Université de Montréal

Adaptation of Agriculture to Climate Change in Québec

The Co-construction of Agricultural Policies in the RCM of Haut-Richelieu

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Adaptation of Agriculture to Climate Change in Québec

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RÉSUMÉ

Les facteurs climatiques ainsi bien que les facteurs non-climatiques doivent être pris en considération dans le processus d'adaptation de l'agriculture aux changements et à la variabilité climatiques (CVC). Ce changement de paradigme met l'agent humain au centre du processus d'adaptation, ce qui peut conduire à une maladaptation.

Suite aux débats sur les changements climatiques qui ont attiré l'attention scientifique et publique dans les années 1980 et 1990, l'agriculture canadienne est devenue un des points focaux de plusieurs études pionnières sur les CVC, un phénomène principalement dû à l'effet anthropique. Pour faire face aux CVC, ce n'est pas seulement la mitigation qui est importante mais aussi l'adaptation. Quand il s'agit de l'adaptation, c'est plutôt la variabilité climatique qui nous intéresse que simplement les augmentations moyennes des températures. L'objectif général de ce mémoire de maîtrise est d'améliorer la compréhension des processus d'adaptation et de construction de la capacité d'adaptation ai niveau de la ferme et de la communauté agricole à travers un processus ascendant, c'est-à-dire en utilisant l'approche de co-construction (qui peut également être considéré comme une stratégie d'adaptation en soi), pour développer une gestion et des outils de planification appropriés aux parties prenantes pour accroître ainsi la capacité d'adaptation de la communauté agricole. Pour y arriver, l'approche *grounded theory* est utilisée. Les résultats consistent de cinq catégories interdépendantes de codes élargis, conceptuellement distinctes et avec un plus grand niveau d'abstraction.

La MRC du Haut-Richelieu a été choisie comme étude de cas en raison de plusieurs de ses dimensions agricoles, à part de ses conditions biophysiques favorables. 15 entrevues ont été menées avec les agriculteurs.

Les résultats montrent que si certains agriculteurs ont reconnu les côtés positifs et négatifs des CVC, d'autres sont très optimistes à ce sujet comme se ils ne voient que le côté positif; d'où la nécessité de voir les deux côtés des CVC. Aussi, il y a encore une certaine incertitude liée aux CVC, qui vient de la désinformation et la désensibilisation des agriculteurs principalement en ce qui concerne les causes des CVC ainsi que la nature des événements climatiques. En outre, et compte tenu du fait que l'adaptation a plusieurs caractéristiques et types, il existe de nombreux types d'adaptation qui impliquent à la fois l'acteur privé et le gouvernement. De plus, les stratégies d'adaptation doivent être élaborées conjointement par les agriculteurs en concert avec d'autres acteurs, à commencer par les agronomes, car ils servent en tant que relais important entre les agriculteurs et d'autres parties prenantes telles que les institutions publiques et les entreprises privées.

Mots-clés: Changements et variabilité climatiques (CVC), co-construction, adaptation, agriculture, Haut-Richelieu, Québec

ABSTRACT

Climatic as well as non-climatic factors should be taken into consideration in the process of agricultural adaptation to climate change and variability. Agricultural adaptation places the human agent at the centre of the adaptation process, which can lead to maladaptation.

Following the discussions on climate change that have attracted scientific and public attention during the 1980s and 1990s, Canadian agriculture has become a focal point of several pioneering studies on climate change and variability (CCV), a phenomenon mainly due to the anthropogenic effect. To deal with CCV, it is not only mitigation that is important but also adaptation. When it comes to adaptation, it is rather climate variability that interests us than just the average increases in temperatures. The overall objective of this MSc thesis is to improve the understanding of the processes of adaptation and adaptive capacity at the farm and the farming community through a bottom-up process, i.e. using the approach of co-construction (which can also be considered as an adaptation strategy in itself), to develop appropriate management and planning tools and to build a better ability to adapt in the farming community. To achieve this, the grounded theory approach is used. The end results are five interrelated categories of expanded codes, conceptually distinct and with a greater level of abstraction.

The RCM of Haut-Richelieu was chosen as the study site because of its several agricultural aspects, aside from its favourable biophysical conditions. 15 interviews were conducted with farmers.

The results show that while some farmers recognized the positive and the negative side of CCV, the others are very optimistic about it as if they only see the positive side; hence the need to see both sides of CCV. Also, there is still some uncertainty related to CCV, which comes from disinformation and desensitization of the farmers mainly in relation to the causes of CCV along with the nature of climatic events. Moreover and given the fact that adaptation has many characteristics and types, there are many types of adaptation that involve both the private actor and the government. Furthermore, adaptation strategies should be developed jointly by farmers in concert with other actors,

starting with the agronomists because they serve as important relays between farmers and other stakeholders such as public institutions and private companies.

Keywords: Climate change and variability (CCV), co-construction, adaptation, agriculture, Haut-Richelieu, Québec

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LIST OF ABBREVIATIONS

CCV	Climate change and variability
CFCs	Chlorofluorocarbons
CGM1	The first coupled global climate model for the Canadian Center for Climate Modeling and Analysis.
CH_4	Methane
CHUs	Corn Heat Units
CO_2	Carbon dioxide
CRAAQ	Centre de référence en agriculture et agroalimentaire
CRESAL	Centre de Recherches et d'Études Sociologiques
FADQ	Financière agricole du Québec
GDDs	Growing Degree Days
GHG	Greenhouse gases
HadCM3	The climate model for the UK Hadley Center for Climate Prediction and Research
IPCC	Intergovernmental Panel on Climate Change
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
OBV	Organisms de Bassins Versants (or Watershed Management Organisations in English)
RCM	Regional County Municipality (or MRC- Municipalité régionale de comté- in French)
TSS	Total suspended solids
UPA	Union des producteurs agricoles du Québec (farmers union in English)
^0C	Degree Celsius

This MSc thesis is dedicated to farmers who farm for the love of farming given their economic adversities, who want to feed themselves their families the region where they live in and the whole world, who love to watch and nurture the growth of plants, who love to live in the presence of animals, who love to work outdoors, who love the weather even when it is making them miserable, who love to live where they work and work where they live, who like to work in the company of their children especially in small-scale farming, who have gone to a lot of trouble merely to be self-employed to live at least a part of their lives without a boss.

Inspired from the quote of Wendell Berry, from his book 'Bringing it to the Table: Writings on Farming and Food' (p. 74).

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Marcel Proust once said:” Let us be grateful to the people who make us happy; they are the charming gardeners who make our souls blossom.”

So I would like to express my deepest appreciation to my family especially to my mother and father who constantly supported me morally and financially in achieving a part of my professional dream. And to my aunt who drove me most of the times to do my interviews with the farmers in the RCM of Haut-Richelieu.

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INTRODUCTION

Main Research Objective:

Help farmers in the RCM of Haut-Richelieu to better adapt to CCV.

Climate change, with its increasing variability, is amongst the most important environmental problems that face humanity in the 21st century. Current and future impacts of climate change on the biophysical environment include: warming of the air (global warming) and ocean; sea level rise; increased precipitation and melting ice, all of which in turn may indirectly affect social and economic systems. According to the latest report of the Intergovernmental Panel on Climate Change (AR5) (2013), the global mean surface temperature could rise from 0.3 degrees Celsius to almost 5 degrees this century. This warming of the global climate has been partly attributed to the burning of fossil fuels that emit carbon dioxide (CO_2) into the atmosphere. CO_2, methane (CH_4), chlorofluorocarbons (CFCs) and water vapour (H_2O) are among the important gases that are capable, in the atmosphere, of absorbing heat from the Earth, while allowing solar energy to pass without obstruction (Haslett, 2008). As a result, these gases allow the atmosphere to act as a greenhouse, and are responsible for the stabilization of the Earth's average temperature at 15^o C (Haslett, 2008), a phenomenon known as the greenhouse effect. Without this natural phenomenon, the average temperature of the Earth would be about -17^o C (Haslett, 2008). It should be noted that global warming is not only due to anthropogenic effects and that natural phenomena such as variations in solar radiation (Appendix 1) can also contribute to this phenomenon (Haslett, 2008).

Given the importance of weather as a basic resource for the evolution of agriculture, not only is there interest in studying the implications of likely changes in climate on agriculture - global and/or local, but there is also a strong interest in finding the best adaptation options (Wang *et al.*, 1992; 1999; Reilly, 1994). More recently and while the adaptation measures are increasing and becoming more integrated within broader policy making (IPCC, 2014), scientists and government officials are questioning the way the Intergovernmental Panel on Climate Change handles its major reports. They say more frequent and more focused reports, such as studies focused on specific regions or phenomena, would be more useful to policymakers (Goldenberg, 2013). In addition, although it is recognized that modern agriculture, at least the main type pursued in industrialized countries, has reduced its dependence on natural factors thanks to technology, the fact remains that amplification of climatic upheavals could, in the future, affect agricultural production even in these countries. In fact, the latter is already happening. In terms of soil erosion and water pollution (negative externalities), modern agriculture has contributed to several environmental concerns.

For Canada and Québec, agriculture remains an important economic sector, in terms of direct employment and its contribution to the national food basket. The Canadian GDP for the Agriculture, fishing, hunting, and forestry sector increased from $23.1 billion in 2007 to $24.8 billion in 2012, meaning an annual growth of 1.2% (Industry Canada, n.d. b). So we can conclude from the latter that this sector is essential to the economic well-being of many regions, sub-regions and communities where activities related to these sectors form the basis of economic life. The Canadian agriculture and agri-food sector is one of the top five industries in Canada, representing between 8 to 11% of the total GDP (AAFC, 2006; Siman, 2014) and 13% of GDP in some regions of Québec (Fontaine, 2010). Regarding the national food basket, agriculture remains an important export activity for the Canadian economy (Bryant *et al*., 2000). In 2012 and among the world's agriculture and agri-food exporters, Canada ranked in fifth place directly after the EU, USA, Brazil and China (CAFTA, n.d). In 2012, Canada contributed to a total of $38,552,218,875 in the agri-food/sea food markets in the United States, China, Japan, Mexico, Hong Kong, The Russian Federation, South Korea, India, United Arab Emirates, and Netherlands (Table 1).

Table 1: Top export markets for Canadian Agri-food Products in 2012[1]

United States of America	**23,606,068,002**
China	5,399,634,568
Japan	4,226,306,694
Mexico	1,784,142,781
Hong Kong	753,494,913
Russian Federation	667,715,334
South Korea	575,021,205
India	532,220,663
United Arab Emirates	519,911,551
Netherlands	487,703,164
Total	38,552,218,875

According to some modeling studies (crop simulation models, agro-ecological zone (AEZ) and the Ricardian model of the transverse approach), described in the recent IPCC reports to estimate the impact of climate change on agriculture, a low to moderate increase in the average global temperature (1-3° C) associated with increases in CO_2 and changes in the volume of rainfall, should benefit crop yields in temperate regions such as Québec and other northern jurisdictions (IPCC, 2007); as a result, this increases the importance for Québec - and Canada - for feeding the world. However, if we talk about climatic variability in Québec, its agriculture remains sensitive to the effects of global warming with the most common manifestations related to droughts, excessive rainfall, floods, diseases and freezing (Bryant *et al*., 2008; DesJarlais *et al*., 2010). As a result, it is crucial that Canadian agriculture, including Québec, adapt in appropriate ways to the stresses it faces, including climate change and its variability. In Canadian agriculture, studies have noted needs and opportunities for planned adaptations (Brklacich *et al*., 1997; Maxwell *et al*., 1997; Bryant *et al*., 2000).

[1] Source: Agriculture and Agri-Food Canada, (2013). Canadian trade data by country and product. Retrieved April 9, 2014 from http://www.ats-sea.agr.gc.ca/stats/6341-eng.htm

While recognizing that reduction of greenhouse gas emissions on a global scale and mitigation of atmospheric greenhouse gases – through strategies that capture and store them in the long-term represent potentially important conditions, it is also important to adapt to the ongoing effects of climate change as well as planning for new or increased effects in the future. Adaptation has received increased attention from several governments and international negotiations (UNFCCC, 1992; Klein and McIver, 1999; Smit *et al*., 2000). Adaptation is seen as a necessary complement to mitigation measures (Frankhausser, 1996, Smith, 1996; Pielke, 1998; Kane and Shogren, 2000). The trend is no longer only about how to save the planet by cutting carbon emissions; it is becoming more imperative to focus on how to save ourselves from the negative impacts of changing climatic conditions (Borenstein, 2013; White, 2013). Without adaptation, climate change is generally problematic for agricultural production, agricultural economies and communities, but with adaptation, vulnerability can be reduced in many contexts and there are many opportunities to make it happen (Nordhaus, 1991; Easterling *et al*., 1993; Rosenzweig and Parry, 1994; Fankhauser, 1996; Smith, 1996; Mendelsohn, 1998; Wheaton and McIver, 1999). The United Nations' Framework Convention on Climate Change, to which Canada is a signatory, identifies agriculture – including food production – as an important vulnerable area (UNEP, 1994; UNFCC, 2006). Adaptation includes the adaptation process and the condition of being adapted (Smit and Pilifosova, 2007). It is about how to approach the linkages between natural and human systems (Smit and Skinner, 2002). For human environments, like agriculture, adaptation can involve preparing for changing climatic conditions; hence, the dominant adaptation response is anticipatory, with the other type of response being reactive. In natural environments, plant and animal populations will also adapt, but in a reactive way, thus suffering the more negative short-term impacts of climate change. We should add that it is the responsibility of human society to ease the independent and spontaneous response of the natural environment to adapt to climate change and its variability.

As for non-climatic factors (such as political, social, cultural and economic conditions), (Bryant (1994) cited in Smit and Skinner, 2002; Kandlikar and Risbey, 2000), they may amplify or exacerbate climate risks, just as they can also reduce or neutralize them.

An adaptation plan to deal with the detrimental effects of climate change can be seen as a planning tool to be used to examine the issue of climate change in context and in all fields of activities of a municipal government, to identify and prioritize the key risks, and to adopt a vision as well as to provide steps for implementing short, medium and long-term adaptation measures to respond to changing climatic conditions.

The general objective of this research project is to enhance the understanding of the adaptation process and adaptive capacity at the farm and farm community levels through a bottom-up process, i.e. a co-construction, to develop appropriate management and planning tools and to build greater levels of capacity for adaptation in the farm community.

The Specific Objectives of this research are to:

a) Assess the role and possibilities of co-construction of public policies and collective action in the RCM of Haut-Richelieu to develop ways of adapting agriculture to climate change and variability.
b) Analyze the roles of different stakeholders and their capabilities, current and potential interventions, aimed at enhancing the adaptive capacity of farmers.
c) Develop recommendations for the future through integrating policies and these actions of co-construction with the different roles of stakeholders. Indeed, the dissemination of information on the risks associated with vulnerability to climate change is consistent with the promotion of adaptive capacity (Smit and Skinner, 2002).
d) Develop appropriate forms of public and collective action in the context of adaptation to climate change and variability.

All these objectives lead to "mainstreaming" which refers to the integration of climate change considerations in a range of policies, programs and decision-making (Patino, 2010), or in other words, the translation of the adaptation approach into practice.

In order to ensure consistency between the different parts of the thesis, the following structure was developed. Chapter 1 is about the co-construction approach as well as adaptation. Chapter 2 presents a literature review on climate change and variability in Québec as well as natural resources and other stress factors in the agricultural context. Chapter 3 describes the study area. Chapter 4 introduces the methodology used. Finally, Chapter 5 presents the results of the interviews along with a discussion.

CHAPTER 1. THE CO-CONSTRUCTION APPROACH AND ADAPTATION

1.1 Co-construction of Public Policies: Definition and Origin

Public policy always involves participation by the state sphere and public authorities (Vaillancourt, 2008). Because it involves only those two, public policy tends not to take into account the needs of the communities concerned which can be quite variable. In this case, it is referred to as the mono-construction of public policy, meaning that the authoritarian state constructs public policy on its own (or mono-constructs) (Vaillancourt, 2008).

When some progressive circles tried to adjust their focus so as to tighten the links between policy and the needs of the communities concerned due to the hindsight gained following the welfare state and employment crisis of the 1980s, the co-construction of public policies emerged (Jetté *et al.*, 2000; Vaillancourt *et al.*, 2003; Vaillancourt *et al.*, 2004). As a governmental policy, the notion of co-construction has been on the table of discussion in the first place in the European Union in 1985 by CRESAL (Centre de Recherches et d'Études Sociologiques Appliquées de la Loire) in Saint-Étienne (Castel, 1985).

As co-construction belongs to some extent to the consultation process, it is necessary to define consultation before proceeding with the definition of co-construction. Consultation is the action, for many people, to agree on a common project. It is a process of dialogue to achieve proposals, policies or projects (Molin, 2008). It is noteworthy however that the co-construction approach goes beyond the consultation process. According to Vaillancourt (2008), the term 'co-construction' has evolved as a result of the participation of different stakeholders in the making of public policy. It also contributes to identifying and building appropriate forms of collective intervention. Co-construction means the participation by stakeholders from civil society and the market in the design of public policy (Vaillancourt, 2008). The term stands upstream from the adoption of public policy. In other words, it really means the creation of public policy. To understand the co-construction process, we should break down the various stages involved in the genesis of public policy, which are the: "identification of the main goals for attaining the general interest; choice of regulation standards to foster quality; determination of funding means (state, private, mixed, etc.); definition of responsibility-sharing with respect to management; arrangement of responsibility-sharing with respect to the delivery of services belonging to public policy; and establishment of the policy for evaluating public policy" (Vaillancourt, 2008, p.18). "The co-construction of public policy is tied to the idea that it can become more democratic if the state agrees not to construct it all on its own" (Vaillancourt, 2008). And the more the co-construction tends to be democratic, the greater will be its likelihood to target a participatory reform according to Pierre (2005). This reform believes that "the state's strength derives from its capacity to call on the resources of all segments of society with a view to achieving collective goals and meeting the collective interest" (Pierre, 2005, p.8-9).

The co-construction of agricultural policies is an ambitious collaboration between different actors, public and private, for the definition of these policies and their application (Vaillancourt, 2008). In addition, Smit and Pilifosova (2007) define planned adaptation of a sensitive system (or unit, business, industry, community, or region of interest) to the current and future effects of climatic changes as a result of deliberate policy on the part of public bodies (or governments) together with other actors of civil society (e.g. the farmers and agricultural companies involved); hence, the co-construction approach can be considered to be a planned adaptation.

To summarize, co-construction is not just a bottom-up approach. The co-construction started mainly between government and high level organizations (e.g. UPA), but increasingly it started from the bottom-up. In other words, where possible higher levels ought to be involved particularly so that bottom-up aspect can have an impact on the upper levels of government.

1.2 Origin of the Adaptation Concept

According to Winterhalder (1980), the concept of adaptation is rooted in population biology and evolutionary ecology, which are considered as natural or biological sciences. Its applications are concentrated on the survival of species and ecosystems, and not necessarily on the viability of individuals within them (Slobodkin and Rapaport, 1974). Tolerance, stability, and resilience are ecological concepts that have been used to describe the tendency of biological systems to adapt to changed conditions, including the processes by which these changes occur.

In social sciences, adaptation is a paradigm (even stated again recently and more specifically in the IPCC report (2014) in terms of incremental and transformational adaptation) under which interaction between humans and their natural environment occurs, leading in turn to a broader meaning. Many scholarly fields such as human and cultural ecology, natural hazards research, ecological anthropology, cultural geography, ecological economics and, more recently, climate impact research, include social science applications and extensions of the adaptation paradigm. Furthermore, in social and economic systems, since human systems adjust in pursuit of goals other than mere survival, individuals have high potential to adapt to changing environmental circumstances. However, it is noteworthy that while the response of biological systems is totally reactive, the responses of human systems (e.g. agriculture) are both reactive and anticipatory, integrating environmental perception and risk evaluation as essential elements of adaptation.

1.3 Characteristics of Adaptations

Distinguishing adaptation can be undertaken by identifying its characteristics. Among the distinguishing characteristics are intent and purposefulness, timing and duration, scale and responsibility, and form.

Intent and purposefulness differentiate between autonomous or spontaneous adaptations and planned or anticipatory adaptations. In socio-economic systems, planned or anticipatory adaptations are undertaken by the public sector in concert with other actors. However, under the private sector, without the intervention of the public sector, adaptations can be autonomous or planned or both. An example on the latter is the decisions of a producer who, over several years, gradually phases out one crop variety in favour of another that seems to cope better under current climatic conditions, and this might be considered autonomous and planned. It is noteworthy that even in autonomous adaptations, private actors plan for adaptation without the deliberate intervention from the government, but they do not act in isolation from the existing cultural, political, social and market institutions.

Timing and Duration

Timing distinguishes responses that are proactive or reactive. On the other hand, duration differentiates adaptation according to their temporal scopes, such as tactical (short-term) responses versus strategic (long-term) responses. It is noteworthy that if farmers are only involved in tactical responses, strategic responses constrain, to a larger extent, the tactical responses of farmers; hence, it is wrong to consider that farmers alone are the decision makers.

Scale and Responsibility

Regarding adaptations, decisions are undertaken at several scales, mainly spatial (i.e. plant, plot, field, farm, region and nation) and by several actors (i.e. private or public agencies and actors).

Where these adaptations are consciously planned, whether by individuals (private adaptation) or public agencies (public adaptation), there is an interest in assessing the performance of such strategies.

To summarize what is said above thus far and since commonly used distinctions of adaptations are purposefulness and timing (Smit and Pilifosova, 2007), autonomous adaptation is undertaken by private agents and it is generally reactive, but it can also be proactive. On the other hand, planned adaptation is undertaken by the public in concert with other actors, and it is anticipatory in general, but it can also be reactive.

Form

Burton *et al*. (1993), Carter *et al*. (1994) and Smithers and Smit (1997), among other authors, have distinguished adaptations according to their form. Such studies consider adaptations according to their administrative, financial, institutional, legal, managerial, organizational, political, practical, structural and technological characteristics.

Types

This section is drawn from Canadian literature and experience. It is also based on the spatial scale, the stakeholders involved, private or public, and their responsibilities. It divides the main adaptation types into four, often interdependent, categories, which are: (1) technological developments, (2) government programs and insurance, (3) farm production practices, and (4) farm financial management. The first two categories are mainly undertaken by public agents and agri-business (which is private), and they are pursued at a broader scale (or macro-scale). The last two categories are undertaken by the producers at the farm level.

To summarize all the above, adaptation is a continuous process. At one end is the pure spontaneous adaptation by private agents; on the other end is the pure planned adaptation by government. Between these extremes, there are plenty of forms of adaptation that involve both the private agent and the government (Figure 1).

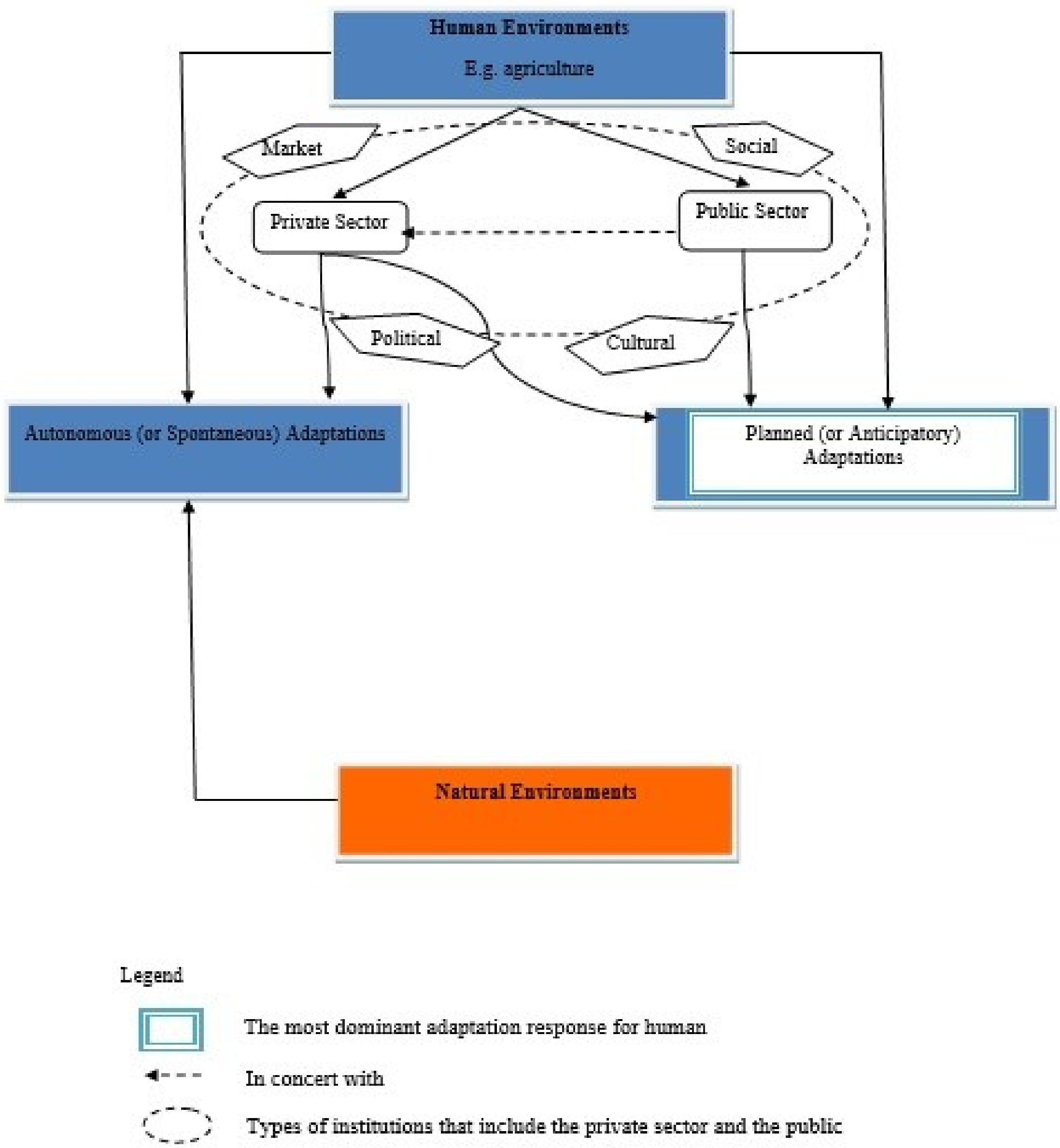


Figure 1: Types of adaptation according to human and natural enviroments[2].

[2] Source: Cherine Akkari, 2014.

CHAPTER 2. CLIMATE CHANGE AND VARIABILITY AND AGRICULTURE IN QUÉBEC

Understanding the importance of climate variability and extremes is the cornerstone in the analysis of adaptation especially for agriculture, which usually adapts well to average or normal climatic conditions, but on the other hand is very susceptible to irregular conditions or extremes (Reilly, 1995; Smit *et al*., 1996; Risbey *et al*. (1999) cited in Smit and Skinner, 2002). After all, adaptation is about reducing the uncertainties, i.e. What are the ranges of impacts to be expected? What exposures and disruptions might we expect? And perhaps most importantly, what does adaptation mean under rising global temperature scenarios? Also, it can be oriented to benefit from opportunities associated with climate change (at least in some regions) (Carter *et al*., 1994; Watson *et al*., 1996; Pielke, 1998; Tol *et al*., 1998; UNEP, 1998; Wheaton and McIver, 1999; Smit *et al*., 2000; Smit and Pilifosova, 2007). Increasing attention has been given to the prospects of farm-level adaptation to changed – and annual variable – climatic conditions, instead of focusing on plant growth and crop yields under long-term climate average climate scenarios (Easterling *et al*., 1992; Rosenberg, 1992; Carter *et al*., 1994; Smit *et al*., 1996). The farm is the point at which ecological, economic and human factors intersect, and where performance is first assessed and decisions about intervention and resource allocation are made. Farm decision-making is an on-going process, whereby producers are continually making short-term and long-term decisions to manage risks coming from a variety of climatic and non-climatic sources (Ilbery, 1985). Even though recent research has focused on farmers as decision makers at the farm scale (Marsden *et al*., 1989; Ilbery, 1991; Bryant and Johnston, 1992; Bryant *et al*., 2000), there has been little empirical analysis of farm-level decision making with respect to climate (Smit *et al*., 1997; Smit and Skinner 2002). Among the latter, and specifically in Québec, are Bryant *et al*. (2008) and Délusca (2010).

Agricultural activity in Québec is concentrated mainly in the South, where climate and fertile soils are favourable for farming, especially in the central regions (Montérégie, Chaudiere-Appalaches and Centre-du-Quebec); these three regions produce more than 58% of total agricultural earnings (MAPAQ, 2008). The total area under cultivation in

Quebec, which was as high as 2.5 million hectares in 1931, had dropped to 1.6 million hectares by 1991. Since then, it has begun to expand again with 1.9 million hectares under production in 2006. Meanwhile, and likewise in the case of most developed countries, the number of farms has fallen considerably, translating into an increase in the average size of a farm (Statistics Canada, 2007).

2.1 Climate Variables in Québec

Climate, with or without climate change and along with the soil type and quality, is a major determining factor for agricultural activities such as crop farming and livestock farming (in terms of feed production). According to a model of regional agricultural adjustment to climatic variability, there are four agro-climatic conditions that are generally held to be of importance for agriculture, which are: (1) growing season length (measured as the frost-free period or growing season start and end); (2) temperature or growing degree days (often expressed in corn heat units), (3) precipitation (drought, excess precipitation); and (4) sudden shocks/storms (i.e. wind, hail, early frost) (Smiths and Smit, 1997). In Québec, the length of the crop growing season and the accumulation of heat during this season are the agro-climatic factors that govern crop selection and yield (DesJarlais *et al*., 2010).

Agriculture is inherently sensitive to climate. Relatively cool and humid climate conditions in Quebec's agricultural areas are favourable to forage crops and cereals such as wheat, barley, oats and rye, which explains to an extent the importance of dairy production. Land dedicated to crops that are more reliant on heat, such as corn and soybeans, tends to be concentrated in the southern parts of Québec. It is noteworthy that the productivity of crops that require more heat is usually greater than for crops that are better adapted to cool climates. Integrating crop models with general circulation model (GCM) output for a 2xCO_2 climate scenario for the period 2040-2069, Singh *et al*. (1998) suggested that corn and sorghum yields in Québec could increase by 20%, whereas wheat and soybean yields could decline by 20–30%. As for canola, sunflowers, potatoes, tobacco and sugar beets, yields are expected to increase (unspecified quantitatively however), while a decrease in yields, also unspecified quantitatively, was anticipated for green peas, onions, tomatoes and cabbage.

Inter-annual climate variability is an important indicator of the agricultural sector's sensitivity to climate conditions. An example of this is the greatest drop in grain corn production that took place markedly in 2000 in the period from 1987 to 2001. This special year was highlighted by excessive moisture and insufficient sunlight to promote growth (Environment Canada, 2002). As an outcome of this problem, crop insurance compensations for corn increased tremendously, reaching a record level of $97 million in 2000, compared to $191,000 in 1999 (La Financière Agricole du Québec, 2006). At the same time, the sub-regions showed different responses to the impacts of climate variability due to their different biophysical environments: soil type, topography, temperature (Bryant *et al*., 2005). This example of crop insurance compensations shows that there is an interest from governments in policy consideration of agricultural adaptation to current climatic variation and uncertainty, apart from the issue of long-term climate change. However, such institutional mechanisms can also lead to maladaptation. In fact, adaptation to climate is a complex process that occurs as a result of the influence of climatic (or environmental) forces as well as other external forces such as the actions of government, economic, socio-cultural and technological factors. Both sets of factors define the context of human-environment interaction at the same time. In human systems, non-environmental forces outweigh – either impeding or mediating – environmental factors; hence, the notion of maladaptation to climate (Smithers and Smit, 1997). Besides Smithers and Smit (1997), the earliest recognition of maladaptation is included in Smit (1993), Burton (1997) and Scherag and Grambsch (1998) and has recently been defined by the IPCC fifth assessment report (IPCC, 2014, p. 857, Chapter 14) as "actions (i.e. inadvertent badly planned adaptation actions or deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions), or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future."

Temperature

In the recent past (1960-2005), the climate of Québec has been changing significantly in terms of rise in average temperatures. In southern Québec, for example, daily mean temperatures increased by 0.2°C to 0.4°C each decade (Yagouti *et al*., 2008). This warming was greater for average night-time temperatures than for daytime temperatures (Zhang *et al*., 2000; Vincent and Mekis, 2006; Yagouti *et al*., 2008). Overall, it is anticipated that temperature will increase in all the territory of Québec (Christensen *et al*., 2007; Plummer *et al*., 2006). This increase in temperatures is also translated into changes in related climatic variables, such as shortened frost season, increase in the number of growing degree-days, and decrease in the number of heating degree-days (Yagouti *et al*., 2008). Moreover, increased temperatures are favourable for crops such as corn and soybeans. Such climatic conditions enable such crops to benefit from summer heat and a longer growing season (Bootsma *et al*., 2004, 2005a, 2005b). Also, their cultivation might expand into new regions with the appropriate soil and topography, such as Saguenay–Lac-Saint-Jean, Abitibi and the Bas-Saint-Laurent–Gaspésie. In addition, according to the same studies of Bootsma, climate change might be less favourable for small grain crop yields. As for the predictions regarding forage crops, the number of harvests per year might increase (Bélanger *et al*., 2002), but nutritional quality might diminish (Gitz *et al*., 2006). Outside the growing season, unfavourable climate conditions will also have implications for agriculture, especially for perennial plants. For instance, warmer autumns, reduced snow cover and increased winter rains, might increase the risk of winter mortality of forage crops (Bélanger *et al*., 2002), which represented about 40% of the area under cultivation in 2007 (ISQ and MAPAQ, 2009).

Precipitation

In terms of precipitation, Québec has experienced an increase in the number of days with low-intensity precipitation (Vincent and Mekis, 2006) as well as changes in solid precipitation (mainly snow), which has diminished in southern Quebec but increased in the North (Brown, in press). Also according to DesJarlais *et al*. (2010), a more active hydrological cycle is and will be consistent with a warmer climate, thus providing:

• an extension of the favourable season for storms and an increase in heavy rains;
• an increase in the accumulation of snow on the ground in the north despite higher temperatures, and a decrease of snow on the ground in southern and central Québec despite the increased winter precipitation throughout the territory.

For southern Québec, there is no significant increase in precipitation during the growing season (especially summer precipitation), but there is an increase in evapotranspiration due to higher temperatures, resulting in an increased probability of water stress (DesJarlais *et al*., 2010). Moreover, according to Bunce (2004), water-use efficiency in plants increases in a CO_2-enriched atmosphere. In fact, due to increased atmospheric CO_2, stomatal conductance will be reduced, leading to an overall decrease of daily water stress; leading in return to a reduced need for increased water irrigation (Brassard and Singh, 2008). However, when combining both factors – evapotranspiration and CO_2 fertilization, their effects on crop productivity remain unclear. Through its impact on the rate of plant development and on the rate of photosynthesis, temperature has a dual effect on plant growth and productivity. The cumulative impact of a temperature change on crop yields then will depend on the direction and relative strength of these two antecedent effects. An increase in temperature will lead to a decrease in crop yields through the acceleration of crop development. For example, in Southern Québec, since future predicted temperatures by Brassard and Singh (2008) are higher than present for all of the three scenarios (CGCM1, HadCM3 A2[3] and HadCM3 B2[4]) and since maize

[3] The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines (Nakicenovic et *al*., 2000).

