Climate Change in the Prairie Agro-ecosystem: Information Exchange and Producer-level Learning

Tyler Tarnoczi

A Thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfillment of the requirement of the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

Natural Resources Institute
University of Manitoba
Winnipeg, MB
R3T 2N2

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

****

COPYRIGHT PERMISSION

Climate Change in the Prairie Agro-ecosystem:
Information Exchange and Producer-level Learning

By

Tyler Tarnoczi

A Thesis/Practicum submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfillment of the requirement of the degree of

Master of Natural Resources Management (M.N.R.M.)

Abstract

As climate change impacts the Prairie agro-ecosystem there is a need to shift away from technologic solutions and expert-prescribed knowledge, to practices consistent with long-term sustainability where social sources of adaptability are utilized through information exchange and learning. This research examines the information that is used to help producers adapt to climate change, specifically regarding soil and water conservation, and how this information reaches farmers through horizontal and vertical linkages. Individual learning that is occurring at the farm-level, as a result of the adoption of different farming practices, is also explored using transformative learning as a theoretical lens. The findings regarding learning and information exchange are then used to explore implications for adaptive policy-making and resilience building.

Results from the 28 semi-structured interviews conducted with producers in two Prairie provinces, Alberta and Manitoba, revealed that information flow in the agro-ecosystem occurs predominantly top-down and horizontally between producers, with very little information flow occurring vertically from the producer level to organizational levels. Top-down information comes from a variety of groups including: government, industry, producer and conservation organizations, social sources of information and personal experience, media, and universities. Examining the frequency with which information flows reveals that there is not one single dominate source. However, when examining each soil or water conservation practice individually, there are usually one or two dominant sources for the information obtained by producers.

Exploring the individual learning process was done by categorizing the learning into three types: instrumental, communicative, and transformative. While all producers learned instrumentally to develop more effective farming methods, there were usually two frames of reference in which instrumental learning

occurred: maximizing profits in the short-term or maintaining economic viably over the long-term. Communicative learning, specifically that which seemed to lead to critical reflection regarding normative ideologies, occurred largely through dialogue between local producers and not between producers and organizations. Three categories of reflection stemming from the communicative learning process included reflection of (1) interrelationships between practices and environmental sustainability; (2) roles and responsibilities as a farmer; and (3) social norms. Producers that demonstrated reflection of this type often showed indications of transformative learning where governing habits of mind are altered through premise-based reflection. Indicators of transformative learning included: questioning roles and social norms; enhanced instrumental competence; learner set on a pathway for further premise-based reflection; enhanced instrumental competence; and, gaining insight into one's own learning style. These indications may act as a guide to suggest in which individuals the transformative learning process might be occurring or it might indicate a foundation where transformative learning could occur. Producers who tended to receive information from a greater diversity of sources, and used experiential or observable means, generally were more likely to show indications of transformative learning.

Based on the findings of this study, to support adaptability to climate change and long-term sustainability in the Prairie agro-ecosystem there is a need to: strengthen horizontal information sharing, foster learning, especially experiential learning; and establish two-way, vertical information pathways. A governance structure which employs adaptive policy-making and adaptive co-management may ultimately make the system more resilient to environmental change.

Acknowledgements

I would like to extend my gratitude to those individuals whose assistance helped to make this thesis possible. First of all, I would like to thank my academic advisor Dr. Fikret Berkes for helping to fund this project and for his committed guidance throughout the research process. I would also like to thank the members of my academic committee for generously providing their time and advice: Dr. John Sinclair of the Natural Resources Institute, for significantly contributing to my understanding of transformative learning. Also, Dr. Henry Venema and Mr. Darren Swanson of the International Institute for Sustainable Development, who provided constructive recommendations throughout, including direction regarding adaptive policy-making.

Thank you to Ian Wishart, President of Keystone Agricultural Producers, and Rick Martin, Senior Project Adviser for the Partners in Habitat Development program with the Eastern Irrigation District, who were crucial in providing interview contacts. I would also like to express my appreciation to all the farmers in the Whitehorse Plains Region and the County of Newell who participated in the research interviews.

This research was made possible by the financial support of the Social Sciences and Humanities Research Council of Canada (SSHRC) through grants held by Dr. Fikret Berkes and the Province of Manitoba though the Manitoba Graduate Scholarship.

Table of Contents

List of Tables

List of Figures

List of Acronyms

EID	Eastern Irrigation District
EFP	Environmental Farm Plan
GCM	General circulation models
MANDAK	Manitoba-North Dakota Zero Tillage Farmers Association
PFRA	Prairie Farm Rehabilitation Administration
RTL	Reduced Tillage Linkages
TLT	Transformative learning theory

Chapter 1 – Introduction

1.1 Background

Climate change and extremes in weather are already impacting Prairie agro-ecosystems. How are farmers learning from these changes already impacting agriculture? What are the pathways for information flow, and what kinds of leaning may be taking place? These questions are important in terms of adaptive policy-making (IISD and TERI, 2006) and resilience building in the Prairie agro-ecosystem.

Agriculture in the Canadian Prairies plays a vital socio-economic role. In 2005, the Canadian agriculture and agri-food system made up 8.0% of the total Canadian Gross Domestic Product (AAFC, 2007). The Prairies region spans 550,000 square kilometres across Alberta, Saskatchewan, and Manitoba representing what is essentially the northern geographic limit of arable farmland in North America (Swanson et al., 2007). The region represents approximately 80% of all the agricultural land in Canada (Statistic Canada, 2001). However, concerns arise when considering the long-term viability of agricultural practices in the face of environmental uncertainty, due to the heavy reliance on external inputs and failure to incorporate natural processes (Pretty, 1998). Sustainable agriculture is defined by Pretty (1998) as a process for learning. This includes the incorporation of natural processes, reduction of external inputs, and the full participation of farmers in a process that is more equitable, self-reliant, and experiential. This process requires dialogue and alliances between agricultural actors to allow for mutual learning and the maximization of social and physical resources (Pretty, 1998). With increasing uncertainty due to climate change, understanding these pathways of information sharing and individual learning are important for fostering adaptation and resilience building.

Climate change is expected to substantially alter the physical landscape of the Canadian Prairies, thereby posing a great risk to agricultural-based livelihoods. The Intergovernmental Panel on Climate Change predicts that warming across central North America will likely be greater than the global average during this century (IPCC, 2007). General Circulation Models (GCM) suggest that the Canadian Prairies will experience warmer than average temperatures and increased evapo-transpiration (Venema, 2006). In addition, water supplies will become increasingly variable as rainstorms become less frequent and more intense (Runnalls, 2007). As a result, soil moisture will decrease and the Prairie region will become increasingly arid, negatively affect crop yields (Venema, 2006; Runnalls, 2007).

While GCMs predict increased winter precipitation under a new climate regime, the gains in moisture are likely to be offset by warmer temperatures, which will result in a smaller snowpack in the Rocky Mountains, and consequently a decreased spring melt (Lapp et al., 2005). Since the majority of the water in the Prairies originates from the snowpack in the Rocky Mountains, and only a very small amount of runoff contributes to the overall flow of the rivers (Cohen, 1991), water consumptive agricultural practices will become increasingly stressed. Furthermore, warming temperatures will result in an increased demand for water and cause more widespread and frequent moisture deficits (Gan, 2000).

According to Krupnik and Jolly (2002) there are three major findings identified by Northern residents regarding climate change that may also apply to the Canadian Prairies. The first is increasing variability. There has always been a certain amount of variability in the regional climate. With climate change, the range of variability may increase. This means that drought periods may be long or erratic, or rainstorms may be more intense and unpredictable. The second finding is that extreme weather events become more frequent with climate change. For example, a one in one hundred year flood may occur more than once in a decade. The third finding is the unpredictability of weather and shifts in seasonal patterns.

This type of unpredictability creates a problem where producers may not know what to except next and how to prepare.

The distresses to agricultural-based livelihoods stemming from these three findings may be managed by fostering collective action through multiple scales. Using multiple levels of authority allows for the utilization of specific institutional expertise, and mitigates weakness through inter-connectedness (Berkes, 2007c). Since complex resource management problems cannot be dealt with at only one level, linkages connecting various institutional levels are important for effective management (Ostrom et al., 2002). There are two types of cross-scale linkages: horizontal and vertical. Horizontal linkages occur across sectors or geographic space (Berkes et al., 2003). They can involve institutions comparing experiences and learning from each other (Berkes, 2004). Vertical linkages are those that span across different levels of organization (Berkes et al., 2003). This may include the sharing of information between an individual farmer and a local agricultural organization. A system with many two directional cross-scale linkages has a higher degree of information sharing and learning occurring (Pretty, 2002) making the system more adaptive to environmental uncertainty and long-tem environmental change (Berkes, 2002).

With climate change in the Prairies, it is important to address issues of vulnerability to weather related uncertainty and long-tem change. This type of change and uncertainty may be dealt with by increasing adaptive capacity and resilience (Berkes et al., 2007). Resilience, as defined by Walker et al. (2004), is the capacity to experience a disturbance, and reorganize during changing conditions, so as to maintain original processes, functions, identity, and feedbacks of the system. Resilience to climate change in agriculture provides farmers with the social and physical resources required to sustain equitable crop yields and livelihoods over the long-term when faced with climate shocks and stresses.

