Canadian experiences in sustainability in agriculture and climate change

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Agriculture has changed dramatically, with food and fiber productivity soaring due to new technologies, specialization and government policies. These changes allowed fewer farmers with reduced labor demands to produce the majority of the food. It is in this context that the concept of “sustainable agriculture” has come into existence. The severity of climate change has motivated strong scientific inquiry within the past decade. These mysteries have largely to do with the unpredictability of climate change, which varies widely across the globe. Many scientists argue that climate impacts are best understood on a regional scale. Unfortunately, it is often difficult to assess regional impacts of climate change due to various reasons. The tools at the disposal of those interested in building up resilience to climate change are therefore often limited, but some degree of speculation can be achieved through research. This paper aims to: investigate the potential impacts of climate change on Canadian agriculture, and assess the possible effects of these changes on the prevalence of sustainable agriculture. The paper concludes that while few predictions have been made on the specific impacts of climate change on sustainable agriculture, possible scenarios can be speculated based on the multitude of climate change studies.

Key Words: Sustainable development, agriculture, climate change, Canada, global trade, mitigation, water availability, and agroforestry.

INTRODUCTION

Agriculture has changed dramatically, especially since the end of World War II. Food and fiber productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favored maximizing production. These changes allowed fewer farmers with reduced labor demands to produce the majority of the food. Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs. Prominent among these are:

- topsoil depletion,
- groundwater contamination,
- the decline of family farms,
- continued neglect of the living and working conditions for farm laborers,
- increasing costs of production, and
- the disintegration of economic and social conditions in rural communities.

A growing movement has emerged during the past two decades to question the role of the agricultural establishment in promoting practices that contribute to these social problems. Today this movement for sustainable agriculture is garnering increasing support and acceptance within mainstream agriculture. Not only
does sustainable agriculture address many environmental and social concerns, but it offers innovative and economically viable opportunities for:

- growers,
- laborers,
- consumers,
- policymakers, and
- many others in the entire food system.

Sustainable agriculture integrates three main goals: (a) environmental health, (b) economic profitability, and (c) social and economic equity. A variety of philosophies, policies and practices have contributed to these goals. Direct impacts on Canadian agricultural production as a result of climate change are also likely to be significant. Locations in higher latitudes, including a large portion of Canada, are expected to be particularly vulnerable to increases in temperature (Barrow et al., 2005). While this will likely result in longer growing seasons, drought is of particular concern. The vulnerability of higher latitudes to temperature increases has especially serious implications for rivers with headwaters at the Rocky Mountains. Several studies have predicted that glacial retreat; decreased mountain snow packs, increased winter runoff, and increased spring snowmelt are likely to contribute to decreased stream flows in many waterways in Canada. (Sauchyn and Kulshreshtha, 2008). Earlier spring flows as a result of warmer winters are likely to result in reduced summer stream flows, when drought is of great concern, particularly for agriculture. While runoff from glaciers may increase initially as a result of temperature increases, water yields from these glaciers will decrease over time, resulting in the eventual loss of glaciers and large reductions in summer runoff (Hock et al., 2005). This is of particular importance to agriculture in Canada, since many of the major rivers used to support agriculture in the prairies are fed by headwaters in the Rocky Mountains. The purpose of this paper is to:

a) investigate the potential impacts of climate change on Canadian agriculture, and
b) assess the possible effects of these changes on the prevalence of sustainable agriculture in Canada.

**METHODOLOGY**

In terms of methodology employed, data used in this presentation have been collected from secondary sources, such as: books, research reports, government publications, and Internet resources. Most of the data are ‘qualitative’ in nature and they have been analyzed using descriptive research method. In order to make the paper interesting from research point of view, figure depicting possible benefits and drawbacks of climate change on agriculture has been shown and few initiatives aimed at sustainable agriculture in Canada have been touched upon.

**Sustainable Agriculture – Conceptual Framework**

Sustainable agriculture can be defined in many ways, but ultimately it seeks to sustain farmers, resources and communities by promoting farming practices and methods that are profitable, environmentally sound and good for communities. Sustainable agriculture fits into and complements modern agriculture. It rewards the true values of producers and their products. It draws and learns from organic farming. It works on farms and ranches large and small, harnessing new technologies and renewing the best practices of the past.