[4] The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2 intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels (Nakicenovic et *al*., 2000).

will undergo an accelerated development followed by soybean and then by wheat (Brassard and Singh 2008), the decrease in crop yields due to the faster development rate would be highest for maize, then soybean, and lowest for wheat (Singh *et al*., 1998; Brassard and Singh 2008). However, the influence of the effect of temperature on photosynthesis depends on whether the increase in temperature brings the crop closer to, or farther from, its optimal temperature range, at which photosynthesis is maximal. Using three climate scenarios (CGCM1, HadCM3 A2 and HadCM3 B2), Brassard and Singh (2008) concluded for Southern Québec that future temperatures (2040-2060) will move farther from the optimal growth temperatures for wheat and potato, and closer for maize and soybean. As a result, yields in the future period (2040-2060) will be higher in the latter case (for maize and soybean) and lower in the latter (for wheat and potato) (Brassard and Singh, 2008).

It is worth noting that an excess of water is also devastating to agriculture. Besides having a direct impact on crops, liquid precipitations have a major influence on runoff, soil erosion and water quality. For example, the spring snowmelt period is particularly conducive to soil erosion and to the loss of soil nutrients (Beaudet *et al*., 2008). Hence, it is important to consider changes in the rainfall intensity and the rain/snow ratio of precipitation, aside from the total amount of precipitation (Nearing *et al*., 2004).

Further, when it comes to soil's vulnerability to water erosion, it is important to note that agricultural land use is also another major factor (Savary *et al*., 2009). However, despite the lack of knowledge on how land management choices made by agricultural producers can increase the risks for soil erosion in the case where an expansion of the cultivated area leaves the soil exposed to erosion (Quilbé *et al*., 2008), such risks can be reduced with improved soil conservation practices and water resource management (DesJarlais *et al*., 2010).

Corn Heat Units

Like all plants, corn requires adequate growing season conditions, especially heat. Corn hybrid varieties are available for a wide range of conditions, including accumulated heat, measured as Corn Heat Units. This example of adaptation is called crop development and it comes under the different types of technological developments (Smit and Skinner, 2002). Crop development means the development of new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions (Smit and Skinner, 2002). In fact, hybrid varieties are developed by combining genetically different parents (not necessarily genetically modified organisms) in order to enhance such attributes of disease and mould resistance, stalk strength, maturity time, and yield (Aldrich *et al*., 1975; Tollenaar *et al*., 1994). It is important to note here that yield and maturity are very important in corn production because of the spatial variations in growing season length, and considerable resources have been devoted to hybrid development of these traits (Joseph and Keddie, 1985); hence, the importance of labeling and classifying corn hybrids according to their CHU designation (Brown and Bootsma, 1993). Hybrids with lower heat requirements (earlier maturing or shorter-season varieties) generally have lower yields. Hybrids developed for higher levels of accumulated heat (later-maturing or longer-season varieties) invariably have higher yields, so long as they reach maturity (Smit *et al*., 1997). For example, a conservative farmer may choose a short-season hybrid which has a great probability of maturing but has lower yields; another farmer may choose a later maturing hybrid which has higher expected yields but is more risky since it needs a higher level of accumulated heat to reach maturity (Smit *et al*., 1997).

Agroclimatic indices such as the average of accumulated Corn Heat Units (CHUs) and Growing Degree Days provide information on the amount of energy potentially received for plant growth. Such indices are very crucial determinants when it comes to the choice of crops and cultivars. As a result, farmers are advised to plant hybrid varieties that match the average CHUs at their location (Smit *et al*., 1997). According to the guide of cultural practices for cereals, maize and oilseeds of La Financière Agricole du Québec (2013, reproduced for 2014), all 14 municipalities of the RCM of Le Haut-Richelieu, surrounding Philipsburg and Iberville meteorological stations, range from 2900 CHU to

3000 CHU. So, La Financière Agricole recognizes that corn hybrids in all the municipalities of the RCM of Haut-Richelieu must be 2625 CHU maximum for the municipalities having a CHU of 2900, 2675 CHU max for the municipalities having a CHU of 2950, and 2700 CHU max for those having a 3000 CHU (FADQ, 2013a, extended to 2015). It should be noted here that the period for calculating the CHU for corn hybrids for the RCM of Haut-Richelieu is 1979-2008 and it was performed by the Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ, 2012).

Furthermore, agro-climatic indices such as corn heat units and growing degree days are not very accurate because they do not take into consideration local factors (e.g. type of soil and drainage), factors that influence plant development (e.g. precipitations, soil humidity and the photoperiod), and other factors such as the quality of soil in terms of its capacity to reproduce and the effects of insects, diseases and weeds, all of which could be altered by climate change. It is noteworthy that according to Bootsma *et al*. (2004), soil humidity does not have that large an influence, as precipitations do, on CHUs and growing degree days.

2.2 Water and Soil Resources

Water Resources

Agricultural activities occupy an important place in the Montérégie region, which is one of the main agricultural regions of Québec. In addition to the St. Lawrence River, the Montérégie is also home to three other important watersheds, which are those of the Richelieu, Châteauguay and Yamaska. However, the degree of pollution of these rivers is a limiting factor that must be taken into account in any use of these waters. Indeed, the issue of water management (which includes drinking water, domestic water, storm water and flood zones) in this region is marked by the pollution of these resources from urban and agricultural areas, especially as some municipalities discharge their waste water to waterways directly, without sewage treatment. Therefore, it is not surprising that these rivers are considered the most problematic because of their contribution to the toxicity of the St. Lawrence River. It is also noteworthy to highlight here that water levels in the St. Lawrence River, where land use and settlement patterns place a stress on the supplies, are projected to decrease continuously due to extreme weather conditions (i.e. frequency, intensity and durations of events) (Wall, 2008). Indeed, in the Montérégie region, most of the rivers are contaminated by the presence of pesticides, including herbicides and insecticides, which are present in concentrations that exceed the limits for the protection of aquatic life (Ministère de l'environnement, 1999). These nutrients are a major cause of eutrophication of rivers (Edmonson, 1969). This acceleration of anthropogenic eutrophication can significantly reduce oxygen available to aquatic life and thus endanger species of fish, reptiles and amphibians, which is also reflected in the quality of drinking water.

In the region of Montérégie, 8930 hectares (or 39.55%) of the total agricultural land in Quebec are irrigated (Bryant *et al*., 2011). For Montérégie-West for instance, the watershed of the Châteauguay River covers part or all of the RCM of Roussillon, the RCM of Haut-Saint-Laurent, the RCM of Le-Jardin-de-Napierville, the RCM of Haut-Richelieu, and the RCM of Beauharnois-Salaberry. Approximately 50% of the territory of the Châteauguay basin is cultivated (Bryant *et al*., 2011). There is also cattle production, mainly for milk production, which represents 88% of the livestock of the basin (Bryant *et al*., 2011), and eventually posing the problem of wastewater management in dairy production. This issue also relates to the north of the St. Lawrence, mainly the RCM of Vaudreuil-Soulanges. In the American sector of the Châteauguay River, poor agricultural practices contribute to the pollution of the water upstream of the basin. In other areas of the basin, cultivated areas are responsible for the problems of water enrichment and the presence of pesticides through drainage and fertilization (Ministère de l'environnement, 1999). In the watershed of the Richelieu River, intensive farming practices make the bacteriological and the physico-chemical qualities of the water very poor (Bryant *et al*., 2011), despite the presence of a wastewater treatment plant (Lamontagne *et al*., 2001). Another obstacle for planning and maintaining the water quality of the Richelieu River is the presence of flood zones along the river (Lamontagne *et al*., 2001). Moreover, the supply of the drinking water of some of the municipalities in the RCM of Haut-Richelieu, such as the municipality of Saint-Jean-sur-Richelieu, is taken directly from the Richelieu River (Lamontagne *et al*., 2001). It is therefore crucial to maintain the quality of this resource. The problem of pollution of the water quality is recurrent in other rivers of Montérégie West such as the Missisquoi Bay and the Yamaska River.

Soil

The Montérégie Region is considered to be the most intensive agricultural region in Quebec because of the rich valley of the St. Lawrence, giving it about 500 000 hectares of arable land (Bryant *et al*., 2011). According to the Canada Land Inventory (CLI), the soils are of category 1, 2 and 3. Most of the territory is covered with clay soil, originating from fluvial sediments on either side of the main rivers that cross the region, namely the St. Lawrence River, the Richelieu River and the Yamaska River.

The soils categories 1 and 2 are the most preferable for agriculture and are predominant in Montérégie West. This soil quality is what makes the Montérégie West region well known for its corn production. Estimated at 7% of the total area under crop production in Montérégie West in 1991, the corn acreage in the region rose to 18% in 1996 and reached 26% in 2001 (MAPAQ, 2006a). For the six RCM of Montérégie West, the surface area estimated for corn production increased from 99,324 ha in 1991 to 117,123 ha in 2001, an increase of 15.2% in 10 years (Délusca, 2010). However, the main problem is the deterioration of the soil under the induced effects of diffuse pollution by pesticides, fertilizers and manure. On an important note here, contaminated soil is a soil in which substances such as hydrocarbons (e.g. oil and gasoline), chemicals or heavy metals are present as a result of industrial or commercial activities. These contaminants can be liquid or solid. Liquid contaminants enter the soil and then join the water table (or groundwater). The solid contaminants are driven by the leaching of rainwater and also reach groundwater or streams directly. Thus, these substances can migrate and contaminate large areas. As a result, when clay soils are contaminated, contamination usually remains localized due the impermeable property of this type of soil.

Indeed, soil protection is a priority in Montérégie West. To this end, efforts are being made for the development of soil conservation structures, windbreaks and cover crops. Efforts will also promote tillage and reduced tillage techniques, leaving crop residues on the soil, reducing runoff and promoting infiltration. As an example, in 2007 in Montérégie West, more than 684 ha were protected by cover crops to protect the soil against wind and water erosion, to remove excess nutrients and to reduce the risk of pollution (MAPAQ, 2007).

2.3 Other Stress Factors

Due to climate change and its increasing variability, there will be an increase in thermal and water stresses in general, threatening crops and especially horticultural production. The increased variability of changing climates causes immediate damage to plants or makes them very susceptible to disease. In fact, when the temperature changes radically and too rapidly, plants are unable to adjust at the same rate; thus, the presence of problems related to sun exposure such as sunscald and crown canker in carrots, lettuces, radishes and a good number of other vegetable crops (DesJarlais *et al*., 2010). Other cases include root asphyxiation in potatoes, corn and soybeans resulting from episodes of heavy rain, which fill low spots with several centimeters of water and create asphyxiating conditions for plant roots. In these situations, secondary fungi can attack the plants if the excess water does not drain off in time (DesJarlais *et al*., 2010).

Insects, weeds, and diseases are all sensitive to temperature and moisture. In changing climates, invasive species, weeds especially, are very adaptable due to their rapid dispersal characteristics, which allow them to shift over large latitudinal ranges and quickly in response to changing climates. However, the effectiveness of weed control treatments can be diminished, partly due to the direct effect of an increased concentration of atmospheric CO_2 on the root growth of weeds (Ziska and Goins, 2006).

Climate change will also present both benefits and challenges for livestock production that still dominates agriculture in Quebec. Benefits would be particularly evident during winter, when warmer weather lowers feed requirements and increases the survival of the young, and reduces energy costs (Rosenzweig and Hillel, 1998). In addition, milder winter conditions may result in greater weight gains for beef cattle raised outdoors, and a reduction in heating requirements for poultry and pig production facilities. Also, challenges would increase during the summer, when heat waves can kill animals (Rosenzweig and Hillel, 1998). In July 2002, the dangers posed by heat waves killed at least 500,000 poultry, despite modern ventilation systems (DesJarlais *et al*., 2010).

CHAPTER 3. DESCRIPTION OF THE CASE STUDY

3.1 Location

Montérégie (Figure 2) is a vast plain of Central Québec, extending from the State of New York in the United States to the St. Lawrence River. It covers a surface area of 11,111 km² for an estimated total population of 1,499,088 inhabitants (Institut de la Statistique du Québec, 2013). This region alone is home for nearly a third of Quebec farms. In addition, it had 7,077 agricultural enterprises in 2012, representing a quarter of farms in Québec (MAPAQ, 2014). Precisely because of the importance of agriculture in this region, it was split into two parts, namely the East and West Montérégie. In the latter, the subject of this study, agriculture is an important economic activity. Indeed, Montérégie West, known as the garden and the orchard of Québec, owes its agricultural vocation to a relatively mild climate and the good quality of its soil (MAPAQ, 2006a). The following data can be used to obtain a good idea of the climatic characteristics of the study area (MAPAQ, 2006b):

- ❖ The climate is amongst the hottest in Québec (Morissette, 1972). It provides the municipalities with up to 3000 Corn Thermal Units (UTM) and up to 2100 degree-days base 5, i.e. above 5^{o} C.
- ❖ The frost-free period can be up to 160 days, generally from mid-April to mid-October.
- ❖ During the growing season, the total of rainfalls varies between 500 mm and 600 mm. During this period, it is also possible to record periods of water deficit during the months of July and August.

Six Regional County Municipalities (RCMs) compose the Montérégie West (Figure 2, in orange) (Vaudreuil-Soulanges, Beauharnois-Salaberry, Le Haut-Richelieu, Les Jardins de Napiervilles, Roussillon and Le Haut-Saint-Laurent.). Partly located in the Montreal Metropolitan Community (MMC), the Montérégie West is located in the northern temperate region and covers a surface land area of 3713.7 km² (estimated in 2008). In the same year, 2008, 3155.8 km² of the territory comprises the agricultural area, of which 2344.3 km² (or 63.1%) is occupied by large farms (Institut de la Statistique du Québec, 2009).

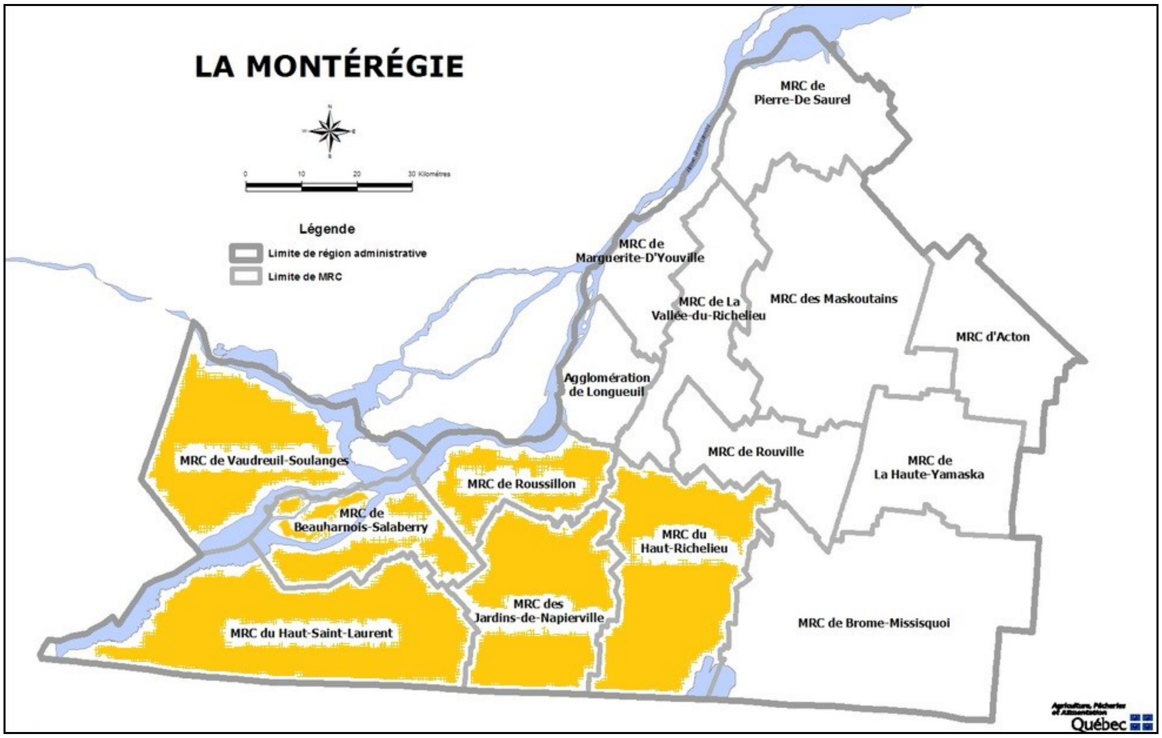


Figure 2: Geographic Representation of Montérégie West (in orange)[5].

3.2 Demography

The total population of Montérégie West was estimated at 555,578 habitants in 2013 (Table 2), representing 37% of the total population of Montérégie (1,499,088 habitants in 2013). In 2001, Montérégie West had a total population of 444,653 inhabitants. Therefore, between 2001 and 2013, there was a population growth in Montérégie West (Figure 3) of 110,925 residents (or an increase of 20%) (Table 2). We can also conclude from Table 2 and Figure 3 that the RCM of Haut-Richelieu is the third RCM in Montérégie West in terms of total population, right after the RCMs of Roussillon and

[5] Source: MAPAQ, (October, 2013). http://www.mapaq.gouv.qc.ca/SiteCollectionImages/Regions/Monteregie-Est/CarteMONTEREGIE.jpg. Modified by Akkari Cherine on 17 July, 2014.

Beauharnois-Salaberry. More specifically, the municipality of Saint-Jean-sur-Richelieu has the largest population (Figure 4 and Figure 5), acting as the capital city of the RCM of Le Haut-Richelieu.

Table 2: Evolution of the population in the RCMs of Montérégie West from 2001 to 2013

	Total Population				Progression 2001-2013	
	2001[6]	2006[7]	2011[5]	2013[8]	Number	Percentage
Vaudreuil-Soulanges	102100	120395	139353	145514	43414	30%
Beauharnois-Salaberry	59137	60802	61950	63456	4319	7%
Roussillon	138172	149996	162187	178430	40258	23%
Le Haut-Richelieu	100573	108892	114344	116603	16030	14%
Les-Jardins-de-Napierville	22820	24111	26234	26964	4144	15%
Le-Haut-Saint-Laurent	21851	21943	21197	24611	2760	11%
Total (or Montérégie West)	444653	486139	525265	555578	110925	20%

[6] Source for the 2001 data: Statistique Canada, Recensement 2001, adapté par l'Institut de la statistique du Québec en 31 janvier 2003. Consulté le 14 Juin, 2014. http://www.stat.gouv.qc.ca/statistiques/recensement/2001/recens2001_16/population/tpoplog16.htm

[7] Source for the 2006 and 2011 data: Statistique Canada, Recensement 2011, adapté par l'Institut de la statistique du Québec en 19 décembre 2012. Consulté le 14 Juin, 2014. http://www.stat.gouv.qc.ca/statistiques/recensement/2011/recens2011_16/population/poptot_superficie16.htm

[8] Source for the 2013 data: La Montérégie, ses municipalités régionales de comté (MRC) et ses territoires de conférence régionale des élus (CRÉ). (ISQ, 2013). Consulté le 14 juin, 2014. http://www.stat.gouv.qc.ca/statistiques/profils/region_16/region_16_00.htm

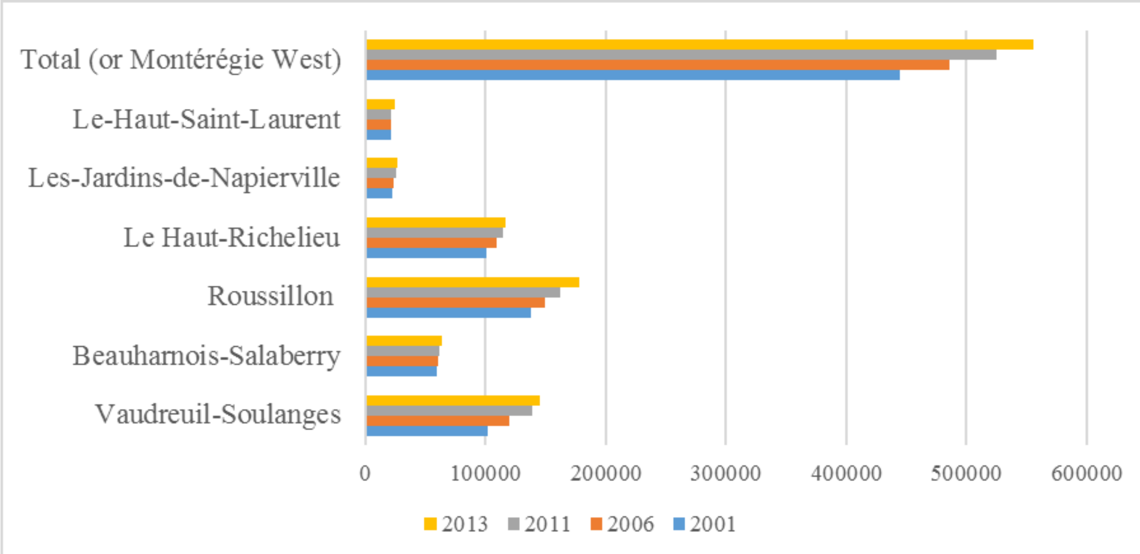


Figure 3: Evolution of the population within the different RCMs of Montérégie West between 2001 and 2013.

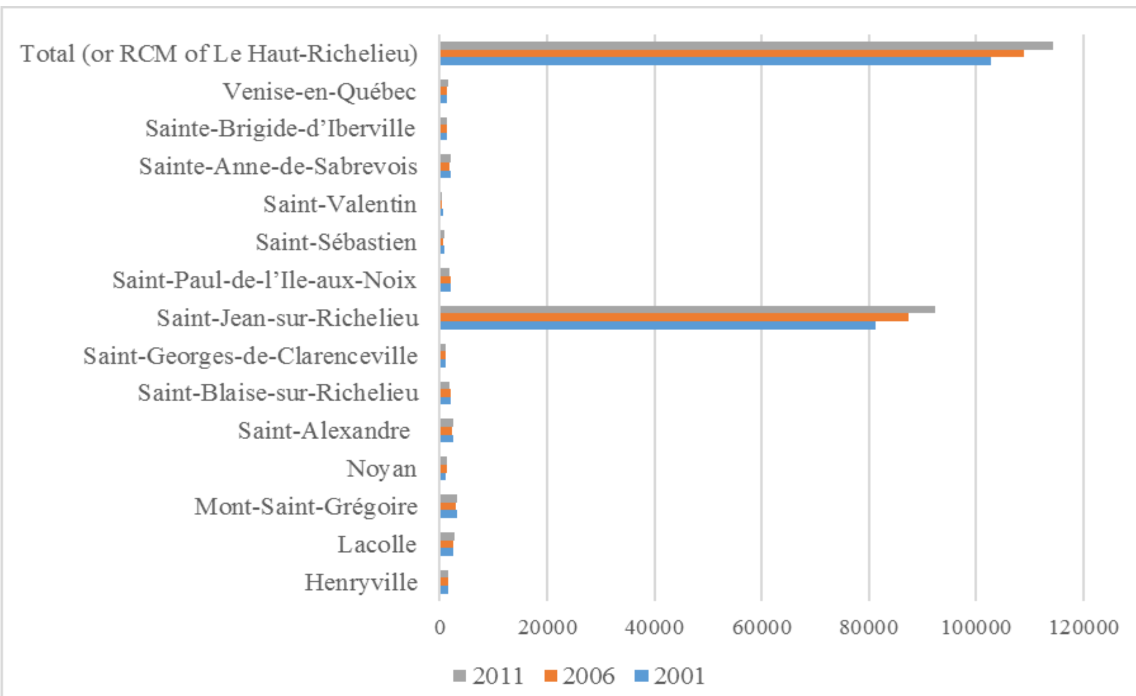


Figure 4: Variation of the population in the RCM of Haut-Richelieu and its municipalities, 2001-2011[9].

[9] Source : Statistique Canada, Recensement 2011, adapté par l'Institut de la statistique du Québec en 19 décembre 2012. Consulté le 14 Juin, 2014. http://www.stat.gouv.qc.ca/statistiques/recensement/2011/recens2011_16/population/poptot_superficie16.htm

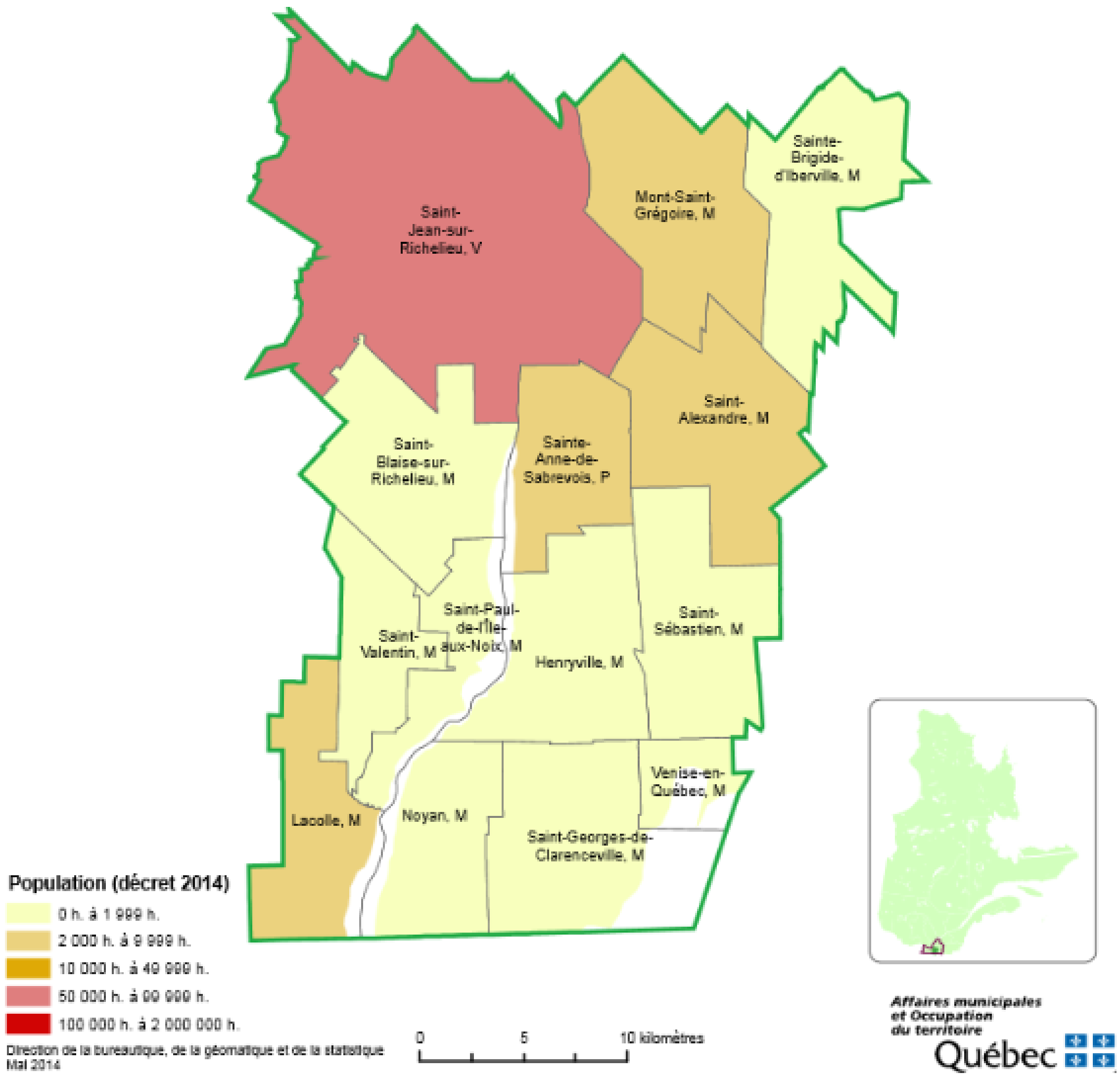


Figure 5: Population variation in the municipalities of the RCM of Le Haut-Richelieu in 2014[10].

Furthermore, according to the projections of scenario A[11], the population will continue to grow by 23% between 2006 and 2031 (Table 3), giving the Montérégie West the largest increase in population in Québec (and accounting for 19% of the total

[10] Source : Institut de la géomatique et de la statistique, (Mai, 2014). Cartographie de la région de la Montérégie. Retrieved from : http://www.mamrot.gouv.qc.ca/pub/organisation_municipale/cartotheque/Region_16.pdf

[11] Reference scenario

population of Québec) (ISQ, 2010). This would be linked primarily to internal migration, with an addition of 1.68 million people by 2031 (Institut de la statistique du Québec, 2010)

Table 3: Variation of the population in the RCMs of Montérégie West, 2006-2031, scenario A[12].

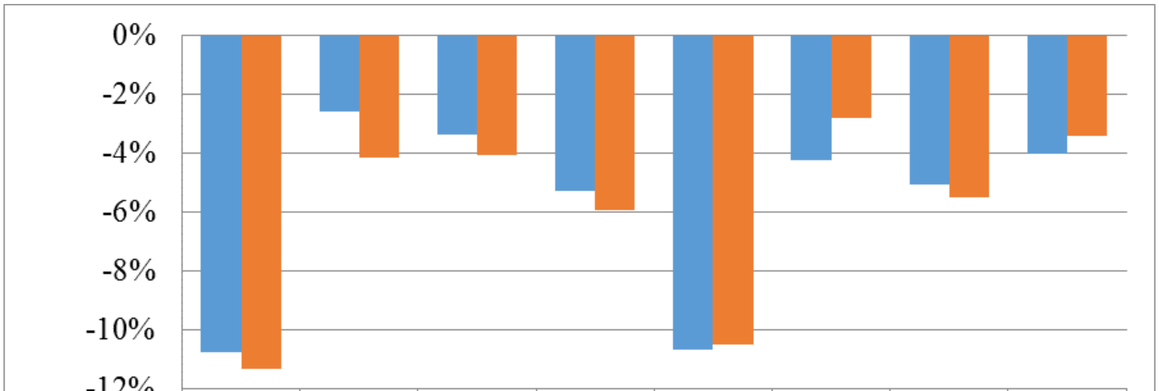
	Population		**Progression 2006-2031**	
	2006	2031	Number	Percentage
Vaudreuil-Soulanges	122089	186213	64124	52.5
Beauharnois-Salaberry	61164	71848	10684	17.5
Roussillon	161151	196754	35603	22.1
Le Haut-Richelieu	109943	138819	28876	26.3
Les-Jardins-de-Napierville	24396	31201	6805	27.9
Le-Haut-Saint-Laurent	25035	26604	1569	6.3
Total (or Montérégie West)	503778	651439	147661	23%

3.3 Number of Farms and Farm Operators, Census Years 2006-2011

The total number of farms in Montérégie West was estimated at 2887 in 2006, representing 9.41% of all farms in Québec. This number, which is constantly decreasing, was estimated at 2740 in 2011. In the periods 2001-2006 and 2006-2011, 266 and 147 farms have disappeared in Montérégie West, respectively. In parallel with the reduction in the number of farms, the number of farmers was at 4355 in 2006 falling to 4,115 in 2011 for Montérégie West. Comparing these observations across Québec, the number of farms and the number of farmers are marked by a decline in the general trend.

Within Montérégie West, between 2006 and 2011, it is the RCM of Le Haut-Richelieu and the RCM of Le Haut-Saint-Laurent that record the smallest loss of farms and farmers. It should also be noted that the downward trend of farms and farmers is observed in all localities of the Montérégie West (Figure 6).

[12] Source : Institut de la statistique du Québec, Perspectives démographiques des MRC du Québec et des régions, 2006-2031.



	Beauharnois-Salaberry	Le haut-Richelieu	Le Haut-Saint-Laurent	Les Jardins-de-Napierville	Roussillon	Vaudreuil-Soulanges	Total MRC	Québec
Farms	-11%	-3%	-3%	-5%	-11%	-4%	-5%	-4%
Farmers	-11%	-4%	-4%	-6%	-11%	-3%	-6%	-3%

Figure 6: Change in number of farms and farmers in Québec and in Montérégie West, 2006-2011.

Changes in the Legal Status of Farms

The legal status of farms has also evolved over time. Individual and family farms are disappearing to make way for the incorporation of companies associated with several interrelated units, with or without a written contract. This is demonstrated by the downward trend in the number of individual sole proprietorship farms whose numbers have dropped from 2,355 in 1991 to 1,382 in 2006 to 1,222 in 2011, in the Montérégie West (Figure 7).

One explanation for this could be the escalating market value of the farms, making their management very expensive; and therefore untenable for individual and family farms to maintain their status (MAPAQ and AGÉCO, 2006). This could be, as discussed in the next section of this thesis, the cause of the gradual disappearance of small-sized farms in favour of larger farms.

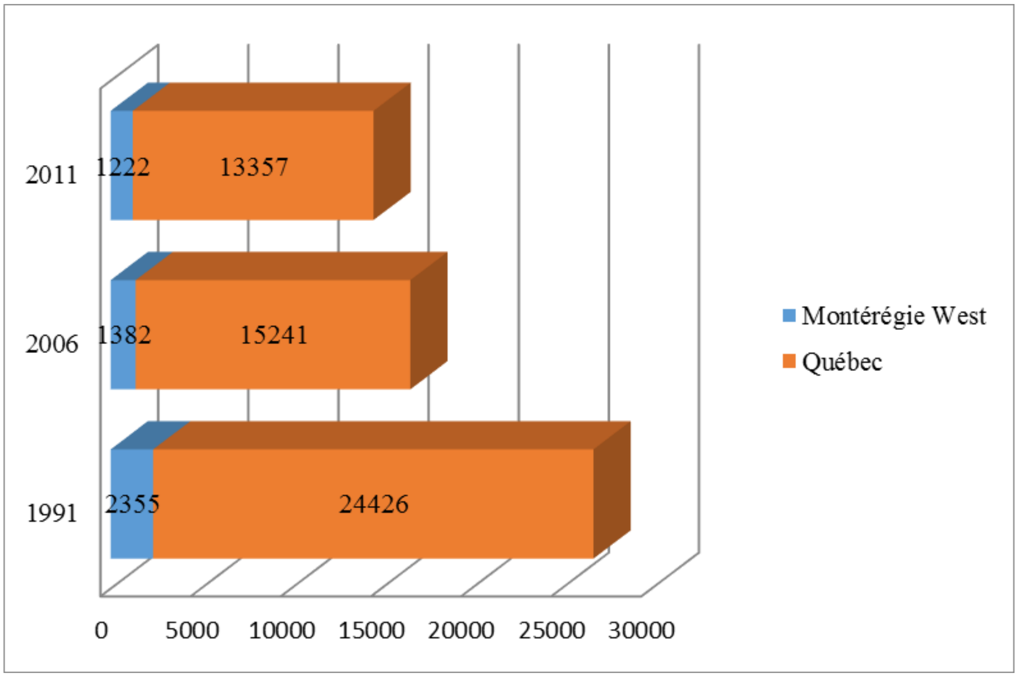


Figure 7: The number of individual farms owned by their farmers in 2011, in Québec and Montérégie West.