Formulating appropriate adaptive responses requires not only understanding progressively changing conditions, but also climate variability and the increased frequency of extreme weather events (Smit and Skinner, 2004). Responding to climate change first requires the realization that uncertainty is inevitable, so that learning to live within the altered environment can occur (Berkes, 2007a). One way to deal with uncertainty is to increase adaptive capacity to climate change by nurturing soil and water resources, both of which are stressed due to climate change (Runnalls, 2007). These conservation techniques sustain productive agriculture and prevent soil exhaustion when water resources are scarce (Wang and Cheng, 2000), and may ultimately build resilience to climate change in the Prairie agro-ecosystems. However, the communication of the information regarding soil and water conservation, as well as the ability to learn and undergo changes in practice may be the ultimate determinate of resilience building. By examining the producer-level learning using transformative learning theory, insights into the learning surrounding adaptation to weather shocks and stresses can be gained.

1.2 Purpose

This research falls within a larger field of inquiry that explores how producers in the Prairie agro-ecosystem have responded to past weather shocks and stresses and how these actions can help producers in the future as the climate continues to change (Myers, 2008; Peace, 2009). The purpose of this research was to study how learning and information sharing regarding climate change occurs at the producer-level. This was achieved by identifying horizontal and vertical linkages, specifically those pertaining to soil and water conservation, through which information is exchanged. Producer-level learning that is occurring through this information exchange was then considered using the theoretical lens of transformative learning.

1.3 Objectives

The objectives of this thesis research were:

1. To identify horizontal and vertical linkages that connects the individual producers to information regarding soil and water conservation

2. To determine the frequency with which information flows from these sources and the content of the information received by producers

3. To consider the individual learning that precipitated the adoption of soil and water conservation practices using transformative learning theory.

4. To use these findings to explore implications for adaptive policymaking and resilience building.

1.4 Approach and Methods

The research was carried out using semi-structured interviews that included open-ended questions. In this way, new or unexpected phenomena that were not considered beforehand could be accounted for (Kvale, 1996). Thirty-two interviews were done in total, 28 with producers and 4 with organizations, in southern Alberta and southern Manitoba. Interviews were conducted in these two areas because they are prone to climate change related hazards (AAFC-PFRA, 2003), and because they have been classified by Swanson et al. (2007) as having a high a potentially high adaptive capacity to deal with climate change.

In the Manitoba study area, the interviews began with an agricultural producer organization (Keystone Agricultural Producers) and then moved onto individual farmers using a peer referencing or snowball sampling technique (Goodman, 1961). In Alberta, the interviews began with the local irrigation district (Eastern Irrigation District) and used the snowball sampling technique to find participants at the producer level. Land titles maps were also used in the Alberta study area to find interview participants. The interview questions focused on identifying the presence of information linkages, the content of the information conveyed, and the learning related to applying soil and water conservation, which is an important response for dealing with climate shocks and stresses.

1.5 Significance of the Study

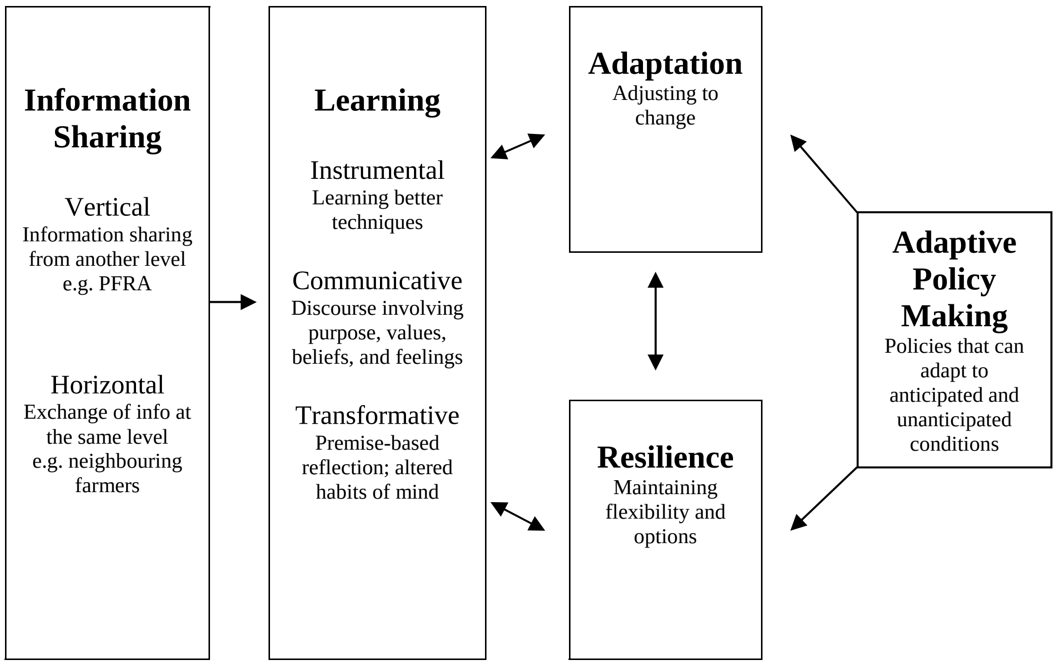
This study has practical importance as little research has been done dealing with resilience building, individual learning, and responses to climate change in the Canadian Prairie agro-ecosystem. Recent challenges to Prairie agriculture including, high input prices (especially fuel and fertilizer), loss of market access and income, declining access to health and education services in rural areas, and large annual variations in available surface water (Swanson et al., 2007), make this resilience study particularly timely. This research contributes to an ongoing dialogue on Prairie climate resilience undertaken by the International Institute for Sustainable Development (IISD) and the Natural Resources Institute (NRI) at the University of Manitoba. Early findings have revealed a wide range of adaptations in responses to past weather shocks and stresses (Myers, 2008; Pearce, 2009). Some of the responses include finding supplementary sources of income, moving to specialty crops, or simply waiting to see what happens. As learning of climate change occurs over time, there is likely to be a narrower range of responses. This process of how individuals lean and come to make adaptive actions to changing climatic conditions is explored in this research. Understanding individual learning and adaptation is ultimately important for fostering resiliency in agriculture.

Resilience can be built by increasing the range of knowledge used for problem solving, learning, and information sharing (Berkes et al., 2003; Berkes, 2007a). Information sharing may raise awareness of the various responses to climate change at the farm level, and inform farmers of soil and water conservation benefits. To explore information sharing, cross-scale interactions occurring both vertically and horizontally must be examined. It is thought that information sharing and learning increases the adaptability of the system, and ultimately leads to greater resilience (Berkes, 2002). But how does this information translate into adaptive action? What is the learning process that occurs? How does learning result in lasting, sustainability-centred ways of thinking about conservation and farming? Under what conditions can these sustainability-centred ways of thinking be fostered? Exploring the relationship between information sharing, learning, adaptation and resilience will be an important outcome in this research.

Conceptually, high levels of information sharing between and across levels of organization are expected to lead to increase producer-level learning (Figure 1). This learning, which occurs at the instrumental, communicative, and transformative levels, is thought to then enhance one's capacity to deal with change (i.e. adaptability) and maintain the options and flexibility available to the individual (i.e. resilience). In some cases, undergoing communicative or transformative learning may lead to additional information sharing resulting in a positive feedback loop. When the system is supported at the governance level by adaptive policy making, the adaptability and system resilience is further enhanced. Under ideal circumstances, adaptive policymaking would also contribute to increased levels of information sharing and learning at the producer level. While information sharing, learning, adaptation, and resilience operate at the individual or producer level, adaptive policy making operates at the policy level. Leadership at the policy making level is therefore needed to enhance system adaptability and resilience.

Another significant aspect of this research is the implications for adaptive policy making in agricultural. It is thought that much of the information received by producers fails to emphasis the potential benefits of soil and water conservation practices and ecosystem services. This outlook is inconsistent with farming practices that support long-term sustainability in the face of changing climatic conditions. For example, farmers who drain wetlands for crop production are likely to see their incomes rise in the short-term, however, this practice neglects the indirect benefits obtained through wetland retention (Heimlich, 1998). While some organizations promote the utilization of ecosystem services regarding soil and water conservation (e.g. Prairie Farm Rehabilitation Administration, Ducks Unlimited), under the current high-external input agricultural system, ecosystem service benefits are predominantly unaccounted for. As an alternative, polices that

Figure 1 – Conceptualization of the Relationship between Information Sharing, Learning, Adaptation and Resilience in the Prairie Agro-ecosystem



operate in an adaptive framework to increase information sharing and learning regarding sustainable farming techniques may be more effective for resilience building in the face of environmental uncertainty.

This research provides insight regarding how learning is occurring at the producer level within the Prairie agro-ecosystem and what makes that learning transformative (e.g. learning that fundamentally alters ones views towards sustainability and farming). Recognizing the conditions whereby learning and information sharing are successful in these case-study areas could provide insight as to how a more open learning environment can be replicated across the entire Prairie agro-ecosystem. This type of open communication in which information adjusts in response to changing climatic conditions could increase adaptive capacity. Providing a supportive adaptive policy framework, in which the flow of dynamic information is facilitated throughout the agro-ecosystem, could enhance learning thereby increasing long-term resilience in this economically important sector.

1.6 Organization of the Thesis

This thesis is organized into six chapters. Following the introductory chapter, Chapter 2 contains a review of the relevant literature. The literature review is organized into five sections that explore the research regarding adaptive co-management, resilience building, soil and water conservation, and learning. The third chapter describes the location of the study and the research methods used. Chapter 4 is the first results chapter and it describes the findings with respect to information linkages in the agro-ecosystem. The second results chapter, Chapter 5, explores the individual learning that is occurring at the producer level using transformative learning theory as a lens. Chapter 6 is a conclusions chapter which addresses the implications of this research for adaptive policy making and resilience building.