Sustainable agriculture has been defined in several ways, for example, as a system that can indefinitely sustain itself without degrading the land, the environment or the people. In short, sustainable agriculture is:

- Economically viable,
- Socially supportive,
- Ecologically sound.

**Potential Impacts of Climate Change on Agriculture and Food Supply:**

It seems obvious that any significant change in climate on a global scale should impact local agriculture, and therefore affect the world’s food supply. Considerable study has gone into questions of just how farming might be affected in different regions, and by how much; and whether the net result may be harmful or beneficial, and to whom. Several uncertainties limit the accuracy of current projections. One relates to the degree of temperature increase and its geographic distribution. Another pertains to the concomitant changes likely to occur in the precipitation patterns that determine the water supply to crops, and to the evaporative demand imposed on crops by the warmer climate. There is a further uncertainty regarding the physiological response of crops to enriched carbon dioxide in the atmosphere. The problem of predicting the future course of agriculture in a changing world is compounded by the fundamental complexity:

a) of natural agricultural systems, and
b) of the socioeconomic systems governing world food supply and demand.

What happens to the agricultural economy in a given region, or country, or county, will depend on the interplay of the set of dynamic factors specific to each area. Scientific studies, typically based on computer models, have for some time examined the effects of postulated climate and atmospheric carbon dioxide changes on specific agro ecosystems - a now common term that
defines the interactive unit made up of a crop community, such as a field of wheat or corn, and its biophysical environment.

Climate change presents crop production with prospects for both benefits and drawbacks, some of which are shown schematically in Figure 1. To address any of them more clearly, there is need to first define the main interactions that link a chain of processes together: food is derived from crops (or from animals that consume crops); crops in turn grow in fields, which exist in farms, which are components of farming communities, which are sectors in nation states, and which ultimately take part in the international food trade system. Understanding the potential impacts of global environmental change on this sequence of interlocking elements is a first step in modeling what will happen when any one of them is changed as a result of possible global warming, and a prerequisite for defining appropriate societal responses.

Climate Change and Global Trade

Many of the projected impacts of climate change involve variations in climate severe enough to impact crop yields and result in changes to the global economy. Climatic variation, in the form of moisture fluctuations due to increased incidences of flooding and drought, increased variability in temperature, overall mean temperature increases, and the increased frequency of extreme weather events are likely to impact Canadian agriculture both directly and indirectly (Gornall, 2010; HLPE, 2012; Thornton et al., 2012). Many studies on the potential impacts of climate change are indicative of vast differences in climate change effects in the northern and southern hemispheres. The implication is that areas in mid to high latitudes may experience an increase in agricultural productivity, due to extended growing seasons, given that drought can be accounted for through the creation of genetically engineered crops. However, agricultural productivity is likely to decrease in southern latitudes due to:

- greater instances of droughts,
- more extreme weather events, and
- increase in temperature (which surpass the optimal levels for crop growth and reproduction).

These factors will likely be exacerbated by the generally lower technical and economic capacity to respond to these changes (Padgham, 2009). This will likely affect Canadian agriculture, which may be expected to compensate for the reduction in food production in the south, which is currently responsible for contributing the greatest diversity of raw food products to the global market.

Furthermore, Canada’s major imports of food products come from Mexico, Colombia, Chile, Guatemala, China, Costa Rica, Brazil, Peru and Indonesia, most of which are considered highly at risk from climate change impacts.
Climate Change and Water Availability in Canada

Direct impacts on Canadian agricultural production as a result of climate change are also likely to be significant. Locations in higher latitudes, including a large portion of Canada, are expected to be particularly vulnerable to increases in temperature (Barrow et al., 2005). While this will likely result in longer growing seasons, drought is of particular concern. The vulnerability of higher latitudes to temperature increases has especially serious implications for rivers with headwaters at the Rocky Mountains. Several studies have predicted that glacial retreating, decreased mountain snow packs, increased winter runoff, and increased spring snowmelt are likely to contribute to decreased stream flows in many waterways in Canada (Stewart et al., 2005; Byrne and Kienzle, 2008; Sauchyn and Kulshreshtha, 2008).