3.3.1 Evolution of farmland areas by production

3.3.1.1 Evolution of farm size

The size of farms in Montérégie West was still marked in 2011 by the predominance of small and medium sized farms with an area of between 10 and 399 acres. However, in some localities including the RCM of Haut-Richelieu and the RCM of Vaudreuil-Soulanges, between 7% and 8% of farms range in size between 760 and 1119 acres. There are also farms over 2,500 acres in size, but in much smaller proportions.

The average size of farms in Québec was 280 acres in 2011 (Statistics Canada, 2011a). A simple comparison shows that the evolution of the average size of farms in Montérégie West is in line with the general trend at the provincial level (Figure 8).

However, by maaking a comparison with the situation in 1991, as reported in the previous paragraph, the main lesson from this analysis is probably the trend towards the decrease of smaller farms in favour of larger ones. Thus, there is an increase of more than 70% of the number of farms in Montérégie West with an area of 760 acres or more (Figure 9).

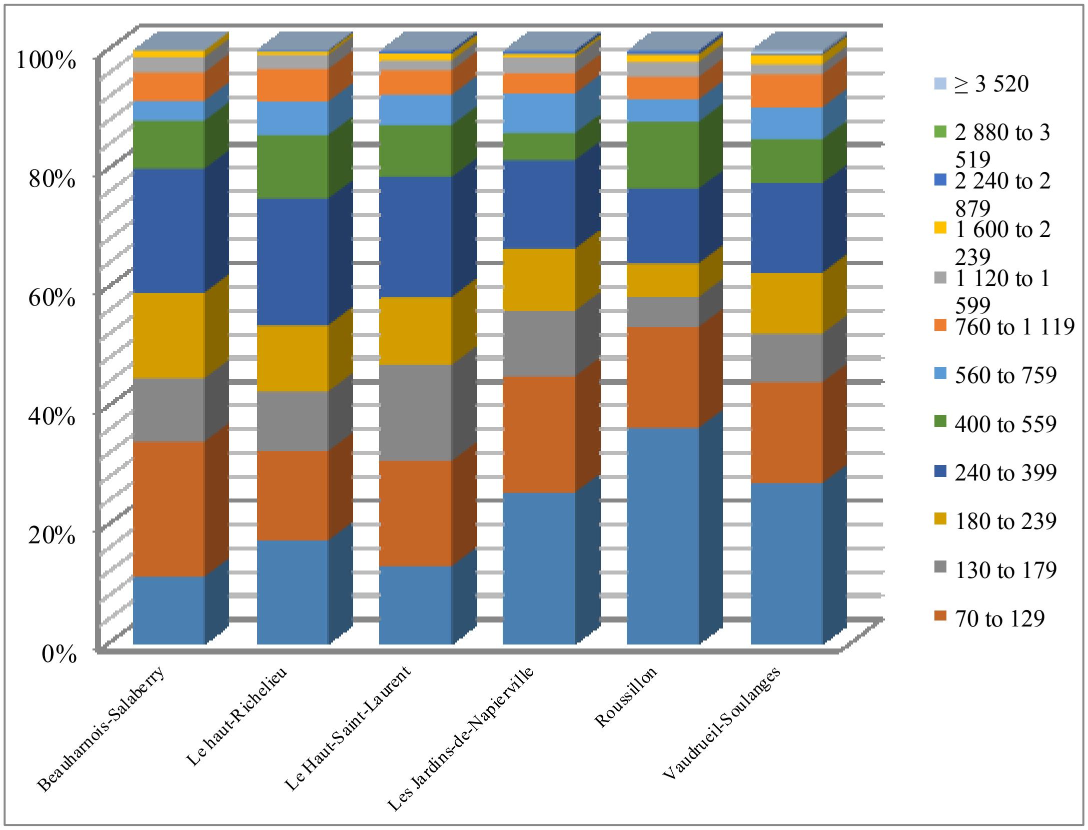


Figure 8: Classification of farms according to their total surface area (in acres) in Montérégie West, 2011.

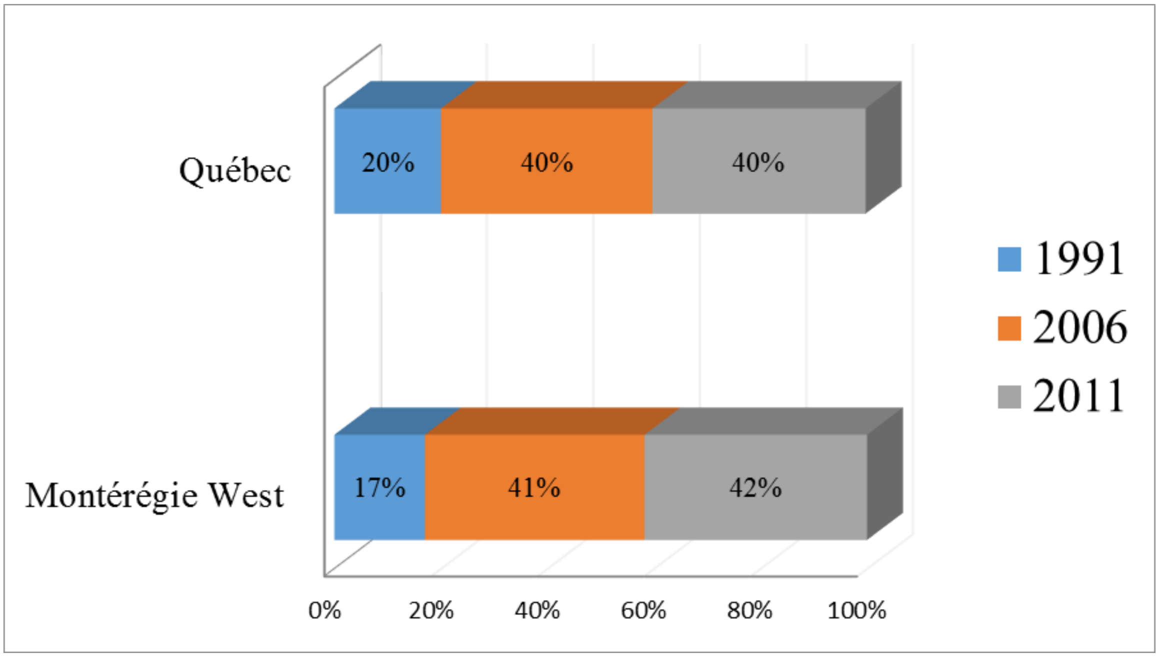


Figure 9: Evolution of farms that have a total surface area of 760 acres and more in Québec and Montérégie West, 1991-2011.

3.3.1.2. Distribution of Farms by Production Sector

The distribution of farms by production sector shows that in Montérégie West, activities related to animal farming (51%) are slightly ahead of those dedicated to crop production (49%) (Statistics Canada, 2011b) (Figure 10).

In Montérégie West, cattle farming comes first, being the main agricultural activity. Other crops and cereal crops and oilseeds also occupy a prominent place in Montérégie West, representing 23% and 14% respectively (Figure 10). The pattern of dominance of the three aforementioned sectors is seen in all the RCMs (Figure 10).

It is noteworthy that the number of farms dedicated to crop production activities in Montérégie West is largely in terms of maize and vegetable cultivation, with 39% and 13% respectively. And when it comes to animal farming the importance is given to cattle and milk production, with 18% and 14% respectively.

Moreover, within Montérégie West, corn production, beef production and dairy dominate respectively, with the RCM of Le Haut-Richelieu having the largest number of farms dedicated to producing grain corn (393 farms) and the RCM of Le Haut-Saint-Laurent with the largest number of farms dedicated to beef production and dairy production - 217 farms and 154 farms, respectively (Figure 11).

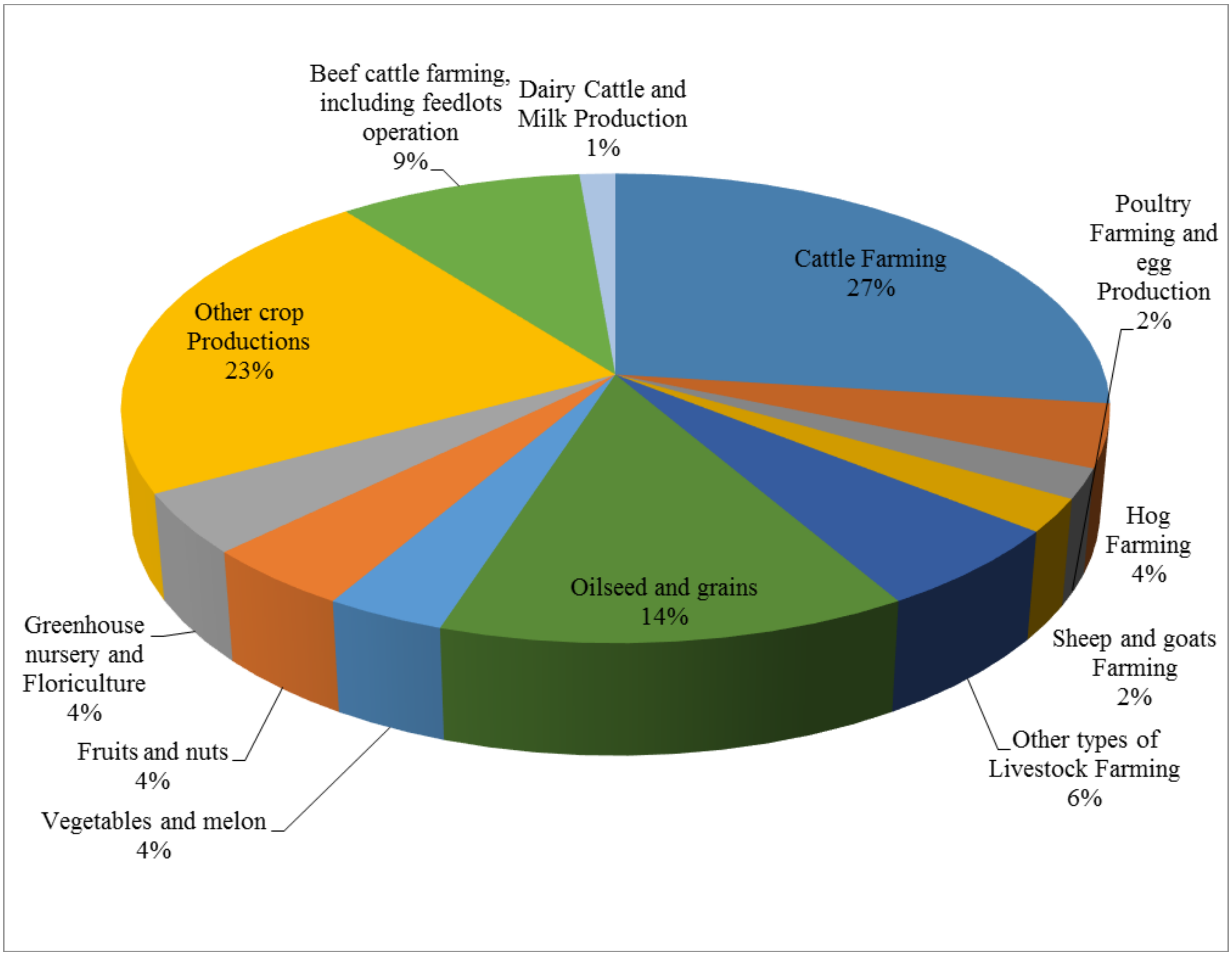


Figure 10: Percentage distribution of different components of agriculture by sector of production in Montérégie West, 2011. Statistics Canada, 2013 Agricultural Census.

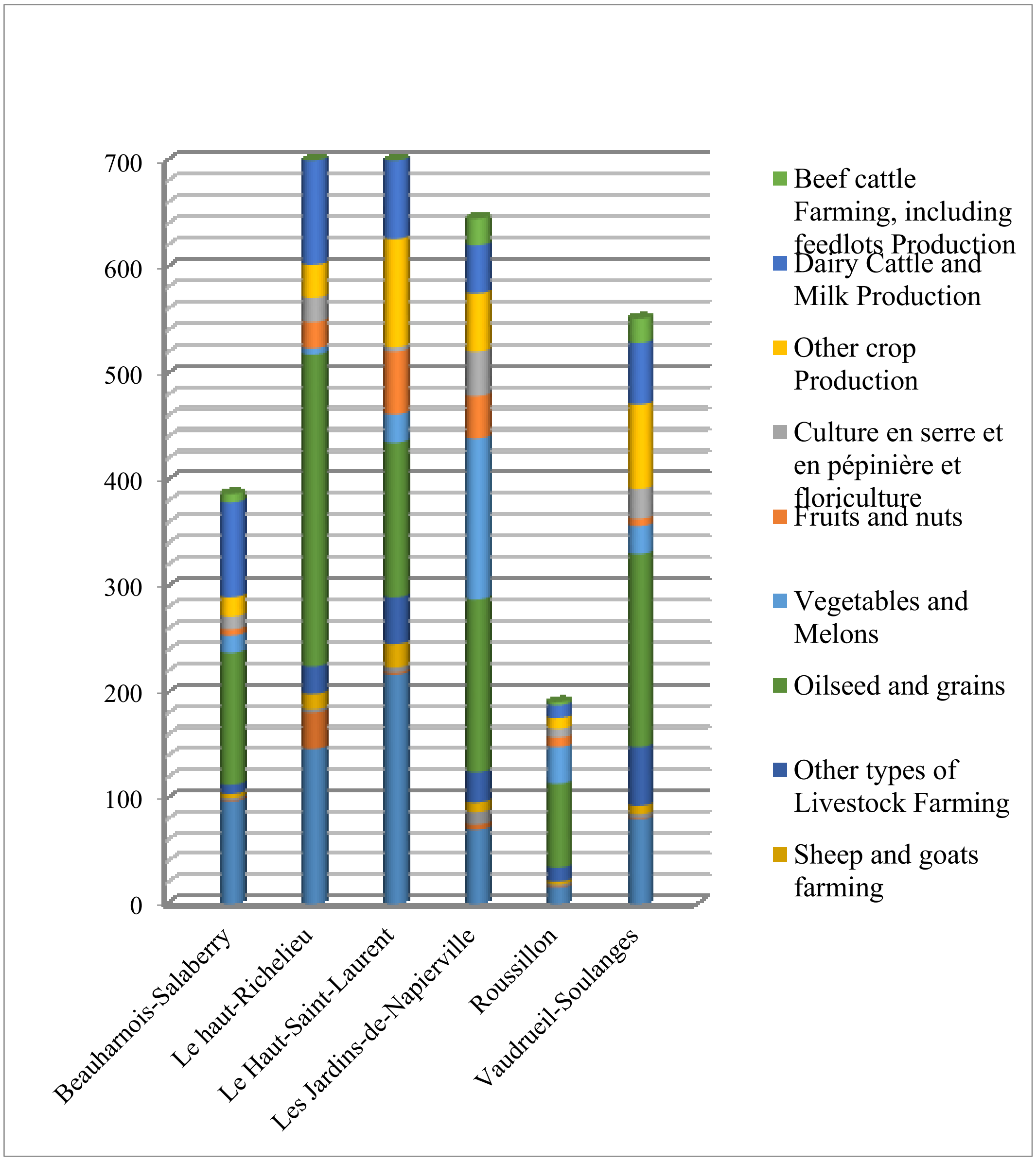


Figure 11: Number of farms of different components of agriculture by sector of production within each RCM in Montérégie West, 2011. Statistics Canada, 2013 Agricultural Census.

Furthermore, farming in the RCM of Haut-Richelieu is fairly diversified – with 50% in crop production and 50% in animal production (Figure 12). Cereal and oilseed production are the main agricultural activities in the RCM of Haut-Richelieu, representing 39% of all the agricultural activities in the RCM in relation to the value of production. Also, cattle farming occupies a prominent place in the RCM of Haut-Richelieu in relation to the value of production, representing 20% of all the agricultural activities in the RCM (Figure 14). When it comes to crop production, corn and soybeans are mainly grown in the RCM of Haut-Richelieu, accounting respectively for 33,626 hectares (or 31%) and 14,569 hectares (or 23% of the area of the crop) of Montérégie West accordingly (Figure 13).

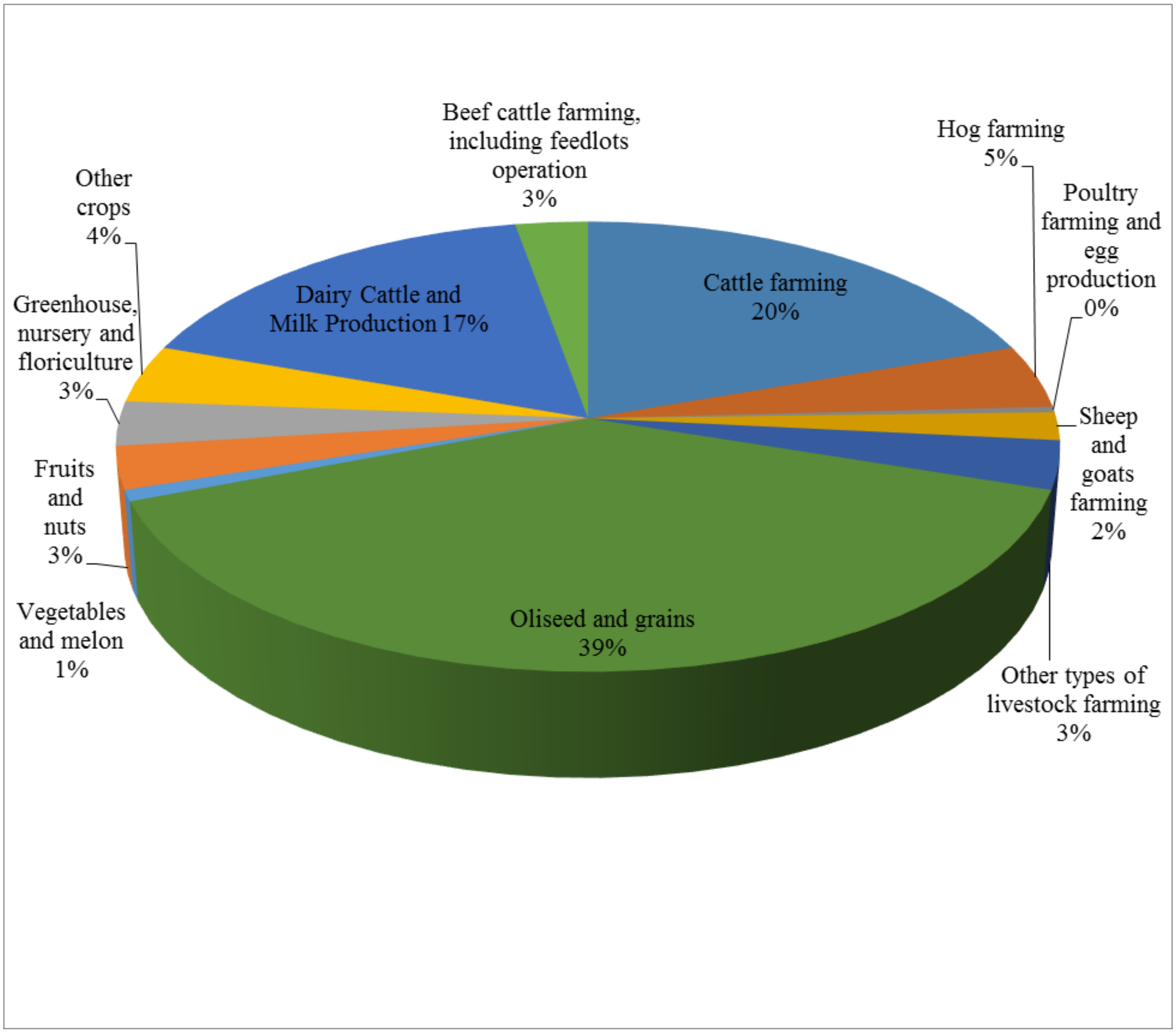


Figure 12: Percentage distribution of different components of agriculture by sector of production, based on revenue, in the RCM of Haut-Richelieu, 2011. Statistics Canada, 2013 Agricultural Census.

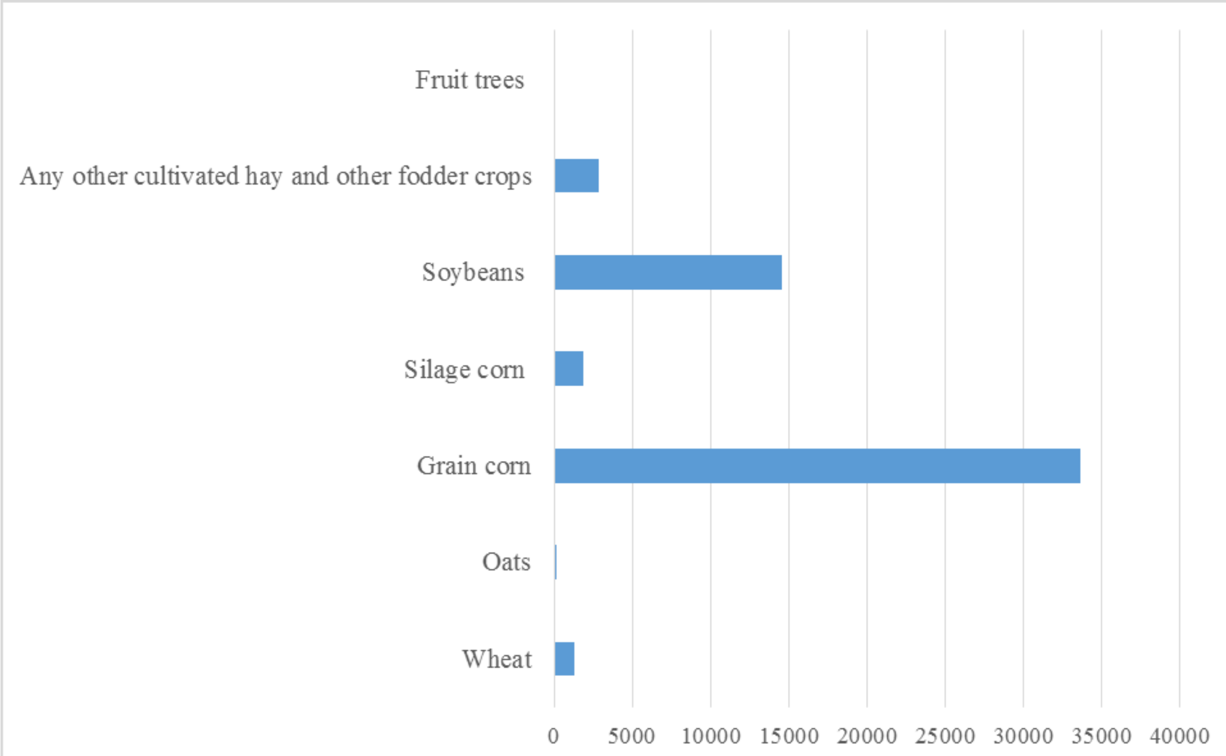


Figure 13: RCM of Haut-Richelieu: Area of cultivated crops in hectares in 2011, Statistics Canada, 2013 Agricultural Census.

3.4 Land Use and Management of Land

Land Use

An analysis of land use in Montérégie West reveals that most of the land is cultivated (or cropland). Indeed, in 2011, the area of cultivated land alone represents 97% of all agricultural land in Montérégie West (Figure 14). For the same period, fallow land is very negligible. For instance, natural land for pasture occupies 2% while seeded pasture represents 1% of the land. Within Montérégie West, in 2011, it is the RCM of Haut-Richelieu that has the largest area of cropland, while the fallow land is greater in the RCM of Jardins-de-Napierville. And when it comes to natural land for pasture or seeded pasture, it is the RCM of Le Haut-Saint-Laurent that is at the top (see Table 4).

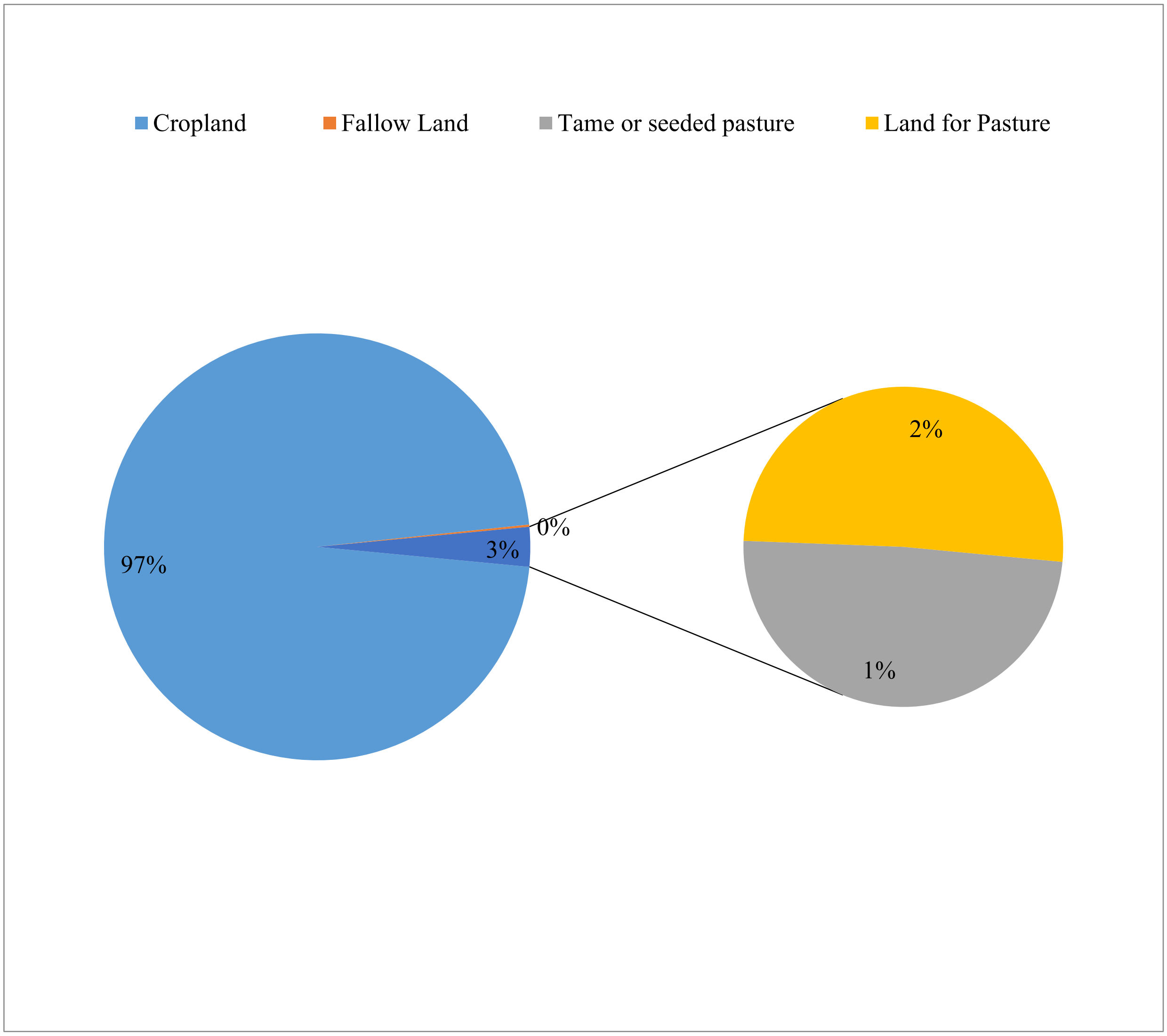


Figure 14: Land Use in Percentage Montérégie Ouest, 2011.

Table 4: Land use in Hectares in Québec and Montérégie West, 2011.

	Cropland	Fallow Land	Tame or seeded pasture	Land for Pasture
Beauharnois-Salaberry	29129	0	263	462
Le haut-Richelieu	60524	29	509	477
Le Haut-Saint-Laurent	48042	57	1611	4 370
Les Jardins-de-Napierville	43949	207	605	1696
Roussillon	15948	25	68	195
Vaudrueil-Soulanges	46086	96	649	1011
Total or Montérégie West	243678	414	3705	3841
Québec	1 874 760	4 529	126 334	134 147

Agricultural Land owned by their Farmers

In Montérégie West, the majority of farmers own the land in use, representing 79% in 2011 (Figure 15). This number is the same for 2006. However, in both periods, this rate is much lower than for Québec (or the provincial average). The RCM of Haut-Saint-Laurent and the RCM of Haut-Richelieu are localities with the largest areas owned by farmers in Montérégie West (Table 5).

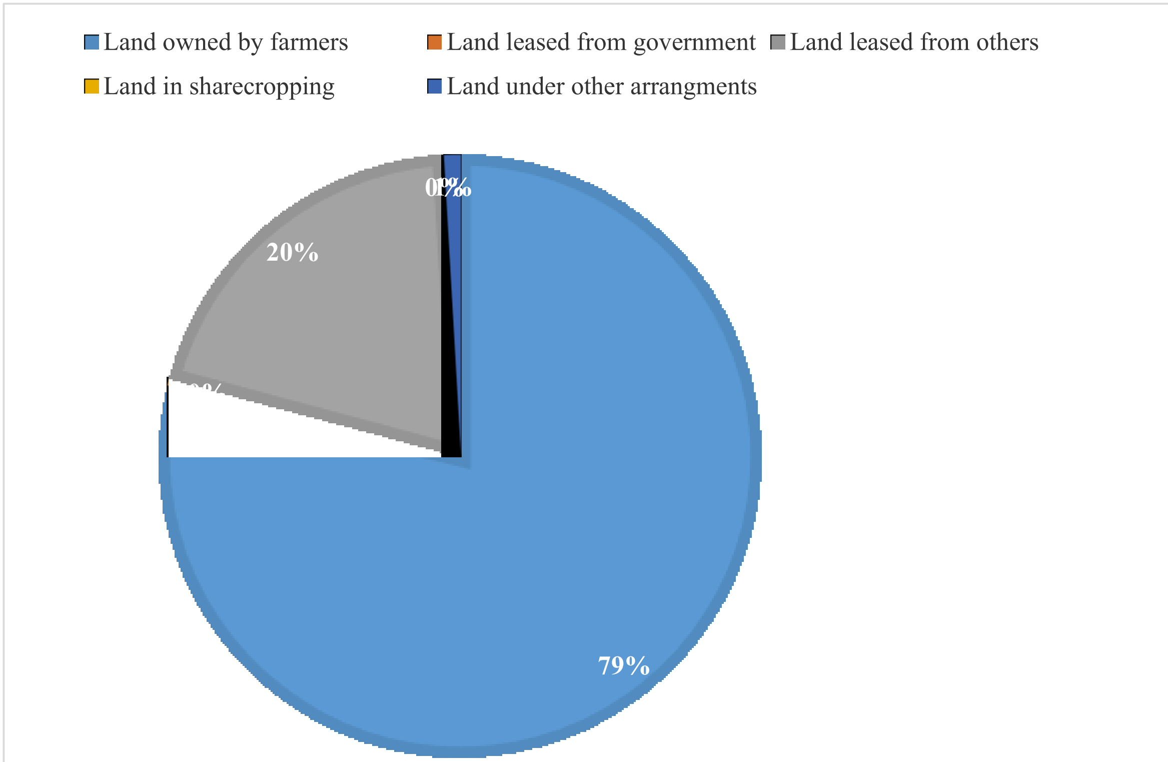


Figure 15: Tenure of Land in Percentage in Montérégie West, 2011.

Table 5: Tenure of Land in Montérégie West and Québec, 2011.

	Land owned by farmers	Land leased from government	Land leased from others	Land in sharecropping	Land under other arrangements
Beauharnois-Salaberry	24 738	X[13]	7 434	X[13]	125
Le haut-Richelieu	57 737	387	13 504	91	431
Le Haut-Saint-Laurent	61 907	274	12 300	156	516
Les Jardins-de-Napierville	42 808	676	16 991	75	726
Roussillon	12 568	X[13]	4 703	X[13]	333
Vaudrueil-Soulanges	42 181	X[13]	13 500	X[13]	504
Total or RCM of Haut-Richelieu	241 939	1337	60 998	322	2 635
Québec	2 807 471	60 528	547 844	4 536	35 855

3.5 Farm Income

Farm income is another revealing element of the agricultural sector. Figure 16 shows that the majority of agricultural enterprises in Montérégie West are in the higher categories of gross farm income compared to Québec. In 2011, 36% of agricultural enterprises in Montérégie West generated an excess of $250,000 in terms of revenue, compared to 29% for Québec.

[13] Supressed to meet the confidentiality of the Statistics Act.

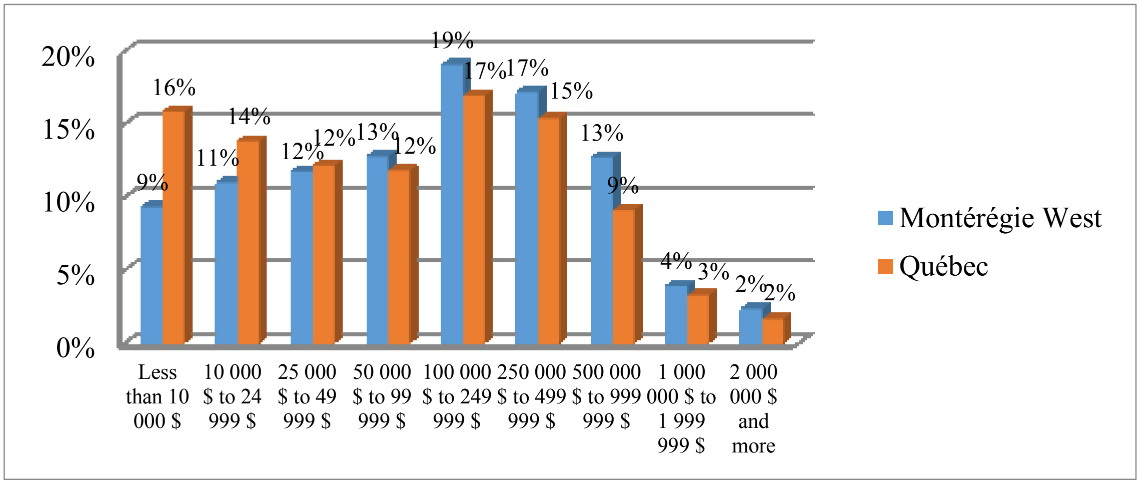


Figure 16:Classification of Farms (%) by Total Gross Farm Income in Montérégie West and Québec, 2011.

Furthermore, the 2011 Agricultural Census shows a trend towards the consolidation of farms in Montérégie West, depending on the value of their agricultural capital (Figure 17).