Chapter 2 - Literature Review

2.1 Changing Climate, Changing Paradigms

The field of natural resource and environmental management traditionally considered resources as simple systems that could be managed as isolated extractions, based on simple models and output objectives (Berkes et al., 2003). Resource management that takes a traditional top-down approach tends to increase vulnerability to those dependent on the resources (Hakim, 2005). In agriculture, this positivist paradigm and centralized approach have manifested into high external input agriculture, in which problems are addressed through reductionism, technological development, and transfer of technology, rather than user participation (Pretty, 1998). With a changing, unpredictable new climate regime, there is an increasing need for the environment to be viewed as a living system that forms a complex interconnected network (Capra, 1996). Farm-level decision-making in response to climate change is beginning to gain acceptance as the role of human agency and farmer perceptions are researched (Smit and Skinner, 2004).

Under the current policy framework, high external-input agriculture is a rationale practice for farmers. Farmers can receive high prices for cereal crops or for continuous maize crops, making diversification uncommon (Pretty, 1998). Often sustainable policies in agriculture that focus on conservation or ecosystem services are *ad hoc* to a framework supportive of high-input agriculture (Smit and Skinner, 2004). This approach does little to address the underlying problems with current policies, and can even create resentment among farmers (Pretty, 1998). Transfer of technology is a key component of these high-input practices. This is indicative of the positivistic view that science should be reproducible (Pretty, 1995). However, such an approach does not account for differences among geographic regions as well as long-term social and environmental costs of high external-input agriculture (Pretty, 1998).

Some innovations that are profitable to a large number of farmers may not be applicable with those facing different geographical, social, economical and cultural circumstances (Chamala et al., 1980). According to Tol et al. (1998), adaptations in agriculture must vary according to differing climate change stresses, weather variability, and location of farms. Policies that are based on technological innovations often only succeed in controlled environments, and not when applied widely (Pretty, 1998). In the face of change and uncertainty, expert prescribed technologies are ineffective. For agriculture to have long-term sustainability, a system of interaction of and joint learning of local skills and knowledge is needed (Pretty, 1998). Roling and Jiggins (1998) state that the maximization of a single variable (e.g. crop production) leads to instability and ecosystem collapse, therefore management should use flexible, diverse, and redundant regulations that monitor and experiment with ecosystem responsiveness.

As an alternative to the realist-positivist epistemology, Roling and Wagemakers (1998) see agro-ecosystems as complex systems in which there is no single prescription. Agriculture is a location specific activity and therefore, needs to focus on local needs and capabilities (Pretty, 1998). However, climate change is based predominantly on global models that are indicators of average change and may not take into account locally observed changes, extreme weather, and unpredictable events (Berkes, 2008). The focus needs to shift to regionally specific agricultural practices. Such practices require matching crops with environmental conditions, incorporating natural process, and reducing external inputs (Pretty, 1998). In a sense, farmers need to become regional experts and manage their farms as ecosystems.

Adjustments in both behaviour and resource technology can help to build adaptive capacity to cope with climate change (Adger et al., 2007). Adaptive capacity is a necessary component for dealing with the vulnerability of a system and reducing the occurrence and degree of potential damages (Brooks et al., 2005). According to Bradshaw et al. (2004), the vulnerability of an agricultural system to climate change is influenced by its adaptive capacity, and hence mush attention is now being directed towards adaptation issues. Adaptive actions enhance the resilience of systems that are vulnerable, and reduce damages caused by climate change and variability to both human and natural systems (Scheraga and Grambsch, 1998). According to Roling and Wagemakers (1998) a sustainability-cantered paradigm for agriculture involves not only information sharing and learning, but also partnerships and participation, so that agricultural innovations are not achieved through the top-down transfer of technology, but through the interactions between people. The participation of farmers in problem solving, and the use of local knowledge, contributes to sustainable agricultural systems that are conducive to adaptation and reliance (Pretty, 1998).

Currently, two programs Prairie farmers use to deal with climate variability include crop insurance and income stabilization. These programs provide farmers with compensation for income lost, but deter farmers from adapting their practices in response to climate change (Schmitz et al., 1994). The crop insurance program has been associated with less diversification and lower levels of off-farm income (Smit and Skinner, 2004; Bradshaw et al., 2004). These types of programs, that build resilience though financial compensation, can also discourage self-reliance among farmers. Gardner et al. (1992) suggests that adaptation measures, like disaster payments and crop insurance, encourage producers to grow high return, high risk crops on marginal lands, increasing vulnerability to climate change. Furthermore, Turvey (2001) states, that since programs such as crop insurance or other production subsidies become the means through which climate-related risks are addressed, resilience building through participatory learning, alliance building, and information sharing may be deemed unnecessary. Rather policies that encourage flawed adaptation strategies, Easterling (1996) suggests the implementation of programs that enhance information exchange and encourages the transfer of agricultural research information that addresses climate change preparation. Having human resources with flexible skills and access to a strong continuing education system is important in enabling farmer adaptation (Easterling, 1996).

2.1.1 Adaptive Co-Management

Recent developments in natural resources management have shown that: change and uncertainty are being understood as inherent in social-ecological system, broad-based participation is needed when responding to change, and that social sources of adaptability (knowledge, learning) need to be emphasized (Armitage et al., 2007). Phal-Wostl and Hare (2004) state that resource management problems are uncertain, complex, and largely unpredictable and they advocate integrated approaches. Given these insights, supportive and enabling institutions are needed to promote social sources of adaptability.

According to Pretty (1995), learning organizations will need to be decentralized and multidisciplinary in order to deal with the complexities related to the multiple linkages and alliances. Smit and Skinner (2004) suggest that adaptive decisions should not be based solely on climatic conditions, but by the joint effect of multiple forces as part of on-going adaptive processes. In addition, regular participation between professional and public actors is required for the needs of farmers to be addressed (Pretty, 1995). This type of approach allows for a combination of different knowledge systems, which is useful in the management of complex systems (McLain and Lee, 1996). Institutional and organization aspects of management should evolve with management practices and the generation of knowledge (Dale et al., 2000). Systems of this type, that are both flexible and location specific, are known as adaptive co-management systems, (Berkes et al., 2003).

Adaptive co-management systems combine the dynamic nature of adaptive management with the idea of linkages, characteristic of co-management (Olsson et al. 2004). Olsson et al. (2004) defines adaptive co-management as “flexible, community-based systems of resource management tailored to specific places and situations, and supported by and working with, various organizations at different scales" (p. 75). Folke et al. (2002) defines adaptive co-management as "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, on-going, self-organized process of learning-by-doing" (p. 20). Regardless of the nuance in definition, these systems take into account local conditions, which is particularity important for regionally specific activities like agricultural. Adaptive co-management can also shift the emphasis of top-down intensive agriculture, to a producer-level learning and experimental practice that is supported by a multitude of actors.

Adaptations to climate change are not discrete actions, but instead work continuously and reflect a multitude factors and stresses (Adger et al., 2007). Both social and biophysical dynamics are combined in adaptive co-management (Olsson et al., 2004). This allows an iterative learning process when responding to changing conditions. According to McIntosh (2000), understanding the management of natural processes involves the co-evolution of social and ecological knowledge embedded in a social memory, where the successful adaptations are entrenched in deep-level values in the community. Adaptive co-management systems have the ability to deal with uncertainty and change thereby contributing to the resilience of complex social-ecological systems (Berkes et al., 2003). Adaptive co-management systems also involve a self-organizing process, which enhances its ability to deal with uncertainty and builds the capacity to adapt to future changes (Olsson et al., 2004).

Adaptive co-management allows for continuous learning and information sharing which translates into participatory action and power-sharing relationships between resource users and regulators. This allows for biophysical as well as human dimensions to be factored into policy, thereby increasing resiliency. All actors in the agricultural network receive mutual benefits by recognizing these social sources of adaptability as important components for resilience building. The ability of social-ecological systems to increase their capacity to learn and their ability to adapt to change in a way that does not impinge on future opportunities is a central component of resilience (Carpenter et al., 2001).

2.1.2 Adaptive Policy-Making

Both adaptive co-management and adaptive policy-making maintain the capacity to deal with changing conditions by employing a process of policy-making with provisions for learning from various actors and levels of organization (Walker et al., 2001; Olsson et al., 2004; Swanson and Bhadwal, 2009). Adaptive policy making involves implementing policies as experiments (Lee, 1999). With this type of policy making, less focus is placed on specific solutions and more emphasis is placed on processes that enable problem-based approaches to changing contexts.

Under changing conditions adaptive policies are important because many polices are developed to operate with a specific range of conditions and when these conditions change, and conventionally constructed polices often do not accomplish their goals (Barg et al., 2006). Adaptive policy-making involves making explicit provisions for both anticipated and unanticipated conditions. Swanson and Bhadwal (2009) provide four adaptive policy mechanisms for dealing with unanticipated conditions and three mechanisms for anticipated conditions. For unanticipated conditions these include: formal review and continuous learning; encouraging self-organization and networks; action at different levels of jurisdiction with priority to the lowest affected level; and promoting variation. For anticipated conditions these include: automatic adjustment of policy; integrated and forward-looking assessment; and multi-stakeholder deliberation.

While the principles of both adaptive policy-making (Swanson and Bhadwal, 2009) and adaptive co-management (Olsson et al., 2004) are similar in nature, they are both helpful in conceptualizing a governance structure for an agricultural sustainable system that is conducive to long-term resilience during environmental uncertainty.

