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Vulnerability of Prairie Agriculture to Climate Change with Implications for its Sustainability

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Abstract

Climate change would bring new challenges for all crop and livestock producers in the Canadian Prairie Provinces. Being a land-locked region of Canada, it also depends on other regions of Canada and other countries for its economic activities. Thus, as climate changes over the globe, the vulnerability would come not only from the impacts within the region but also from those felt in other jurisdictions. Agriculture is an industry that is highly sensitive to climate change. Although in general these changes are positive (due to higher temperatures leading to longer growing season) for the Canadian Prairies, increases intensity and frequency of climate extremes (droughts and floods) may make agriculture more vulnerable in the future, and the region may face limit to sustainability. Much of these impacts on sustainability are through economic/financial in nature. However, producers are highly adaptable to changes, including changes in weather. However, their adaptive capacity may be severely limited on account of factors such as: lack of information about future changes in climate, lack of financial resources to undertake adaptation, and lack of institutions supporting such adaptation. All of these, unless removed (or moderated), would limit sustainability of Prairie agriculture in the future.

Keywords: *Climate Change; Sustainability; Canadian Prairies; Agriculture; Vulnerabilities*

Background

Agriculture is a major primary industry the Prairie Provinces. It is highly vulnerable to climate [1] and water availability in various forms. At the same time, water resources are also seriously affected by climate change over a period of time. Thus, a combination of climate attributes coupled with water availability would affect agricultural production and ultimately the sustainability of the industry in the future. Having a small population base, much of region's agricultural products are exported. Thus, agriculture in the region would be affected both regionally and globally. The Canadian Prairie Region has already experienced major changes in agricultural production and are expected to have among the largest climate changes in the world, and therefore will be exposed to greater effects. Some of these changes would have a positive effect (reduced vulnerability) on the region's agriculture while many others would make it more vulnerable to climate change and thereby reduce the level of sustainability.

Sustainability is an elusive concept but has been popularized among the laymen as well as subject-matter specialists. In fact, it has become a buzz word used by many without understating its full meaning. Concerns for sustainability of agriculture arose from the environmental concerns of 1950's and 1960's. For the decision-makers, the goal of agriculture pursuits now is more long-run in nature. Instead of maximizing profit (or production) in the short-run, producers/society take a perspective that also considers long-term maintenance (that

is, sustainability) of production [2]. This has led to the most common way of defining sustainability which is to take into account the impact of the sector's activities on the environmental services, although other types of capitals are equally important. Tillman., *et al*. [3] has defined sustainable agriculture as practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered. This, according to Pretty [4], centres on the need to develop agricultural technologies and practices that: (i) do not have adverse effects on the environment (partly because the environment is an important asset for farming), (ii) are accessible to and effective for farmers, and (iii) lead to both improvements in food productivity and have positive side effects on environmental goods and services.

Agriculture industry, though the use of fertilizers and pesticides can have a detrimental impact on the environment. However, the same time, the economic and social aspects of the changes created by the agriculture industry cannot be totally ignored. Climate change would therefore, affect sustainability from both economic as well as environmental point-of-view. However, one may conclude that if the negative externalities are lower for a given system, it may be deemed as more sustainable.

There may be several ways that climate change may be related to sustainability of the Prairie agriculture. Although in general, for countries located in the higher latitudes, the effect of climate change has been predicted to be positive [5] there may still be some changes that may lead to detrimental impacts on economic and environmental changes affecting sustainability of the industry. With this in mind, relationship between climate-induced changes are described in this study and linked to the issue of sustainability for the region's agriculture.

Material and Method

Climate change related avenues

Climate change differs from weather changes since it a change in the long term weather conditions of a region. The Intergovernmental Panel on Climate Change [5] refers it as anthropogenic climate change (also known as global warming), since it is a human-induced phenomenon. It describes changes in the state of the atmosphere over time scales ranging from decades to millions of years. Global warming, a measure of climate change, is a rise in the average global temperature. Weather records from across Canada show that every year since 1998-that's 20 years ago now-has been warmer than the 20th century average [6].

A change in climate would have two essential features: Change in the level of climatic indicators and change in the climate variability. Both of these can affect agricultural production and its sustainability. Effect of climate indicators would be felt almost immediately, while that of climate variability would be realized more in the long run. Climate variability is a critical driver of year-to-year impacts on agricultural systems, and thus on agricultural production. These changes create ecological impacts, and through that affect managed ecosystems' response to such variability. Unfortunately, not much is known on the effect of climate variability and reaction of producers to such variability. For this reason, this paper is devoted mostly on the changes in climate change related indicators.

