriculture and Rural Development works in the area of agricultural climate change, serving on the cross-government Alberta Climate Change Adaptation Team and developing agricultural carbon offset protocols for voluntary use in Alberta's carbon market.

**John Zylstra**, P.Ag., Agriculture Land Management Specialist, Alberta Agriculture and Rural Development has many insights into agricultural adaptation to climate change in the Peace River Region of Alberta and contributed to the early development of regional land use plans in Alberta.

A key role of government is to secure common goods and services that individuals cannot provide. This is done by developing a range of strategies, policies and plans to achieve outcomes that are implemented through legislation and regulations, through the use of instruments such as incentives or directives, or by using measures like standards or certificates. Although significant drivers are required for regulations, these may be set to trigger only at threshold changes in quality or supply of resources. Voluntary arrangements, education and outreach programs have also been successfully adopted to support strategic policies. Market-based instruments, such as taxes and tradable permits, have recently been used to alter price signals and create cost incentives. Although preference may be given to one approach, most jurisdictions rely on multiple policy approaches to achieve their goals.

Intensification of sustainable food production may be one of the better responses to climate change[2]. Increased efficiency of resource use for increased agricultural productivity will be a key policy driver in this context, including the need to enhance the quality and accessibility of the biophysical resource base. Figure 1 illustrates the challenge of linking variations in both biophysical and human elements, highlighting the need to target management to minimize adverse impacts in vulnerable areas. Another important policy driver related to a changing climate will be sector and public preparedness for a range of possible scenarios, such as strategies for stabilization of farm incomes. Although recovery from impacts that are gradual and widespread allows time to fine tune adaptation approaches, recovery from severe and highly uncertain climatic impacts can require many years. Broader drivers of policy to support

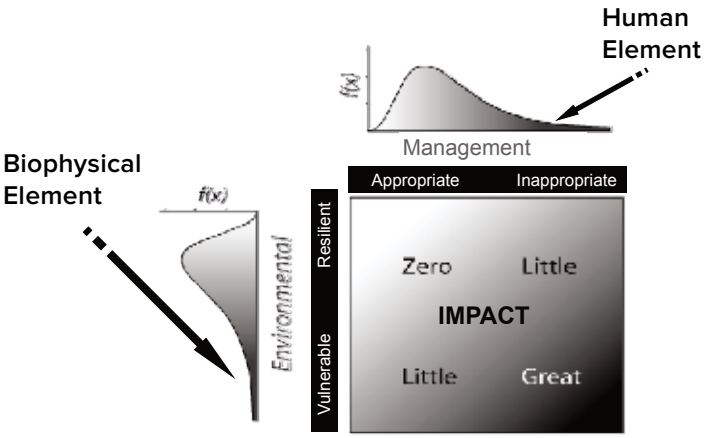



**Figure 1:** *Linking two forms of variance to focus efforts for greatest impact (P. Nowak, personal communication, February 12, 2014).*

adaptation include the need to diversify the economic base of the Canadian Prairies as well as external pressures, such as standards set in other countries and expectations arising from different cultural preferences.

Proactive government policy will anticipate change and balance long term goals of enhanced resource use with immediate term goals of competitiveness; proactive government policy will not simply respond to impacts. In view of the many uncertainties and influences on decision making, focus should be on enhancing resilience or 'adaptive capacity' that is the broader ability of agricultural producers, regions or sectors to cope with climate-related risks and opportunities[3].

**Current status:** Government policies that promote a vibrant, growing agricultural industry on the Canadian Prairies are already enhancing the resiliency of agricultural systems to a changing climate. Increasingly, regional land use planning initiatives are taking unique watershed and socio-economic characteristics into account when designing strategies in consultation with key stakeholders and the public. Evaluation of recent flood disasters is informing new planning efforts to minimize future impacts. Areas of high vulnerability within regions are being recognized for targeted actions, such as controlling cattle access to streams to address water quality. Public funding supports technologies that provide real-time data about field conditions that are being integrated into early warning systems. Government-backed crop insurance programs are providing a broadening range of options to mitigate risks of crop failures for farmers. Policies at provincial and national levels have supported a strong science and technology basis for progress towards continuous improvement of farm-scale management through research and extension programs. There are signals; however, that the social licence to operate will be challenged if the public concerns, valuations and expectations are not a part of the dialogue in future policy development.