2.2 Adaptability and Resilience-Building

For agricultural policy to be successful on a broad scale, farmers must build on their capacity as enablers of innovation rather than receivers and users (Pretty, 1998). Adger (2001) argues that adaptation responses to climate change are not global scale issues, but are instead made up of individual actions and collective responses at the local level. Since impacts of climate change are spatially and socially differentiated, adaptation to climate change occurs at the resource-user level rather than as global commons (Adger, 2001).

Since pragmatic scientific solutions do not address underlying social causes, focusing solely on technical solutions to natural environmental problems is insufficient (Woodhill and Roling, 1998). Furthermore, human intervention in the management of biological systems is often not well understood (Adger et al., 2007). Social dimensions must be examined along with biophysical dimensions using an integrative problem solving method (Woodhill and Roling, 1998). According to Pahl-Wostl and Hare (2004) the interaction between soft relational and hard factual aspects must be combined to effectively deal with human-environmental systems. Although current policy encourages farmer dependency on external inputs and technologies, there is potential for increased sustainability through the development of social sources of adaptability. Social sources of adaptability such as, information sharing, learning, participation, partnerships, and alliances can lead to sustainable systems that have the ability to cope with change and uncertainty (Adger, 2000). This may require the utilization of local knowledge and the establishment of dialogue and alliances between actors so that social and biological resources are maximized in a manner that provides rapid feedback regarding adaptations (Pretty, 1998).

Adger et al., (2007) states that current adaptation to climate change can ultimately lead to increased resilience to climate change over the long-term. Coping strategies, that are used when faced with the effects of climate change today, may establish themselves to become the adaptive strategies in the future (Berkes, 2008). Both short-term coping and long-term adaptive strategies determine the resilience of a system to climate change (Berkes, 2008). Riebsame (1991) distinguishes short-term adjustments, as adaptations of a system, and long-term cumulative adaptations, as the resiliency of a system. In agriculture, short-term adaptations are the often the first line of defence against climate change, and are an effort to keep the agricultural system in its current state and therefore, resilient (Easterling, 1996). Long-term adaptations on the other hand reflect a fundamental change in social preferences and reflected government policies (Easterling, 1996). According to Berkes et al. (2007), adaptation and the building of adaptive capacity are not technical challenges, but long-term social processes.

By increasing the range of knowledge for problem solving through learning and information sharing, resilience building occurs (Berkes et al., 2003; Berkes, 2007a).

Folke et al. (2003) identifies four critical behavioural responses that are required for resilience building in dynamic social-ecological systems. These include: learning to live with change and uncertainty, fostering diversity, using a variety of different knowledge sources for learning, and creating opportunities for self-organization (Folke et al., 2003). For adaptive responses and resilience building to occur, these four behavioural responses are important for responding to feedbacks and environmental unpredictability. In particular, learning to live with change and uncertainty involves monitoring and understanding ecological systems, and turning these into development opportunities (Folk, 2003). Scheraga and Grambsch (1998) states that lost opportunities can be as bad as negative impacts; therefore it is imperative for policies to exploit the favourable effects of climate change.

In order to effectively deal with uncertainty, change, and surprise, diversity and ecological memory must be stored in social memory so as to maintain adaptive capacity (Folke et al., 2003). Combining diverse knowledge systems and diverse decision making processes may be needed for understanding complex systems and nurturing an adaptive learning process (Pretty, 1995; Smit and Skinner, 2004). Furthermore, the creation of opportunities for self-organization is needed for complex systems of multi-level governance (Folke, 2003). This often requires constant monitoring and adjustment from resources users through adaptive co-management regimes (Folke, 2003).

2.3 Soil and Water Conservation

2.3.1 Introduction to Adaptation Strategies

The development of resource management innovations and farm-level responses to climate change has the potential to address risks associated with decreasing moisture, raising temperatures, and extreme weather events (Smit and Skinner, 2004). These farm level responses may include adaptations of planting and harvesting practices such as earlier planting, longer-season cultivars, greater diversity of cultivars, planting depth of seeds, and earlier harvesting (Easterling,1996). While planting and harvesting adaptations are important, the focus of this research will be on farm-level adjustments that utilize ecosystem services to conserve moisture. The enhancement of system resilience has been attained through community-based resource management where ecosystem services and ecosystem resilience are maintained (Adger et al., 2007). Moisture conservation tactics include conservation tillage, substitution of crops that are less water intensive, microclimate modification, and irrigation scheduling (Easterling, 1996). Since the Prairies are expected to experience warmer temperatures and increased evapo-transpiration (Venema, 2006), these moisture-conserving adaptations are likely important for building resilience to climate change.

2.3.2 Soil Moisture Conservation Techniques

Many of the soil moisture conservation practices that are well developed to combat drought may also be useful for climate change (Easterling, 1996). Although increased evaporation and warmer temperatures are not preventable, soil moisture depletion can be mitigated at the farm level through use of conservation tillage practices (Hamilton, 1998). Conservation tillage is an adaptation method that conserves soil moisture. The process involves the previous year's crop residue being left on the field in order to increase water infiltration, reduce evapo-transpiration, and prevent wind and water erosion (Rosenburg, 1989). Zero tillage or no-till is often considered the ultimate in conservation tillage, as it involves no soil disturbance for the purpose of weed control (MAFRI, 2008). In order to sow the crop, seeds are drilled into the ground without ploughing the soil (Pacala and Socolow, 2004). Soil conservation practices such as surface residues and conservation tillage reduce the effects of surface sealing and force the water to move more slowly across the soil, therefore moisture content increases as runoff is reduces and water infiltration increases (Unger, 1990).

The substitution of crops to those that are less water consumptive is another method of conserving soil moisture. Some crops, such as wheat, use less water and are more stress resistant to warm dry weather than corn for example (Rosenburg, 1989). However, drastic crop substitutions can require high capital investments thereby limiting its adoption by farmers (Easterling, 1996). Bradshaw et al. (2004) suggests that crop diversification has failed as an adaptive response for Prairie farmers because of high start up costs, disadvantages associated with economies of scale, difficulty learning how to produce a new crop, and the lack of alternative crops for the agro-climatic conditions of the Canadian Prairies

2.3.3 Water Conservation Techniques

As the Prairie region becomes increasingly arid and soil moisture decreases (Venema, 2006) water conservation will need to address shifting precipitation patterns, floods, and droughts (Smit and Skinner 2004). Adaptive measures at a regional level may include modified irrigation systems, transferring and diverting of water, and desalination technologies (Easterling, 1996). At the farm level, adaptations may include mechanical innovations such as drainage systems, recharge areas, and land contouring (Easterling, 1996). Water conservation strategies are especially important for the agricultural industry due to its heavy reliance on water resources for irrigation. In the Prairies, agriculture accounts for about half of all water used, and over 75% of this water is consumed (Gan, 2000). Irrigation systems are extensive in the southern Prairies with 630,000 hectares being irrigated in the year 2000, of which 500,000 hectares are in southern Alberta (Gan, 2000).

Irrigation, as a substitute for precipitation, is an important tool for stabilizing crop production in the event of drought (Easterling, 1996). However dependence on irrigation, particularly in southern Alberta, has made agriculture extremely vulnerable to periods of drought (Wheaton, 2005). The utilization of ecosystem services, that increase moisture, reduces the need for irrigation and hence reduces vulnerability (Royer and Gouin, 2007). Ecosystem service utilization is important for sustaining productive agriculture and preventing soil exhaustion when water resources are scarce (Wang and Cheng, 2000).

Irrigation scheduling is an adaptation measure that farmers can take to directly lessen their water consumption. Irrigation scheduling involves timing or monitoring water consumption for the conditions of the field so that water is used only when needed (Easterling, 1996). This practice requires farmers to monitor local conditions and obtain information about soil moisture conditions.

Wetlands are important in agriculture because of their ability to mitigate environmental variability by regulating the flow of water and trapping nutrients (Heimlich et al., 1998). According to Motha and Baier (2005) wetlands are a critical resource because they provide species habitat, store atmospheric carbon, recycle nutrients and minerals, purify water, and naturally control floods. Wetlands not only moderate the water flow during extreme weather events like floods, but they also release water during times of low flow (Roberts and Leitch, 1997). With climate change bringing about more frequent and intense periods of drought and flood, water flow regulation will become increasingly important. Wetlands account for 14% of Canada’s landmass (Motha and Baier, 2005); however, in agricultural regions wetlands are typically converted to agricultural land or are subject to agricultural drainage (Hartig et al., 1997).

Microclimate modification is another tactic the can increase moisture and reduce vulnerability to climate change (Easterling, 1996). Pyke and Andelman (2007) suggest that land use and land cover activities interact with climate to determine the meteorological and land surface conditions. Modified local climatic conditions resulting from changes in land surface can mitigate climatic impacts brought about by global climate change (Marland et al., 2003). For example, tree planting and wetland restoration can be used as strategic climatic management tools, to increase the resilience of ecological systems and reduce agricultural vulnerability to climate change at a local level (Pyke and Andelman, 2007). Other ways of affecting the microclimate of an area is through the use of shelterbelts, which decrease wind erosion, reduce runoff, and enhance snow trapping (Easterling, 1996).

2.3.4 Moving Beyond Biophysical Adaptation

Biophysical adaptations and new technologies alone may be insufficient for building long-term resilience to climate change. According to Roling and Wagemakers (1998) such innovations must be integrated with the human dimensions, particularly learning, to deal with environmental uncertainty. Climate change will enviably bring unpredictable consequences; therefore, the processes of sharing information and learning about soil and water conservation techniques within the agricultural community must be made sustainable (Pretty, 1998). This requires supportive institutional networks as well as human networks that allow knowledge to be accessed and shared.