Source of vulnerability to producers

Climate change would bring forth many challenges for agricultural producers. Figure 1 presents a list of positive and negative effects that are relevant for the Canadian Prairie farmers. Under a changed climate, the initial change observed is in the climate-related indicators-effect on temperature, precipitation, frequency of extreme events, and sea level rise. Although the last indicator is not directly relevant to the Prairie region but could be of major importance for some parts of the world, thereby indirectly affecting the Prairie region. Five types of vulnerabilities are identified in figure 1. The first generation (or direct source) of these vulnerabilities would be created by change in climate indicators which would affect economics of agriculture as well the environment. These direct impacts would lead to several second generation (associated) impacts (Vulnerability 2) that would create other economic-environmental changes. The third generation vulnerability would result from increased frequency and intensity of extreme events-droughts and floods, and other water-induced changes. Being a trading region, the Prairie agriculture would also be affected through changes in the trade levels, creating fourth

generation vulnerabilities. The fifth generation vulnerability would be a result of impact on producers through making adaptations to climate change. Each of these vulnerabilities are described in the next section.

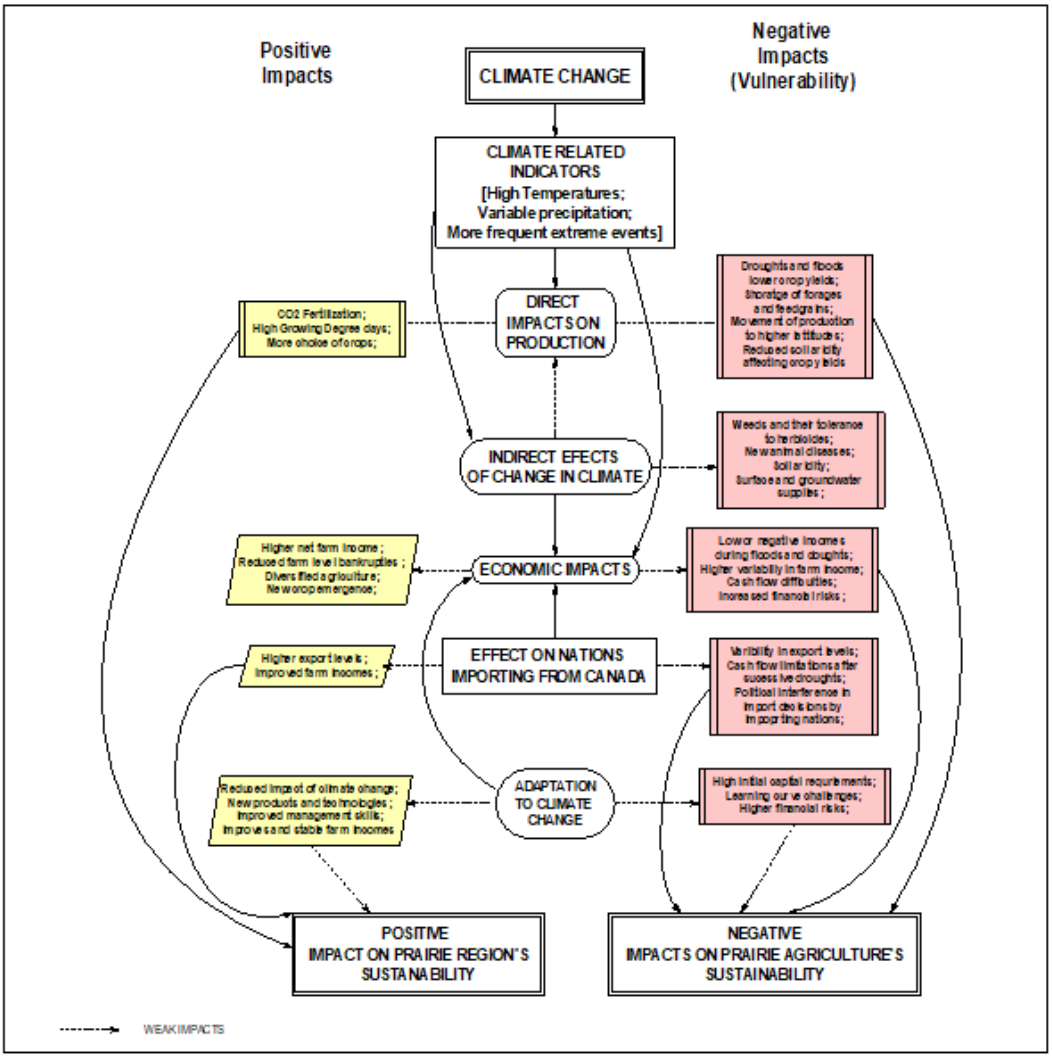

Figure 1: *Nature of positive and negative (vulnerabilities) resulting from climate change on an agricultural system.*

Results

Vulnerabilities created by first generation impacts of climate change

The change in climate indicators would have a profound impact on the Prairie agriculture through changes in bio-physical impacts. These biophysical impacts include higher overall aridity, more frequent extreme rainfall events, shifting precipitation patterns, more frequent agricultural and hydrological droughts, and negative water quality impacts because episodic extreme events would produce heavy

nutrient loads and longer periods of low flow in stream and rivers [7]. Changing rainfall, temperature, carbon dioxide (CO_2) levels and other climatic variables will affect average crop and pasture productivity, quality and nutrient cycling, pest and disease activity, livestock production and reproductive rates [8].