**Policies to heighten resiliency:** In order to specifically increase resiliency to the highly variable and uncertain impacts of a changing climate, future government policy should develop a range of approaches to support outcomes that include: i) optimized management to ensure quality of biophysical resources, ii) sector and public preparedness for a range of possible climate change scenarios, and iii) diversification to broaden the basis for responding to change. A variety of simultaneous approaches can be used to support the development of innovations needed to address uncertainties and reduce risks, including incentives, market-based instruments, or tradable permits. Although regulation may be required in some cases, a range of approaches can be designed to meet specified outcomes, such as options to either change management or make payments into a fund to support future technological improvements. Outcomes that support resiliency will require innovation from a strong research base, the use of metrics to regularly gauge progress and fine tune policy approaches, as well as public and private sector involvement to apply existing momentum and increase the range of human and financial assets that are directed towards adaptation of the agricultural sector to a changing climate. Policies to increase the responsibility of Professional Agrologists to assess, assist with and document improved farm-scale management could also support outcomes of increased resiliency of agricultural systems.

Since moisture is scarce or arrives at inopportune times in many parts of the Prairies, optimized management to ensure high quality of water resources will be fundamental to enhancing the resiliency of agricultural systems to a changing climate. Efforts to increase food production and economic activity must target improvements and innovation in water use efficiency. Schreier and Wood[4] outline various ways for government policy to support the development of a strategic approach to water use in Canadian agri-food production. In addition to creating incentives to promote innovations in water use efficiency, they note a need for research to develop methods to measure and analyse water footprints from a whole systems perspective. These measures may become a basis for identifying standards that can be used to encourage management that meets or exceeds specified criteria. Comprehensive assessment is needed to capture externalities and reflect full costs of production. Inventory and risk assessment tools are also needed to synthesize results and assess water use scenarios in different regions in order to target vulnerable areas for management that avoids or reduces adverse impacts. Support of on-farm pilot studies and farm level education are important components that support adoption of practice improvements to increase water use efficiency.

*The Oldman River dam was constructed in 1992 in response to the many droughts experienced by Southern Alberta farmers.*
(credit: D. Flaten)

Resiliency will be enhanced by policies that support the development of multiple approaches to encourage preparedness for a range of possible climate change scenarios. Area-specific contingency plans will help to operationalize a range of strategies and provide a basis from which to develop further innovations and improvements. Government initiatives to construct infrastructure to support increased resiliency will be needed, such as facilities that store water and increase irrigation capacity. Monitoring systems are also important components of preparedness strategies, allowing governments and industry to respond to risks in early stages, when issues are usually more manageable.

Policy instruments to target outcomes of increased diversification of agricultural production according to areas of strength will provide new opportunities from which to build success in uncertain futures. Incentives to leverage momentum and private investment through collaboration with other efforts to diversify the economic base on the Prairies will be an important means of bringing new ideas and assets from a broad range of industry, research, and stakeholder perspectives. Review of policies to support resiliency and adaptation to climate change in other areas than agricultural production, such as municipal development and health services, will identify new opportunities where momentum can be increased by collaboration and integration. A variety of policy approaches can be designed to reward progress towards attaining desired outcomes at multiple levels (e.g. farm, processor, distributors and general public). Policies to encourage integration of new knowledge and technology to optimize resource use and productivity will bring added benefits of increased competitiveness and reduced risk. These approaches will also require collaborative and transparent processes of assessment, planning and prioritization with regular evaluation of metrics to measure progress towards identified outcomes of increased resiliency.