Easterling (1996) suggests that agriculture in North America has the capacity to deal with unpredictability and adapt in an efficient manner to climate change based on information from historical analogs to climate change (e.g. adapting crops to new areas, resource scarcity, drought, depletion of groundwater etc). Furthermore, Easterling (1996) argues, many of the financial incentives, public policies, and management practices already exist to deal with climate change; however, information systems and human resources require strengthening. The challenge is establishing and enhancing the communication of these ideas through programs that foster alliance building. Smit and Skinner (2004) state that while governments and agri-business are responsible for developing technological and resource-based adaptations; implementation of these technologies is a decision that must be made at the farm-level. The difficult and most important component of climate change adaptation is not research, but farm-level adoption (Easterling et al., 1993).

2.4 Learning to Adapt to Climate Change

2.4.1 Introduction to Learning

To help cope with climate change, detailed knowledge and experiences need to be shared among actors (Berkes, 2008). Sharing of information requires the persistence and reinforcement of cultural values that favour generosity, reciprocity, and communitarianism, over individualism (Berkes, 2008). Adaptive co-management may provide an effective pathway to achieve open communication of knowledge regarding ecosystem services in agriculture. Strategies for adaptive co-management include dialogue at both the national and local levels, as well as a combination of redundant institutions of different types and approaches to facilitate experimentation and learning (Dietz et al., 2003).

The collaboration of a diverse set of groups and actors at different levels within the human-ecological network is a cornerstone of adaptive co-management (Olsson et al. 2004). For learning to occur, collaborative or mutual development and sharing of knowledge is needed between multiple stakeholders (Armitage et al., 2007). Folke et al. (2005) states that management systems that are resilient have the capacity to adapt to uncertainty by drawing upon a diverse range of knowledge. In order to connect players across levels and scales, social networks are developed, thereby facilitating the flow of information, and the acquisition of knowledge and expertise in resources management (Olsson et al., 2004).

2.4.2 Types of Learning

Social networks that connect players across a variety of levels and scales may lead social learning. Pahl-Wostl and Hare (2004) define social learning as "an iterative and ongoing process that comprises several loops and enhances the flexibility of the socio-ecological system and its ability to respond to change" (p. 195). Social learning is an iterative feedback between the learner and the environment; therefore change is exerted on the environment as a result of learning, and likewise the environment changes the learner (Berkes, 2007b). Social learning allows for natural resources management solutions to be part of an ongoing learning and negotiation processes in which communication, perspective sharing, and the development of adaptive problem solving strategies play an integral role (Pahl-Wostl and Hare, 2004).

Most management systems can cope with departure from normal procedures (in agriculture this may include a change in tillage technology) (Pretty, 1995). This departure is known as single-loop learning. Single-loop learning involves modifying management strategies and actions without questioning the underlying assumptions of the strategies or actions (Armitage et al., 2007). Sinclair et al. (2008), states that single-loop learning involves getting better at a process within an existing governing context. Double-loop learning involves evaluating and changing fundamental governing variables (Sinclair et al., 2008). Pretty (1995) argues that most organizations do not have mechanisms for dealing with double-loop learning as it questions, and can potentially change, the values and procedures under which the organization operates.

Transformative learning theory, unlike single and double loop learning, is not based on social learning, but individual learning in adults. Transformative learning is the process whereby frames of reference (i.e. assumptions through which we understand experiences including habitat of mind and points of view) are transformed through critical reflection, discourse, action based on reflection, and assessment of the action (Mezirow, 1994; Mezirow, 1997). Mezirow (1994) also distinguishes between instrumental learning (learning to control the environment) and communicative learning (trying to understand what someone means). Transformative learning theory focuses on the process of learning and takes into account the social context in which learning occurs (Sinclair and Diduck, 2001; Taylor, 2007). The focus of transformative learning is on contextual learning, critical reflection of underlying assumptions, and validating meaning by assessing reasoning (Mezirow, 1995).

The critical reflection aspect of transformative learning can promote cognitive development and promote socio-political change (Mezirow, 1994; Mezirow, 2000). Sinclair et al. (2008) notes that transformative learning can contribute to a more sustainable, democratic, socially and ecologically responsible governance system that allows actors to develop solutions to complex issues. By enabling learning and meaningful public engagement, transformative learning can lead towards taking sustainable action regarding the management of natural resources (Sinclair and Diduck, 2001; Sims and Sinclair, 2008)

Dealing with uncertainty in agriculture requires critical thinking or the ability to question the underlying assumptions of the actions, values, and claims to knowledge of a practice (Woodhill and Roling, 1998). According to Olsson et al. (2004) acquiring knowledge and associated management practices cannot occur in isolation, as it is a continuous and dynamic process that requires social and institutional networks. Transformative learning, in which actors engage in both autonomous thinking and social participation (Mezirow 1997), may ultimately result in sustainable environmental decision-making in the Prairie agro-ecosystem.

2.4.3 Knowledge Networks

The building of social networks facilitates social learning and adaptability. Adaptive practices may be fostered through cross-scale links that are strong, open, and two-directional. Strong vertical and horizontal linkages create empowerment and interdependence among affected parties, while the absence of strong cross-scale linkages creates disempowerment (Berkes et al., 2007). Natural resources management needs to take place at multiple scales and hence, there is a need to link these scales horizontally and vertically (Berkes, 2002). This type of polycentric approach recognizes that effective resource management requires links across multiple scales and seeks deliberate redundancy through overlapping centers of authority (Berkes, 2007b). Adaptive management takes into account ecological interactions and resource use patterns that occur at different levels thereby enabling cross-scale linkages (Holling et al., 1998). The idea of learning by doing, which is central to adaptive management, is based on social learning between individuals, organizations, and institutions (Berkes, 2002).

Social-ecological systems that have a large amount of cross-scale linkages are often associated with greater system resilience (Berkes, 2002). Resilience is built through linkages where partnerships between resources managers and users encourage trust building, learning by doing, and developing capacity (Berkes, 2002). According to Levin, there are two features that can make systems resilient. The first is the presence of effective feedback mechanisms that allow for pragmatic action (Levin et al., 1998). The second is the maintenance of heterogeneity and available diversity options for changing systems (Levin, 1999).

Therefore, it makes sense from a resilience point of view to develop institutional linkages that promote diversity of actions.

Promoting resilience through a diversity of actions is consistent with the idea of increasing institutional capacity. Savitch (1998) defines institutional capacity as an organization's ability to absorb responsibilities, increase operation efficiency, and improve accountability. According to Ostrom (1999) high institutional capacity can enhance the capability of the participants to reach a particular solution. At the individual level, Putnam's (2001) notion of social capital stresses the importance of community networks in providing assistance during difficult times. Social capital involves the ability to absorb external pressures and shocks associated with both political and economic change (Adger, 2000). Social capital also comprises the predisposition of people to cooperate and make the best use of available resources (Pretty, 2002). Berkes et al. (2007) suggests that a stepwise evolution toward adaptation is made possible by social learning and the building of social capital. Pretty and Ward (2001) state that social capital facilitates co-operation and deters private action that may result in resource degradation. Four elements that are central to social capital are: relations of trust; reciprocity and exchanges; common rules; and connectedness in networks and groups (Pretty and Ward, 2001)

According to Siemens (2005) connectivism, a learning theory that focuses on the idea that the connections that enable learning are more important than knowledge that is currently held at any given point. Connectivism is based on learning and knowledge resting in many diverse sources or specialized nodes, and the capacity to nurture these connections between nodes is needed for continual learning and adaptive decision-making (Siemens, 2005).

2.4.4 Learning Adaptive Responses

Since effective transformative learning may ultimately result in action (Mezirow, 1994; Mezirow, 1997), the effectiveness of information sharing may come from gauging the extent to which transformative learning is occurring. In the context of resilience building in agriculture, the transformation could be determined through adoption of adaptive practices, in particular the degree with which soil and water conservation measures are being undertaken.

Environmental crisis has been shown to be a starting point in which management practices can be reshaped to create organizational structures and incorporate different types of knowledge (Olsson et al., 2004). A crisis may emphasis the need for reorganization, which is a platform for social learning and collective action (Lee, 1993). The translation from learning to collective adaptation is evident in the Racken area of western Sweden where lake acidification led to public monitoring and actions to reduce acidification through liming activities. These public groups were ultimately given decision-making power over local fishing operations thereby increasing flexibility for further self-organization (Olsson et al., 2004). This system of knowledge generation and management takes a learning-by-doing approach to respond to dynamic ecosystem fluxes (Olsson et al., 2004). This model of local level empowerment as a way of coping with urgent environmental matters may be applied to the Prairie agro-ecosystem so that producers become empowered in management decision-making.

By increasing network linkages, solutions for coping with climate change may arise thereby contributing to the social-ecological resilience of the agricultural system. Systems in which there is a large degree of learning and information sharing through cross-scale linkages have the potential for a higher degree of adaptability and ultimately resilience in the agro-ecosystem. According to Armitage et al. (2007), horizontal and vertical linkages, which build adaptive capacity and institutional resilience, are the central components for effective decision-making in adaptive co-management. These linkages are critical in the expansion of social networks to more robust and empowering management regimes (Adger et al., 2007).

2.5 Summary: Supporting Learning and Adaptation

2.5.1 Adaptive Co-Management

Folke (2003) states that the simplification of landscapes has generated steady resource flows in the short-term, but over the long-term this simplification has eroded resilience. However, resiliency may be attainable through an adaptive co-management system. Olsson et al. (2004) lays out several conditions that can be created to facilitate the emergence of adaptive co-management. These include: legislation that enables public participation and power sharing; funding for responding to environmental change and self-organizing remedies; monitoring natural processes to enhance learning and management decisions; enhancing information flow through social network building; combining information from various sources; making sense of combined sources of information and knowledge so that meaning and action can be taken; and platforms for knowledge sharing and learning.