Earlier spring flows as a result of warmer winters are likely to result in reduced summer stream flows, when drought is of great concern, particularly for agriculture (Rood et al., 2008; Sauchyn and Kulshreshtha, 2008). While runoff from glaciers may increase initially as a result of temperature increases, water yields from these glaciers will decrease over time, resulting in the eventual loss of glaciers and large reductions in summer runoff (Hock et al., 2005). This is of particular importance to agriculture in Canada, since many of the major rivers used to support agriculture in the prairies are fed by headwaters in the Rocky Mountains. A study on the Athabasca lowland of northeastern Alberta predicts an average summer stream flow decrease of 8-26% in catchment areas, and maximum declines up to 71% for some channels in particularly dry years, which will likely occur as early as 2050 assuming an average warming of 3°C (Nemeth, 2008). The Athabasca, North Saskatchewan, Slave and Peace Rivers are all considered particularly vulnerable to decreased summer flows.

Climate change impacts are also expected to be exacerbated by oil sand development. The development of the CNRL Horizon mine alone is expected to reduce discharge into the Athabasca River by up to 30,000 m³ per day (Bruce, 2003). Severe reductions in flow for the Athabasca River have already been observed over the past 30 years, and a 50% decrease in runoff for the vast majority of the Athabasca Basin (Nemeth, 2008). The rate of bitumen extraction currently occurring within the Athabasca Delta is known to require more water than the Athabasca River can sustain given the predicted decreases in stream flow as a result of climate change (Nemeth, 2008). In the southern portion of Canada, mean temperatures of the Great Lakes are expected to rise significantly. One study examined the potential temperature changes in Lake Ontario, and predicted a rise of 4.5°C by 2055 (Environment Canada, 2008). Evaporation rates will increase as a result, which is likely to reduce water levels. Furthered by reduced runoff as a result of increased instances of drought, the water level in all of the Great Lakes is expected to drop by 0.5 to 1 meter (Environment Canada, 2008). According to Environment Canada, a rise in mean temperature by 2-4°C could lower discharge from Lake Ontario by up to 24%. Subsequently, water levels in the St. Lawrence River are expected to drop by 1 meter (Environment Canada, 2008). Environment Canada also predicts the drying out of several wetlands as a result of temperature increases, and increased concentrations of pollutants and sedimentation as a result of reduced precipitation and runoff (Environment Canada, 2008). This evidence insinuates that major impacts on intensive agriculture are highly probable, since these systems utilize large amounts of water for irrigation. While Canada alone contains a significant portion of the world’s freshwater, the vast majority of this water is contained within glaciers, and is therefore not useable. Glacial melt is likely to release much of this freshwater as a result of climate warming, however the supply of water from these sources is limited.

Climate Change and Agricultural Pests:

Pests and diseases are known to thrive when crops are under stress. Increased insect problems, plant and livestock disease outbreaks, and weed survival advantages are likely to become increasingly problematic with climate stress (USGCRP, 2009; CCSP, 2008). This could result in increased reliance on chemical pesticides to propel production toward meeting market goals. Alternatively, integrated pest management may be utilized, which has many advantages over chemical usage. These advantages include the reduction of pest populations and the probability of developing pest resistance, and the overall reduction of environmental pollution such as soil and water toxicity. Many indirect advantages also exist, such as lowered crop input requirements that result from improved practices such as intercropping, which increase beneficial insects and wildlife while simultaneously decreasing soil erosion problems and increasing soil structure through soil stabilization and organic matter conservation.
Pest resistance to pesticides is likely if their continued use is not interrupted through the use of other methods of pest control. Roundup ready crops engineered by Monsanto® enable the widespread use of roundup to eliminate pests without harming crops. While Monsanto® addresses the issue of chemical resistant pests on their website, they encourage the use of other chemical pesticides to ensure that all pests are eliminated, thereby removing the threat of survival by pests with resistant genes. This method of pest control is currently widely used throughout Canada due to production pressures from the capitalist global economy, which makes alternate pest control measures less economically viable (more on this in the next section). The projected increase in the instances of drought may increase the importance of water availability, resulting in high input crops becoming vastly inefficient in some areas, thereby increasing the production pressure on areas with high resource availability. This is often referred to as local comparative advantages (FAO, 2012), and describes the suitability of some areas over others for specific production purposes. It is therefore possible that intensive monoculture crop systems will prevail over alternative cropping systems, despite the rise in recognition for their effectiveness. Currently, the Food and Agriculture Organization of the United Nations (FAO) is developing land suitability models for various crops in order to prepare for the mitigation of climate change effects. While this is an essential component of mitigating climate stress on agricultural productivity, the prevalence of sustainable agriculture remains dependant on how such innovations are utilized. The prevalence of sustainable agricultural practices is therefore likely to be dependent on the economic viability of these alternatives.