Although the challenges of adaptation to a changing climate are considerable and fraught with high uncertainty, comprehensive, dynamic and outcome-based government policy approaches can draw on past and current successes to heighten the resiliency of agricultural systems to impacts of future conditions on the Canadian Prairies.

## How Will Technical Innovation Help Us to Deal With Climate Change Risk?

**Don Flaten**, Ph.D., P.Ag., is a Professor in the Dept. of Soil Science at the University of Manitoba, where he specializes in nutrient management and crop nutrition.

Technical development is widely recognized as a substantial contributor to the capacity of Canada's agri-food industry to adapt to climate change[3-7]. Climate change will spur the development of a variety of technical innovations to deal with the challenges of variable weather and climate change directly, or indirectly through consequences such high input prices, rising cost of transportation, or greenhouse gas emission penalties. New opportunities to earn carbon credits or grow new, higher-yielding crops in a warmer, longer growing season, will also encourage further innovation.

**Continuous development and adoption will continue to be imperative:** The agri-food sector is a highly competitive industry where, if we don't innovate as quickly or as well as

### Red Queen Effect

"... Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Lewis Carroll

*Through The Looking-Glass*

*"we will need to continue to invest in a combination of measures that enhance our capacity to be flexible"*
(credit: W. Reimer)

our competitors, we will fall behind. As Julian Alston[8] states, it's similar to the classic "Red Queen Effect" in evolution, where our industry resembles the Red Queen's world from Lewis Carroll's *Through the Looking-Glass*, "it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" Individually and collectively, we will need to continue to invest in a combination of measures that enhance our capacity to be flexible and adapt to new realities that will face the agri-food sector in the next decades.

**Technical developments are difficult to predict:** Historically, technical developments have been difficult to anticipate or predict. No one knows when another plateau in productivity may be reached or transcended; in large part because the fundamental nature of discovery is that it is a path that leads into unknown territory. In some cases the complexity of development from the basic through applied to commercialization stages will require both focused and comprehensive approaches to ensure acceptance by the user of the technology, the producer, as well as the general public. Situations in which industry and/or public confidence is challenged will increase development costs. At the 2014 annual meeting for the Weed Science Society of America in Vancouver, Damon Palmer, from Dow AgroSciences, estimated it now costs $250 million to research and develop a new crop protection product[9] and those costs are not likely to decrease. In other cases, especially where there is less perceived risk to human health or the environment, development of new techniques and technology may be faster than in the past because science and engineering tools for development have progressed substantially and because technology transfer is a global industry. Shifting drivers in the decision making process make predictions of future trends a subjective exercise, especially when one attempts to gauge the impact of future technologies applied collectively.

**Technical developments require investment**: One aspect of technical development is easy to predict: without any investment of time, effort and money, technical development is not going to occur. This important link between investment and return may be cause for some concern going forward to 2050. Traditionally, Canada's federal and provincial governments have been large investors in agricultural research, which has yielded large dividends to the regional and national economies. However, as noted by Veeman and Gray[10] in their review of agricultural production and productivity in Canada, real public agricultural research expenditures in Canada for crops and livestock has been declining. That total domestic research and development, a "knowledge stock" variable that is calculated as a 20-year stock of federal, provincial, and private sector research and development expenditures, has levelled off for crops and livestock in Prairie agriculture since 1990[10] is of even greater concern. This stagnant to declining investment in agriculture research has occurred even though return on investment in agricultural research and development is widely recognized as paying very large dividends for public, private, and producer group investors[7,10,11,12].

*"Electronic communication technology enables farmers to access information directly"*
(credit: C. Jorgenson)

**New technology and techniques have no effect unless they are adopted:** The rate of adoption of new technology is unpredictable[13]. Social factors such as education, attitudes and access to information are important; as are economic factors such as profitability, access to capital, and degree of risk or uncertainty. Electronic communication technology enables farmers to access information directly from public and private research organizations through a variety of channels, including web pages and Twitter. There is concern that the research community cannot meet the demand for information and lead research programs, and this has started to give rise to information brokers or consultants who are paid by industry. The economic incentives for farmers to integrate new knowledge or technology into their operations are linked to market opportunities and financial risk capacity. As major exporters of commodities and manufactured food and beverage, adoption of new technologies will be driven by international competitiveness, stability of trading partners and policy incentives or barriers to adaptation.