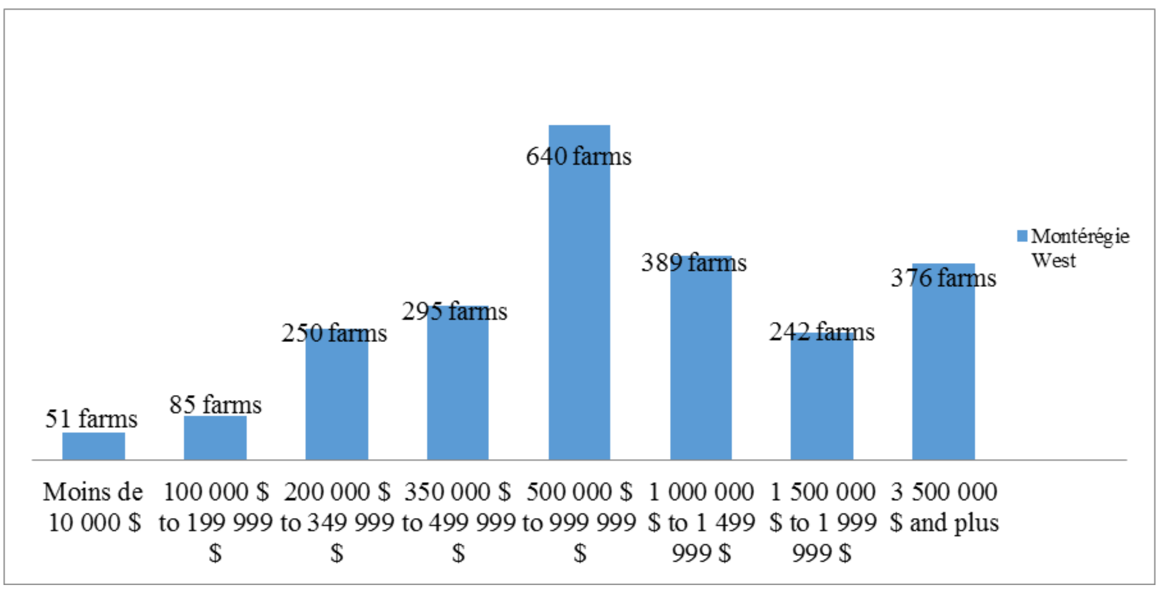


Figure 17: Farms claasified by total farm capital in Montérégie West, 2011.

3.6 Farm Capital and the Value of Agricultural Lands

The distribution of farm capital is another important indicator of the profile of the agricultural sector. In 2011, land and buildings represent more than 2/3 of the total value of farms in Montérégie West (84%), against 13% for the market value of all machinery and agricultural equipment and only 3% for the value of livestock and poultry (Figure 18). Figure 19 shows that the market value of the land is more important in Québec compared to Montérégie West.

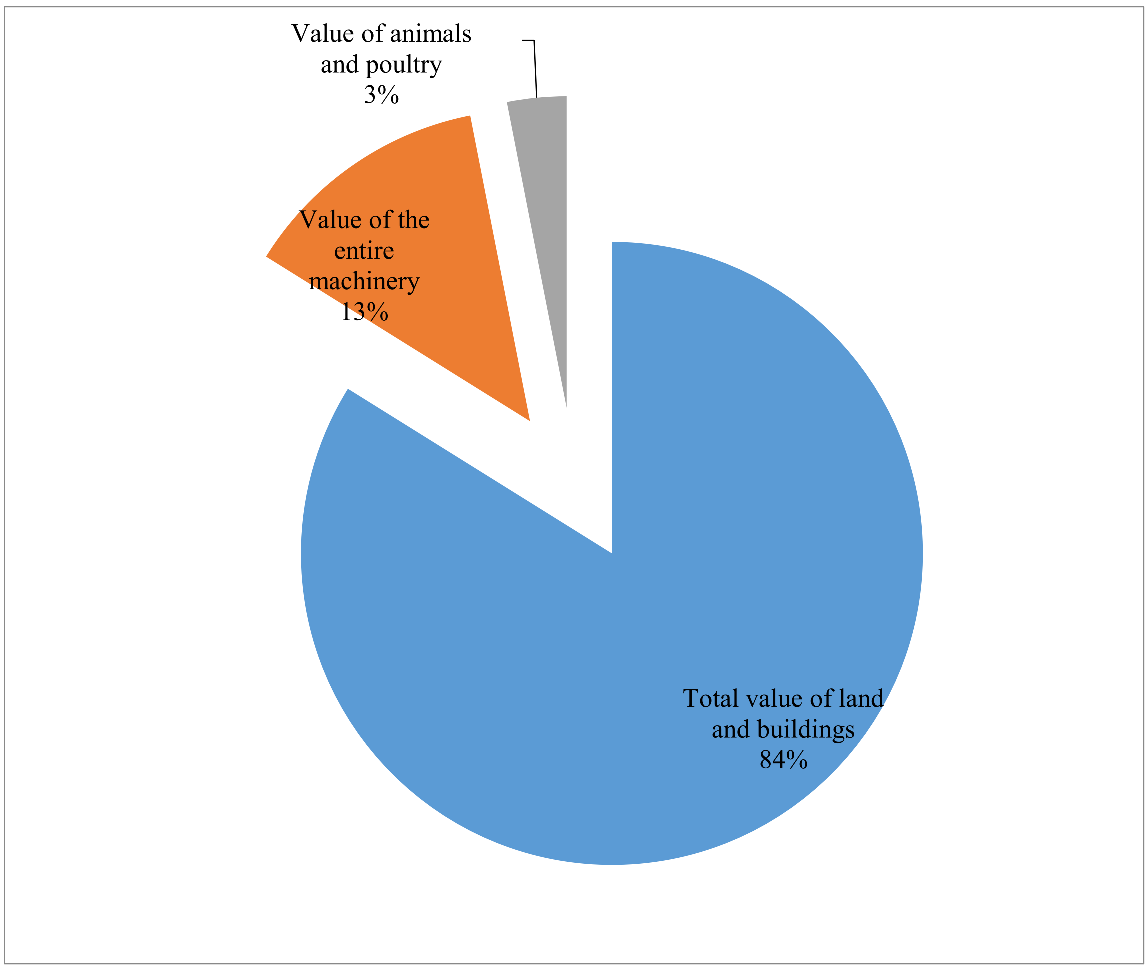
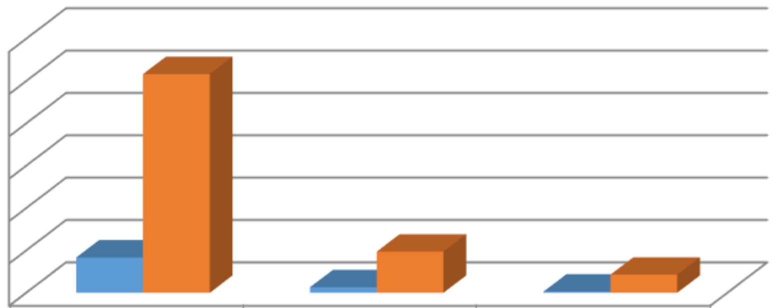


Figure 18: Value ($) of Farm Capital (en %) in Montérégie West, 2011.



	Total value of land and buildings	Value of the entire machinery	Value of animals and poultry
Montérégie West	4172063008	649561496	153276782
Québec	25827165626	4860342534	2138557886

Figure 19: Value ($) of Farm Capital, in Québec and Montérégie West, 2011.

3.7 Agricultural Labour

A farm is also a business that generates expenditures among which there are the wages of employees. In 2011, payroll (hired labour) on farms in Montérégie West amounted to almost 100 million dollars ($ 99,943,428), of which 36% was paid to members of the farmer's family and the rest (64%) to other employees (Figure 20). This distribution of salary expenses remained substantially the same for Québec (41% and 59% respectively), and there has been no noticeable change since 2006.

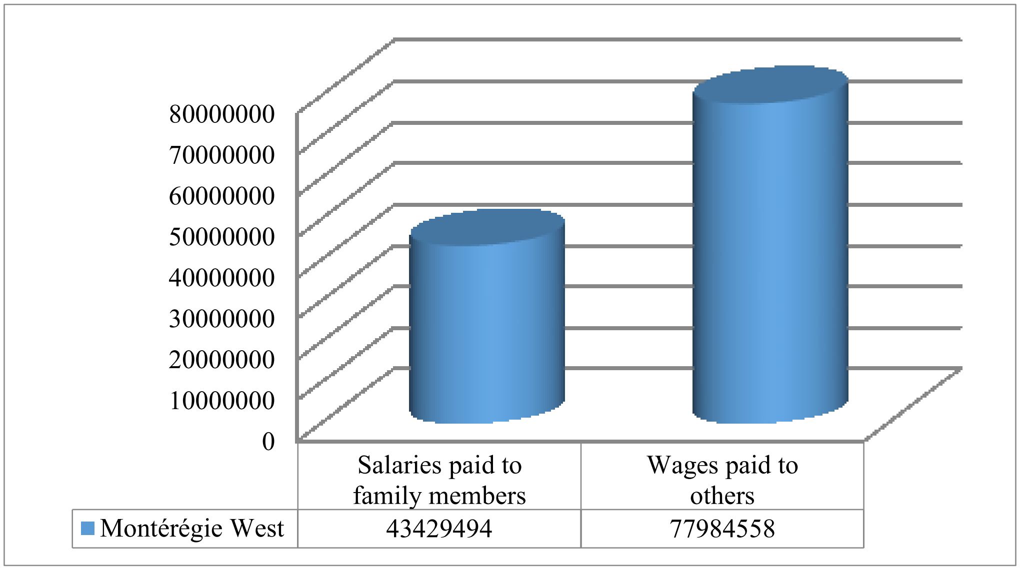


Figure 20: Payroll distribution in Montérégie West, 2011.

3.8 Agricultural Inputs and Cultural Practices

Generally, the use of agricultural inputs such as herbicides, insecticides, fungicides and chemical fertilizers varied significantly in Montérégie West over the last twenty years, especially regarding the use of herbicides, fungicides and chemical fertilizers between 1991 and 2010. For instance, there was an increase in the use of herbicides in contrast to the use of fungicides and fertilizers (see Figure 21). And this increase is associated with the dominant plantation of maize and soya. Insecticides are mostly used for growing vegetable crops and orchards.

For the RCM of Haut-Richelieu, there is an increase in the three major varieties of pesticides (see Figure 22).

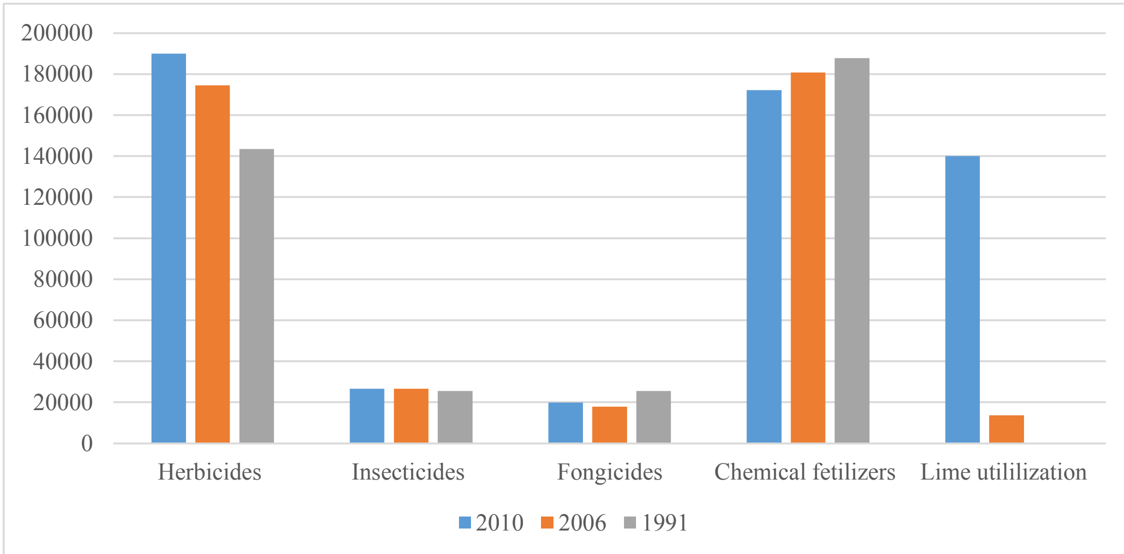


Figure 21: Evolution of product application on agricultural lands (in hectares) in Montérégie West, 1991-2010.

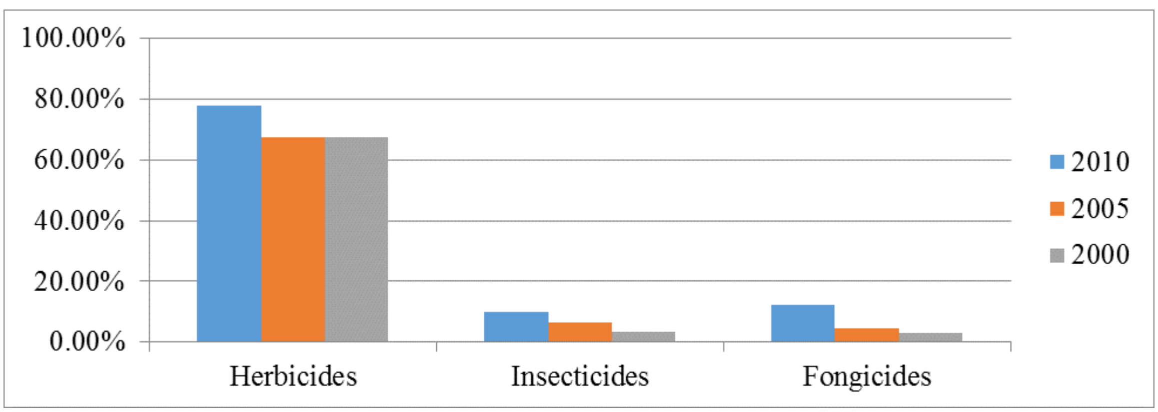


Figure 22: Evolution of the biggest categories of pesticides in the RCM of Haut-Richelieu.

Arable land is only a surface layer of soil on the surface of the earth, and only about a foot in depth. This layer is fertile and therefore represents a growth medium for plants. Nevertheless, it also serves to retain water, air and organic waste. It can thus transfer nutrients contained in these plants. However, this thin layer is very fragile since it can be seriously affected by wind or water erosion.

Erosion is a natural phenomenon, but some agricultural practices accelerate soil erosion. When farmers plough too deeply, they reduce the particle size, which makes the soil more vulnerable to erosion. Leaving the soil bare for long periods, as in the case of several monocultures, contributes to soil erosion since it is not retained by vegetation. Excess of weeding is another factor that contributes to erosion. Erosion makes the land less productive and causes an increase in suspended solids (TSS) in the river, which can facilitate the presence of pesticides and fertilizers in the rivers. And increase in TSS reduces photosynthesis and some water bodies may even suffer from eutrophication. In fact, a high concentration of TSS can change the bed of rivers and can cause the siltation of spawning grounds. Figure 23 shows a decrease in all the uses of cultural practices to limit soil erosion in the farms of the RCM of Haut-Richelieu.

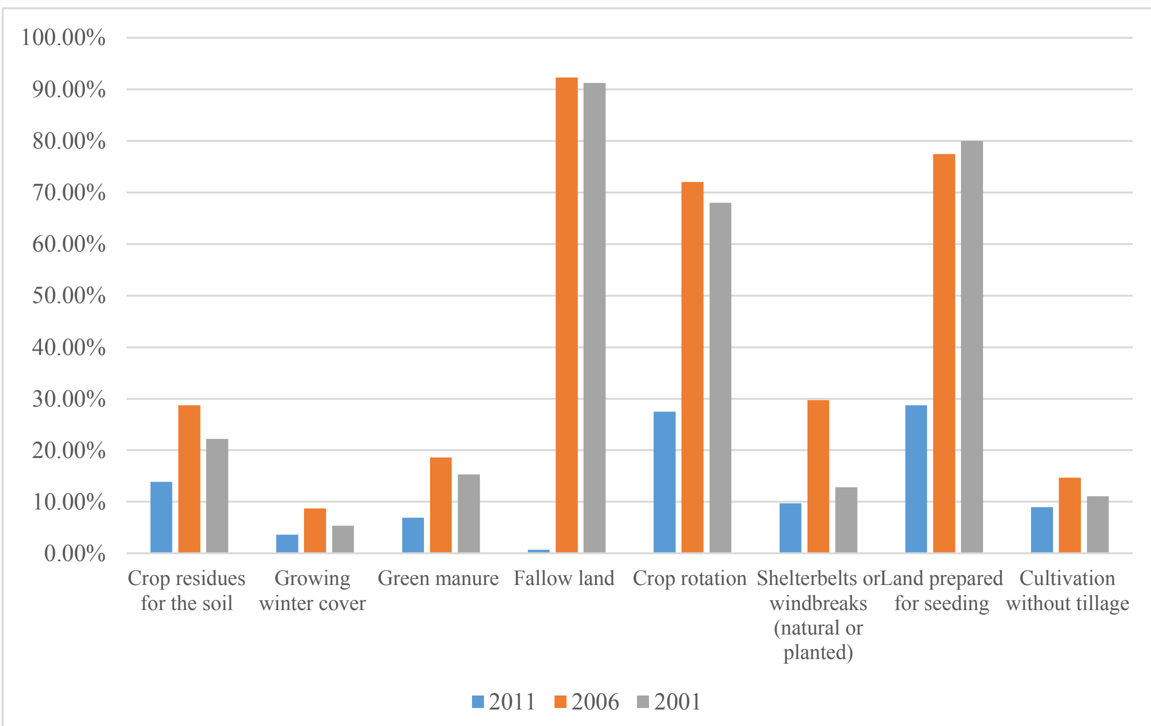


Figure 23: Evolution in % of farms using cultural practices that aim to limit soil erosion.

3.9 Crop Insurance and Crop Damage

In Québec, the FADQ has a responsibility to protect agricultural producers against a number of natural risks that can cause yield losses. Also regarding crop insurance in Montérégie West, the past decade has been marked by a significant increase in the insured acreage of major crops. In 2010, the insured acreage for corn, wheat, soybeans and hay, showed a marked progression from 81,291 hectares in 2000 to 122,200 hectares in 2010, an increase of 50% between 2000 and 2010. Corn is still the main insured crop in Montérégie-West (FADQ, 2010; FADQ, 2013b), representing 62% of the total insured crop acreage in Montérégie-West in 2010 (FADQ, 2010). And the most insured acreage of corn for the period 2000-2010 is found in the RCM of Vaudreuil-Soulanges and the RCM of Roussillon respectively (FADQ, 2011 cited in Bryant *et al*., 2011). During this same period, insured acreage for the major crops peaked during 2002 and 2007, which underscores the presence of unfavorable climatic events that have caused damage to crops (FADQ, 2011 cited in Bryant *et al*., 2011).

Moreover and apparently, there is a weak correlation between the insured crop acreage and the compensated one. For example, in 2007, a record year for insured agricultural land in Montérégie West, only 1% of the insured agricultural land was compensated for corn (FADQ, 2011 cited in Bryant *et al*., 2011). And it is the RCM of Haut-Richelieu that registered the largest number of compensated grain corn producers in 2000 and in 2006 for the period 2000-2010 (FADQ, 2011 cited in Bryant *et al*., 2011). The evolution of the compensated agricultural areas during the past decade is much greater for corn grain and soybean because of the relative importance of these crops and their sensitivity to climatic variation, compared to wheat and barley (FADQ, 2011 cited in Bryant *et al*., 2011).

The compensation is mainly due to less favourable weather conditions to crops, therefore justifying the importance of agricultural (or crop) insurance. The main cause of damage to grain corn in Montérégie-West and in the RCM of Haut-Richelieu remains excessive rain and to a lesser extent, frost (late and early) and drought (FADQ, 2011 cited in Bryant *et al*., 2011). For the RCM of Haut-Richelieu, these causes of damage to grain corn for the period 2000-2009 have remained the same, in order of importance too, for the period 1982-2003 (Bryant *et al*., 2005).

CHAPTER 4. METHODOLOGY

4.1 Grounded Theory Approach

Since the co-construction of agricultural public policies increasingly started as a bottom-up approach, the methodology employed here is grounded theory. The latter began as a bottom-up method, based upon actual research experience (Glaser and Strauss, 1965). Its origin comes from the work of Barney Glaser and Anslem Strauss as a method of enquiry used in qualitative research and developed from their collaborative work in medical sociology, in 1965. The aim of the method is to explore basic social processes and to understand the multiplicity of interactions that produces variation in that process (Mead, 1934). It is frequently applied in social sciences (e.g. human geography) especially for qualitative research.

According to Glaser (1963, 1998), the theory emerges from a process of data collection through primary data (i.e. interviews and/or focus groups) and secondary data (collected from literature review and data from organisations such as Statistics Canada and other websites) (Figure 24).

This approach is a way to develop tools or agricultural policies or recommendations in the fields of adaptation of agriculture to climate change and variability at the farm level in a decentralized (bottom-up) manner involving a group of actors. This type of approach is used for connecting indicators and integrating and managing interaction between individuals, and collective and scientific knowledge. It is no longer the optimum which is sought but a compromise, not only a compromise between the actors involved, but a compromise between practice and theory; and this is reached by a dynamic process of progressive adjustment and learning. It is more likely to suit the diversity of actors' values or visions. During the application of a grounded theory approach, data analysis and interpretation and theory building occur at the same time as data collection. It is a pro-active approach. What makes it original is the regional nature of the approach. The theory is formed based on actors' issues and representations, thereby encouraging their appropriation. In other words, it is an approach where adaptation takes place as a bottom-up process, with the possibility of government stepping in to provide incentives.

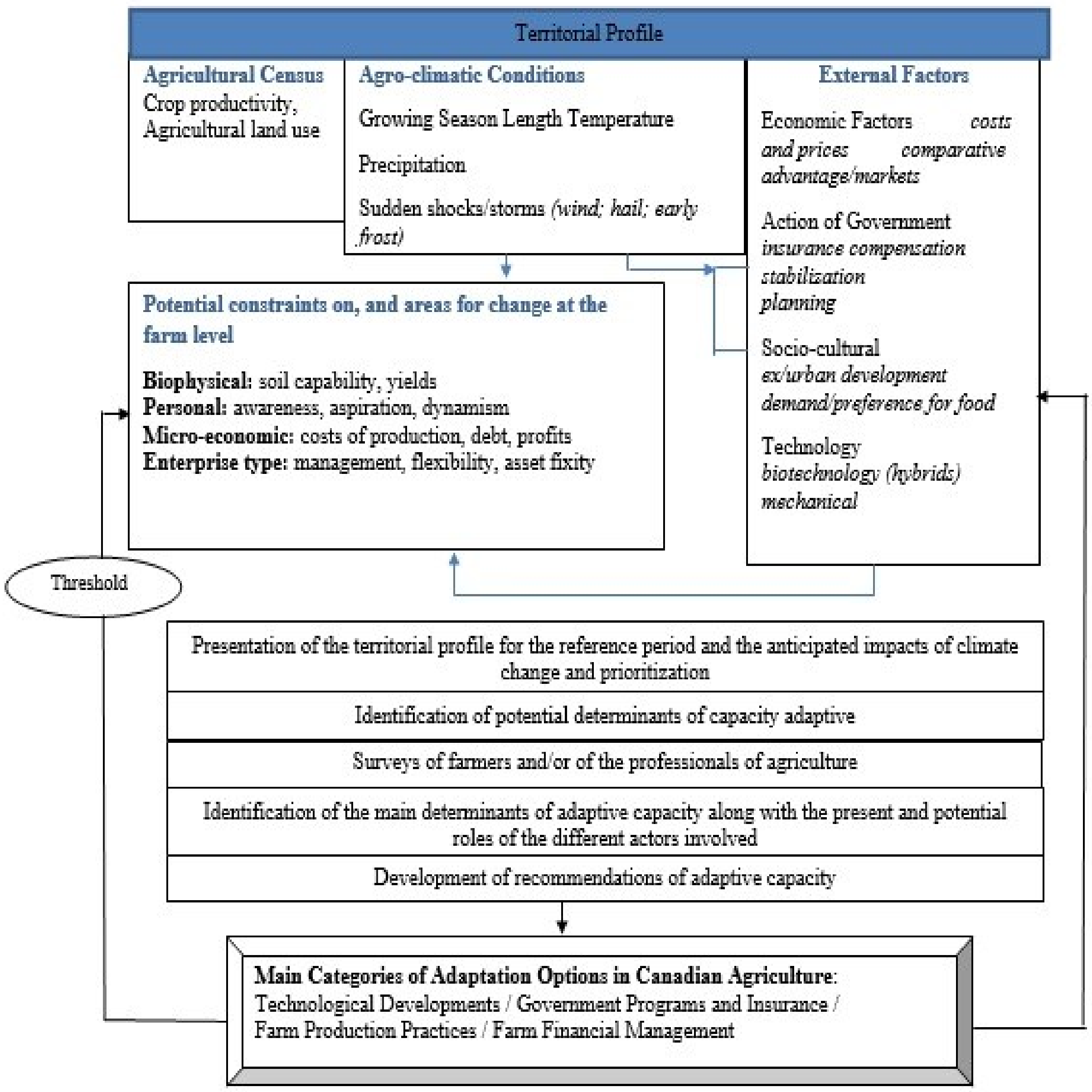


Figure 24: Steps of the Methodology[14]

[14] Source: Akkari Cherine, 2013. Inspired from and Smiths and Smit (1997) and from Délusca (2010).

4.1.1 Size and Type of Sampling

Glaser (1998) stated that within classic grounded theory there is no sample size, nor are limits set on the number of participants or data sources; it just involves sampling for saturation and completeness and is basically theoretical, which leads to an ideational sample rather than a representative sample. According to Stern (2007), sampling size is not a very important criterion in a qualitative research approach as long as the researcher can identify the key participants for his/her research objective. In addition, it is the responsibility of the researcher to be able to establish confidence between him/herself and the respondents. For these reasons, the respondents were selected based on the snowball sampling strategy, which was originally developed by Coleman (1958-1959) and Goodman (1961) as a means for studying the structure of social networks. Snowball sampling is one of the three most common sampling methods used in qualitative research (Mack *et al*., 2005, p.16). It is a strategy that helps to:

(1) Identify information-rich cases (or the well-suited interview participant),
(2) Recruit hard-to-reach (or hidden) populations, that is, groups that are not easily accessed through other sampling strategies; this underlies the non-probabilistic form of this sampling strategy, and
(3) Establish a trust between the interviewer and the interviewee (mainly because it takes advantage of the social networks of identified respondents).

4.2.1.1 Recruitment of the Participants

At first, the recruitment of the participants was attempted via more formal structures or organisms, such as the UPA and agro-environmental clubs, to reach the possible maximum number of actors. However, with the failure of the latter due to administrative and bureaucratic barriers, an informal approach was taken and it turned out to be much more successful particularly in terms of time required.

Since the targeted audience are the farmers, taking into account their hectic schedules was a must for the planning of the interviews. Therefore, contacts with farmers started at the end of the Fall.

The first initial contact was made by phone. Its objective was to explain to the participants the research objectives for this thesis and ultimately to seek their agreement for participation in the interviews. An appointment was made only after the formal approval of the farmer. The interviews were conducted either at the farmer's home or at his/her farm. At the end of each interview, the respondent was asked to provide the coordinates of other farmer(s) in the area who might be interested in participating in the study. This approach is very effective in the sense that sending a letter of introduction to the participants was not needed. Indeed, using the snowball method was very facilitating by the fact that existing social relations between farmers were skillfully played on, as discussed in the previous sub-section 'Size and Type of Sampling'.

4.2 Data Collection

Usually, it is argued that interviewing a diverse group of actors is one of the primary characteristics of grounded theory because it maximizes similarities and differences of information (Creswell, 2009, p.13). However and as stated before, theoretical sampling is different than statistical sampling. So sometimes, it may only require a few groups or similar group(s) to gain sensitivity to differences between groups and to establish a definite set of conditions when a particular category needs to be recognized (Glaser and Strauss, 1967). The main primary data for this thesis comes from interviewing one type of group of actors – farmers. The other primary data comes from agronomists, and it is used for gleaning and/or cross-checking the different information provided by the farmers (Appendix 5).

Secondary data have already been collected and represented. The concept of secondary data appears to have first entered the literature around 50 years ago with Glaser (1963, p.11). As one can see from the previous sections, there is a substantial documentation on the adaptation of agriculture to climate change and variability in the

Canadian context in general and in Québec in particular. Also data such as from the Agricultural Census of Statistics Canada are also helpful to analyze the evolution of the bio-food sector in Québec in general and in Montérégie West and the RCM of Haut-Richelieu in particular. Both data- primary and secondary- are useful in developing the co-construction of agricultural public policies.

4.2.1 Semi-structured Interviews

Semi-structured interviews are the most commonly used methods of data collection, especially in qualitative research (DiCicco-Bloom and Crabtree, 2006). Campbell et al. (2013) considers the semi-structured interview data as the empirical backbone of much qualitative research in social sciences. Semi-structured interviews, consisting of open-ended questions, were undertaken for this thesis because they are well suited for the exploration of the perceptions and opinions of respondents regarding complex- and sometimes sensitive issues (Barriball and While, 1994). They also enable probing for more information and clarification of answers (Barriball and While, 1994), and allow the respondent to express an opinion without being influenced by the researcher (Foddy, 1993, p.127).

Primary data collection was done by carrying out 15 interviews in total, for a period of around 4 months (from November 14/ 2014 until February 10/2015). Each interview did not take more than 1 hour. Even though contacts started to be made at the end of the Fall of 2014, farmers were still quite busy during this time of the season; so interviews were organized to not be too time-consuming for the farmers. Each interview was individual and registered on an audio-tape with the agreement of the farmer. Fortunately, all 15 farmers contacted agreed on registering their answers or discussions. And of course, notes were also taken during each interview. Later on, the interview recordings were transcribed verbatim. Further and since the majority of the farmers mentioned the importance of the agronomists, a focus group between three agronomists was done on March 25 in the municipality of Napierville to glean and/or to cross-check the various information given by all 15 farmers. The focus group lasted 1 hour sharp and all the three agronomists in the focus group agreed on registering the discussion fortunately. The results of the focus group is found in Appendix 5.

The interviews began with general questions that help to determine the profile of the participant (i.e. municipality, sex, age, type of production and total cultivated surface area). The other questions are open-ended and they explore the set of issues about adaptation to climate change and variability in the RCM of Haut-Richelieu (Appendix 2 and 4). More precisely, the questions explore how farmers view climate change, how they view adaptation in the context of climate change and what they have done (i.e. which strategies they take?) to adapt, and what they need to in order to better adapt. Some questions encourage the farmer to analyze his/her position in relation to the global warming phenomenon (e.g. "Do you think your farm is already adapted to climate change? How? or "Do you think that agriculture in the region can adapt to climate change?"). Other questions led the farmer to take a position against climate change (e.g. “Do you think that agriculture should adapt to climate change?”, or “What are the determinants of adaptive capacity by order of importance?”, or “What are the factors that guide you in the selection of crops in your farm?”).

4.3 Data Analysis

In grounded theory, data collection, note-taking, coding and memoing occur simultaneously from the beginning: phase 1. Sorting occurs when all categories are saturated: phase 2. Writing – phase 3 – occurs after sorting (Dick, 2000; Fadul, 2007, p. 100) (Figure 25). The two phases tend to be cognitive and comprehensive. The third or the last phase tends to be cognitive, comprehensive and reflexive. Since there is a constant comparison (or comparative analysis), it is important to note here that these three phases overlap each other (Stern, 1980), which also means that grounded theory is quite difficult to explain by a diagram or scheme. The latter applies on Figure 25 and Figure 26.

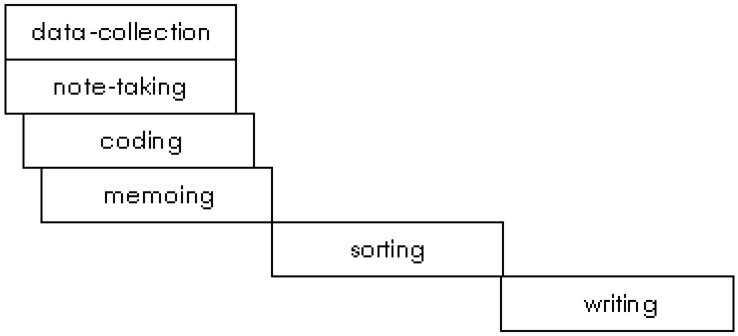


Figure 25: The overlapping phases of Grounded Theory, Dick (2000).

Data Collection and Note-taking:

A Grounded Theory study begins with a general opening of the subject area (Dey, 1999, p. 3). From this initial point, the study is continually focussed towards an area of social concern. Once a data site has been selected, collection of data (primary data) begins, which is usually in the form of open-ended interviewing and transcription (and transcription is needed to complete the note-taking process), but can include acquisition of secondary data such as documents and literature. By saying “all is data”, Glaser meant that “exactly what is going on in the research scene is the data, whatever the source, whether interview, observations, documents. It is not just what is being, how it is being and the conditions of it being told, but all the data surrounding what is being told” (Glaser, 2001, p. 145).

Coding:

The process of coding begins right after the collection of empirical data. Coding implies categorizing the data to reflect the various issues represented during the interviews. The Glaserian Grounded Theory method uses three levels of coding – open coding, selective coding, and theoretical coding (Figure 26). Open coding is the initial phase of grounded theory analysis (Glaser and Strauss, 1967; Strauss and Corbin, 1990). The coding stages can overlap since constant comparison is at the core of coding.

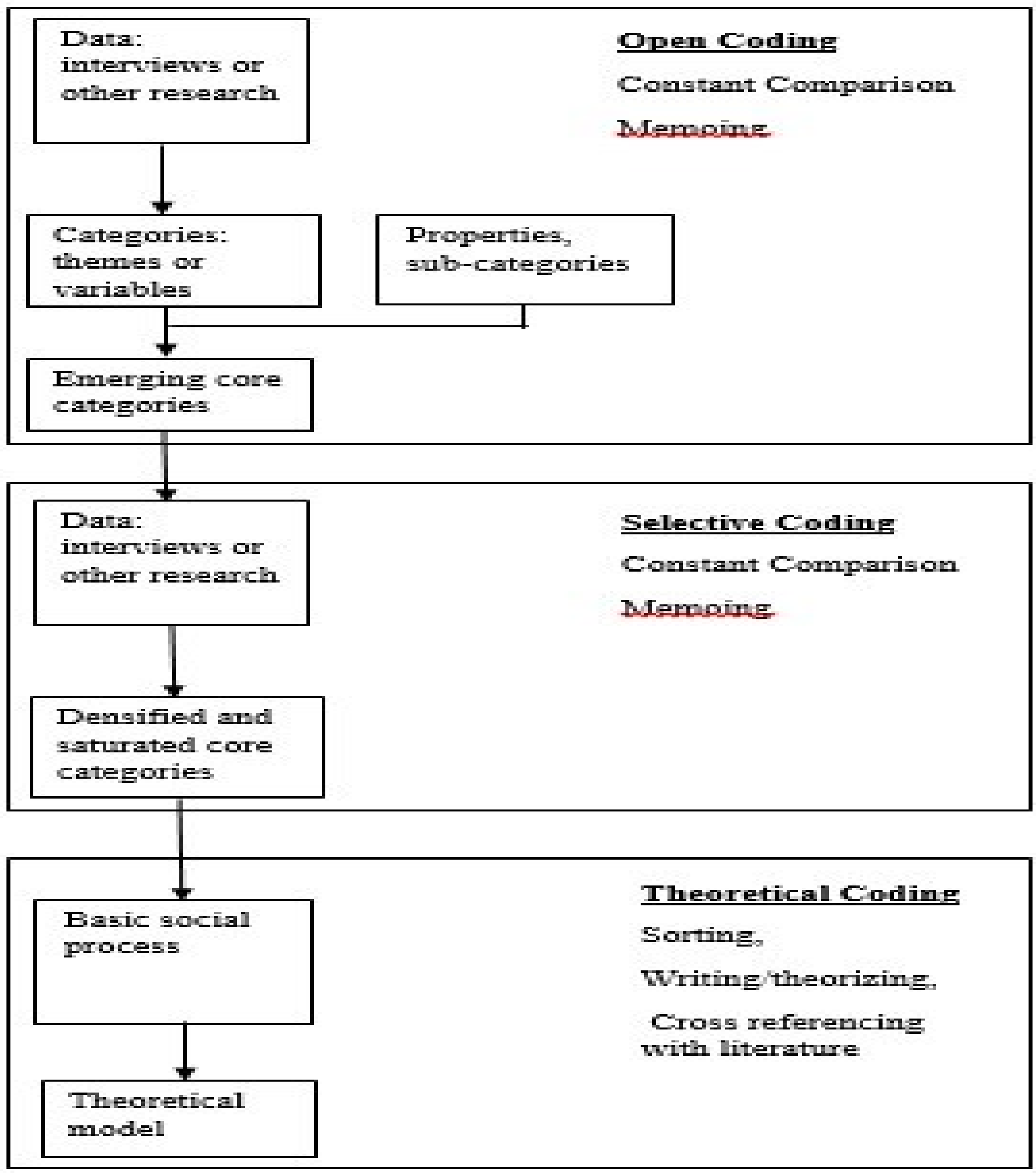


Figure 26: The three levels of coding used in Grounded Theory (based on Jones and Alony, 2011).