Climate Change Mitigation

International organizations such as the UN and FAO have developed climate change mitigation strategies which directly involve sustainable agricultural practices. Unfortunately, most countries have yet to adopt such strategies by providing the financial support required to influence food systems toward systems that are more resilient to climate stresses. Many governments, including the Government of Canada, appear to lack an interest in supporting sustainable agricultural practices. Similarly, corporate bodies, which retain a great degree of the monetary power required to support the evolution of an entire food system, lack the incentive to create products which promote agricultural sustainability. While some large organizations, such as the Gates Foundation, are providing financial support to small scale agriculture, much of this support favors genetic engineering technology, in which corporate bodies retain the majority of financial capability.

Technology has the capacity to support agricultural diversity to ensure greater resilience to climate change impacts, however privatization of genetic material through seed patenting continues to threaten the independence of small scale agriculture. The capitalist system that has developed and thrived over centuries is a system which functions based on financial self-interest. Therefore, the prevalence of sustainable agriculture can only abound in two ways: through dire necessity as a result of severe climate change impacts, whereby action is taken upon localities to produce food in a way that is independent from the global market, or by making it more attractive to investors, in which influence resides with the public through consumer choice. The rise of the organic food market is an example of increased public interest in food production as it pertains to environmental and human health. However, the organic market does not yet represent sustainable agriculture in its entirety [The High Level Panel of Experts (HLPE), 2012].

Many misconceptions about sustainable agriculture persist, which have largely to do with the fact that sustainable agriculture involves a multitude of integrated practices, and is not confined to the elimination of pesticides. While this misconception may create new interest among the public regarding food production, it can also serve to hinder sustainable agriculture. Certification requirements for organic agriculture are often very expensive and difficult to meet, due to issues such as chemical persistence in the soil from previous farm owners. The impact of pesticides becoming taboo may prevent many small scale farmers from entering a profitable market, through the refusal to recognize their role in sustainable farming. It therefore seems likely that small scale farmers that use integrated agricultural practices to produce food sustainably will continue to be limited by local perceptions. In the event that a locality invests in local farms, sustainable agriculture can sustain itself economically. However, in areas where little is understood about sustainable agriculture, the options of all people within that locality are extremely limited. It is possible that small scale sustainable agriculture may become prevalent in response to climate change impacts and the resulting necessity for alternative practices to intensive systems, however it is difficult to propose this conclusively since corporate and government interest continues to remain in large scale intensive operations (Collins, E., and Chandrasekaraan, K., 2012).

Climate Change and Technology

The number of studies in support of genetic engineering of food crops as a solution to mitigate climate change effects is overwhelming, and the evidence that this technology will have a major role in climate change mitigation is incontrovertible. The way in which this technology is used, however, is the defining difference between a food system that is supported by intensive
agriculture, and one that is sustainable. The benefits gained from planting genetically modified crops can be maximized through the use of sustainable agriculture techniques. Pest resistant varieties will become increasingly important to combat the growing number of pests that will likely result from warmer, shorter winters in Canada.

In the event that climate variations cause severe crop stresses, plants will likely become more vulnerable to pest damage, further increasing the need for efficient pest management options. In combination with intercropping or agroforestry, genetically modified crops can be used to effectively buffer crops against pest damages by promoting resistance, and reducing pest promoting agricultural methods such as monocultures. Furthermore, companion planting techniques can encourage the proliferation of predatory insects, which are known to efficiently reduce pest populations if the correct methods are employed.