**How much innovation can be imported, borrowed or adapted:** Many people in the agri-food industry will continue to look elsewhere for technologies and techniques that might be new to them, but which are not really new. For example, soybean acreage in Manitoba has exploded over the last 10 years. Even though soybeans are a relatively new crop for most Manitoba farmers, they have been grown in the US and Central Canada for decades, so our farmers and agronomists are adopting and adapting techniques and technology for soybeans that are well proven in other

regions. Nevertheless, the extent to which innovation can be imported or borrowed without any adaptation remains an important issue. The interactions between soil, crop, climate and market factors will result in unique challenges and rewards for agricultural production in the Prairies vs. the US and Central Canada.

**Responding to the indirect side-effects of climate change challenges and opportunities:** As the agri-food industry and society react to the challenges and opportunities associated with climate change, incentives for innovation will be created. For example, public demand for greenhouse gas mitigation may introduce substantial carbon credits, along with new regulations and penalties for greenhouse gas emissions. This regulatory environment could have a major impact on energy use in crop rotations and the need for new tools to enhance and validate carbon sequestration practices. As another example, warmer and longer growing seasons coupled with improved crop genetics may enable high yields of grain corn or other high yield crops to be grown across the Prairies. This could put a substantial strain on transportation capacity to provide sufficient amounts of fertilizer, as well as transportation access to move the higher grain volume to traditional export positions. Regionally this could translate into decisions that constrain the expansion or corn acres or promote more investment in livestock production to create local market for the energy and proteins crops grown.

**Climate change adaptation will have to fit with other challenges and opportunities:** Obviously, climate change is not the only challenge or opportunity that our agri-food industry will need to address. Some of the other major drivers that will shape the agri-food industry over the next 40 years will be complementary with efforts to adapt to or mitigate climate change and some will not. For example, carbon credits and concerns about agricultural sustainability, soil erosion and degradation may drive farmers towards innovations that improve soil quality (eg., water infiltration and water storage), which can improve farm profitability and sustainability, as well as the capacity of the land and cropping system to adapt to climate change. Conversely, if tight or negative margins force farmers towards short term exploitation strategies for management of land resources, their capacity to adapt to climate change may be reduced.

**Innovation's capacity to help adapt to climate change is helpful but limited:** Innovative technologies and practices can help to reduce the frequency of weather-based problems in our agricultural systems but extreme events will continue to periodically overwhelm our capacity to adapt. The probability and consequences of those periodic failures will likely vary among adaptation strategies. For example, the risk of flood damage to agricultural land from intensive rainfall or snowmelt events might be mitigated with levees, diversions, streambank stabilization measures, or reassignment of land use. Each of those strategies has a different risk in terms of the probability and consequences of failure. That type of risk is important to determine and then communicate to our professional colleagues, policy-makers and the general public.

## Educational Systems for 2050 – Lessons from History

**Michael Trevan**, Dean, Faculty of Agricultural and Food Sciences, University of Manitoba

*"Education is what survives when what was learned has been forgotten"*
(B.F. Skinner 1964, *New Scientist*, 21 May)

*"[Education] has produced a vast population able to read but unable to distinguish what is worth reading, an easy prey to sensations and cheap appeals"*
(G. M. Trevelyan 1942, in *English Social History*)

Taken together these quotes are pivotal to the type of educational systems we will need by 2050. Education is not school, especially when dealing with the so-called "wicked" problems of growing population, war and conflict, diminishing extractable resources, social and environmental activism, fluctuating demographics, economic boom and bust, internet generated experts and critics, and the vagaries of climate change and weather instability.