Memoing:

According to Glaser (1978, p. 83), memoing is "the core stage in the process of generating theory, the bedrock of theory generation." Memos should develop ideas and codes. These ideas should develop freely, be stored centrally, and be sortable (Glaser, 1978, p. 83). Memoing continues in parallel with data collection, note-taking and coding. In fact, a memo is a note to yourself about some hypothesis you have about a category or property, and particularly about relationships between categories. To summarize, a theory is concealed in your data for you to discover. Coding makes visible some of its components. Memoing adds the relationships which link the categories to each other.

Sorting:

Sorting implies putting or arranging categories based on their similarities.

Writing-up:

Writing comes after coding, memoing and sorting. It is often just a matter of writing a first draft by integrating the theories or hypotheses into a coherent argument.

Given the fact that are several methods in applying grounded theory, Chesler (1987) was the one – and maybe the first – who clearly described the steps used in grounded theory. Hence data analysis for this thesis followed his method. There are seven analytical steps according to Chesler (1987) (Figure 27).

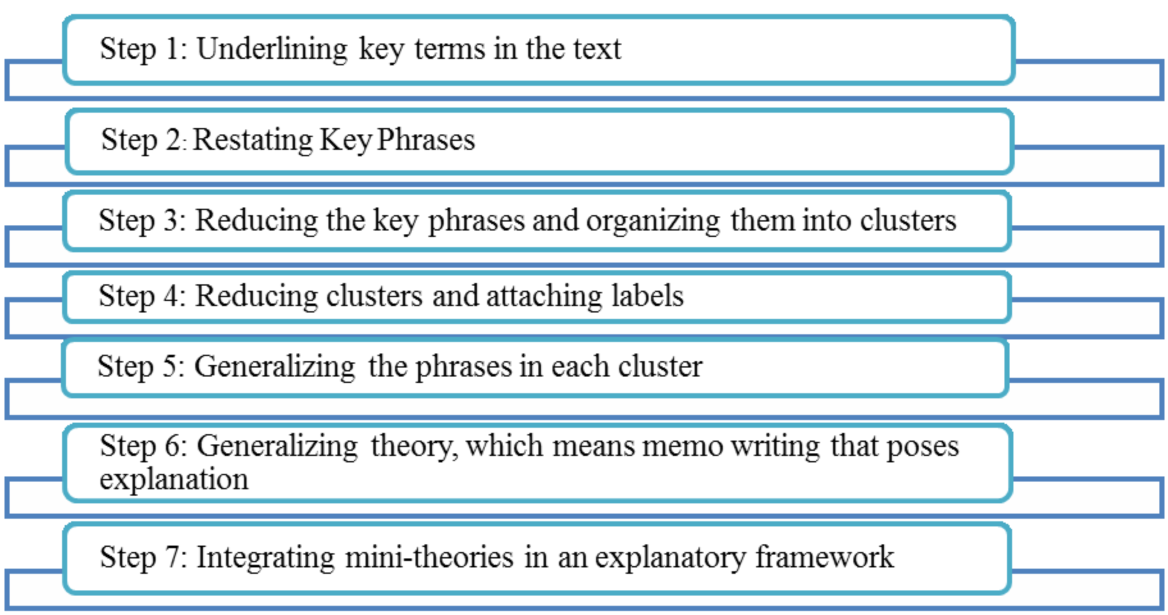


Figure 27: Analytical steps in Grounded Theory according to Chesler (1987).

“In vivo” coding, which uses participants’ own language and imagery, is done directly on the text, line by line. It is the first step in preparing a coding or analysis scheme. Of course, each interview was transcribed. Then in the text and by careful reading, key terms are underlined and restated. Step 3, which involves reducing the phrases to organise them into clusters, is repetitive since it is done several times. The latter implies de-constructing the data to later arrange into codes (or, in other words, following a constant comparison method). The process of the constant comparison method is also critical for step 4, which is known as pattern coding or meta-coding (Charmaz, 1983; Miles and Huberman, 1984). Comparisons are constantly made after the reduction in number and the combination of clusters. The end result of this step is the creation of five (5) categories of expanded codes, conceptually distinct and with a greater level of abstraction.The last three steps of Chelser (1987) include analysis and interpretation of the codes. However, they are undertaken in an inductive manner rather than a deductive manner.

For the coded data, Excel and SPSS were used mainly to produce a table of frequencies along with the variables. Results are considered significant (or in a majority) when the frequency is at least 73% (Appendix 4).

CHAPTER 5. RESULTS AND DISCUSSION

5.1 Results of the Interviews

This section presents the results of this study with the main objective of enhancing the understanding of the adaptation process and adaptive capacity at the farm and farm community levels through an ascendant approach (or bottom-up) approach, i.e. a co-construction, to develop appropriate management and planning tools and to build greater levels of capacity for adaptation in the farm community. In other words, this thesis approached the co-construction process through analyzing the role of different actors in the adaptation of farmers to climate change and variability through an ascendant form (mainly by interviewing farmers, the main actors around which adaptation process should be focussed). From that point of view, we can only investigate how different group of actors collaborate with farmers to help them adapt to climate change and variability and identify the pertinent (or present) actors along with their potential roles. The Grounded Theory method is used to analyze the data from the interviews conducted with a total of 15 farmers located mainly in the RCM of Haut-Richelieu. From the farmers' point of view, the study explored the process of agricultural adaptation to climate change and variability especially with emphasis on the relationships between the different actors and institutions involved in the adaptation process to CCV.

The results of this section are presented in its following sub-sections. The first sub-section is about the general information about participants. The second sub-section deals in detail about the five principal categories (of the open-ended questions) (see below).

5.1.1 Participants' Profile

This section presents general information about the participants, which are: sex, age group, municipality, production type, and the total cultivated surface area.

The interviewees were not from all of the different 14 municipalities of the RCM of Haut-Richelieu (Table 6).

Table 6: The Municipality of each interviewee in the RCM of Haut-Richelieu, Inquiry 2014-2015.

Interviewees	Municipality
1	Mont-Saint-Grégoire
2	Mont-Saint-Grégoire
3	Sainte-Brigide-D'Iberville
4	Saint-Jean-sur-Richelieu
5	Sainte-Brigide-D'Iberville
6	Mont-Saint-Grégoire
7	Mont-Saint-Grégoire
8	Saint-Jean-sur-Richelieu
9	Mont-Saint-Grégoire
10	Saint-Jean-sur-Richelieu
11	Saint-Sébastien
12	Saint-Valentin
13	Saint-Valentin
14	Saint-Paul-de-l'Île-aux-Noix
15	Saint-Jean-sur-Richelieu

Figure 28 represents the sex of the farmers interviewed in percentage. However, one should note that this aspect – sex – is not relevant to this kind of study, because as in many similar cases, (male) farmers are encountered in association with their spouses, and both participated in the majority of the interviews.

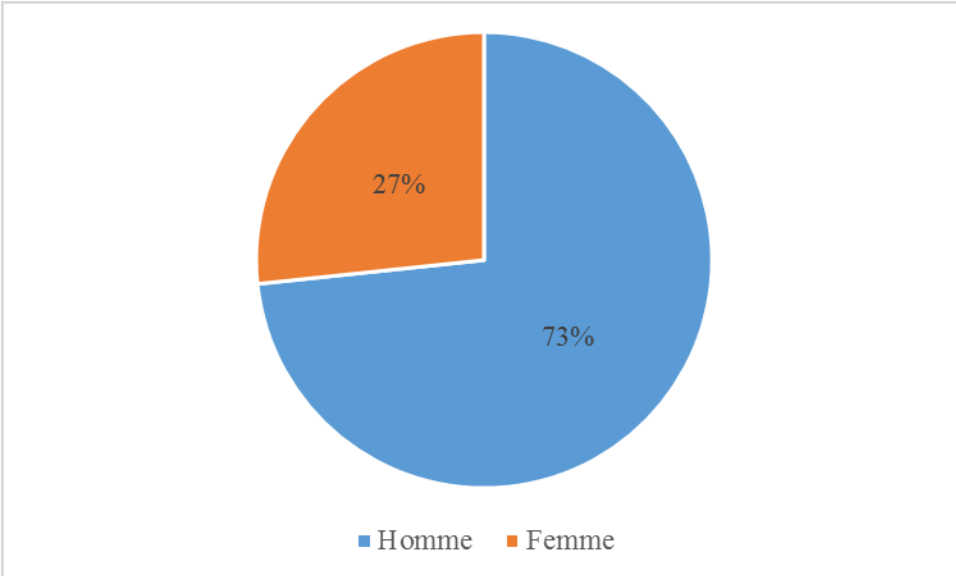


Figure 28: Representation of the Sexe of the Farmers Interviewed in Percentage, RCM of Haut-Richelieu, Inquiry 2014-2015.

One aspect that has the potential to highlight the farmers' experience in general is the age group. Figure 29 shows that the interviewees have quite a good experience in farming. It should be noted that this aspect is related to sex (in the sense that age group varies according to sex), which is not relevant to this study due to what was previously stated; hence, the aspect of age group is not very relevant to this thesis. However, age group is at least more relevant to this research topic compared to sex, because it is an indicator of the potential situation with respect to the farm's succession. Figure 29 also raises the question of farms' succession in the RCM of Haut-Richelieu.

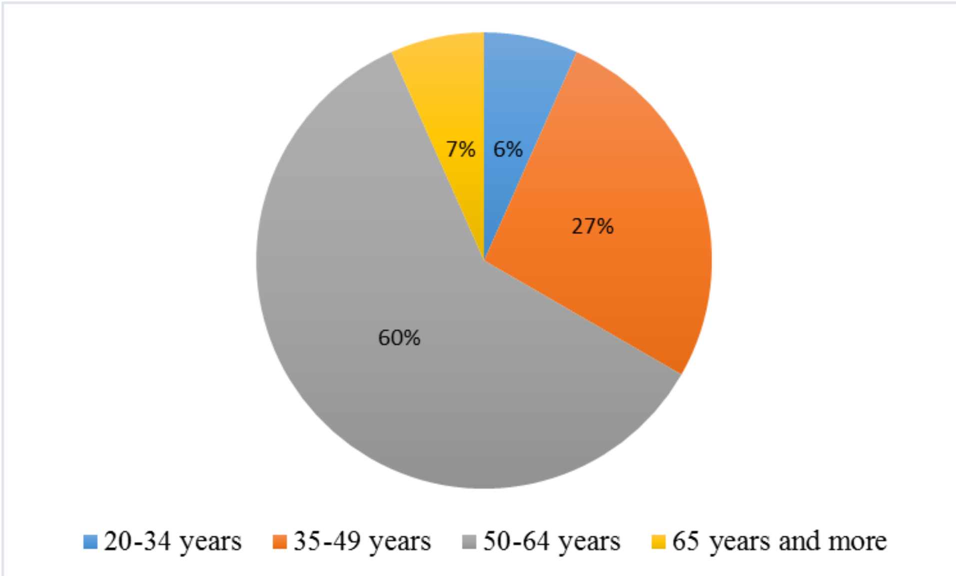


Figure 29: Age group of the farmers in percentage, RCM of Haut-Richelieu, Inquiry 2014-2015.

A third aspect, which is very relevant or pertinent to this study, is the agricultural production type. One of the specificities of agriculture lays in its diversification between many production sectors. So any study must take account of this diversity. As stated earlier (Figure 12), major (or field) crop production (oilseed and grains) is dominant in the RCM of Haut-Richelieu and Figure 30 assures the latter.

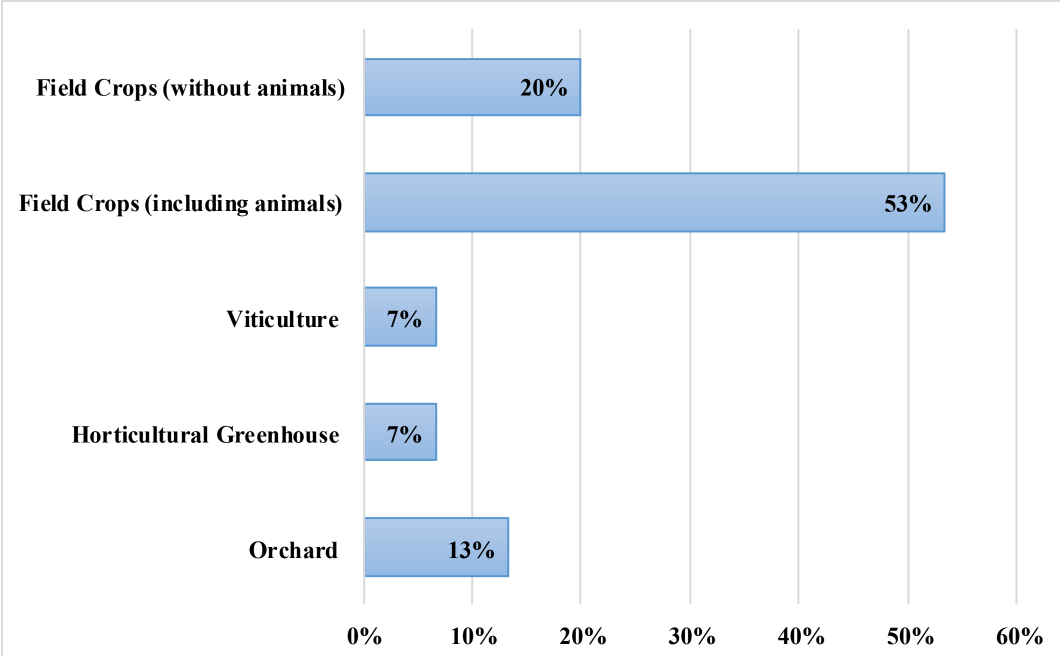


Figure 30: Percentage Distribution of Different components of Agriculture by Sector of Production, RCM of Haut-Richelieu, Inquiry 2014-2015.

All 15 participants together had a total of 2,539.37 hectares in terms of cultivated surface area (Table 7). This again highlights the importance of crop production in the RCM of Haut-Richelieu but also undermines the presence of animal farming to some extent. We can also say here that this fourth aspect, total of cultivated surface area, is not very relevant to this thesis because of what has been stated earlier, i.e. sample size is not a very important criteria in a qualitative research as long as the researcher can identify the key participants for his/her research objective (Glaser, 1998; Stern, 2007).

Table 7: Total cultivated suface area (in hectares) for all 15 participants in RCM of Haut-Richelieu.

Number of Interviewees	Total Cultivated Surface are in Hectares
1	5
2	8.21
3	0.5
4	2.2
5	500
6	30
7	140
8	50
9	44.46
10	1120
11	230
12	170
13	88
14	81
15	70
Total	2539.37

5.1.2 Results of the Open-ended Questions

This sub-section presents the analysis of the five principal categories, which are the following:

(1) Advantages and challenges of agriculture in the RCM of Haut-Richelieu,

(2) Strategies and measures taken by the farmers to adapt to CCV,

(3) Actors involved along with their current and potential roles in helping farmers to adapt to CCV,

(4) Determinants of adaptive capacity, and

(5) Recommendations from the analysis of these previous 4 categories, by integrating policies and actions of potential co-construction with the different roles of stakeholders.

In each category addressed, direct quotes are included to help illustrate and understand the current process that some qualify as emerging theory. For all 15 farmers, the analysis of each open-ended question is presented in Appendix 4.

5.2.2.1 Advantages and Challenges of Agriculture in the RCM of Haut-Richelieu

In this section, farmers spoke about the advantages and difficulties they face during their jobs.

While farmers in the RCM of Haut-Richelieu recognize that having lots of major crop production – with or without animal farming – is an advantage for their region, they also acknowledge the negative consequences that farm consolidation is having on local, regional and national levels.

"Having several farms with a strong vocation on major crop production is very beneficial for the image of our RCM" [Farmer B]

However, as negative consequences:

"*Intensive agriculture and monoculture are destroying our farms, rendering our soil more vulnerable than ever. We used to have more trees and animals than now*" [Farmer O].

"*For a small rural municipality, we are treated like any other urban or peri-urban municipality in the RCM. It is not fair given the fact that the conditions between municipalities are different*" [Farmer J].

"*There are lots of governmental subventions for the producers of corn and soy, but not for other crops like hay ("we are punished because we grow hay; because we do something good for our environment!") or any other type of production (i.e. biological farming)*" [Farmer M].

"*In Québec, we have lots of policies and regulations, which constitutes a barrier to our food production. So it is clear that policies are more important than climate change. We have to constantly feed our region and the world, to financially thrive, while we are* *competing with other countries where production costs are lower and regulations are less present*" [Farmer B].

Even the municipal taxes are considered as barriers for the farmers' adaptation to CCV.

"*... In addition, you have to pay municipal taxes for forests ("some farmers cut the trees to produce more corn and soy") but it does not work like this; it's not to our advantage. Municipal taxes must be removed and the government has to pay it like in Europe because simply it is not in our advantage*" [Farmer M].

Another challenge on the regional and local scales is the preservation of agricultural land in the face of unprecedented urban sprawl and industrialization. For most of the farmers, the proximity to urban areas and high land speculation (i.e. high price of agricultural lands associated with high competition for agricultural land purchase) are seen as a significant pressure on rural areas.

"*There are lots of demands on building commercial parks in the municipality of Saint-Jean-sur-Richelieu*" [Farmer N].

"*The government is taking the good agricultural lands for the development of the highway 10-30. Therefore the solutions that the government has are not realistic because they are short-term solutions*" [Farmer M].

There is a minority of the interviewees which views the presence of investment funds as a good opportunity.

"*Agriculture in our region is quite well adapted because of the presence of investment funds*" [Farmer E].

These investment funds are also a competitor more for the upcoming generation of farmers, which makes more difficult the acquisition of land. It is understandable that the shareholders of the funds want to stabilize their returns and diversify their portfolios by buying farmland. But if they buy land at much higher prices than what farmers would pay for them, they may not be able to touch the expected returns and even crash if the evolution of commodity prices is not favourable. The latter encourages the consolidation of farms, which is very risky.

The problem of farm succession and the need of agricultural labour were also highlighted by some of the farmers.

"*Since there are some young people who are interested in farming, they go and study agriculture in MacDonald College or in Saint-Hyacinthe. However, the majority of them does not have money or a sufficient amount to operate a farm. It is unfortunate*" [Farmer B].

The fortunate ones are those who make their farm a family (or inherited) heritage

"*I do not have a succession problem on my farm. I have a son who wants to continue to help me on the farm. He is in his last year at McDonald Campus. Moreover, my father who is 81 years old is already helping me*" [Farmer K].

"*We need labour to help us in farming and in accounting. A farmer works 24/24 hours*" [Farmer I].

On the other hand, the proximity to urban areas has its own advantages such as the ease to high labour, the ease of inland infrastructures (which facilitates the exportation process), and the proximity to private companies (i.e. ethanol companies) that consume the grains (which in return also makes transportation of grains cheaper).

As mentioned earlier, agriculture is one of the most vulnerable sectors to climate change and variability. Agricultural producers in Montérégie suffer the negative effects of global warming as well as those of other agricultural regions of Québec. In fact, all producers admit having seen a changing climate, which is not what it was before. The seasons are increasingly unstable especially when excess rain interludes with successive periods of drought. This often results in delays in seedling dates, which have an impact on yields. Figure 31 ssummarizes the most recurrent climate events by order of importance over the last twenty years according to respondents.

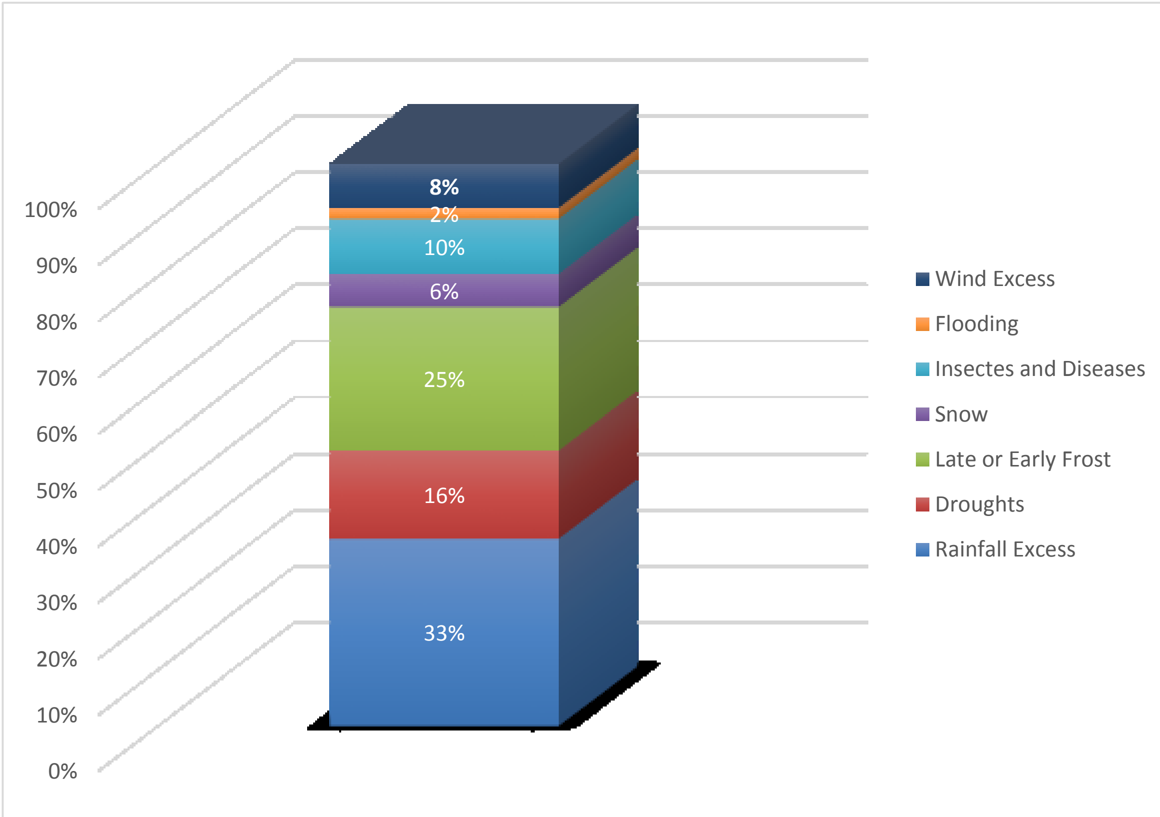


Figure 31: The most recurrent climatic events by order of importance over the last twenty years according to respondents, RCM of Haut-Richelieu, Inquiry 2014-2015.

"*We have already started to adapt. It has been several years since we had to begin to adapt; that's for sure… especially rain – rainfall excess is incredibly abundant in our region. It is much easier to deal with insects since they are not very recurrent and much easier to treat*" [Farmer B].

"*Adaptation is to have vegetables that are of good quality despite climatic extremes (i.e. droughts or rainfall excess*" [Farmer F].

"*In my opinion, the question of adaptation is a personal matter. For me it is an emergency to adapt. There is little snow in the RCM of Haut-Richelieu. Summer temperatures are very hot and we are having floods that we never had before*" [Farmer N].

Beyond the sensitivity of agriculture to climate change and variability, some farmers acknowledge the beneficial aspect of climate change such as the increase in the length of the growing season. However and while acknowledging the latter, farmers are still not sure of the length of the growing season. While some see it as long or getting longer, it is still short to others.

"*We adapt when it is necessary. Everything depends on the observation. The average of crop maturity is earlier than that of the last ten (10) years. Thirty (30) years before, we harvested the Macintosh on 21 September. Now we harvest the Macintosh on the 9th or 10th of September. Rainfall became more abundant in the last ten years or so; variation in precipitations is very huge*" [Farmer B].

"*If the growing season continues to increase, we might plant peanuts*" [Farmer E].

"*Climate change is very beneficial because it implies a warmer climate, which is very beneficial for my production. An addition of 10 ^{0} C will not have any negative effect on my yields*" [Farmer A].

"*Climate change is in our favour. We like it. The winter is less long. And there is more CO_2 in the atmosphere, which means crops grow better. Fertilization is still low though. However, the diesel that is being burned has to be cleaner now, which means low sulfur (good for those who have asthma)… So now we have to put extra sulfur in our fields*" [Farmer N].

While few do not feel the effect of climate change, they do recognize that climate change is mostly man-made.

"*We do not feel completely the effects of climate change here. We are not in a flood zone… besides, climate change is more related to how we cultivate. Deforestation has an impact on global warming of the planet. Agriculture has changed – more machinery and fewer animals. The soils are depleted. More corn and soybeans, fewer prairies. And less and less farm succession*" [Farmer H].

Uncertain Future

Despite what is being said about the effects that climate change has on agriculture, it is obvious that farmers live in uncertainty. For some, inaccuracy is present in weather forecasts (i.e. unpredictability of specific growing season conditions) or to the vague consequences of climate change presented by the media.

"Weather forecasts are not accurate at all (Saint-Bernard and Lacolle weather stations); so we look at the moon (an old farm sayings)" [Farmer M].

Another uncertainty is related to the 25% cut in agricultural support programs (or agricultural insurance subsidies), particularly the elimination of the income stabilization insurance program.

"*When the 2011 Lake Champlain and Richelieu River floods happened, my crops were largely affected (because my farm neighbours the Richelieu River). Though I was insured, the agricultural support programs didn't really help me; I had to compensate the majority of the losses by myself"* [Farmer N].

To summarize what has been said above, CCV is already affecting agriculture in the RCM of Haut-Richelieu claims. Farmers in the RCM of Haut-Richelieu acknowledge climate change and suffer its consequences. Besides CCV, agriculture is confronted by many challenges such as globalisation, proximity to urban areas, access to investment funds, the problem of farm succession and some drastic agricultural policies. It is also clear that outside the media world, farmers do not have a complete understanding of climate change, which aggravates in return the uncertainty related to climate change. In addition, claims about weather forecasts have already steered up some controversies. According to M. Phillips of Environment Canada, "Environment Canada's forecasts aren't always right, but that their predictions are more realistic than the almanac" (Koorsh, 2014). It is important to note here that farmers (or the general public) need to really understand that some aspects of the weather (such as temperature and pressure, or even mean wind speed at some broad spatial scale) are rather easier to predict than others (e.g., precipitation, cloudiness, or local turbulence). Hence, if someone is particularly sensitive to rain and snow, that person may hold the belief that the weather man does not know what he's talking about, while another person who is more attuned to temperature forecasts may claim that the same weather man is actually doing quite well. Therefore, the performance of popular sayings may also be variable depending on what they claim to predict and who they are. Furthermore, any reduction (or removal) of crop insurance subsidies would mean that risks would be more fully borne by farmers, in which case a more careful consideration by farmers of the likelihood of certain CHU accumulations might be warranted – rather than weighting expectations heavily on the conditions of the previous year.

5.2.2.2 Strategies and Measures Undertaken by Farmers of the RCM of Haut-Richelieu to Adapt to Climate Change and Variability

This sub-section or second category is about how the respondents see adaptation and how they adapt.

The second question of the questionnaire is about the definition of the word ‘adaptation’ in the context of climate change and variability. According to Figure S3 (Appendix 4), 60% of the participants recognized adaptation as a way to improve their situation on the farm to cope with the extremes (or variability) that are associated with climate change. To a lesser degree, some farmers concluded that one should not separate climatic factors from non-climatic factors in the process of agricultural adaptation to climate change and variability. The other minority (representing 13%) sees that reducing the GHG effect is a means to cope with CCV. It seems that for this group of participants (the 13%), adaptation naturally implies mitigation (or vice versa).

For the participants, the word ‘improve our situation’ meant to increase the yields, to have products of good quality and to not completely suffer the negative consequences of climate change. All in all, participants have acknowledged the fact that climate change is happening. There is one farmer who said that farmers are not in the adaptation phase yet because they are currently suffering the consequences of CCV.

"*We are observing the changes and we are not at the stage of adaptation. I use the word 'suffer', we are suffering*" [Farmer D].

In addition and while seeing that the adaptive capacity of the region is well developed (the range is between fair and excellent) (Appendix 4), the majority of the participants also agreed that adaptation of agriculture to CCV is a must and a non-reversible process (in the sense that climate does not adapt to agriculture). Some of the respondents added that adaptation is an on-going process; a mode of survival acquired by constant learning and experiences.

"*Adaptation is a must; we do not have any other choice. Adaptation is an on-going process; it is not like a light that you turn off and on whenever you want. Climate does not adapt to agriculture*" [Farmer G].

In terms of intent and purposefulness, adaptation in the RCM of Haut-Richelieu is basically spontaneous because it is taken by private actors – farmers and/or agro-environmental clubs. The majority of the respondents talk to or has an agronomist on their farms (or is a member of an agro-environmental club). And there is one farmer who already has an experience of more than 11 years in doing research on his farm (farmer and agronomist at the same time, in other words). However, some of the money that goes to the agro-environmental clubs comes from the government; so we can say here that the government is indirectly or partially involved in the adaptation process of the farmers. Also, farmers know the crop varieties that are better adapted to climate through their own trial and error.

"*We know the best adapted vegetable varieties by trial and error*" [Farmer F].

"*We do experiments on the field crops, especially for the cows. Every year, at the end of the growing season, we compare different varieties of corn and soybeans on a test plot to see which variety is the most adaptable*" [Farmer M].

However, farmers do the latter to gradually phase out one crop variety in favour of another that seems to cope better under current climatic conditions. Thus in this case, under the private sector mainly, and with a partial intervention of the public sector, adaptation alternates between autonomous and planned adaptation.

In terms of timing and duration, the majority of the participants adapts in a proactive way (strategic or long-term responses) while the minority adapts in a reactive way (tactical or short-term response (Appendix 4).

Eventually and after a while, when adaptations are consciously planned there is an interest in assessing performances of such strategies. Fortunately, the majority of the respondents systematically evaluates the types of adaptation. They do so by evaluating the yields and/or detecting the presence of insects and diseases (Sub-section 5.2. of the fifth question, Appendix 4), and some of the public actors (e.g. public agricultural institutions such as MAPAQ and FADQ) are involved in such evaluations. Others do not evaluate their types of adaptation because they simply trust the private companies to offer them the different varieties of cultivars. This confirms what has been said before, which is that even in autonomous adaptations, private actors plan for adaptation without the deliberate intervention from the government, but they do not act in isolation from the existing cultural, political, social and market institutions. More precisely, Figure S9 and Figure S12 (Appendix 4) assure the latter.

Regarding the cultural practices that aim to protect soil against erosion, already listed before in Figure S8, they are still present according to the respondents.

Moreover, when it comes to the types of adaptation in the RCM of Haut-Richelieu, they belong to two categories of Smit and Skinner (2002), which are: farm production practices and farm financial management. Question 8 and Figure S6 (Appendix) are about the measures and strategies that farmers take to better cope with CCV. One of the steps that the participants take before undertaking an adaptation activity is investment (i.e. subscribing to crop insurance, investment in drainage[15]), which belongs to the category of farm financial management. The other types of farm production practices are shown in Figure S8.

[15] 70,000$ for 40 hectares

5.2.2.3 Actors Involved Along with their Future Potential

It is obvious that the agro-environmental clubs[16] are the actors who accompany the participants for most of the time, especially when in need for consultation or support. That is when farmers systematically evaluate their adaptations. Agro-environmental clubs (AEC) offer professional support to all farmers who pay a membership fee and /or an hourly rate. At the same time, AEC are funded through the Prime-Vert program and the Partnership Agreement MAPAQ-UPA on AEC consulting services for sustainable development of the farms. Agricultural public institutions like UPA, MAPAQ and FADQ also help the farmers to some extent (e.g. diffusion of information, analysis of data about estimated yields and volumes of crops). They help farmers in their adaptations mostly in an indirect way. For instance, the participants look at the local weather forecast all the time and it is usually the government or its associated public institutions that develop early warning systems to provide daily weather and seasonal forecasts. Private companies have a special place too, by offering personal and practical support and guidance to the farmers. However, few farmers have mentioned them during the interviews. While some trust them and see them as an opportunity in technical and practical terms, others do not because they see them as sellers (ideologically threatening them).

"*It has been 2 years that I trusted the private companies in offering me the different varieties of cultivars, which is ideologically unfortunate*" [Farmer C].

"*One should not trust the private companies all the time*" [Farmer L].

Moreover, the majority of the participants said that they need help – financial, personal or both – to enable them to adopt better adaptation strategies in the face of CCV, and that that help should come from a different variety of sources (Figure S14).

"*There is always a place for improvement. I do not trust the government – labour intensive and more risk. It's too slow… even with the MacDonald College. Paper and pencils. We do not do agriculture in an office. The time we take to fill the papers, we do*

[16] Agronomists usually provide yield maps, cumulated on a GPS, to see which areas has lower vs. higher yields

not work. It's good if the government provides us with interest-free loans and grants. Even with agronomists: they provide us with good coaching but it is limited to a specific job. The credit union is not the best in terms of funding, but it's better than governmental programs. We must be aware of the new information (varieties and equipment). If we don't have experience, we should at least trust the experiences of other farmers" [Farmer B].

"*Yes, we need help but it is not urgent. 1) Consulting services (agronomists). 2) Monetary aid [FADQ, government programs, e.g. the research and development program (R&D), the Green Funds (Fonds Verts)]. It does not concern only agriculture; it is the entire population*" [Farmer C].

"*Yes, I need help. Support in terms of information (the MAPAQ logically and the vegetable seed companies for technology and practice)*" [Farmer E].

"*Yes, the help should come a little bit from everywhere. The government, the UPA, the Financière agricole du Québec. And the bank. Climate change will affect the Bio farms first, but there are no subsidies/supports for Organic Agriculture (vs. conventional farming)*" [Farmer F].

"*Yes, everyone needs help, especially in research! The agro-environmental clubs are the ones who can provide that help. For sure it is not the government because its administration is too slow!*" [Farmer H].

"*Yes, I need help. Agronomists (to know what changes to make). The Ministry of Agriculture and the FADQ for interest-free loans or grants (for financial assistance)*" [Farmer E].