Olsson and Folke (2001) describe the importance that individuals can have in facilitating horizontal and vertical linkages in the adaptive co-management process. For this type of collaboration in environmental management to be successful, the issue of trust is a fundamental competent (Pretty and Ward, 2001; Olsson et al., 2004). Individual leaders are also important for this type of collaboration as they bring management vision, institution building, and organizational change (Olsson and Folke, 2001; Kiptot et al., 2006). According to Granovetter (1983), the innovators, who are first people to adopt a new technology or practice, are usually a less integral part of the social system than the early adopters. Granovetter (1983) also states that transitivity of information is more effective for reaching a large number of people when linkages between individuals are weak.

2.5.2 Knowledge and Learning

Knowledge and learning are key components required for the building of adaptive capacity and resilience. Agriculture in the face of change cannot rely on market forces to lead technological change towards sustainability (as is the case with enhancing productivity) since the ecological costs are often externalized to future generations or other sectors (Roling and Jiggins, 1998). Instead, sustainability in agriculture must be facilitated through learning (Roling and Jiggins, 1998). Adger et al. (2007) notes that human and social capital are as important for adaptive capacity as income and technological capacity.

According to Pahl-Wostl and Hare (2004) key ingredients for social learning in resource management include: awareness diverse goals and perspectives; the identification of a shared problem; understanding interdependence, understanding the complexity of the management system, learning to work together, trust, and the creation of both informal and formal relationships. Fisk et al. (1998) states that working together and group skills such as listening, negotiating, and decision-making are important when learning about new farming practices. Other important components for collaborative relationships include the perception that decisions are being made fairly, the expectation of conflict between individuals and organizations, and making the transition where teacher and learning switch roles to allow for the effective exchange of ideas (Fisk et al., 1998). Pretty (1995) provides a list of several important elements for learning and taking action in agricultural systems echoing some of the same components listed above including, a focus on cumulative learning between all participants, the integration of diverse perspectives, and the importance of group learning, inquiry, and interaction. Also mentioned is the importance of taking the context specific nature of agriculture into account, the facilitation of experts, and the strengthening of building of local institutions to allow for sustained action and initiation of problem solving (Pretty, 1995).

Key strategies for successful learning include the building relationships across diversity, working together to support structures groups and networks that act to empower, and allowing for information and innovation exchange (Fisk et al., 1998). Other important strategies for successful learning raised by Fisk et al. (1998) include the encouragement of systems thinking through a broad collective base, engaging large institutions, NGOs, and existing community-based organizations with the mission of sustainable agriculture, the integration between farm systems at both the national and local level, and the evaluating the success of a project. Hamilton (1998) lays out some of the key factors needed to move toward sustainability in agriculture. These include: a multi-disciplinary project team, market research exercise, a constructivist approach, the pursuit of change as an emergent property as opposed to a predetermined end point, the integration of extended knowledge and ecological systems, using technical experts as facilitators and as equal participants in joint learning activities, and multiple outcomes to accommodate the diverse perspective of actors.

For learning at the individual level Mezirow (1994) identifies six ideal conditions for learning to take place. These include: accurate and complete information, freedom from coercion, openness to alternative perspectives, ability to reflect critically upon presuppositions, equal opportunity to participate, and the ability to assess arguments in a systematic manner and accept a rational consensus as valid.

2.5.3 Facilitation and Platforms

Facilitation of learning is important for fostering producer level capacity to anticipate and to enhance desirable ecological process (Roling and Jiggins, 1998). Campbell (1998) argues that facilitation is critical in establishing platforms for negotiation and decision-making that requires actor participation and the exchange of information. Several factors that are needed for effective facilitation in agriculture including: bringing together important actors, developing a common problem, building of agreement, meditation conflict, and negotiation and decision-making (Campbell, 1998). Taylor (2007) states the importance of the facilitator is to promote: openness and trust, participation and self-dialogue, and the exploration of alternative perspectives in order to foster transformative learning. According to Sims and Sinclair (2008) a facilitator must be trusting, empathetic, caring, and of high integrity.

Effective platforms are important for facilitation, information exchange, and learning to occur. Since resilience building may require social learning platforms for resource use, negotiation is needed to address conflicting interests between stakeholders (Roling and Jiggins, 1998). Platforms can be one-time meetings, elected committees, appointed boards, or government bodies; however, the key is that stakeholder interests are represented (Roling and Jiggins, 1998).

2.5.4 Support Institutions and Policy Contexts

In practice, institutions that support social learning can be difficult since they may clash with entrenched interests, embedded values, and institutions that limit the open exchange of ideas and innovations (Van Woerkum and Aarts, 1998). Furthermore, conventional farming associations as well as marketers and processors of agricultural products may resist the emergence of new farming practices that are better able dealing with a new climate regime (Roling and Jiggins, 1998). The emergence new farming techniques requires a transformation of the agricultural institutional framework. According to Roling and Jiggins (1998), this transformation may be achieved by supporting non-formal education and farmer-to-farmer extension, thereby allowing this information to percolate throughout the community.

For policy to be conductive to a changing paradigm that integrates social sources of adaptability, profitability, and farm survival is essential (Roling and Jiggins, 1998). However, making agriculture more sustainable to climate change may be impossible with unrealistically low food prices (Roling and Jiggins, 1998). Policy that takes changing climate into consideration must be able to adapt to both anticipated and unanticipated conditions since strategies that are effective in one location may be ineffective or create new vulnerabilities and negative side effects in other places or groups (Adger et al., 2007; Swanson and Bhadwal, 2009).

2.5.5 Barriers to Learning and Adaptation

When exploring some of the conditions required for effective learning and adaptation to take place, it is important to also examine factors that can deter resilience building in response to climate change. Adger et al. (2007) notes that barriers to implementing adaptation fall under two categories: natural constraints and human constraints. Natural constraints are the inability of ecological systems to adapt to the climate change due to the rate or the magnitude to alteration (Adger et al., 2007). Human constraints include technological, financial, cognitive, behavioural, social, and cultural constraints as well as knowledge gaps for adaptation and impediments to flows of knowledge (Adger et al., 2007). An example a financial constraints that Smit and Skinner (2002) found to be common among farmers, is lack of adequate financial resources needed for irrigation systems, improved crop varieties, and diversification of farm operations. As a result, this constrains their use of adaptation measures.

When considering any adaptation policy the benefits should exceed the costs so that the policy is economically justified (Smith, 1997). The financial resources used to adapt to change must also be weighed against other adaptive measures or the notion of simply living with the change and not taking any adaptive action (Scheraga and Grambsch, 1998). Adger (2001) states that the perception of impacts and the cost of the adaptation response will ultimately determine which polices are employed to reduce to vulnerability. However, the adaptation process is complex, and perfect adaptation by all individual farmers an unrealistic assumption (Adger et al., 2007).

Informational and cognitive barriers are particularly difficult to study since knowledge of climate change and possible mitigation solutions may not lead to adaptation (Adger et al., 2007; Bennett and Howlett, 1992). Even though individuals may be concerned and well informed about environmental issues, the social context in which they are embedded offsets a behavioural response (Folke, 2003). Social barriers to adaptation arise from the difficultly in establishing broader social and development initiatives since adaptation to climate change is usually not done in a stand-alone fashion (Adger et al., 2007). Cognitive barriers may also arise because of farmer's perceptions of risk, vulnerability, and adaptive capacity differ (Adger et al., 2007). Studies have shown that barriers to appropriate adaptive behaviour are also obstructed when communications regarding climate change are presented in a way that appeals to fear and guilt (Moser and Dilling, 2004).

Chapter 3 – Methods

3.1 Introduction

This chapter outlines the methods used for this research project. To address the three research objectives, a qualitative approach was most appropriate. Creswell (1994) lists several assumptions that are involved in quantitative research, including:

- The primary concern is process, not products or outcomes
- Reality is constructed by the individual involved in the research
- The researcher is the primary instrument for data collection and analysis
- The language is personal and informal
- The research is based on inductive logic where the researcher builds abstractions concepts, hypotheses, and theories

While there are many different approaches to qualitative research (Creswell, 1994), interviews are particularly valuable in allowing the researcher to understand the subjects' point of view and to uncover the meaning of their experience (Kvale, 1996). Using a qualitative research interview technique allows for the collection of information at both the factual and meaning level (Kvale, 1996). In this way, verbal data can be obtained through a purposeful line of questioning (Miller, 2004). McNamara (1999) points out interviews are especially useful in getting the story behind the participant's experience by pursuing in-depth information. Unlike other qualitative methods, interviews allow for the collection of information of behaviours, attitudes, and beliefs of the participant in a direct and specific manner. Since this research will attempt to identify transformative learning, which deals with changes in beliefs and values through critical reflection, interviews are a suitable tool for this type of data collection.

In this research semi-structured interviews are used. Semi-structured interviews are particularly useful as the interviewer does not use ready-made categories and is open to new and unexpected phenomena that were not considered beforehand (Kvale, 1996). Semi-structured interviews are an effective tool for exploring transformative learning (Daley, 2001; Sinclair and Diduck, 2001; Kovan and Dirkx, 2003). Furthermore, semi-structured interviews allow the interviewer to pursue in-depth information around the topic (McNamara, 1999). While structured interviews follow a predetermined list of questions, semi-structured interviews are more open-ended, informal, and conversational, using pre-determined questions only a guide to ensure the interview is flowing and on topic (Kvale, 1996). Semi-structure interviews allow for a clear set of replicable questions that ensure reliable, comparable qualitative data, that also allows for alternative insights, leaving the researcher free to follow leads (Bernard, 1988).