Learning how to be adaptable and adaptive comes from a variety of inputs and situations, only some of which are found in the traditional classroom. In the rapidly changing world of today and tomorrow access to "information" is instant and universal, the key question is how the validity of that information might be ascertained. Will we need teachers to stand in front of a class and attempt to fill their students' heads with presently known facts? Clearly this is not even necessary today, the student has multiple means of accessing "facts", but few means to validate their relevance or accuracy, or to understand possible connections between apparently incongruent fields.

A student is not just the registered attendee of an educational institution who aims to gain a qualification, but anyone who is motivated to learn for whatever reason.

When Wilhelm von Humboldt founded the University of Berlin in 1810, he set in train the beginnings of the type of university that we know today, one that links research to teaching, producing both innovations for industry and society, and knowledgeable people. Humboldt's fundamental belief was that a university education was not defined by a

teacher-student relationship, but rather that learning was a student centred research activity guided by the professor.

A consequence of the interaction between the Humboldtian ideal and society over the last 200 years has been the continual creation of new research driven academic disciplines. This and the reductionism of parceling knowledge into ever narrower fields, has resulted in graduates from universities coming to know more and more about less and less, an almost inevitable consequence given the continual doubling of the total body of knowledge.

Another essential part of this 19th century model was the generation of new knowledge and its dissemination; if you needed to know you had to access knowledge within the university as part of that "community of scholars". But is this model still relevant to today's needs, let alone those of the mid 21st century?

For example, today's agriculture students may learn about the two separated entities: the fate of pesticides in the environment from a course in soil or environmental science; and about weed or pathogen control from a plant scientist or pathologist. Would it not be more useful to deliver that knowledge in one integrated course? Should not the teaching and learning offered by a university be relevant to the future needs of a student, rather than being based on the history of academic disciplines? And should it not provide the student with the analytical and synthesizing skills so that they can see connections and evaluate contradictions?

In their book *Academically Adrift: Limited Learning on College Campuses*, Richard Arum and Josipa Roksa[14] report the results of their surveys of US university and college students. Their study showed that 45% of college students do not gain in critical thinking, complex reasoning or writing skills during their 4 years as a student, less than 17% of their time is spent in class or studying, over 29% of graduates never or rarely read print or on-line news, and only 15% discuss politics or public affairs daily (another 46% on a weekly basis). Students may be socially engaged, but they are not academically engaged, nor is a significant proportion gaining an understanding of the process of discovery, that is learning how to learn.

In the 19th century change was dramatic and was viewed optimistically (at least by those whose voice was heard) as something that could have a positive effect on individuals and society. In the 21st century change has come to be viewed as a potentially detrimental challenge, one that threatens our comfortable preconceptions: that receiving teaching equals accomplishments that become qualifications that guarantee a life-long, well-paid job. Those days are gone: perhaps they never actually existed.

*"development of the individual and society through academic programs or outreach activities, that help the individual to learn how to learn"*

To meet the challenges of the future, today's young people need institutions and processes that help them develop into effective researchers, active and critical learners, and analytical thinkers something for which our present educational institutions with their emphasis, or obsession, of testing for information retention, seem ill-suited. Whether it is for the nurturing of the young or all citizens, should we not give up our focus on validating qualifications for the convenience of employers, and concentrate instead on delivering that 19th century vision of simultaneous development of the individual and society through academic programmes or outreach activities, that help the individual to learn how to learn: to populate society with analytical and critical researchers and thinkers, who can go on to become visionary leaders whose role will be to guide society successfully through the complex issues of the next 50 years? For without knowledgeable, adaptable citizens and educated, visionary and ethical leaders our future society must founder on the rocks of uncertain and rapid change.

## Conclusion

Is the agri-food sector on the Canadian Prairies equipped for the known and unknown challenges both for the next 35 years? The answer to this important question lies in part with sector and public investment in dialogue, policy, innovation, and education.

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# Photos by AIA Members

*Protecting the Harvest*
Kira Gerow

*Healthy animals represent healthy future*
Saikat Basu

*Wild Food (Cloudberry)*
Mike Gamache

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