"*No, I do not think farmers need help. In my opinion, any agricultural enterprise or farm should be profitable to survive itself. It is the money of the farmer that should always support himself / herself. If you do not have the sufficient amount of money, get out. If you continue to help the agricultural producers, they will always continue to ask for help. It's not fair that the government alone provides financial assistance; there are other actors in agricultural production. Furthermore, turkey production is the only production that* *never had help from the government. It works alone very well. This is the consumer's demand that plays an important role as well*" [Farmer K].

"*Yes, I need help. The government should invest in research (e.g. to keep the Good Soil because big equipment and machineries are causing soil compaction). But what is even better is the research done on the farm in cooperation with MAPAQ. The government should pay for the farms that are willing to do research, to encourage them. Agronomists help us in filling out the stack of papers for the government. The UPA and the CPTAQ give us legal aid*" [Farmer M].

"*The government policy is not good at all, but not on the financial level (i.e. the bureaucracy goes too slowly). They are not realistic. They give subsidies for corn and soybeans only, but not for hay (we think of our cows and it is much better for the environment). We are punished because we do something good. In addition, you have to pay municipal taxes for forests but it does not work, it's not in our advantage. Municipal taxes must be removed and the government has to pay it like in Europe because it is not to our advantage. The government is taking good land for the development of 10-30 highway. Therefore, these are short-term solutions. I am not saying that I need a subsidy; the government always subsidizes things that are not good for the environment. We have to fill out So Many papers; it is unbelievable! It is crooked when they announce that agriculture will receive millions of dollars as subsidies, but it is not for us, the producers, it's just to provide work for many officials leaving little room for farmers. For instance, the government makes one law for the Whole of Québec: You have to spread the manure during the Growing season to protect the environment. However, the Growing season in our region starts one month earlier and ends one month later, but the law does not change! So public policies should be more localized, taking into account the specific properties of each region*" [Farmer M].

"*Yes, I think that farmers need help. The UPA could do more. Agro-environmental clubs do a lot but it is private. Another problem is that each club includes 30-35 farmers as members, and the number of farmers who want to be associated with these clubs is* *increasing. So new agro-environmental clubs must be created; and this implies more money*" [Farmer O].

5.2.2.4 Determinants of Adaptive Capacity

It is clear that there are several climatic and non-climatic factors that affect the decisions of farmers when adapting to CCV. These factors are considered as elements of decisions as well. Question (11) eleven of the questionnaire let the participants give the current to near-future principal determinants of adaptive capacity (Figure S11, Appendix 4). Add to the latter the factors that the interviewees take into consideration before making an adaptation activity (Figure S9 in Appendix 4). Apparently and while recognizing the importance of both factors, the respondents are keen on the fact that climatic and non-climatic factors cannot be held constant in the process of adaptation to CCV. Even some of them stated that one should not separate climatic from non-climatic factors in the process of agricultural adaptation to CCV.

5.2.2.5 Recommendations

The recommendations in this sub-section are related to the analysis of the previous (4) four categories. They integrate policies and actions of co-construction with the different roles of stakeholders. The integration of relevant adaptation measures in the context of CCV will require strategic decisions by different government agencies, farm communities and institutions. Taking into account all of these players along with the long-term implications of their actions, adaptation requires changes in values as society does not reform by decrees. So it is important to develop adaptation strategies based on a vision and shared values, which are:

- ❖ Need to codify and plan the implementation of adaptation actions.
- ❖ Assistance from financial partners to support the efforts at the national level.
- ❖ Agricultural research on different subjects must continue its efforts.
- ❖ One should not dissociate climatic from non-climatic factors when it comes to any type of adaptation to CCV.
- ❖ When it comes to agricultural adaptation, farmers are on the first level because they are the ones who will adopt the adaptation strategies.

- ❖ Adaptation strategies should be developed jointly by farmers with the collaboration of other actors.
- ❖ Diversify the sources of income of farm households in response to the risk of income loss related to climate change.

Government and its associated institutions (MAPAQ, UPA, FADQ):

- ❖ Promote or encourage agricultural research (i.e. subsidies for farmers doing research on their farm/with the collaboration of some public institutions, research for better soil conservation).
- ❖ Create a consultation workshop and focus groups with the involvement of different actors.
- ❖ Provide interest-free loans and grants for the farmers from time to time.
- ❖ Ensure better integrated water resources management (water surface and underground management).
- ❖ Promote the use of natural phosphate and the collection of leaves for land fertilization.
- ❖ Promote value added to agricultural produce through storage, conservation and transformation.
- ❖ Encourage certain types of crop rotation given the fact that not all of them are good for soil activity, and hence yields, in the long run.
- ❖ Take into account the specific characteristics of each region, RCM and municipality when adopting a certain law or regulations.
- ❖ Create more agro-environmental clubs.
- ❖ UPA should be more attentive to the needs of farmers.
- ❖ Give more subsidies for other types of production, especially for organic production (and other environmental-friendly agricultural practices); not only corn and soybeans.
- ❖ Remove the forest taxes for the farmers except for forest producers and prohibit the farmers who cut the trees to plant corn and soybeans instead.
- ❖ Take into consideration the differences in municipal taxes since the revenues differ from one municipality to another (rural vs. urban or peri-urban municipality).

- Decrease the number of bureaucratic units in order to accelerate the application of governmental policies, or at least hire someone to fill in the necessary papers for the farmers. The fact that horizontal communication is difficult and that multiagency coordination often goes astray can be used as a pretext to pursue bureaucratic and political motivations by excluding rival agencies. More bureaucratic units mean greater complication of the decision process. In fact the more voices and bureaucratic procedures involved, the greater the likelihood of delay, confusion and duplication.
- Observe the differences in tax levels.
- Clarify the nature of (and probabilities associated with) climatic variability in addition to the development of early warning systems providing daily weather and seasonal forecasts.
- Encourage on the long term (i.e. financial terms, open new or more agricultural programs in school from an early age) more young people to study agriculture to solve the problem of farm succession and stop the process of investment funds from other investors.
- Change crop insurance programs to influence risk management strategies at the farm level.
- Financial support for OBV (Organisms de Bassins Versants or Watershed Management Organisations).
- Coordinate the interventions with the appropriate or concerned actors or organizations (e.g. ministries or institutions) when climate related risks happen.
- Secure additional financial resources to respond to the necessary needs of adaptation strategies employed by the farmers.
- Develop private insurance to reduce climate risks on production at the farm level.
- Develop and implement policies and programs to improve water management practices and agricultural lands, at the farm level.

Agronomists:

- More research.
- Dissemination campaign and training for farmers. And training should be focused on several farming activities.

- Sensitization of farmers on climate change.
- Strengthening and maintenance of soil and water conservation activities.
- Promote, develop and disseminate local species that are more resistant to drought and other extreme climatic events.
- Strengthen networks between the farmers of the region.
- Organize more focus groups between the farmers.

Farmers:

- Preparation and distribution of a cultural calendar for the implementation of various agricultural operations.
- Use more agricultural practices that conserve the soil (and enhance the yields).
- Establish a constant contact with the neighboring farmers and promote their activities.

Climatologists:

- Undertake more research in the context of climate change and variability and the associated causes.
- Give the public means to evaluate local and short-term events in order to place them in an adequate context and scale. For instance, the frequency calendar and the graph of cumulated frequencies are good examples (Rebetez, 1996).
- Climate models on a local scale.
- Data from Environment Canada needs to be more accurate.

To conclude for the recommendation part that a form of territorialisation of public and collective intervention, and policies, is necessary. This essentially requires forming partnerships between the federal and especially provincial level, on the one hand, and regional and local actors on the other hand. However, one should note here that it is difficult to obtain social quality and public policy by relying only on state intervention (Vaillancourt, 2008). And that is where the distinction between co-construction and co-production of policy begins to be helpful. Besides, at the local level, it is critical to provide training for actors in the use of various tools for helping farmers and groups of farmers, and as well in the whole field of climate change. For instance, developing a credible and respected local presence, depending on each region, is in effect equivalent to developing a form of extension network.

5.2. Discussion

In this second section of chapter 5, the results of the interviews will be discussed in relation to the specific objectives of this thesis.

a) Assess the role and possibilities of co-construction of public policies and collective action in the RCM of Haut-Richelieu to develop ways of adapting agriculture to climate change and variability.

As said earlier in Chapter 1, co-construction is a planned adaptation strategy that includes the involvement of public actors with the consultation of private agents. And given the fact that the farmers in the RCM of Haut-Richelieu adapt spontaneously with the indirect involvement of the public agents, the co-construction process is not present yet in the RCM of Haut-Richelieu. The governmental institutions should be directly (and more) involved in the process of agricultural adaptation to CCV. Overall and according to the participants, the adaptive capacity in the RCM of Haut-Richelieu is good. However, if the public agent intervenes more, the adaptive capacity will be enhanced. So yes, there a possibility of co-construction in the RCM of Haut-Richelieu as there is always a place for improvement, but the sooner the better. For instance, the farmers' union arranges meeting with agronomists from time to time. These meetings should also include the farmers, along with other actors, of the region. What is even better is the adoption of an adaptation tool by the government. An adaptation tool is a method that guides non-climate change experts through a series of analytical steps to examine the implications of climate change on their policies, plans, and operations, and determine appropriate response options. It is noteworthy that the government alone cannot do all; and hence cannot bear the consequences of climate change alone.

b) Analyze the roles of different stakeholders and their capabilities, current and potential interventions, aimed at enhancing the adaptive capacity of farmers.

The results of this specific objective were elaborated in section 5.2.2.3.

c) Develop recommendations for the future through integrating policies and these actions of co-construction with the different roles of stakeholders.

The recommendations are found in section 5.2.2.5.

d) Develop appropriate forms of public and collective action in the context of adaptation to climate change and variability.

The application of the recommendations stated in section 5.2.2.5 can also considered as forms of public and collective action in the context of CCV. In addition, given the fact that adaptation strategies should be developed jointly by farmers with the collaboration of other actors, the organization of focus groups and/ or workshops by the government and the agronomists twice a month at least is essential. Therefore developing a climate context monitoring tool for the latter becomes the cornerstone of group discussions. The tool is designed to guide a process of monitoring changes in the context of CCV on a constant base. For instance, the climate context monitoring tool developed by CARE (http://www.careclimatechange.org/files/toolkit/Climate_Context_Monitoring_Tool.pdf) represents a good example to begin with.

Furthermore, implementing the co-construction approach (Figure 34) is a way to develop new tools (or toolkits) in the fields of adaptation of agriculture to climate change and variability at the farm level in a decentralized (bottom-up) manner within a group of actors. This type of approach is used for connecting indicators and integrating and managing interaction between individual, collective and scientific knowledge. It is no longer the optimum which is sought but a compromise and this is reached by a dynamic process of progressive adjustment. This type of approach where practices which are considered to be positive or innovative are institutionalized which is more likely to suit the diversity of actors' values (Chéron and Ermisse, 2008). The approach combines action-research (progressive and collective learning) and grounded theory (beginning with data collection and then formulating a hypothesis or theory by comparative analysis). It is a pro-active approach. What makes it original is not only the participatory nature of the construction, but also the regional nature of the approach. It is based on a selection process that nests principles, criteria and linking indicators to the actors' issues and representations, thereby encouraging their appropriation. In other words, it is an approach where adaptation takes place as a bottom-up process, with government stepping in to provide incentives.

The use of this approach is based on a generic foundation established on three phases and eight chronological stages which, depending on the case, follow from specific work by the pioneering group or from participatory work by the stakeholders. The pioneering group refers to the team (often small in size, sometimes a single person) in charge of facilitating and coordinating the development of indicators, either as the initiator of the approach or because they have been given the task. As specified previously, the co-construction approach suggested here is based on a mode of interaction between the members of the pioneering group and the stakeholders involved, which is deliberately flexible and light. Hence, it is possible to imagine closer action-research partnerships in the future. This figure below (Figure 32) illustrates a procedural and interactive process, particularly when the learning function is determinant. It also shows the links between phases and stages. Three phases set the pace for the implementation of the suggested approach:

- a preparatory phase (four stages) which tends to be cognitive and comprehensive
- a principle and criteria selection phase, which is at the heart of the approach (two stages) and tends to be comprehensive and participatory
- a validation phase (two stages) which may be described as participatory, reflexive and cognitive.

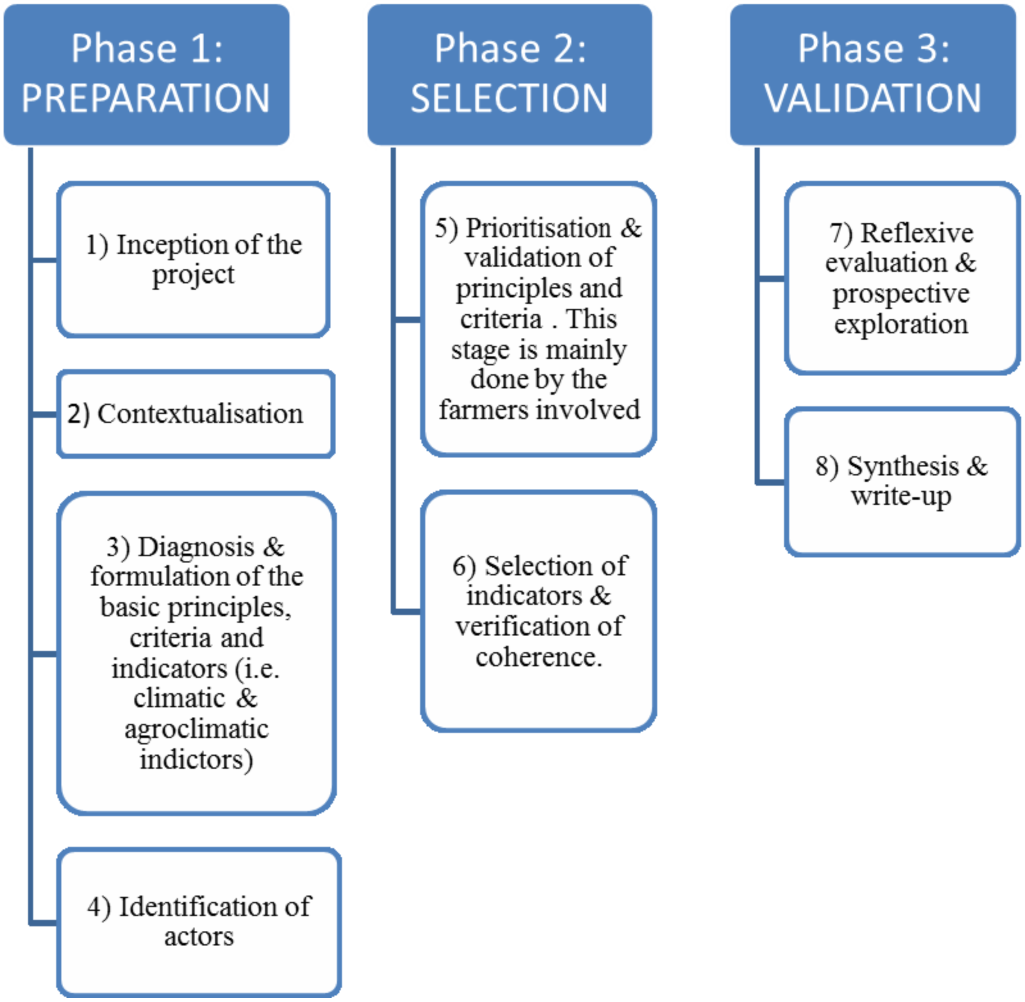


Figure 32: Implementation process of the co-construction approach[17]

The co-construction approach is a decision-making process, which consists of the following (4) four sequential steps: (1) problem recognition; (2) specification of strategies; (3) specification of the decision criterion or criteria; and (4) selection of the optimum strategy. Each alternative to solve a recognized problem is a strategy. So while decision making is largely a matter of selecting one of the strategies available, it is pointless to consider alternatives that cannot possibly be implemented. Therefore the need for a decision criterion that evaluates each strategy and expresses the desirability of the outcomes obtained from each strategy. Managing the policy process involves the players, a policy dialogue, the right timing and communications.

[17] Source: Akkari Cherine, 2013.

The involvement of players is and should be done at the various stages of the policy process. Though the actors differ from one situation to another, the common thing is that those who are actively involved in the process are those who will have to diagnose, design, implement, monitor, evaluate, or significantly change their behaviour or are financially personally affected by a policy. The active participation of a broad spectrum of stakeholders is important because it contributes to the legitimacy of policy and may engender higher acceptance among stakeholders even if implementing agencies lack the resources or authority to effectively monitor and enforce compliance. The dialogue is an important management tool that is applied to all stages of the policy process and that varies from one stage of the process to another. It facilitates the exchange of ideas, information, analytical results and policy options, approaches and tools, and it ultimately contributes to the transparency and effectiveness of decision-making in the policy arena, especially at the stage of design. Moreover, getting the timing right is another key element for managing a policy. For instance, the timing of participation of key players is particularly important to achieving successful policy formulation, enactment and reform. And, because time horizons vary, knowing when to press forward and when to relent, are complementary-not contradictory qualities in achieving success. Therefore both persistence and patience are required. The final management element in the policy process is communication. Communication is the final management element in the policy process. It is closely linked to the other elements: players involved in the policy process communicate and interact with other participants in an attempt to reach consensus, sharing information, and informing and educating the public. Policy dialogue is an important mechanism for communicating information; and Getting the timing right implies an awareness of the pace and steps involved in the policy process, which are gleaned through communication.

Conclusion

This thesis has as an objective to enhance the understanding of the adaptation process and adaptive capacity at the farm and farm community levels through a bottom-up process, i.e. a co-construction, to develop appropriate management and planning tools and to build greater levels of capacity for adaptation in the farm community. To get there, Grounded Theory, which is a qualitative approach, was adopted. Grounded Theory is one of the most common methods used in human geography. It generates a theory about a particular phenomenon from empirically observable data by giving the participants the chance to express their opinions. Primary and secondary data sources were used. Interviews are primarily related to the farmers who were the target audience of this thesis. A total of 15 farmers were asked a series of questions prepared in advance, covering aspects related to measures implemented that can render their farms more profitable, their appreciation of climate change and the strategies used to address CCV. It is noteworthy to say that 15 farmers do not represent all the farmers in the RCM of Haut-Richelieu.

Agriculture faces many challenges. All the participants acknowledged the presence of CCV. And while some farmers recognized the positive and the negative side of CCV, the others are very optimistic about it as if they only see the positive side; hence the need to see both sides of CCV. Also, there is still an uncertainty related to CCV, which comes from disinformation and desensitization of the farmers mainly on the causes of CCV along with the nature of climatic events. Therefore what Ilbery (1991) stated is still relevant to this study, which is: There would seem to be opportunities to reduce vulnerabilities to climatic variation not by developing new hybrids for this purpose, but by clarifying the nature of (and probabilities associated with) climatic variability, so that individuals can select hybrid mix strategies consistent with their risk preferences, rather than this seemingly reckless gambling with nature. To add that human expectations regarding weather and climate scenarios sometimes lead to perceptions which are not supported by observational data (Rebetez, 1996). Short-extreme events are not necessarily an indicator of long-term shift in climate (Rebetez, 1996), while it is important to note here that human perception of long-term tendencies are limited compared to short-term extreme events (White, 1985; Farhar-Pilgrim, 1985).

Though the vulnerability and adaptation practices (measures or strategies in other words) are not the same for all sectors of production, and can be even contradictory sometimes, the participants recognized that both climatic and non-climatic factors are important in the process of adaptation to CCV. For instance, a horizontal agricultural production (e.g. an orchard) requires more labor than a vertical one (e.g. corn or soya). Adaptation is a non-irreversible process in a sense that agriculture adapts to climate but not vice versa. Like the co-construction of public policies, adaptation is not a one-shot event but a continuing process. Adaptation and the co-construction of public policies are not linear processes in a sense that they often take time- days, weeks, months, or years, and require iterative efforts- shifting back and forth between stages. Also, both of them are complex because they frequently involve climatic as well as socio-economic factors. And it is true that adaptation is a necessary complement to mitigation measures. However, mitigation naturally implies adaptation by many actors. Moreover and while adaptation has many characteristics and types (Bryant *et al.*, 2000; Kandlikar and Risbey, 2000; Smit *et al.*, 2000), there are plenty of forms of adaptation that involve both the private agent and the government. Although it is true that adaptation is somehow based on previous experiences, learning from previous mistakes often seems minimal because of two main reasons, which are: (1) the complexity of causes and effects of CCV makes it difficult to pin down definitive lessons; and (2) adaptation is a complex and long process. The context (e.g. frequency and magnitude of events) can change by the time a lesson is learned. After all and as Mitchell and Tanner (2006) stated, adaptation is "an understanding of how individuals, groups and natural systems can prepare for and respond to changes in climate or their environment".

Furthermore, adaptation strategies should be developed jointly by farmers in concert with other actors, starting with the agronomists because they serve as important relays between farmers and other stakeholders such as public institutions and private companies. While the latter is a must, some farmers still prefer to use the soft approach, which is a strategy that is based on network interacting between other farmers mainly through the constant quest and information sharing. And in order to have an anticipative adaptation, farmers as well as other stakeholders need to be informed and sensitized; therefore the importance of research for two main purposes, which are: (1) develop new concepts, tools, practices, products and services for managers as well as policy-makers, (2) answer questions that arise when a management process is implemented or while research is conducted.

References

Adger, W.N. and Kelly, P.M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation & Adaptation Strategies for Global Change,* 4(3/4) : 253–266.

Agriculture and Agri-Food Canada, (May, 2006). *An Overview of the Canadian agriculture and Agri-Food system.* ISBN 0-662-43933-3. Catalogue A38-1/1-2006E-PDF. Project 06-003-rp. Pdf format: http://s3.amazonaws.com/zanran_storage/dsp-psd.pwgsc.gc.ca/ContentPages/12028530.pdf

Aldrich, S. R., Scott, W. O. and Leng, E. R. (1975). *Modern corn production*. Champaign, IL: A & L Publications.

Anderson, K. (6 February, 2013). Are we heading for 6° temperature rise? Retrieved from: *Environmental Research Web*: *http://environmentalresearchweb.org/cws/article/opinion/52289*

Assani, A.A., Landry, R. and Laurencelle, M. (7 December, 2012). Comparison of interannual variability modes and trends of seasonal precipitation and streamflow in Southern Quebec. *River Research and Applications*, 28(10): 1740-1752. DOI: 10.1002/rra.1544.

Bariball, K.L. and While, A.W. (1994). Collecting data a semi-structured interview: a discussion paper. *Journal of Advanced Nursing,* 19: 328-335.

Beaudet, P., Beaudin, I., Michaud, A., and Giroux, M. (2008) Le transport du phosphore, Fiche technique #3, Centre de référence en agriculture et agroalimentaire du Québec, p. 11, http://www.craaq.qc.ca/Publications?p=32&l=fr&IdDoc=1997

Bélanger, G., Rochette, P., Castonguay, Y., Bootsma, A., Mongrain, D. and Ryan, D.A.J. (2002). Climate change and winter survival of perennial forage crops in Eastern Canada. *Agronomy Journal*, 94:1120-1130.

Benioff, B., Guill, S. and Lee, J. (1996) *Vulnerability and Adaptation Assessments: An international handbook*. Dordrecht, Kluwer Academic Publishers.

Bootsma, A., Anderson, D. and Gameda, S. (2004). Potential impacts of climate change on agroclimatic indices in southern regions of Ontario and Quebec. ECORC ContributionNo. 03-284. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada.

Bootsma, A., Gameda, S., McKenney, D.W. (2005a) Impacts of potential climate change on selected agroclimatic indices in Atlantic Canada. *Canadian Journal of Soil Science,* 85: 329–343.

Bootsma, A., Gameda, S., McKenney, D.W. (2005b) Potential impacts of climate change on corn, soybeans and barley yields in Atlantic Canada. *Canadian Journal of Soil Science*, 85: 345–357.

Borenstein, S. (15 June, 2013). Climate talk shifts from curbing CO2 to adapting. *The Associated Press.* Retrieved from: http://globalnation.inquirer.net/77731/climate-talk-shifts-from-curbing-global-warming-to-adapting#ixzz2WWvPzvwd

Brassard, J.P., Singh, B. (2008). Impacts of climate change and CO2 increase on agriculture production and adaptation options for southern Québec, Canada. *Mitigation and Adaption Strategies for Global Change*, 13: 241-265.

Brklacich, M., McNabb, D., Bryant, C., Dumanski, J. (1997). Adaptability of agriculture systems to global climate change: A Renfrew County, Ontario, Canada pilot study', in B. Ilbery, Q. Chiotti and T. Rickard (eds.), *Agricultural Restructuring and Sustainability: A geographical perspective*, Wallingford, CAB International, pp. 351–364.

Brown, D.M., Bootsma, A. (1993). Crop heat units for corn and other warm-season crops in Ontario. Ontario of Ministry of Agriculture and Food Factsheet No. 93-119, Agdex 111/31, pp. 4.

Bryant C.R., B. Smit, M. Brklacich, T.R. Johnston, J. Smithers, Q. Chiotti, B. Singh. (2000). Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change* 45, 181-201.

Bryant, C.R. (1994). *Strategic management and planning for local and community economic development: I.* The organization. Econotrends limited St. Eugène, Ontario.

Bryant, C.R.,Johnston, T.R.R. (1992). Agriculture in the city's countryside. Pinter Press, London, and University of Toronto Press, Toronto, p. 226.

Bryant, C.R., Singh, B. et Thomassin, P., Baker, L., Délusca, K., Savoie, M., Doyon, M. et Seyoum, E. (June, 2008). Evaluation of Agricultural Adaptation Processes and Adaptive Capacity to Climate Change and Variability: The Co- construction of New Adaptation Planning Tools with Stakeholders and Farming Communities in the Saguenay-Lac-Saint-Jean and Montérégie Regions of Quebec. Université de Montréal and McGill University Research Team. Submitted to Natural Resources Canada, Climate Change Impacts and Adaptation Program (CCIAP), Project A1332.

Bryant, C.R., Singh, B., DesRoches, S., Thomassin, P., Baker, L., Madramootoo, C., Délusca, K. and Savoie, M. (2005). Climate variability in Quebec: lessons for farm adaptation from an analysis of the temporal and spatial patterns of crop insurance claims in Quebec. National Conférence on: Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity, Natural Resources Canada, Montréal. May 4- 7, 2005.

Bryant, C.R., Smit, B., Brklacich, M., Johnston, Th.R., Smithers, J., Chiotti, Q. and Singh, B. (2000). Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change*, 45(1): 181-201.

Bryant, C.R., Brklacich, M., Thomassin, P.J., Délusca, K., Woodrow, M. and Daouda, O. (November, 2011). Adaptation et vulnérabilité au changement et à la variabilité climatique : co-construction de politique et d'action locales et régionales. Profil territorial de la Montérégie-ouest. Projet de recherche financé par le Conseil de Recherche en Sciences Humaines du Canada (CRSH). Université de Montréal, Carlton University and McGill University.

Bunce, J.A. (2004). Carbon dioxide effects on stomatal responses to the environment and water use by crops under field conditions. *Oecologia*, 140:1-10.

Burton, I., Kates, R.W. and White, G.F. (1993). The Environment as hazard. The Guilford Press, New York, NY, USA, pp 290.

Burton, I. (1997). Vulnerability and adaptive response in the context of climate and climate change. *Climatic Change* 36, 185–196.

Brown, R.D. (2010) Analysis of snow cover variability and change in Quebec, 1948-2005, Hydrological Processes, in press.

CAFTA, (n.d.). Agri-food exports. Retrieved April 9, 2014 from http://cafta.org/pages/agri-food-exports/. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Campbell, J.L., Quincy, C., Osserman, J. and Pedersen, O.k. (2013). Coding In-depth Semistructured Interviews: Problems of Unitization and Intercoder Reliability and Agreement. *Sociological Methods and Research*, 4(3): 294-320. Sage Publications.

Canadian Soybean Council, (2010). *Canadian Soybean Dispatch*. http://www.soybeancouncil.ca/LinkClick.aspx?fileticket=oUtQI_5a2sk%3D&tabid=182&language=en-US

Carter, T.R, Parry, M.L., Harasawa, H. and Nishioka, S. (1994). *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations,* London, Department of Geography, University College London.

Castel R., (1985). *L'expert mandaté et l'expert instituant*. In : Situations d'expertise et socialisation des savoirs, C.R.E.S.A.L.

Centre de référence en agriculture et agroalimentaire (CRAAQ), (2002). *Ré-évaluation des unités thermiques disponibles au Québec pour le maïs et le soya*, p. 12.

Charmaz, K. (1983). The Grounded Theory Method: An Explication and Interpretation, in: Emerson (dir.), Contemporary Field Research, Little Brown, Boston.

Chen R. S. and Kates, R. W. (1994). Global environmental change. Special issue, *World and Food Security*, 4(1).

Chéron, M. and Ermisse, L. (2008). Repères sur l'évaluation au regard du développement durable. *Cahier n° 2*, octobre 2008, Observatoire national des Agenda 21 et des pratiques territoriales de développement durable, p. 84. http://www.observatoire-territoires-durables.org/spip.php?article1055

Chesler, M.A. (1987). Professionals' views of the "dangers" of self-help groups: Explicating a grounded theoretical approach, in: Center for research on social organization working paper series, d.o.S., The University of Michigan (dir.), Ann Arbor, Michigan.

Climat-Quebec, (2001-2014). Climate monitoring. Weather events summaries. http://www.climat-quebec.qc.ca/home.php?id=summary_weather_events&mpn=climate_mon&lg=en

Cochrane, M. (15 July, 2013). Weather you believe it or not. *Retrieved from http://damnthematrix.wordpress.com/tag/floods/page/6/*

Coleman, J.S. (1958-1959). Relational Analysis: The Study of Social Organizations with Survey Methods. *Human Organization*, 17: 28–36.

CRAAQ, (7 mars, 2012). *Colloque en agroclimatologie: Outils disponibles et changements climatiques.* Hôtel et Suites Le Dauphin, Drummondville. ISBN 978-2-7649-0276-9. PDF: http://www.craaq.qc.ca/documents/files/Publications/EAGR1201_Cahier_participant.pdf

Creswell, J.W. (2009). Research Design: Qualitative, Quantitative, and Mixed Approaches. Thousand Oaks, CA: Sage.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, S., Held, I., Jones, R., Kolli, R.K., Kwon, W.-T. , Laprise, R., Magana, Rueda, V., Mearns, L., Menendez, C.G., Raisanen, J., Rinke, A., Sarr A. and Whetton, P. (2007). Regional Climate Projections. In Climate Change 2007: The Physical Science Basis, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S. Salomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignot and H.L. Miller (ed.), Cambridge University Press, Cambridge and New York, pp.847-940].

De Elía, R., Biner, S. and Frigon, A. (19 March, 2013). Interannual variability and expected regional climate change over North America. *Climate Dynamics,* 41(5/6): 1245.

Délusca, K. (February, 2010). Évaluation de la vulnérabilité des fermes productrices de maïs-grain du Québec aux variabilités et changements climatiques : Les cas de Montérégie-Ouest et du Lac-Saint-Jean-Est. Thèse présentée à la Faculté des études supérieures en vue de l'obtention du grade de Philosophiae Doctor (Ph.D.) en géographie. Faculté des arts et sciences, Département de géographie, Université de Montréal.

DesJarlais, C., Chaumont, D., Larrivée, C., Lease, N., Allard, M., Bourque, A., Gosselin, P., Houle, D., Roy, R., Savard, J.-P., Turcotte, R. and Villeneuve, C. (2010). Learning to adapt to climate change. Ouranos, Montreal, 128 p. ISBN : 978-2-923292-04-5.

Dey, I. (1999). Grounding grounded theory: guidelines for qualitative inquiry. San Diego: Academic Press.

DiCicco-Bloom B, Crabtree B.F. (2006). The qualitative research interview. *Medical Education*, 40(4): 314-321.

Dick, B. (2000). Grounded-theory: a thumbnail check. Available online at: http://www.scu.edu.au/schools/gcm/ar/arp/grounded.html, or PDF: http://www.aral.com.au/DLitt/DLitt_P59ground.pdf

Easterling, W.E., Crosson, P.R., Rosenberg, N.J., McKenney, M.S., Katz, L.A. and Lemon, K.M. (1993). Agricultural impacts of and responses to climate change in the Missouri-Iowa-Nebraska-Kansas region. *Climate. Change*, 24(1–2): 23–62.

Easterling, W.E., Rosenberg, N.J., Lemon, K.M. and McKenney, M.S. (1992). Simulations of crop responses to climate change: Effects with present technology and currently available adjustments- The "smart farmer" scenario'. *Agriculture and Forest Meteorology*, 59: 75-102.

Edmonson, W.T. (1969). Eutrophication in North America. In: *Eutrophication: causes, consequences, correctives* (National Academy of Sciences, Washington, D.C.), pp. 124-145.

Environment Canada. (2002). Les dix principaux evenements météorologiques canadiens de 2000. Retrieved from: http://www.msc.ec.gc.ca/media/top10/2000_f.html

Financière Agricole du Québec (FADQ), (2013a). *Guide des norms reconnues par La Financière Agricole en matière de pratiques culturales: céréales, maïs-grain et soya*. 2013- prolongé à 2015. Direction des communications et marketing, La Financière Agricole. PDF: http://www.fadq.qc.ca/fileadmin/fr/cent_docu/prog/assu/asrec/guid_norm/cmo_2013.pdf

La Financière agricole du Québec (FADQ). (2011): *Données sur les assurances agricoles et les dommages aux cultures*. In: Adptation et vuln*érabilité de l'agriculture et des communautés au changements et à la variabilité climatique: co-construction de politique et l'action locales et regionals. Profil territorial de la Montérégie-ouest* [Bryant, C.R., J.P. Thomassin, K. Délusca, M. Woodrow and D. Oumarou]. Université de Montréal, Carlton University and McGill University. CRSH, Agriculture et Adaptation.

La Financière agricole du Québec (FADQ). (Mars, 2010). *Rendements de reference 2010 en assurance récolte.* Direction de la recherche et du développement. http://www.fadq.qc.ca/fileadmin/fr/cent_docu/docu_publ/stat/asrec/rend_reel/rend_reel_2010.pdf

La Financière agricole du Québec (FADQ). (May, 2013b). *Rendements de référence 2013 en assurance récolte.* Direction de la recherche et du développement. http://www.fadq.qc.ca/fileadmin/fr/cent_docu/docu_publ/stat/asrec/rend_refe/rend_refe_2013.pdf

Fadul, J. (2007). A workbook for a course in general psychology. Published by Lulu Press, Inc. ISBN: 978-1-4303-2057-9.

Fankhauser, S. (1996). The potential costs of climate change adaptation. In: Adapting to Climate Change: An International Perspective [Smith, J., N. Bhatti, G. Menzhulin, R. Benioff, M.I. Budyko, M. Campos, B. Jallow, and F. Rijsberman (eds.)]. Springer-Verlag, New York, NY, USA, pp. 80–96.

Farhar-Pilgrim, B. (1985). Social Analysis, in Kates, Robert W et al. (eds): Climate Impact Assessment Studies of International Climate and Society. Chichester and New York, pp. 323-350.

Foddy, W. (1993). Constructing questions for interviews and questionnaires. Theory and Practice in Social Research. Cambridge, UK. Cambridge University Press.