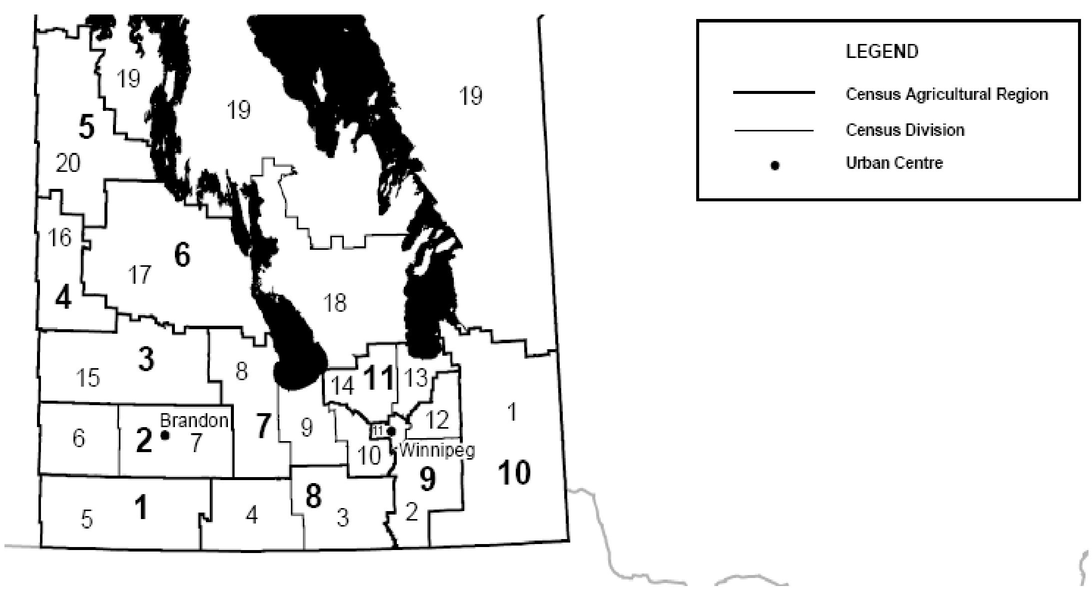
3.2 Study Areas

The Prairie Climate Resilience Project conducted by the International Institute for Sustainable Development, the Prairie Farm Rehabilitation Administration (PFRA), and the University of Manitoba have complied census data to estimate the relative adaptive capacity to climate change in agriculturally based communities in the Prairie region. Indicators representative of adaptive capacity were grouped into six determinates including: 1) Economic resources; 2) Technology; 3) Infrastructure; 4) Information, skills and management; 5) Institutions and networks; and 6) Equity (Swanson et al., 2007). The adaptive capacity ranking is for 53 Federal Census Divisions across Alberta, Saskatchewan, and Manitoba.

Southern Alberta and parts of southern Manitoba have a relatively high level of adaptive capacity based on the institutions and networks determinate as outlined by the Prairie Climate Resilience Project (Swanson et al., 2007). The institutions and networks determinate takes into account social capital, internet use, e-mail use, and access to agri-education institutions (Swanson et al., 2007). These aspects of adaptive capacity are likely related to learning and information sharing. Therefore, areas that estimate high adaptive capacity based on the Prairie Climate Resilience Project's institutions and networks determinate, may be promising settings to observe instances of learning and information sharing in the agro-ecosystem.

The first area in which interviews were conducted was in census division 10 (see Figure 2) in southern Manitoba. This census division, known as the Whitehorse Plains region, includes the Red River Valley, west of the Red River. The Whitehorse Plains region includes parts of three Regional Municipalities: Cartier, Macdonald, and St. Francois Xavier. This area is one of three drought-prone regions in Manitoba (AAFC-PFRA, 2003) and is also susceptible to flooding, and other extreme weather events related to climate change. The Red River Valley has a shortage of both surface water and groundwater making irrigation infrastructure expansion difficult (AAFC-PRRA, 2003).

Figure 2 - Census Divisions of Southern Manitoba. Source: Statistics Canada. Online: http://www.statcan.ca/english/agcensus2006/maps/mancar.pdf



Since market forces encourage the production of value-added crops that require irrigation (AAFC-PRRA, 2003), it will become increasingly challenging to ensure an adequate irrigation supply with warmer and drier conditions in the area. This census area has been estimated as having a high level of adaptive capacity according to the institutions and networks determinate (Swanson et al., 2007) and therefore served as the study area for this research.

The second area where interviews were conducted was census division 2 (see Figure 3) in southern Alberta. While drought impacts all of Alberta, it is the most severe in the southern half the province (AAFC-, 2003). Currently 97.5% of the consumptive use of water in Alberta comes from surface water sources, 71% of which is used for irrigation (AAFC-PFRA, 2003). The economies in southern Alberta have an unreliable surface water supply and a gradually declining supply of groundwater (AAFC-PFRA, 2003) which will be increasingly stressed as climate change decreases water supply and increases demand (Lapp et al., 2005). Census division 2 has a high level of estimated adaptive capacity according to the institutions and networks determinate (Swanson et al., 2007), and therefore served as the study areas for this research. More specifically, the interviews were conducted in the Eastern Irrigation District (EID) which encompasses the County of Newell (see Figure 4).

Figure 3 - Census Divisions of Southern Alberta. Source: Statistics Canada. Online: http://www.statcan.ca/english/agcensus2006/maps/abcar.pdf

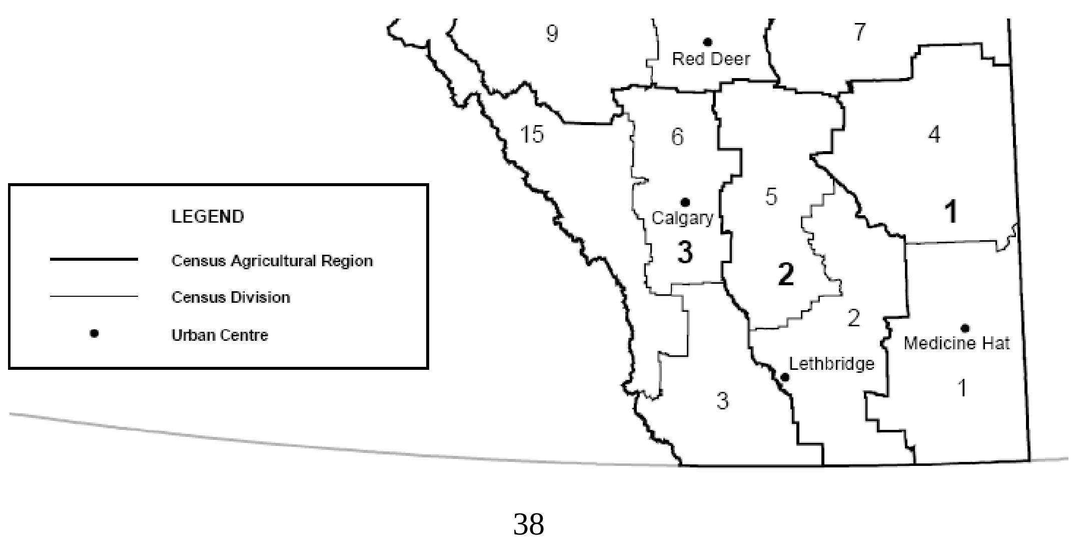
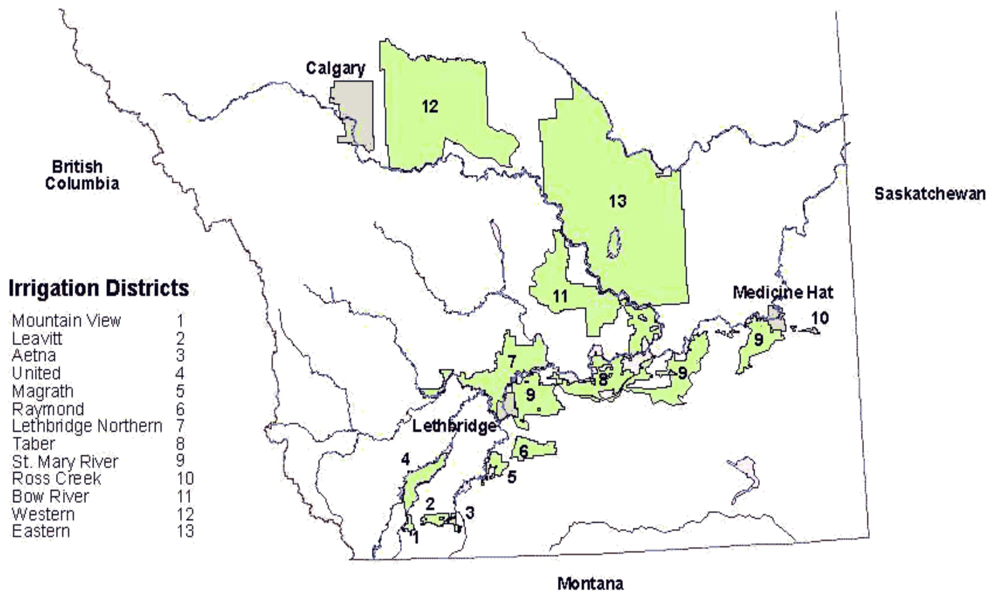


Figure 4 – Irrigation Districts of Alberta. Source: Alberta Agriculture. Online: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr4475/$FILE/irrbase.gif



3.3 Data Collection

Semi-structured interviews were the primary source of data collection. There were three criteria used to vet respondents: 1) the respondent was the owner (or lessee) and primary decisions maker on the operation; 2) the producer's agricultural practice was in the designated study area; and, 3) the operation was a non-live stock production farm or mixed crop farming and livestock production (Table 1). Since the majority of the literature that deals with adaptive agricultural practices to climate change focus on non-animal production farming (Easterling, 1996; Pretty, 1998; Smit and Skinner 2004), these farm types were expected to provide the most relevant information for the study.