The integration of various methods of agriculture is essential in reducing the potential damages of climate change. This can function on various scales, from integrated pest management of a single plot of land to integrated watershed management. The crop suitability indices used by the FAO to create maps of crop suitability areas are an excellent example of how agriculture can be employed sustainably by matching crops to lands that are most suitable for resource efficient growth. Drought resistant crops can be used in conjunction with water conservation methods to promote water use efficiency, thereby reducing water waste. Significant reductions in water usage could be achieved if water conservation methods such as grey water recycling and the use of rain barrels were used on small scale operations. Community gardens, backyard gardens, and green roof agriculture could effectively reduce the pressure on large scale farms to provide crops for export and for distribution throughout Canada. While many watershed-scale alternatives to intensive agriculture are likely able to support greater crop yields than intensive operations, the promotion of small scale solutions, in various combinations, is likely to have a significant impact on food production pressures as well. Other methods of sustainable agriculture, such as methods that increase organic matter input, are also known to increase crop yields significantly. It can therefore be argued that the prevalence of sustainable agriculture is likely to increase due to climate change pressures (Intergovernmental Panel on Climate Change (IPCC), 2007).

The U.S Environmental Protection Agency recommends various sustainable agricultural practices to lessen the effects of climate change on agriculture, including the diversification of crops, water and soil conservation measures, shifting livestock breeding practices and grazing patterns, and the development of disease and pest resistant crops and livestock species (U.S EPA, 2012). While technological innovations are widely recognized as an essential component of dealing with climate change, alternative solutions have yet to be fully recognized for their importance as potential buffers against the potentially disastrous effects of climate change.

**Initiatives**

Agriculture is integral to Canadian society, making significant contributions to economy, rural communities, and food security. It is also intimately connected to the environment. Not only are resources such as soil and water vital to agricultural productivity, but agriculture both affects and is affected by the local, regional, and global environment.

In recent years, Canadians have made significant commitments toward a more sustainable society. The Government of Canada has signed international conventions; federal and provincial governments have implemented environmental legislation, policies, and programs; and municipalities have adopted environmental by laws. Citizens and industry have also contributed through numerous actions. The challenge of achieving a more environmentally sound agriculture has been taken up by farmers, and the agriculture industry has undertaken many initiatives to ensure its sustainability. If more-sustainable agriculture is to become a reality, objectives and indicators of progress are needed to guide these efforts. Recognizing the need for indicators, and in response to recommendations made by several groups, Agriculture and Agri-Food Canada (AAFC) initiated the Agri-Environmental Indicator Project in 1993.

**Future of Sustainable Agriculture in Canada:**

The future of sustainable agriculture and its prevalence in Canada is currently largely dependent on societal values to make gradual changes in priorities within our market based food system. Canada is still at a point where science and technology are somewhat undervalued, and financial profitability forms the basis of many national decisions. It is undoubtedly important for Canada to maintain a stable economy; however it seems that equilibrium between this matter of importance and that of scientific evidence has been lost and must be regained in order for Canada to address climate change issues appropriately through the changing of practices which are known to perpetuate climate change. While the prevalence of intensive agriculture in Canada continues to threaten the uprising of sustainable agriculture, it is possible that the role of intensive agriculture in perpetuating climate change through greenhouse gas
emissions will soon be recognized, and actions taken to reduce the climate stress resulting from these systems. Sustainable agricultural practices do not perpetuate the cycle of greenhouse gas emissions of current intensive agricultural practices, which account for 13.5% of global emissions, the majority of which are nitrous oxide (N2O), through the application of fertilizers, and methane emissions from intensive livestock operations (CH4). Furthermore, an increased dependence on small scale farms to reduce the burden of large production facilities is a viable alternative to fulfill the requirements of a global economy which may begin struggling to meet food production goals as a result of climate stresses. Monoculture production systems may begin to wane as a result of a decreasing demand for cash crops utilized in the production of bi-products, such as those made from maize and soy beans. If this occurs, the diversification of farms is likely to take place to ensure continued profitability. Changes in human diet as a result of diet limitations resulting from extreme climate changes can further perpetuate agricultural diversification by decreasing the demand for processed foods, which currently account for 42% of the total agricultural production in Canada, and which can arguably be considered a luxury that may no longer be financially viable to support in the event that climate change impacts are severe (Agri-food Canada, 2012).