Fontaine, H. (24 Juillet, 2010). Agriculteurs québécois: 770 millions de subventions aux producteurs. *La Presse*: http://affaires.lapresse.ca/economie/quebec/201007/23/01-4300860-agriculteurs-quebecois-770-millions-de-subventions-aux-producteurs.php

Food and Agriculture Organization of the United Nations (FAO), (2010): *Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*. FAO, Rome, Italy.

Gitz, D. C., Ritchie, J. C., Krizek, D. T., Springer, T. L., Reeves III, J. B. and V. Reddy. (2006). Effect of temperature and CO_2 on forage nutritive value of 'Pete' eastern gamagrass. In Proceedings of the Fifth Eastern Native Grass Symposium, [ed. M. A. Sanderson, P. Adler, S. Goslee, J. C. Ritchie, H. Skinner, and K. Soder], 107–114. Washington, DC: USDA NRSC and USDA ARS.

Glantz, M. (1992). Global warming and environmental change in sub-Saharan Africa. *Global Environmental Change*, 2: 183-204.

Glaser, B.G. (1963). Retreading research materials: the use of secondary data analysis by the independent researcher. *American Behavioural Science*, 6(10): 11-14.

Glaser, B.G. (1978). Theoretical sensitivity. The Sociology Press, Mill Valley, California.

Glaser, B. G. (1998). *Doing grounded theory. Issues and discussions*. Mill Valley, CA: Sociology Press.

Glaser, B. G. (2001). *The grounded theory perspective: Conceptualization contrasted with description*. Mill Valley, CA: Sociology Press.

Glaser, B. G., and Strauss, A. L. (1965). Awareness of dying. Chicago, IL: Aldine Publishing.

Glaser, B. G. and Strauss, A. (1967). The discovery of grounded theory. Aldine Publishing Co, Chicago.

Goldenberg, S. (2013, September 4). Scientists call for overhaul of UN 'blockbuster' climate reports. *The Guardian*: http://www.theguardian.com/environment/2013/sep/04/scientists-overhaul-un-climate-report-ipccGoodman Leo A. Snowball Sampling. Annals of Mathematical Statistics.

Goodman, L. A. (1961). Snowball Sampling. Annals of Mathematical Statistics. 32: 148–170.

Hare, F. K. (1991). Contemporary climatic change: the problem of uncertainty. In: Resource Management and Development: Addressing Conflicts and Uncertainty [B. Mitchell, (ed.)]. pp. 8-27. Oxford University Press, Don Mills.

Haslett, S. (5 September, 2008). Coastal Systems. Introduction to Environment Series. Routledge. 2nd Edition. ISBN- 10: 0415440610, ISBN- 13: 978-0415440615. http://www.craaq.qc.ca/data/DOCUMENTS/EVV026.pdf

Ilbery, B. (1985). *Agricultural Geography: a social and economic analysis*. Oxford University Press, Oxford.

Ilbery, B. (1991). Farm diversification as an adjustment strategy on the urban fringe of the West Midlands. *Journal of Rural Studies* 7, 207-218.Smit, B., R. Blain, and P. Keddie. (1997). Corn Hybrid Selection and Climatic Variability: Gambling with Nature? *Canadian Geographer*, 42: 429-438.

Industry Canada, (n.d. b).Canadian industry statistics. Gross domestic product (GDP): Agriculture, Forestry, Fishing and Hunting (NAICS 11). Retrieved April 30, 2014 from https://www.ic.gc.ca/app/scr/sbms/sbb/cis/gdp.html?code=11&lang=eng

Institut de la statistique du Québec and Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec. (2009). Profil sectoriel de l'industrie bioalimentaire du Quebec, edition 2008, Institut de la statistique du Quebec and Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec, p. 122.

Institut de la Statistique du Québec, (2009). *Bulletin régional Édition 2009. CRÉ Vallée-Du-Haut-Saint-Laurent.*

Institut de la Statistique du Québec, (2013). La Montérégie, ses munipalités régionales de comet (MRC) et ses territoires de conference regionals des élus (CRÉ). *Statistiques et publications.* http://www.stat.gouv.qc.ca/statistiques/profils/region_16/region_16_00.htm

IPCC, (November, 2007). Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

IPCC, (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].

IPCC, (2014). Part A: Global and Sectoral. Aspects. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IRI (International Research Institute for Climate and Society) (n.d.). The science and practice of seasonal climate forecasting at IRI. Tutorial 2. Earth Institute. Columbia University. Accessed on 21 February, 2015. http://iri.columbia.edu/climate/forecast/tutorial2/

Jetté, C., Levesque B., Mager L. and Vaillancourt Y. (2000). *Économie sociale et transformation de l'État-providence dans le domaine de la santé et du bien-être: une recension des écrits (1990–2000)*, Sainte-Foy, PUQ, p. 202.

Joseph, A.E. and Keddie, P.D. (1985). The diffusion of grain corn production through Southern Ontario, 1971-1981. *The Canadian Geographer,* 29(2):72-168.

Jones, M. and Aloney, I. (2011). Guiding the use of grounded theory in doctoral studies- an example from the Australian film industry. *International Journal of Doctoral Studies,* 6: 95-114.

Kandlikar, M. and Risbey, J. (2000). Agricultural impacts of climate change: If adaptation is the answer, what is the question? *Climatic Change*, 45: 529-539.

Kane, S.M. and Shogren, J.F. (2000). Linking adaptation and mitigation in climate change policy. *Climatic Change*, 45(1) : 75–102.

Klein, R.J.T. and MacIver, D.C. (1999). Adaptation to Climate Variability and Change: Methodological issues. *Mitigation and Adaptation Strategies for Global Change* 4 : 189-198. Washington, D.C., Resources.

Coorsh, K. (18 Spetember, 2014). 'T-Rex' of winters in store for Canada: Old Farmer's Almanac. CTVNews Canada: http://www.ctvnews.ca/canada/t-rex-of-winters-in-store-for-canada-old-farmer-s-almanac-1.2012804

Lamontagne, L., Martin, A., Crenon, L. and Cossette, J-M. (2001). Etude pedogologique du comte Saint-Jean (Quebec). Agriculture et Agroalimentaire Canada. Mack, N., Woodsong, C., MacQueen, K.M., Guest, G. and Namey, E. (2005). Qualitative research methods: a data collector's field guide. USAID (U.S. Agency for International Development) and FHI 360 (Family Health International). Research Triangle Park, North Carolina, USA. ISBN: 0-939704-98-6.

Mack, N., Woodsog, C., MacQueen, K.M., Guest, G. and Namey, E., (2005). *Qualitative Research Methods: a data's collector's field guide.* Family Health International. Module 2: Observational skills. http://www.fhi360.org/sites/default/files/media/documents/Qualitative%20Research%20Methods%20-%20A%20Data%20Collector%27s%20Field%20Guide.pdf

Marsden, T., R. Munton, S. Whatmore and J. Little (1989). Strategies for coping in capitalist agriculture: an examination of the responses of farm families in British agriculture. *Geoforum,* 20(1): 1–14.

Maxwell, B., Mayer, N. and Street, R. (1997). *The Canada Country Study: Climate Impacts and Adaptation, National Summary for Policy Makers*, Environment Canada.

Mead, G. H. (1934). Mind, self, and society. Chicago, IL: University of Chicago Press.

Mendelsohn, R. (1998). Climate-change damages. In: Economics and Policy [W.D. Nordaus, (ed.)]. Issues in Climate Change for the Future.

Miles, M. and Huberman, M. (1984). Qualitative data anakysis. Beverly Hills. Sage Publications.

Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec (MAPAQ), (2006a). Profil bioalimentaire de la Montérégie: p. 92.

Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec (MAPAQ), (2006b). Régions du Québec. http://www,mapaq,gouv,qc,ca/Fr/Regions/

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), (2007). Direction régionale de la Montérégie Ouest, *bilan des réalisations 2006-2007.* MAPAQ, (25 November, 2010). *Bilan des realisations 2009-2010.* GTA Agri-Vision. Le Courrier- C-13. http://collections.banq.qc.ca/ark:/52327/bs2006894

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), (2008). Profil régional de l'industrie bioalimentaire du Québec — estimations pour 2007, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, p. 164.

Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec (MAPAQ), (2014). Directions régionales de la Montérégie, secteurs est et oust. Dossiers régionaux: Portrait agroalimentaire de la Montérégie. http://www.mapaq.gouv.qc.ca/fr/Publications/Portrait_agroalimentaire_monteregie.pdf

MAPAQ et AGÉCO. (2006). Profile bioalimentaire de la Montérégie.

Ministère de l'environnement, (1999). Portrait régional de l'eau. *Consultation publique sur la gestion de l'eau au Québec*. Montérégie, Région administrative 16.

Mitchell, T. and Tanner, TM. (2006). *Adapting to climate change: challenges and opportunities for the development community.* Tearfund, Teddington.

Molin, C. (2008). *Guide de la co-construction des politiques agricoles périurbaines d'agglomération*. Terres en Villes : http://www.terresenvilles.org/upload/pubdoc/pdc_20081128034756_guideco-construction.pdf

Morissette, H. (1972). Les conditions du développement agricole au Québec. Québec, Canada, Les Presses de l'Université Laval.

Music, B. and Caya, D. (2007). Evaluation of the hydrological cycle over the Mississippi River Basin as simulated by the Canadian Regional Climate Model (CRCM). *J. Hydrometeorology*, 8(5), 969-988. DOI: 10.1175/JHM627.1. Cited in: [Bryant, C.R., B. Singh, P. Thomassin, L. Baker, K. Délusca, M. Savoie, M. Doyon, M. et E. Seyoum]. Evaluation of Agricultural Adaptation Processes and Adaptive Capacity to Climate Change and Variability: The Co- construction of New Adaptation Planning Tools with Stakeholders and Farming Communities in the Saguenay-Lac-Saint-Jean and Montérégie Regions of Quebec. Appendix B: The Regions-Territorial Profiles. Université de Montréal and McGill University Research Team. Submitted to Natural Resources Canada, Climate Change Impacts and Adaptation Program (CCIAP), Project A1332.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, H.J.M., Fenhann. J, Gaffin, S., Gregory, K., Grubler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, S., Mori, S., Morita, T., Papper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N.and Dadi, Z. (2000). Special Report on Emissions Scenarios. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Nearing, M.A., Pruski, F.F. and Oneal, M.R. (2004). Expected climate change impacts on soil erosion rates: A review. *Journal of Soil and Water Conservation*, 59(1):43-50.

Nordhaus, W.D. (1991). To slow or not to slow: The economics of the greenhouse effect. *The Economic,* 101 : 920–937. Patino, L. (September, 2010). *Understanding Climate Change Adaptation and Adaptive Capacity.* Synthesis Report. PRI Project. Sustainable Development.Ottawa, ON. Policy Horizons Canada. ISBN: 978-1-100-16609-4. PDF format: http://www.horizons.gc.ca/sites/default/files/Publication-alt-format/2010-0041-eng.pdf

Pielke, R.A. (1998). Rethinking the role of adaptation in climate policy. *Global Environmental Change*, 8(2): 159–170.

Pierre, J. (June, 2005). ¿Poder para... o poder sobre?: repensando la fuerza del Estado. *Reforma y Democracia*, 32.

Plummer, D.A., Caya, D., Frigon, A., Cote, H., Giguere, M., Paquin, D., Biner, S. Harvey, R. and de Elia, R. (2006) Climate and climate change over North America as simulated by the Canadian RCM, Journal of Climate, 19(13):3112-3132.

Quilbé, R., Rousseau, A.N., Moquet, J.-S., Savary, S., Ricard, S. and Garbouj, M.S. (2008). Hydrological response of a watershed to historical land use evolution and future land use scenarios under climate change conditions. *Hydrology and Earth System Sciences*, 12:101-110.

Rebetz, M. (1996) Public expectation as an element of human perception of climate change. *Climatic Change*, 32:495-509. Kluwer Academic Publishers. Printed in the Netherlands.

Reilly, J. (1995). Climate change and global agriculture: recent findings and issues. *American Journal of Agricultural Economics*, 77:727–733.

Reilly, J. M. (1994). Crops and Climate Change. *Nature*, 367:118-119.

Rey-Valette, H., Clément, O., Aubin, J., Mathé, S., Chia, E., Legendre, M., Caruso, D., Mikolasek, O., Blancheton, J-P., Slembrouck, J., Baruthio, A., René, F., Levang, P., Morissens, P. and Lazard J. (2010). An approach to co-construct sustainable development indicators in aquaculture. IIFET. Montpellier Proceedings. PDF format: http://archimer.ifremer.fr/doc/00012/12297/9088.pdf

Risbey, J., Kandlikar, M., Dowlatabadi, H., and Graetz, D. (1999).Scale, context, and decision making in agricultural adaptation to climate variability and change. *Mitigation and Adaptation Strategies for Global Change*, 4: 137–165.

Rosenberg, N.J. (1992). Adaptation of agriculture to climate change. *Climatic Change*, 21: 385-405.

Rosenzweig, C. and Parry, M.L. (1994). Potential impact of climate change on world food supply. *Nature,* 367 : 133–138.

Rosenzweig, C., and Hillel, D. (1998). *Climate Change and the Global Harvest: Potential Impacts of the Greenhouse Effect on Agriculture*. Oxford University Press.

Savary, S., Rousseau, A.N. and Quilbé, R. (2009). Assessing the effects of historical landcover changes on runoff using remote sensing and hydrological modelling. *Journal of Hydrological Engineering*, 14(6):575-587.

Scheraga, J.D., Grambsch, A.E., 1998. Risks, opportunities, and adaptation to climate change. Climate Research 11, 85–95.

Shi, W. and Tao, F. (2 July, 2014). Vulnerability of African maize yield to climate change and variability during 1961-2010. *Food Security*, 6(4): 471-481. DOI: 10.1007/s12571-014-0370-4. Springer Publisher. Online ISSN: 1876-4525.

Siman, E. (May, 20014). *Agriculture and agri-food sector. Report*. Elgin Middlesex Oxford Workforce and Development Board (EMO WPDB).

Singh, B., El Mayaar, M., André, P., Bryant, C.R. and Thouez, J.P. (1998). Impacts of a GHG-induced climate change on crop yields : effects of acceleration in maturation, moisture stress and optimal temperature. *Climatic Change*, 38 : 51-86.

Smit, B. and Skinner, W. M. (26 March, 2002). Adaptation Options in Agriculture to Climate Change: A Typology. In : Mitigation and Adaptation Strategies for Global Change **7:** 85–114, 2002. Kluwer Academic Publishers. Printed in the Netherlands. Smit, B. (1994). Climate, compensation and agriculture. In: Proceedings of a Workshop on Improving Responses to Atmospheric Extremes: The Role of Insurance and Compensation, pp. 29-37, Theme papers. Environment Canada, Toronto.

Smit, B. and Pilifosova, O. (2007). Adaptation to Climate Change in the Context of Sustainable Development and Equity. In Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability.

Smit, B., Burton, I., Klein, R.J.T. and Street, R. (1999). The science of adaptation: a framework for assessment. *Mitigation and Adaptation Strategies*, 4: 199-213. Kluwer Academic Publishers. Printed in the Netherlands.

Smit, B. (1993). Adaptation to Climatic Variability and Change: Report of the Task Force on Climate Adaptation. Canadian Climate Program. University of Guelph, Ontario.

Smit, B., I. Burton, R.J.T. Klein, and Wandel, J. (2000). An anatomy of adaptation to climate change and variability. *Climatic Change*, 45: 223–251.

Smit, B., McNabb, D. and Smithers, J. (1996). Agricultural Adaptation to Climatic Variation. *Climatic Change*, 33: 7–29.

Smit, B., Blain, R. and Keddie, P. (1997). Corn hybrid selection and climatic variability: Gambling with nature? *Canadian Geography*, 41: 429–38.

Smithers, J. and Smit, B. (1997). Human adaptation to climatic variability and change. *Global Environmental Change*, 7(2): 129–146.

Smith, J.B. (1996). Using a decision matrix to assess climate change adaptation. In: Adapting to Climate Change: An international Perspective [J.B. Smith, N. Bhatti, G. Menzhulin, R.

Benioff, M.I. Budyko, M. Campos, B. Jallow and F. Rijsberman (eds.)]. New York, Springer, pp. 68–79.

Smith, J.B. and Lenhart, S.S. (1996). Climate change adaptation policy options. *Climate Research*, 6(2): 193–201.

Smiths, J. and Smit, B. (1997). Agricultural system responses to environmental stress. In: Agricultural Restructuring and Sustainability: A Geographical Perspective [B. IIbery, Q. Chiotti and T. Rickard (eds.)], pp. 167-184. Wallingford, UK: CAB Direct International. ISBN: 0-85199-165-3.

Stern, P.N. (1980). Grounded theory methodology: its uses and processes. Image, 12(1). Reprinted in Glaser, Barney, ed. (1994). More grounded theory methodology: a reader. Mill Valley, Ca.: Sociology Press. [pp. 116-126].

Stern, P.N. (2007). On solid ground: essential properties for growing grounded theory. In: Bryant & K. Charmaz (Eds.). The SAGE handbook of grounded theory, pp. 114–126. London: Sage

Slobodkin, L.B., and Rapoport, A. (1974). An optimal strategy of evolution. *Quarterly Review of Biology* 49: 181–200.

Statistics Canada. (2007). Recensement de l'agriculture, section 1 — un portrait statistique de l'agriculture, Canada et provinces: années de recensement 1921 à 2006, Statistics Canada.

Statistics Canada. (2011a). 2011 Farm and Farm Operator Data. Chapter 1. Highlights and analysis. Snapshot of the Canadian Agriculture. http://www.statcan.gc.ca/pub/95-640-x/2011001/p1/p1-01-eng.htm#III

Statistics Canada. (2011b). Montérégie-Ouest: répartition des exploitations agricole par secteur de production. Agricultural census, 2011.

Strauss, A. and Corbin, J. (1990). Basics of qualitative research, grounded theory procedures and techniques. New York: Sage Publications.

Tol, R.S.J., Fankhauser, S., and Smith, J.B. (1998). The scope for adaptation to climate change: what can we learn from the impact literature? *Global Environmental Change*, 8(2): 109–123.

Tollenaar M., Nissanka S.P., Aguilera A., Weise S.F., Swanton C.J. (1994). Effect of weed interference and soil-nitrogen on 4 maize hybrids. *Agronomy Journal*, 86: 596–601.

UNEP (United Nations Environment Program), (1994). United Nations Framework Convention on Climate Change. Geneva: iucc / UNEP.

United Nations Environment Program (UNEP), (1998). *Handbook on Methods for Climate Impact Assessment and Adaptation Strategies*, 2. Institute for Environmental Studies, Amsterdam. University of Southern Denmark. (13 September, 2013). Unexpected interaction between ocean currents and bacteria may weaken ocean's ability to absorb carbon dioxide. ScienceDaily. Retrieved June 29, 2014 from www.sciencedaily.com/releases/2013/09/130913101817.htm

UNFCC, (2006). Handbook. Bonn, Germany: Climate Change Secretariat. ISBN: 92-9219-031-8. PDF format: http://unfccc.int/resource/docs/publications/handbook.pdf

Vaillancourt, Y., Aubry F. and Jetté, C. (2003). *L'économie sociale dans les services à domicile*. Presses de l'Université du Québec, Quebec City, p. 341.

Vaillancourt, Y., Aubry, F., Kearney, M., Thériault, L. and Tremblay, L. (2004). *The Contribution of the Social Economy Towards Healthy Social Policy Reforms in Canada: A Quebec Viewpoint*. In: Social Determinants of Health. Canadian Perspectives [Dennis Raphael (Ed.)]. Toronto, Canadian Scholars' Press Inc., 311–329.

Vaillancourt, Y. (July, 2008). Social Economy in the co-construction of public policy: La démocratisation des politiques publiques: Une vision canadienne et québécoise. Occasional Paper Series, 3.

Verma, U., Piepho, H.P. and Kalubarme, M.H. (May, 2012). Multi-level mixed modelling for weather crop yield relationships on agro-climatic zones basis in Harayana Northern India. *Advances* *and Applications in Statistics,* 28(1): 1-22. Pushpa Publishing House. http://www.pphmj.com/abstract/6855.htm

Vincent, L.A. and Mekis, E. (2006) Changes in daily and extreme temperature and precipitation indices for Canada over thetwentieth century. *Atmosphere Ocean*, 44(2):177-193.

Wall, E. (2008). Climate change and rural issues: Le plus ça change le plus c'est la même chose. *Journal of Rural and Community Development,* 3(2):1-6. Faculty of Environmental Sciences, Guelph University.

Wang, Q. J., Nathan, R. J., Moran, R. J. and James, B. (1999). Impact of climate Changes on the Security of the Water Supply of the Campaspe System. Proceedings of the 25th Hydrology and Water Resources Symposium, Vol. 1, 6-8 July 1999, Brisbane, Institution of Engineers, Australia, Water 99 Joint Congress, pp. 135-140.

Wang, Y.P., Handoko, Jr. and. Rimmington, G.M. (1992). Sensitivity of wheat growth to increased air temperature for different scenarios of ambient CO_2 concentration and rainfall in Victoria, Australia: A simulation study. *Climate Research*, 2: 131–149. Word Bank (2008): The Global Monitoring Report 2008. Washington, Available at http://siteresources.

Watson, R.T., Zinyowera, M.C. and Moss, R.H. (1996). *Climate change 1995: impacts, adaptation and mitigation of climate change: Scientific-Technical Analysis.* Cambridge University Press, Cambridge.

Wheaton, E.E. and McIver, D.C. (1999) A framework and key questions for adapting to climate variability and change. *Mitigation and Adaptation Strategies*, 4: 215–225.

White, A.Y. (1985). Perception, in Kates, Robert W et al. (eds): Climate Impact Assessment Studies of International Climate and Society. Chichester and New York, pp. 323-350.

White, C. (27 March, 2013). The other job. *The Carbon Pilgrim.* *http://carbonpilgrim.wordpress.com/2013/03/27/the-other-job/*

World Bank, (2010). *Development and climate change*. World development report. The International Bank for Reconstruction and Development. Washington, DC. Hardcover ISBN: 978-0-8213-7989-5. Softcover ISBN: 978-0-8213-7987-5. PDF format: http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1226014527953/WDR10-Full-Text.pdf

World Bank, (2011). *Climate-Smart Agriculture: A Call to Action*. Washington, DC.

Winterhalder, B. (1980). Environmental analysis in human evolution and adaptation research. *Human Ecology,* 8(2): 135-170.

Yagouti, A., Boulet, G., Vincent, L.A., Vescovi , L. And Mekis, E. (2008) Observed changes in daily temperature and precipitation indices for Southern Quebec, 1960-2005. *Atmosphere-Ocean*, 46(2):243-256.

Zhang, X., Vincent, L.A., Hogg, W.D. and Niitsoo, A. (2000). Temperature and precipitation trends in Canada during the 20th century. *Atmosphere-Ocean*, 38(3):395–429.

Ziska, L.H. and Goins, E.W. (2006). Elevated atmospheric carbon dioxide and weed populations in glyphosate treated soybean. *Crop Science*, 46:1354-1359.

Appendices

<u>Appendix 1:</u>

<u>An example of solar radiation leading to global warming- Arctic Amplification Feedback Loops:</u>

Warming of the Arctic, also coined as Arctic amplification, is an important feature of observed and projected climate change. Arctic warming determines the fate of the whole planet from global warming. Because ice has greater reflectivity (also known as albedo) than the ocean or land, the Arctic is expected to experience the greatest rates of warming compared with other regions of the world. Over the past century, Arctic temperatures have risen 1.4°C (2.5°F) or twice as much as the rest of the planet (IPCC, 2007). Melting of highly reflective snow and ice reveals darker land and ocean surfaces, increasing absorption of the sun's heat and further warming the planet, especially in the Arctic regions.

Arctic carbon feedbacks are methane emissions and methane is 72 times more powerful than CO_2 for 20 years after emission. In general, there are four positive feedback loops that are causing the rapid warming of the Arctic: (1) Decrease in snow or ice cover leads to the loss of albedo, which causes more warming; (2) Decrease in Tundra area leads to an increase in the soil decomposition, leading to more carbon dioxide and further warming. At the same time, the decrease in Tundra area also leads to an increase in methane producing microbes, which means more methane emissions and more warming; (3) Rise in ocean temperature leads to more methane emissions, released from methane hydrates, meaning more warming; and (4) Decrease in sea ice cover leads to the exploitation of oil and gas reserves, leading to further warming.

Most scientists state that the main factor in the accelerating rate of Arctic warming is the loss of albedo and the heat gain resulting from the accelerating Arctic sea ice loss (Holland and Bitz, 2003; Serreze *et al*., 2009). It is during the summer where the loss of sea ice albedo amplifies Arctic warming. Another important cause of albedo loss is the black carbon (soot) deposited on Arctic snow from Northern hemisphere air pollution. In addition, the predominant thermal inversion in winter intensifies the Arctic amplification. In fact, the ability of the Arctic winter-time clear-sky atmosphere to cool to space decreases with inversion strength (Hazeleger *et al*., 2010). Moreover, the water flowing from the Atlantic Ocean to Arctic Ocean is about 2°C warmer today than it has been for at least 2,000 years (Spielhagen *et al*., 2011). Most probably, this is linked to the Arctic amplification of global warming (Kinnard, 2011).

Appendix 2:

Questionnaire- Translated to English in Appendix 4

Nom du répondant : ____

Municipalité : ____

Sexe: Femme____ Homme____

Groupe d'âge: 20-34 ans____
35-49 ans____
50-64 ans____
65 ans et plus ____

Adresse : ____

Téléphone : ____

Courriel : ____

Professionnel _________ ou Exploitant agricole _________

Si professionnel :

Organisation ou association auquel vous appartenez : ________________________

Si exploitant agricole :

Nom de l’exploitation : ____

Type de ferme : ____

Superficie totale: ____

1) Forces et faiblesses (générales) de la région du point de vue agricole?

Forces	Faiblesses

2) Dans le contexte des changements climatiques, comment définiriez-vous le mot «adaptation»? :

3) D'après vous, l'agriculture dans votre région est-elle bien adaptée pour faire face aux changements climatiques? Pourquoi / comment ? :

4) L'agriculture doit-elle s'adapter aux changements climatiques ? :

5) Avez-vous adopté ou prévoyez-vous des mesures pour faire face aux changements climatiques? :

5.1) Si vous avez pris des mesures, pourriez-vous indiquer le(s) type(s) d'adaptation? :

5.2) Évaluez-vous systématiquement les mesures (ou les types) d'adaptations effectuées? :

Si oui, comment?

5.3) Quand est-ce que vous estimez qu'il est nécessaire ou indispensable de s'adapter?:

6) Quelles sont les stratégies que vous faites lorsque vous remarquez un changement qui touche sur votre exploitation? :

7) Par ordre d'importance, quels sont les facteurs que vous considérez avant d'effectuer une activité d'adaptation? :

8) Pouvez-vous nous citer en quelques points les étapes suivies avant d'effectuer une activité d'adaptation? :

9) Par ordre d'importance, quels sont les facteurs qui vous guident dans le choix des cultures à pratiquer sur vos fermes? :

10) D'après vous, quelle est la capacité d'adaptation de votre région? :

11) Par ordre d'importance, quels sont les déterminants de la capacité adaptative de l'agriculture dans votre région? :

12) Pensez-vous que les agriculteurs dans votre région ont besoin d'une aide ou appui afin de pouvoir adopter des stratégies d'adaptation aux changements climatiques?

Si oui, qui selon vous pourraient apporter cette aide? :

Appendix 3 :

Codification on Excel

V1= **Municipality** (text)

V2= **Sex [H=1, F=2]**

V3= **Group of age**

Themes	Codes
20-34 ans	1
35-49 ans	2
50-64 ans	3
65 ans et plus	4

V4= **Production type** [Verger=1, Serre horticole=2, Viticulture=3, Grandes cultures (avec animaux)=4, Grandes cultures (sans animaux)=5]

Themes	Codes
Verger	1
Serre horticole	2
Viticulture	3
Grandes cultures (avec animaux)	4
Grandes cultures (sans animaux)	5

V5= **Total Surface Area (number)**

V6 **Ag Strengths**

Themes	Codes
V6.1. Facteurs biophysiques	0-1
V6.2. Producteurs laitiers et/ou grandes cultures	0-1
V6.3. Proximité des milieux urbains	0-1
V6.4. Agriculture dominante	0-1

0=absent, 1= present

V7 **Ag Weaknesses**

Themes	Codes
V7.1. Contraintes socio-économiques	0-1
V7.2. Proximité des milieux urbains	0-1
V7.3. Contraintes naturelles et/ou biophysiques	0-1
V7.4. Contraintes agricoles	0-1
V7.5. Prévisions météo	0-1

0=absent, 1= present

V8= **Définition de l'adaptation**

Themes	codes
De faire face aux CVC tout en réduisant l'effet de serre comme agriculteur et en améliorant la qualité et le rendement de nos produits en même temps	1
D'améliorer notre situation pour faire face aux conditions climatiques et socio-économiques (le marché)	2
D'améliorer notre situation pour faire face aux aléas climatiques, aux extrêmes (CVC seulement)	3

V9 **l'agriculture dans votre région est-elle bien adaptée pour faire face aux changements climatiques?**

Themes	Codes
Oui	1
Non	2

V10 **Pourquoi?**

Themes	Codes
V10.1. O: CVC sont très bons pour notre production	0-1

V10.2. O: Ouverture des agricultures (aux CVC et à la diversité des produits)	0-1
V10.3. O: Relève institutionnelle (bonne diffusion d'information, amélioration des fonds de terre)	0-1
V10.4. N: Agriculture intensive	0-1
V10.5. N: Agriculteurs sceptiques aux CVC	0-1
V10.6. N: Extrêmes dominants	0-1

0=absent, 1= present

V11 **Avez-vous adopté ou prévoyez-vous des mesures pour faire face aux changements climatiques?**

Themes	Codes
Oui	1
Non	2

V12 **Type(s) d'adaptation**

Themes	Codes
Adaptation spontanée	1
Adaptation planifiée	2

V13 **Évaluez-vous systématiquement les mesures (ou les types) d'adaptations effectuées?**

Themes	Codes
Oui	1
Non	2

V14 **Comment?**

Themes	Codes
Évaluation des rendements et/ou insectes	1
N.A.: confiance aux compagnies privées	2

V15 **Quand?**

Themes	Codes
Dès maintenant	1
Lorsque la température affecte nos produits ou rendements	2

V16 **Stratégies**

Themes	Codes
V16.1. Nivellement du sol et drainage	0-1
V16.2. Irrigation et/ou utilisation des pesticides, fertilisant ou d'autres méthodes naturelles pour contrer les maladies et les insectes	0-1
V16.3. Modification du calendrier des travaux ou la façon de faire	0-1
V16.4. Changement de type de cultures ou (la rapidité) de semences	0-1
V16.5. Modification du travail du sol	0-1
V16.6. Protection du sol	0-1

0=absent, 1= present

V17 **Par ordre d'importance, quels sont les facteurs que vous considérez avant d'effectuer une activité d'adaptation?**

Themes	Codes
V17.1. Conditions climatiques	0-1
V17.2. Pérennité de l'entreprise	0-1
V17.3. Conditions du marché	0-1
V17.4. Protection de la planète	0-1
V17.5. Moins d'heures de travail	0-1

0=absent, 1= present

V18 **Pouvez-vous nous citer en quelques points les étapes suivies avant d'effectuer une activité d'adaptation?**

Themes	Codes
Observation, renseignement et investissement	0-1

0=absent, 1= present

V19 **Par ordre d'importance, quels sont les facteurs qui vous guident dans le choix des cultures à pratiquer sur vos fermes?**

Themes	Codes
V19.1. Indices thermiques	0-1
V19.2. Le marché	0-1

V19.3. Pérennité de l'entreprise	0-1
V19.4. L'expérience des producteurs agricoles	0-1
V19.5. La disponibilité des variétés de cultures et leurs résultats (adaptabilité et rendements)	0-1
V19.6. Disponbilité des fonds d'investissement	0-1

0=absent, 1= present

V20 **D'après vous, quelle est la capacité d'adaptation de votre région?**

Themes	Codes
Moyenne	1
Bonne	2
Forte	3

V21 **Par ordre d'importance, quels sont les déterminants de la capacité adaptative de l'agriculture dans votre région?**

Themes	Codes
V21.1. Conditions climatiques	0-1
V21.2. Relève institutionnelle	0-1
V21.3. La main d'œuvre	0-1
V21.4. Relève agricole	0-1
V21.5. Politique gouvernementale	0-1
V21.6. Market Conditions	0-1
V21.7. Financial Support	0-1
V21.8. Technologie	0-1

0=absent, 1= present

V22 **Pensez-vous que les agriculteurs dans votre région ont besoin d'une aide ou appui afin de pouvoir adopter des stratégies d'adaptation aux changements climatiques?**

Themes	Codes
Oui	1
Non	2

V23 **Si oui, qui selon vous pourraient apporter cette aide?**

Themes	Codes

V23.1. Institutions agricoles publiques	0-1
V23.2. Institutions ou compagnies agricoles privées	0-1
V23.3. Coopérative	0-1

0=absent, 1= present

Appendix 4:

This Appendix presents the results of each open-ended question then it provides a brief summary of all answers. Excel and SPSS were used here to generate a table of frequencies according to each variable.

The first open-ended question is about the advantages and disadvantages of agriculture in the RCM of Haut-Richelieu. Regarding the advantages of agriculture in the RCM of Haut-Richelieu, biophysical factors, such as climate and good soil quality, occupied the first place (Figure S1). On the other hand, socio-economic constraints-- mainly the problem of farm succession, high price of agricultural lands associated with high competition for agricultural land purchase, high taxes for rural areas, and globalisation (which leads to no control over the market price) - occupied the first place in the agricultural disadvantages in the RCM of Haut-Richelieu. Biophysical and natural constraints- such as extreme climate events, wind and soil erosion, capricious land (or clay soil), and flat ground (which implies a need for drainage) - occupied the second place in the agricultural disadvantages (Figure S2). Proximity to urban areas came in the second place in terms of agricultural advantages and in the third place in terms of agricultural disadvantages. This is normal because while providing positive consequences such as the ease of inland infrastructures (which facilitates the exportation process), the ease to hire labour, and the proximity to private companies (i.e. ethanol companies) that consume the grains, proximity to urban areas presents a pressure on rural areas in many ways (e.g. harmonious cohabitation between rural and urban areas, people in rural areas are taxed similarly to those in rural areas).

Moreover, some participants viewed the presence of major field crops (mainly corn, soy and cereals) along with milk production as positive points (Figure S1) while others agreed that intensive agriculture and monoculture (known as agricultural constraints in Figure S2) are damaging agricultural practices.

All what is being said above until now in this sub-section confirms, to some extent (because one RCM cannot represent the whole Montérégie Region), that the Montérégie Region is considered to be the most intensive agricultural region in Québec because of the rich valley of the St. Lawrence, giving it about 500 000 hectares of arable land (Bryant *et al*., 2011). According to the Canada Land Inventory (CLI), the soils are of category 1, 2 and 3. Most of the territory is covered with clay soil, originating from fluvial sediments on either side of the main rivers that cross the region, namely the St. Lawrence River, the Richelieu River and the Yamaska River. The soils categories 1 and 2 are the most preferable for agriculture and are predominant in Montérégie West.