Climate change impacts on agriculture has been a mixture of both positive and negative changes [9]. On the positive side, crop yields and pasture productivity may increase but different studies suggest different results [10]. Generally speaking these increases would be a result of longer frost-free season, which has increased by about 30 days over the past decade, as well by increased heat units. However, on the negative side, higher temperature and more variable precipitation would affect crop yields, particularly that of Canola and wheat in Saskatchewan [11], as well as increased exposure of crops to high temperatures (30 - 36ºC) may reduce yields of corn, soy, and wheat Schauberger., *et al* [12].

Second generation impact of climate change and effect on agricultural production

Risk of really cold weather (below -30ºC) has been fading on the Canadian prairies, which could have several detrimental effects on crops and livestock. For crops, emergence of new weeds, pests and diseases of plants and trees, affects survival of pests and diseases to plants and trees, as well as to farm animals. Their occurrence might affect agricultural productivity and economic position of producers. New herbicides may have to be developed since the existing herbicides and insecticides may not be as effective as currently. For livestock production, emergence of new diseases might also have a detrimental impact on producers. Unfortunately, information on these changes is not available for the Prairie region.

Climate change would affect water quantity due to reduced output of glaciers that feed the Prairie Rivers. Decreased water availability would be concerning to all producers but particularly to those irrigating their crops. Declining rainfall will have a profound effect on surface water and groundwater supplies. Related to this is change in the form of precipitation, more of which, due to higher temperature, would be received as rain rather than snow. This water is more prone to run-off and may result in soil aridity for the growing season.

Third generation vulnerabilities created by climate change

In addition to higher temperatures and higher variability in precipitation, climate change would bring forth higher frequency and intensity of extreme events-droughts and floods. Such higher frequency of extremes will affect crop yield and pasture performance, in addition to livestock productivity through feed shortages. Flooding of agricultural lands would become more frequent and intense. Such events in the Southeast Canadian Prairies caused a damage of $1 billion in 2014 [13]. Similar event did take place in 2011 with an estimated cost to the Manitoba economy of $1 billion.

Extreme events can create havoc on agriculture. Although Prairie farmers have the capacity of enduring one-year drought, those droughts that are back to back or lasting over a longer period of time, can destroy the regional economy as well as ecosystems significantly. Southern part of the Prairie region is more prone to droughts. Of the top 11 most costly natural disasters, seven of them were caused by droughts in the Prairie region. In fact, the 2001 - 2002 drought created a direct impact on the agriculture of about $5.8 billion as loss of farm income [14].

Available evidence indicates that the scale of aboriginal people engaged in agricultural agriculture is very small. Only one Canadian First Nation has been reported to be engaged in agricultural activities-the Blood Tribe Agricultural Producers (BTAP) of the Blood Tribe research in Southern Alberta. Although in terms of bio-physical impacts of climate change on these communities, situation will be no different than that reported above. However, adaptation to it could be a different story. These operations of the BTAP are vulnerable due to very poor socio-economic conditions on the reserve Magzul [15]. Other First Nation's communities may face similar situations

Fourth generation climate-change-induced vulnerabilities

Economics of crop production in Canada will be a joint outcome of changes within Canada and those outside the Canadian boundaries (both in the exporting and importing countries). International markets will play an important role in determining the economic impact of climate change on agriculture in the Prairie region. As most of the crops are sold in the international market place, their prices would be significantly influenced by conditions not only within Canada but also in the rest of the world. Climate change would affect other parts of the world differently-both exporting countries and importing countries. For example, for US agriculture, most crops would show gains in crop yields to certain thresholds of temperature increase, which may increase their potential for exports, but such is not the case with Australia. European countries are also expected to have a decrease in production, although results may vary from country to country. On the developing countries scene, consensus seems to be a decrease in the potential production. Given that demand in many of these countries, caused primarily by population growth, would most likely increase, potential for Canada to export would likely exist. Major source of vulnerability would lie in the policy changes instituted by importing nations.