Changes in livestock practices are also known to be capable of reducing methane emissions significantly. Intensive livestock operations are increasingly becoming recognized for their high output of greenhouse gas emissions and unethical practices. According to Agri-Food Canada, providing livestock with feed that consists of a greater proportion of legumes can increase livestock food conversion ratios, thereby reducing methane emissions (Agri-Food Canada, 2012). Livestock breed selection can improve the efficiency of production by choosing breeds that are specialized for localities, such as harder heritage breeds, thereby increasing agricultural diversity. Improved grazing practices, such as planting legumes within pastures, and the implementation of rotational grazing practices to improve nutrient cycling and plant productivity, while also promoting soil forming processes, can ensure that lands remain viable for years to come. All of these practices are much more easily implemented on small scale farms. Many studies, including those by the FAO and the UN, conclude that small scale agriculture is capable of producing greater yields per unit of land than intensive operations. In Canada, there exists a multitude of opportunities for increasing the total land area used for food production. Rooftop agriculture within Toronto alone could account for 50 million square miles of rooftop area suitable for green roof construction. It is only a matter of whether Canada will begin to make these shifts early enough to provide a buffer against climate change. I truly believe that Sustainable agriculture is not only a feasible concept, but an essential element of survival in the face of climate change. It is also a powerful method for regaining control over our food systems, and finally putting our foot down against the corporate food system which continuously exploits living organisms, including humans, and forces us further into the mechanical drone of consumerist behavior, where only few benefit from the strife of many. Indisputably, these are the best reasons we have to shift our agricultural practices to more sustainable ventures, and to stop fuelling an engine that is destined to burn out.

RESULTS

Agriculture is integral to Canadian society. Thus, it must balance a wide array of demands and environmental challenges that are continually evolving in their nature and complexity. A major challenge is achieving long term environmental sustainability of production. At the same time, agriculture is increasingly valued by Canadians for its environmental benefits, including its provision of some wildlife habitat; the visual beauty of farmland; and environmental services, such as nutrient cycling and the storage and filtering of water. Governments, farmers, and others have worked together for many years to promote research, programming, and related actions to address environmental concerns. However, an environmentally sustainable form of agriculture is now more urgently needed. The policy challenge in agriculture - to ensure optimal and sustainable social, economic, and environmental benefits - has become more pressing and complex than ever.

Furthermore, Canadian agriculture has made considerable progress in conserving the natural resource base which supports production, although some soils remain above tolerable levels of degradation risk. With regard to agriculture’s compatibility with natural systems, performance is mixed. Several environmental risks have increased and environmental conditions have sometimes worsened. The main factor responsible has been an intensification of agriculture across much of the country resulting from structural changes in farming and increased market demand for some products.

The agri-environmental indicator study has made extensive use of available data, research and expertise, and revealed key strengths and limitations in the national capacity to assess the environmental sustainability of agriculture. In order to enhance analytical capacity, additional research is required to further understand agriculture–environment interactions and processes, and more work is needed to address data limitations and gaps. There is a need for ongoing efforts by policy makers, producers, researchers, analysts, educators, and consumers to achieve a more environmentally sustainable agriculture – an integral component of the noble goal of sustainable development.
sustainable agriculture industry (Agriculture and Agri-Food Canada, 2000).

CONCLUSION

Climate change affects agriculture and food security in a variety of ways, so choosing the best mitigation and adaptation techniques requires thorough research. It is possible that the negative effects of climate change will intensify Canadian agriculture as the urgency to provide for a global food economy increases. As a large portion of the global food supply is threatened by the projected decrease of food production in southern latitudes, increased pressure on Canada to provide food to the global market may result in a greater demand on large industrial farming operations, since they are already perceived to be more productive than small scale sustainable agriculture. To sum up, “driving forces will continue to evolve and influence environmental outcomes in agriculture. Potential risks to the environment will continue to increase as output expands”. Ongoing responses will be required by industry, governments, and Canadians so that social, economic, and environmental objectives for agriculture are achieved.

REFERENCES


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