The dominant aspect of agriculture in the RCM of Haut-Richelieu came in last place (Figure S1). Indeed, protected by the agricultural zoning law in Québec, the permanent agricultural zone represents around 90% of the territory of the RCM of Haut-Richelieu.

In addition, a few farmers complained about the weather forecasts (Figure S2).

"Weather forecasts are not accurate at all (Saint-Bernard and Lacolle weather stations); so we look at the moon (or old farm sayings)" [Farmer M].

Claims about weather forecasts have already steered up some controversies. According to M. Phillips of Environment Canada, "Environment Canada's forecasts aren't always right, but that their predictions are more realistic than the almanac" (Coorsh, 2014). One important point is that farmers (or the general public) need to really understand is that some aspects of the weather (such as temperature and pressure, or even mean wind speed at some broad spatial scale) are rather easier to predict than others (e.g., precipitation, cloudiness, or local turbulence). Hence, if someone is particularly sensitive to rain and snow, that person may hold the belief that the weather man does not know what he's talking about, while another person who is more attuned to temperature forecasts may claim that the same weather man is actually doing quite well. Therefore, the performance of popular sayings may also be variable depending on what they claim to predict.

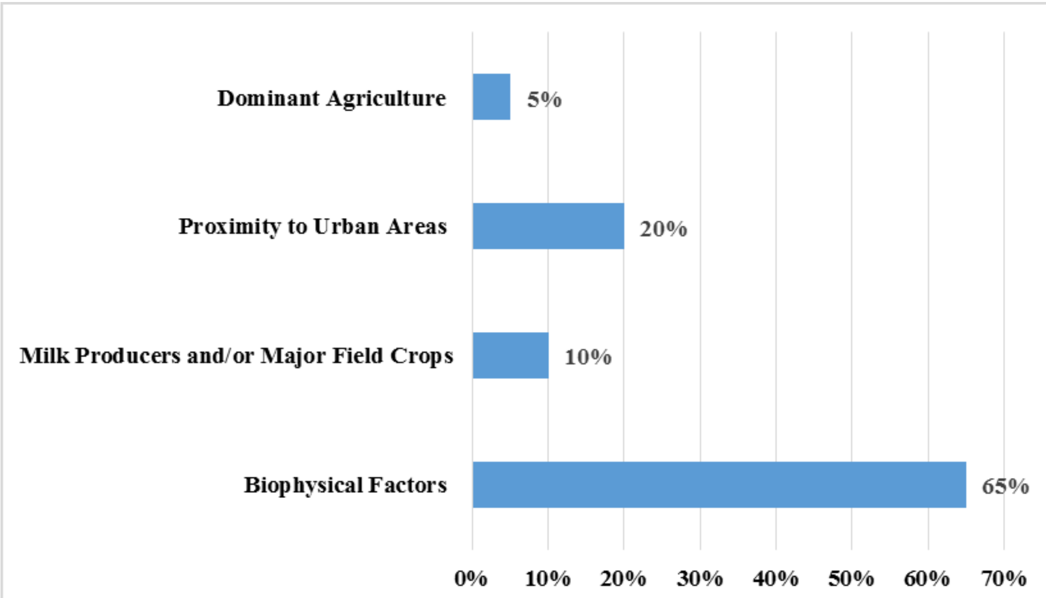


Figure S1: Representation in percentage of the agricultural advantages of the RCM of Haut-Richelieu according to the participants, Inquiry 2014-2015.

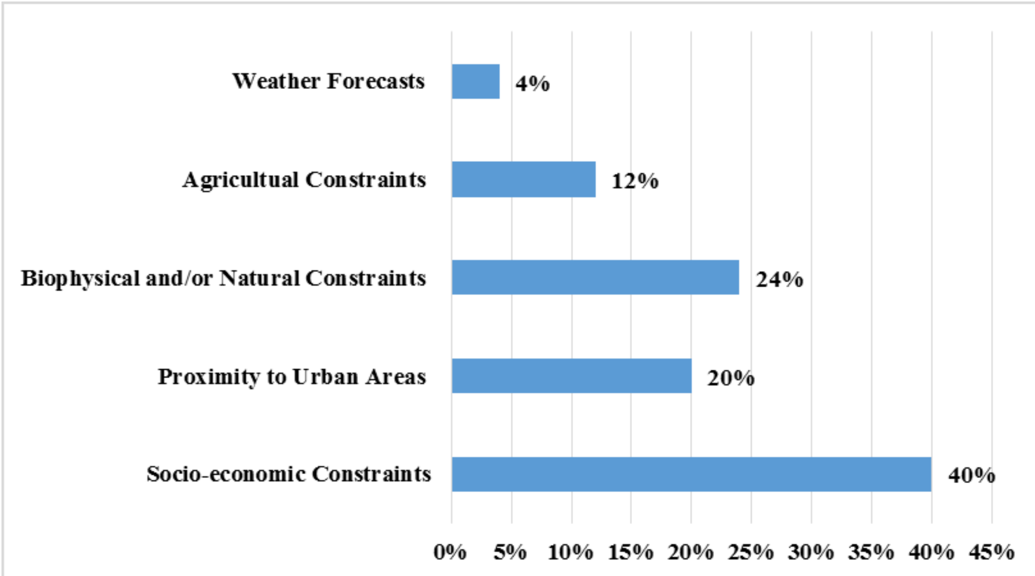


Figure S2: Representation in percentage of the agricultural disadvantages of the RCM of Haut-Richelieu according to the participants, Inquiry 2014-2015.

The second question is about the definition of the word 'adaptation' in the context of climate change and variability. According to Figure S3, 60% of the participants recognized that extremes (or variability) are associated with climate change. To a lesser degree, some farmers concluded that one should not separate climatic factors from non-climatic factors in the process of agricultural adaptation to climate change and variability. The other minority (representing 13%) acknowledged climate change by reducing the GHG effect as a means to cope with it.

For farmers, the word 'improve our situation' meant to increase the yields and not to suffer the negative consequences of climate change. All in all, participants have acknowledged the fact that climate change is happening.

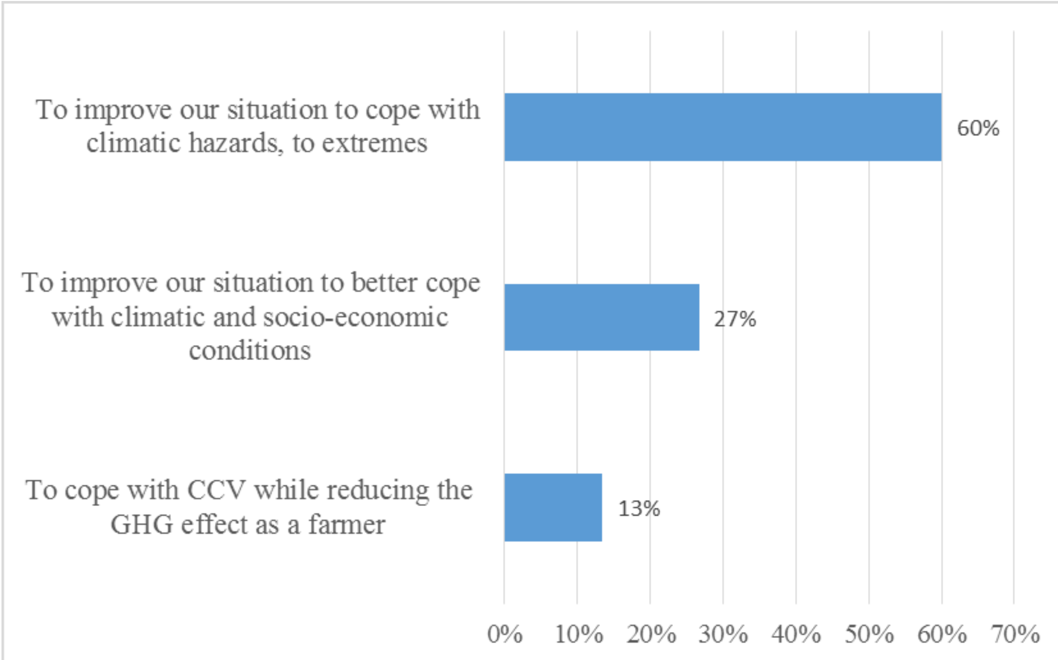


Figure S3: Respondents' definition of adptation to climate change and variability, RCM of Haut-Richelieu, Inquiry 2014-2015.

The third question investigates whether the participants see if agriculture in the RCM of Haut-Richelieu is adapted or not to climate change. In the context of climate change and variability, the majority (Figure S4) thinks that agriculture is well adapted providing the four main reasons, which are: (1) Climate change is good for agricultural production, (2) Agricultural enterprises are financially in a good shape, (3) Good diffusion of information, and (4) Farmers are open to have diverse products. On the other hand, those who think that agriculture in the RCM of Haut-Richelieu is not well adapted provided four main reasons, which are the following: (1) Extreme weather events which are hard to cope with, (2) Some farmers remain skeptic about climate change, (3) Intensive agriculture – which is practiced in the RCM of Haut-Richelieu – is rendering the soil more vulnerable to climate change, and (4) Agricultural machineries and equipment still have to evolve to better cope with the negative effects of climate change.

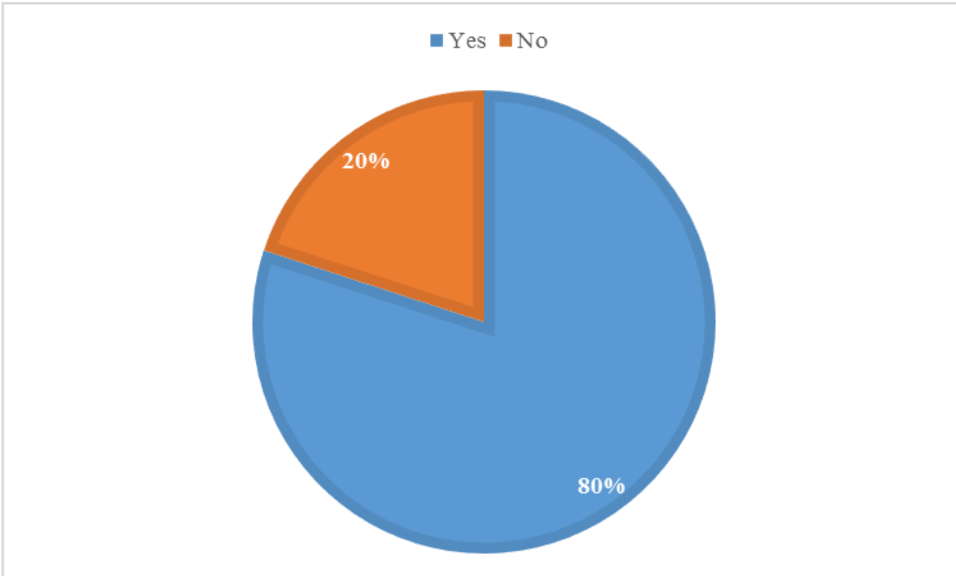


Figure S4: Agriculture in the RCM of Haut-Richelieu is well adapted to cope with climate change according to the participants, Inquiry 2014-2015.

The fourth question is about whether participants see that agriculture 'should' adapt or not to climate change. According to Figure S5, 93% said yes because they do not have any other choice as farmers; climate does not adjust to agriculture. The minority who said that agriculture should not adapt to climate change was very optimistic about the consequences of climate change, as if climate change did not have any negative effect on his/her production type.

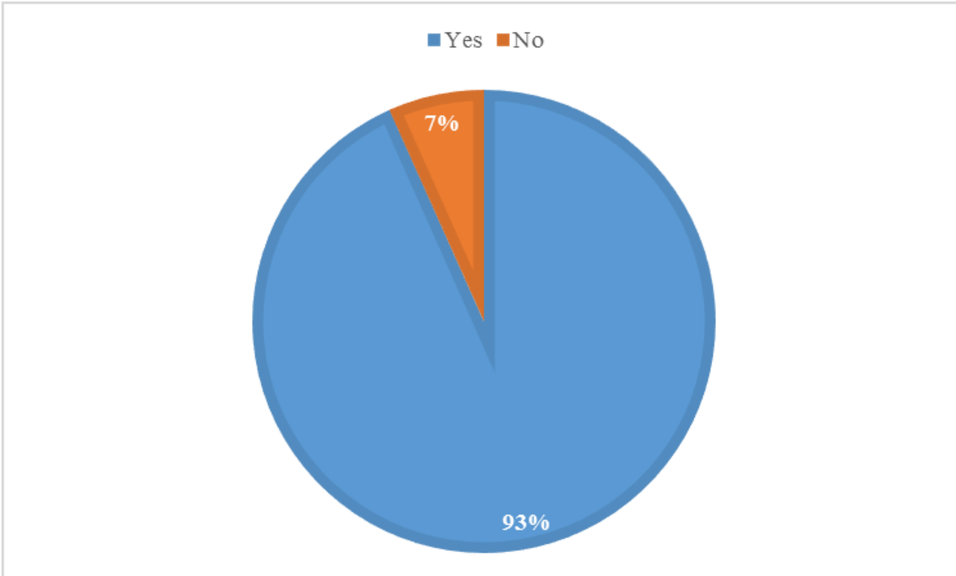


Figure S5: Agriculture should adapt to climate change in your opinion?

The fifth question is about whether the participants have adopted measures or not to cope with climate change. 93% (Figure S6) have already adopted measures or strategies to cope with climate change. 7% did not adopt any measures because they simply trust the private companies in offering them the cultivars, which could be ideologically unfortunate.

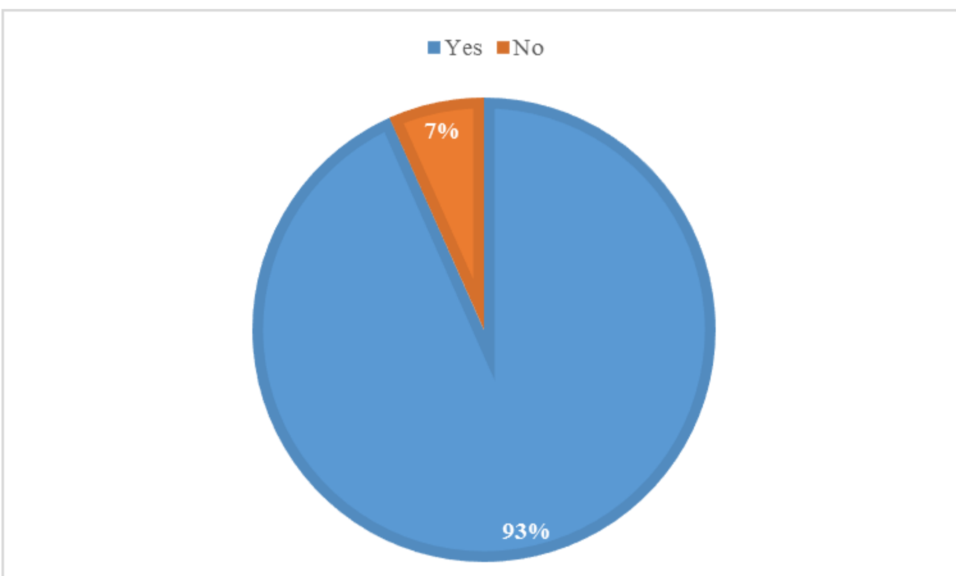


Figure S6: Have participants adoped measures to cope with climate change?

Sub-section 5.1 of the fifth question is about the adaptation type that the participants undertake to adapt to climate change and variability. In general, all 15 farmers adapt spontaneously.

Sub-section 5.2 of the fifth question investigates whether participants systematically evaluate or not the types of adaptation. The majority of the respondents evaluate the yields and or detect the presence of insects. Others do not evaluate their types of adaptation because they simply trust the private companies in offering them the cultivars, as previously stated.

Sub-section 5.3 of the fifth question asks when participants think it is necessary or essential to adapt. According to Figure S7, the majority thinks that it is necessary to adapt from now while the minority adapts when temperature affects their products or yields negatively.

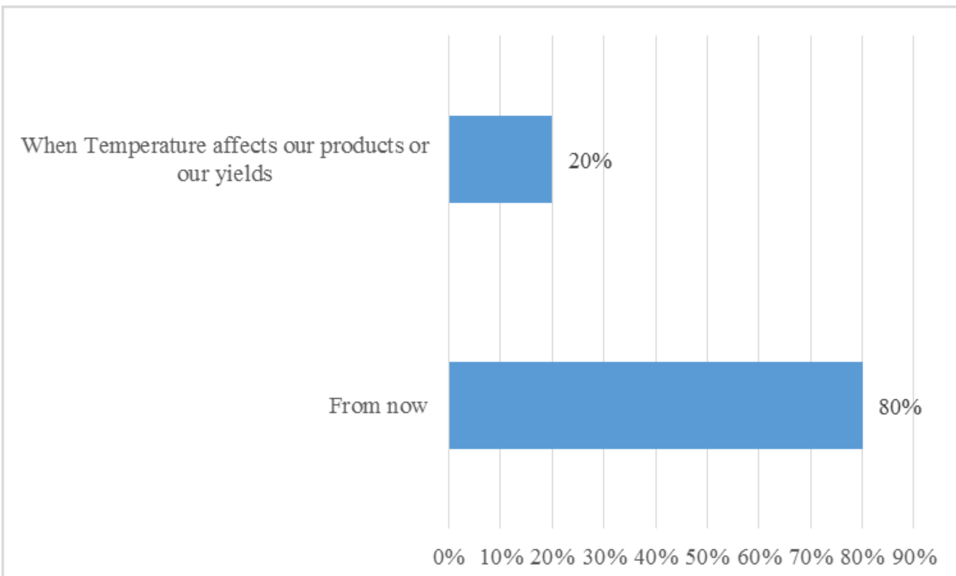


Figure S7: When do you estimate that it is necessary to adapt ?

Question 6 is about the strategies that the participants undertake when they notice any change that affects their yields or production (Figure S8).

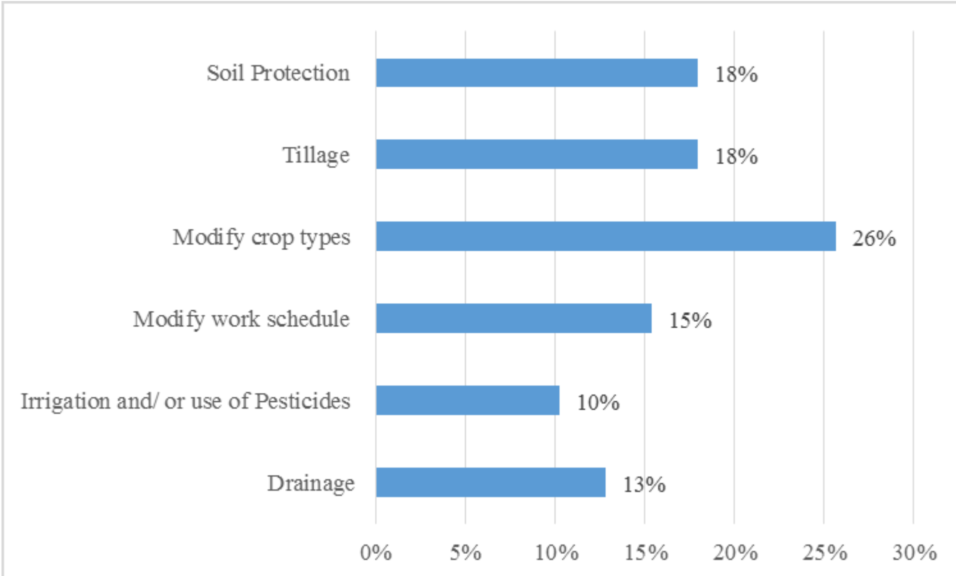


Figure S8: Strategies adopted by farmers to adapt to climate change in the RCM of Haut-Richelieu, Inquiry 2014-2015.

Question 7 is about the factors that the participants consider before making an adaptation activity (Figure S9).

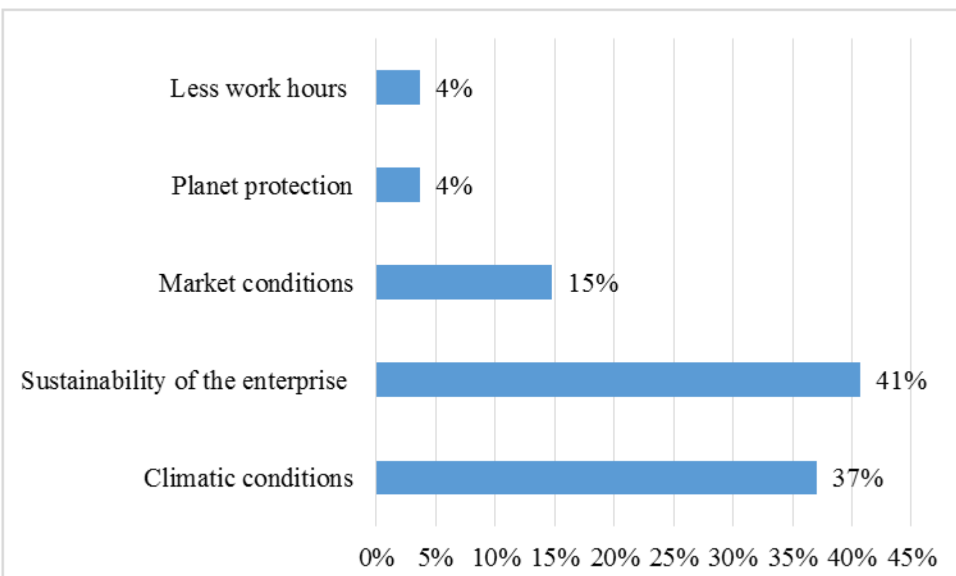


Figure S9: Factors that participants consider before making an adaptation activity, RCM of Haut-Richelieu, Inquiry 2014-2015.

Question 8 is about the steps, in brief, that farmers take before making an adaptation activity. Basically, all 15 farmers take the same steps, which are: (1) observation, (2) inquirer or consultation, and (3) investment.

Question 9 is about the factors that guide farmers in the selection of crops to grow on their farm (Figure S10).

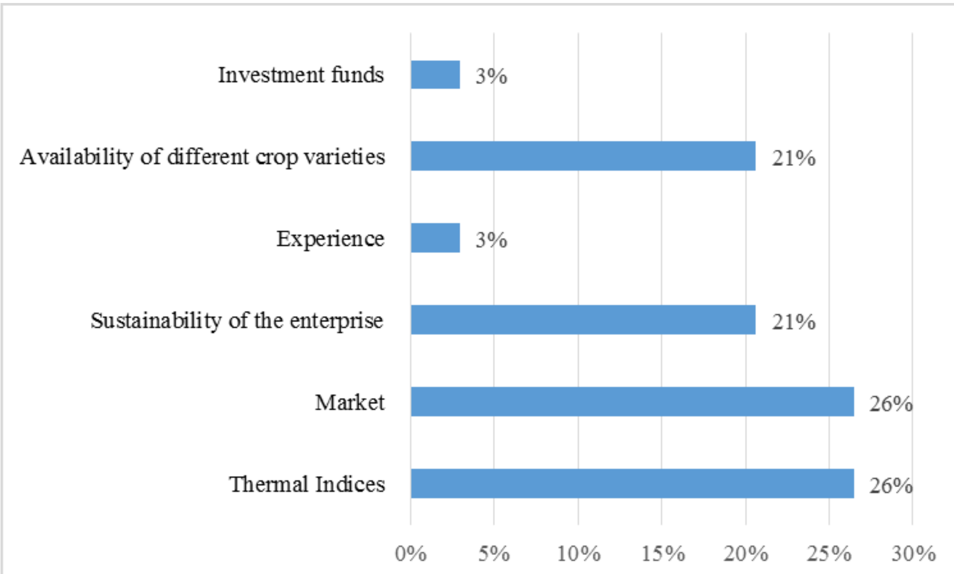


Figure S10: Factors that guide farmers in the selection of crops to grow on their farm, RCM of Haut-Richelieu, Inquiry 2014-2015.

Question 10 investigates the adaptive capacity of the region from the participants' point of view (Figure S11).

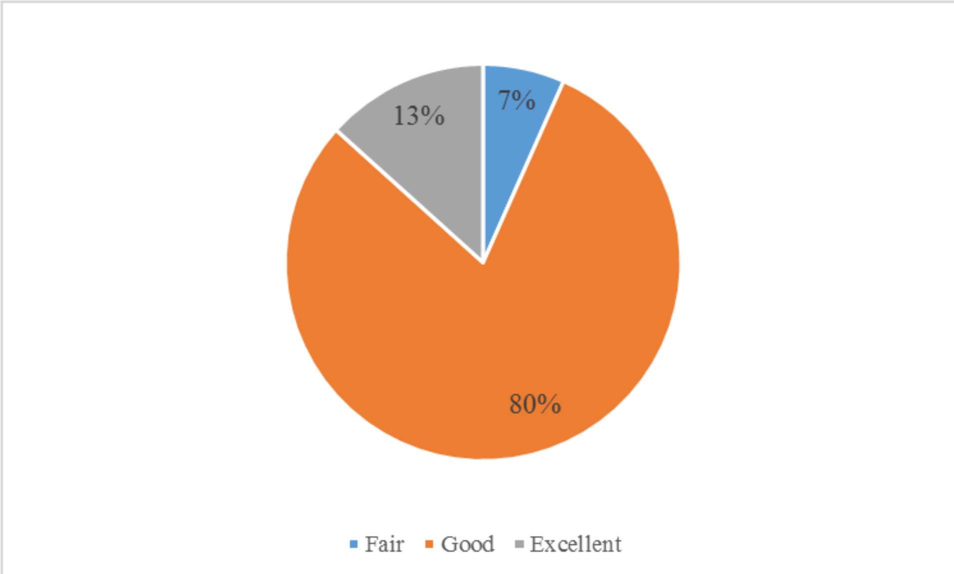


Figure S11: Adaptive capacity of the region from the participants' point of view, RCM of Haut-Richelieu, Inquiry 2014-2015.

Question 11 identifies the determinants of the adaptive capacity in the RCM of Haut-Richelieu (Figure S12).

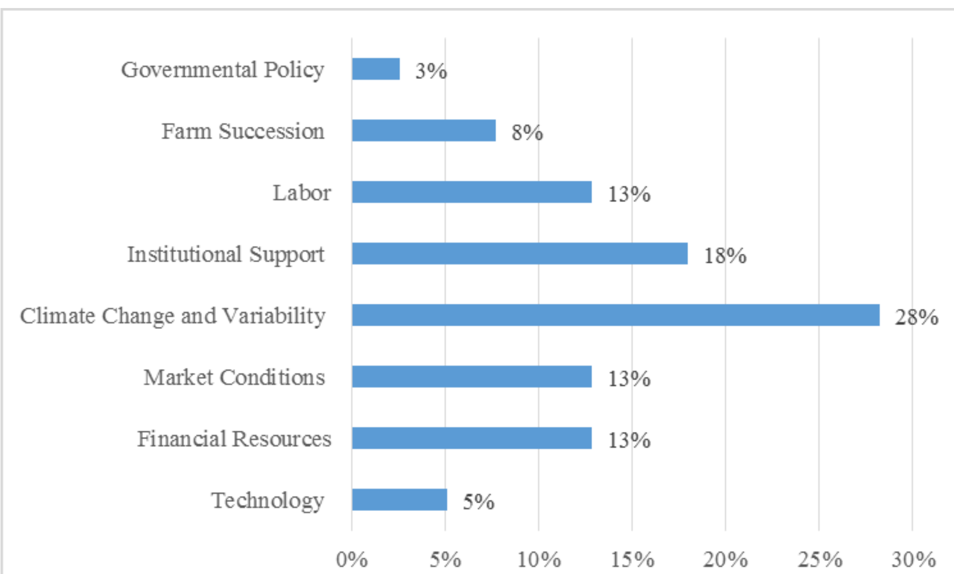


Figure S12: Determinants of adaptive capacity in the RCM of Haut-Richelieu, Inquiry 2014-2015.

The final question is divided into two sub-sections. The first set asks participants if they believe that farmers in the RCM of Haut-Richelieu need help or not (Figure S13). The second set investigates which actor(s) can help farmers to better adapt to climate change and variability (Figure S14).

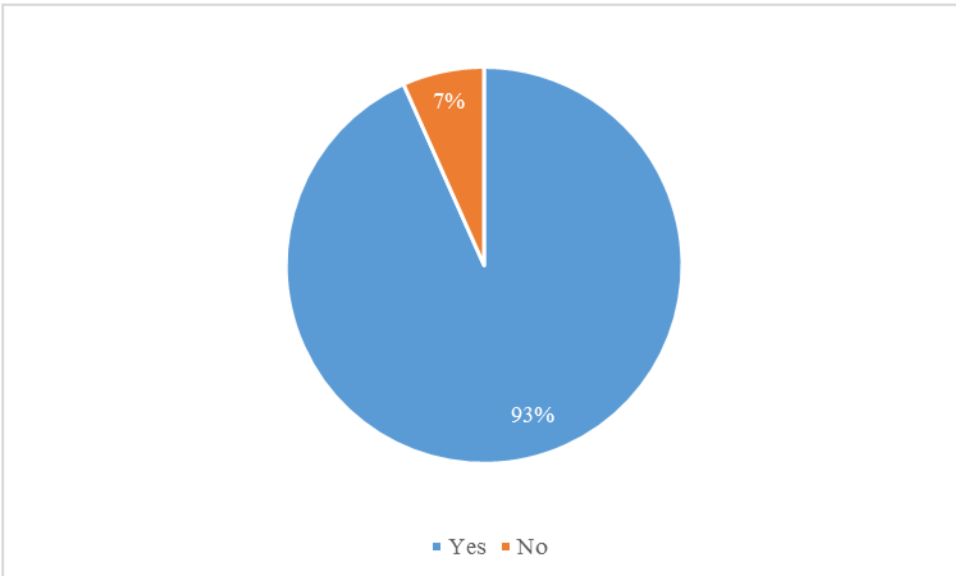


Figure S13: In your opinion, do farmers in your region need help?

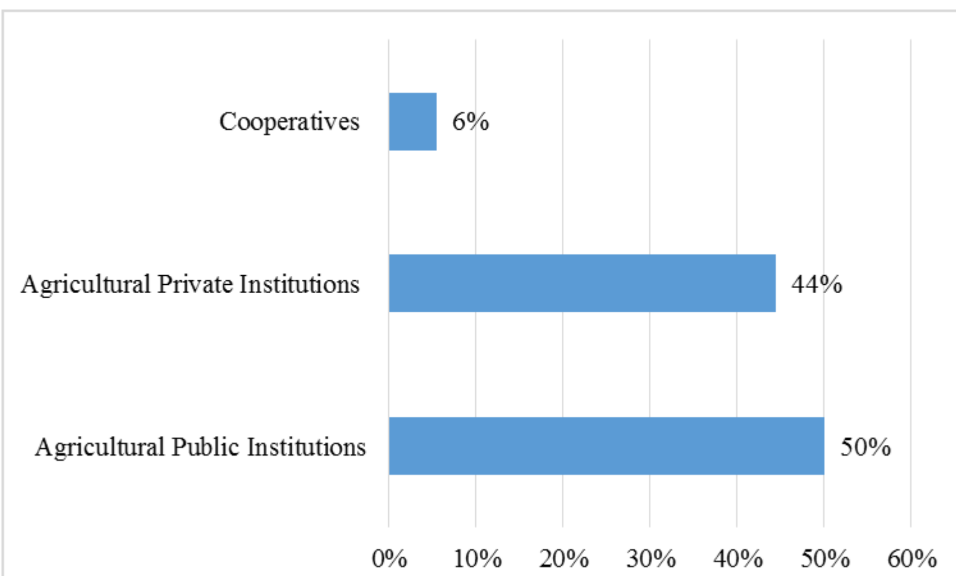


Figure S14: Potential actors who can help farmers to better adapt to CCV.

Appendix 5:

This appendix presents in brief the results of the focus group discussion between the three agronomists:

Agricultural advantages in the RCM of Haut-Richelieu according to the agronomists:

- A very dynamic agricultural aspect (e.g. diverse agricultural enterprises that are financially healthy).
- The presence of research agents (e.g. large supply of agro-environmental clubs) and techno transfer in our region.
- Fertile agricultural lands.
- CHUs are increasing.
- But the will is absent.
- Proximity to urban areas and to markets of Montréal and USA.

Agricultural disadvantages in the RCM of Haut-Richelieu according to the agronomists:

- Disinformation and desensitization on the causes of CCV in the region.
- Lack of crop rotation.
- Conflicts related to cohabitation between rural and urban areas.
- Environmental problems (e.g. bad water quality and biodiversity loss).
- High agricultural land prices.

To agronomists, the word 'adaptation to CCV' means:

- Ability of an agricultural enterprise to adjust its way or producing and remain profitable while coping with CCV at the same time.

- Is to change some agricultural practices in a sense to have an anticipated adaptation instead of reactive adaptation (mainly to be shocked when a sudden climatic event happens).
- Is to eventually adapt our crops (e.g. grow oranges) especially by trying to get the maximum of temperatures (e.g. adapt or choose crops that are mostly adapted to high CHUs)

Agronomists see that agriculture in the RCM of Haut-Richelieu is more or less adapted to CCV because of the following reasons:

- Lack of crop rotation.
- Some farmers are still more or less informed about the causes of CCV.
- Biodiversity loss.
- Large supply of agro-environmental clubs.
- Agricultural enterprises have a good economic capacity to adapt.
- Good amount of precipitations, which decreases the risk of having droughts.
- Absence of will.
- Fertile agricultural lands.
- Accessibility to drainage.

According to the agronomists, agriculture has to adapt to climate change because of the following reasons, which are:

- To use the maximum advantage that climate is already giving us.
- Agricultural production is based on a natural ecosystem.
- We do not have any other choice. We are already witnessing upheavals linked to climate.

Agronomists have already adopted some measures to cope with CCV. For instance:

- Research and development (R&D) on a new variety of cultivars.
- Crop diversification
- Drainage.

Like farmers, agronomists think that it is necessary to adapt:

- From now
- When temperature affects yields or a certain product, making sowing within the usual time of the growing season impossible.

Factors that agronomists consider before making an adaptation activity are the following:

- Climatic factors.
- Technical feasibility.
- Available funding.
- Yield loss.
- Impact on the environment.

According to the agronomists, the determinants of the adaptive capacity of agriculture are the following:

- Openness of farmers to change their cultural methods.
- Market.
- Financial capacity.
- Availability of the agro-environmental services.

All agronomists agreed that farmers in the RCM of Haut-Richelieu need help and that the agronomists, themselves, should provide that help.

During the discussion between the agronomists:

- The notion of co-construction is evident.
- Adaptation has to go through a different land management (i.e. water management).
- Farmers have to be in the forefront when it comes to agricultural adaptation to CCV. However, this presents an important bias since there are other actors who are directed towards agriculture before becoming farming in the first place.
- One must take into account the experience of the farmers.
- To have an anticipative adaptation, we should sensitise and educate the farmers. Farmers should see the negative side as well as the positive side of CCV. They notice climatic changes mainly related to rainfall events, but they do not make a link to CCV.
- We have some agricultural advantages, but the will is not present.

Agronomists need:

- More research to document and support their various actions and services that they provide for the farmers.
- More knowledge on the local level. For instance, we need local climate models and more information on rainfall along with its associated events.
- Environmental approach directly linked to the management of water quality instead of CCV.