Fifth generation vulnerabilities created by climate change

The resilience and vulnerability of farms or agricultural regions to extreme weather is a function of the level of adaptive capacity of a given system. This, in turn, is determined by a number of social factors: financial, natural and social capital, and past experience with, and response to, extreme weather. In the prairie region, agricultural producers are fairly adaptive and can take advantage of some of the effects, however, others may be very challenging. These effects include water scarcity, excess moisture and heat. Some of the adaptive practices like zero-till, stockpiling feed, increasing farm size, insurance, large-scale infrastructure (such as dams) have been the practices adopted in the past Warren [16]. Adoption practices under droughts for mixed farms in may include purchasing feed during period of feed shortages, as well as early weaning combined with limit feeding strategies to reduce the feed demand and also reduce the financial burden during drought periods [17].

Challenges to adaptation include implementation, finances, institutions, lack of preparation, political resistance, and cost of inaction [18]. Some of the practices for adaptation to climate change require financial resources, which increases produces financial vulnerability. At the farm level, adaptation is affected by financial resources, including debt load of agricultural producers.

Implications for sustainability

Climate induced changes may affect sustainability of Prairie agriculture through changes affecting various forms of capital assets. Agricultural systems depend on services produced by five types of assets. These include: natural, social, human, physical and financial capital. These changes would be both direct as well as indirect in nature. Direct effect on sustainability would be caused by changes in climatic-indicators and probability of extreme events. Indirect impacts would be a result of those created through water resources, and through opportunities for trade with other countries. Relationship between capital assets and climate change-induced vulnerability ae summarized in table 1.

One of the major change of the increased temperature and higher variability in precipitation would be through impact of soil aridity. It is estimated that under the changed climate parts of the region would become drier [19]. This may also be a result of change in the form of precipitation in the region-from snow fall vs. rain. As average winter temperature increases, more of the precipitation in the region would be received as rain. Much of the rain come as the increasing aridity in the Southwest, affecting crop choices and their economic returns. This would have some effect on the economic aspect of the sustainability of agriculture in the region.

Type of Capital	Positive Climate Induced Changes	Negative Climate Induced Changes
Natural (Environmental goods and services)	Higher crop yield may produce more root mass and reduce greenhouse gas emissions	• Increased area under cultivation due to shift in production possibility may lead to would lead to increase environmental damage. • Increased aridity may affect soil quality • Continued aridity may result in desertification
Social		More stress on farmers due to higher frequency of extreme events
Human	Improvement in labor productivity	New diseases might affect human health, particularly those of infants and young adults.
Physical	Land prices might increase e to higher productivity	Flooding may damage man-made capital assets.
Financial	• Carbon fertilization could increase yields of crops, thereby leading to improved financial capital. • New crop choices could improve diversification and sustainability. • On average, higher cash flow and increased net worth. • Land process might increase.	• Reduced economic indicators particularly as a result of extreme events. • Possible reduced export potential in peiod of tight supply. • Cost of making adaptations could be high and take time. • In some periods, cash flow may be limiting.

Table 1: *Effect of climate induced-changes on type of capital.*

The other effect of water availability on sustainability would be through streamflow. Presently, major streams in the region are glacier-fed, supplemented by local run-off. As climate changes, much of glacier-fed water would be reduced, yielding in lower volume of streamflow. This would have serious limitation to development of irrigation in the region, which is an avenue to crop and livestock production sustainability. A similar concern has been raised for the Southwest U.S.A. by MacDonald [20]. Changes in the agricultural productivity of the region in response to water shortages and/or reallocation will have direct implications for farm incomes, as well as food supply and security, leading to more economic unsustainability.

For livestock production, climate change would impair production (growth, meat and milk yield and quality, egg yield, weight, and quality) and reproductive performance, metabolic and health status, and immune response [21]. The process of desertification will reduce the carrying capacity of rangelands and the buffering ability of agro-pastoral and pastoral systems. Other systems, such as mixed systems and industrial or landless livestock systems, could encounter several risk factors mainly due to the variability of grain availability and cost, and low adaptability of animal genotypes. Regarding livestock systems, it will be strategic to optimise productivity of crops and forage (mainly improving water and soil management), and to improve the ability of animals to cope with environmental stress by management and selection.

Summary and Conclusion

Many opportunities for and threats to agriculture would be created under the changing climate. The overall effects depend very much on the effectiveness of adaptation and the intensity and frequency of climate extremes, such as drought, flood, and heat. The convergence of these characteristics is a major challenge.

Major gaps exist in our knowledge for both level of bio-physical impacts, as well as social and economic impacts. Within the bio-physical impacts, main gaps seem to be regarding livestock, insects, diseases, sustainability, effects of climate extremes, management and effectiveness of adaptation, food security, effect of CO_2 on productivity and quality of food, among many others. On the economic and social impacts very little is known on the long-term impacts of climate extremes, economics of northward shifting of Prairie agriculture, economics of mitigation measures, and adaptation measures on the producers and communities, among others.

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