The interview questions explored the learning that lead up to individual farmers' adoption of a soil or water conservation practices. The focus was on soil and

Table 1 – Profile of 28 Producers in Alberta and Manitoba

Province	Farm Size (Acres)	Farm Type	Years Farming, Owner
AB01	500	Potatoes, Cereal, Oilseed	27
AB02	600	Potatoes, Cereal	17
AB03	800	Forages, Pedigree Seed	12
AB04	3200	Cattle, Cereal, Forages	53
AB05	11000	Cattle, Forages	26
AB06	2000	Forages, Oilseed, Pedigree Seed	33
AB07	640	Cereal, Forages, Oilseed	16
AB08	1300	Alfalfa, Cattle, Cereal, Oilseed	38
AB09	3000	Cattle, Cereal, Forages, Oilseed, Soy Beans	38
AB10	320	Alfalfa, Cereal	33
AB11	400	Beans, Cereal	1
AB12	1100	Beans, Cereal, Forages, Oilseed, Sugar Beets	8
AB13	1600	Beans, Cereal, Oilseed, Peas, Pedigree Seed	6
AB14	700	Cattle, Cereal, Oilseed, Forages,	6
MB01	4700	Cereal, Grass Seed, Oil Seed	36
MB02	1700	Cereal	35
MB03	1400	Cereal, Oil Seed	46
MB04	3600	Cereal, Oil Seed, Soy Beans	35
MB05	2000	Alfalfa, Cereal, Oil Seed	8
MB06	2000	Cereal, Oil Seed	35
MB07	2000	Cereal, Oil Seed	29
MB08	3000	Cattle, Cereal, Oil Seed	40
MB09	3500	Cereal, Oil Seed, Soy Beans	29
MB10	3200	Pedigree Seed (Cereal, Oilseed, Soy Beans)	43
MB11	1500	Cereal, Oil Seed	32
MB12	1400	Cereal	32
MB13	2500	Cereal	46
MB14	1500	Cereal, Oil Seed	31

water conservation practices that are considered particularly important for mitigating the effects of weather-related shocks and stresses. Thus soil and water conservation serves as an appropriate pathway to explore learning. Given that climate change is expected to bring about increased variability, unpredictability, and more frequent extreme weather events like drought and flood (Krupnik and Jolly, 2002), soil and water conservation practices that preserve ecological features such as wetlands, shelterbelts, groundcover, are a climate-adaptation priority in the Prairie agro-ecosystem (Venema, 2006). While some of these practices are already being adopted by farmers to a certain degree, it is useful to explore the learning that has been occurring in recent years, as this might provide an insight into future learning and climate change adaptation.

Interviews were collected mainly from individual farmers, but also came from producer and conservation organizations (Ducks Unlimited in Alberta and Keystone Agricultural Producers in Manitoba), government bodies (PFRA in Manitoba), and the irrigation district (EID in Alberta). In total four interviews were done with organizations and 14 interviews were done with individual farmers in both Manitoba and Alberta for a total of 32 interviews.

Interviews began with local organizations (Keystone Agricultural Producers in Manitoba, and Ducks Unlimited in Alberta) and then a snowball sampling system was used to recruit research subjects at the producer level who in turn provided more names of potential research subjects. Peer-referencing or snowball sampling begins with a set of initial subjects who served as the starting point for an expanding chain of referrals, with respondents from an initial referral recommending subsequent subjects (Goodman, 1961).

This method of sampling is based on the assumption that linkages exists between the respondents and others in the target population (Kiptot et al., 2006). This technique can potentially be used to determine linkages and social networks as respondents provide an expanding set of potential contacts (Spreen, 1992). In Alberta, land titles maps, obtained online, were also used as a source of new interview participants.

More emphasis was placed on learning from the perspective of individual farmer as opposed to institutions since the literature emphasizes the importance of farm level adaptations to climate change (Easterling, 1996; Smit and Skinner, 2004;

Adger et al., 2007). By focusing the interviews at the farm level, the information that is successfully being transferred to producers was identified. Focusing the interviews at the organizational level would likely result in a distorted, top-down view of information linkages. In other words, information that an organization claims to be distributing, may not actually play a practical role at the farm level.

Interviews were conducted in person and via telephone. The interviews involved asking the volunteers open-ended questions from the planed interview guide (see Appendix A). This interview guide allowed for the identification of cross-scale linkages and an exploration into the type of learning. The design of the survey is based on transformative learning theory where action, critical reflection, and assessment of the action are explored in detail (Mezirow, 1994; Mezirow, 1997).

3.4 Data Analysis

Data analysis for this research began with the transcription of recorded interviews. The transcribed interviews where then analyzed to gain a sense of emerging trends, concepts, and patterns. The information sharing portion of the results was sorted into tables based on: 1) the sources of information for a particular soil or water conservation practice, and 2) the content of the information involved in each practice (e.g. specific tillage techniques and equipment used). Analysis of the data for individual producer-level learning was colour-coded to determine relationships in the transformative learning process for each interview participant. Analysis of the learning process included the identification of the types of soil and water conservation practice, sources of information, frames of reference, indicators of critical reflection, and indicators of transformative learning. Tables and figures were then constructed based on this information.

3.5 Validity and Reliability

Validity and reliability are important for research to have worth, utility, and attaining rigor in qualitative research (Morse et al., 2002). The need for reliability and validity checks in research are important for determining the quality and accuracy of data collection techniques as well as quality of the data itself (Fritz, 1990). Validity and reliability can be achieved by using verification strategies that are embedded within the qualitative research design and are self-correcting during the course of the research itself as opposed to assessing the validity of the research once it is complete (Morse et al., 2002). Van Meter (1990) states that snowball sampling can ensure reliability in data collection by including built in checks that increase the validity of the data.

While the validation of data that pertains to one's beliefs, values, or feelings is beyond the scope of this research, producer's sources of information could be validated. This was done by looking at documents and websites that farmers claimed to receive information from and verifying the presence of said information. For example, one farmer in Manitoba claimed that he received information regarding tillage practices from the Manitoba Provincial Government's Agriculture website. By searching this website I was able to confirm that the Manitoba Provincial Government does in fact offer information on tillage practices. By interviewing various farmers and agricultural institutions, validation of information distribution also occurred through triangulation. Triangulation involves collecting data from a diverse range of sources thereby increasing the validity of the data (Miller and Dingwall, 1997). For example several farmers in the Alberta study area mentioned that they receive information regarding shelterbelts from the EID. The numerous accounts of the EID as being a source of information for shelterbelts, along with confirmation from an EID employee during an interview validated this information. Using this technique enhanced project legitimacy and rigor of the fieldwork interviews.

Chapter 4 – Information Exchange in the Agro-Ecosystem

4.1 Introduction

Information sharing is an important aspect for coping with a changing climate. The exchange of information regarding soil and water conservation can lead to learning and the eventual adoption of sustainable practices. According to Ostrom et al. (2002), complex resources management problems need to be dealt with at various institutional levels and the linkages between these levels are important for effective management. Information exchange between these multiple levels also mitigates weakness through inter-connectedness as specific expertise at various levels is utilized (Pomeroy and Berkes, 1997). These linkages can occur both horizontally (i.e. across sectors or geographic space) or vertically (across different levels of organization) (Berkes et al., 2003). It is expected that information sharing and learning would be more prominent in a system with many two directional horizontal and vertical linkages. Systems that show a high degree of interconnectivity tend to be more adaptive to environmental uncertainty and long-tem environmental change (Berkes, 2002).

This chapter will address the first two research objectives: 1) Identify horizontal and vertical linkages that connect the individual producers to information regarding soil and water conservation; and 2) Determine the frequency with which information flows from these sources and the content of the information received by producers. Information linkages are examined for each individual soil or water conservation practice. Before examining the sources and content of information received at the producer level, it is important to establish the nature of the institutional landscape and the platforms where information exchange occurs.

4.2 Institutional Landscape and Platforms for Information Exchange

Responses have been categorized into six major groups that characterize the specific organizations and institutions cited in the interviews. These six groups include: Government, Industry, Producer/Conservation organizations, Social/Experiential sources, Media, and Universities/Research conferences. The specific organizations and institutions that compose these groups are described below (Table 2). The organization's platforms or means of conveying information are also described in more detail in this section.

Table 2 – Summary of Players in the Prairie Agro-ecosystem

Government	Industry	Producer/ Conservation Organizations	Social/ Experiential	Media	Universities /Research Conferences
Federal Provincial Municipalities or Counties	Seed Chemicals Seed-Chemical Packages Equipment Agriculturalist or Agronomists	Ducks Unlimited Producer Organizations Irrigation District Other Conservation Organizations	Family Neighbours or Other Farmers Personal Experience	Farm Publications Other Media	Research Conferences Post-Secondary Institutions

Government

Government is used to refer to all information coming from the Federal and Provincial government, as well as municipalities or counties. The Federal Government conveyed information to producers through the PFRA, federal research institutions, and the Environmental Farm Plan (EFP) program. The Provincial government passed information along through agricultural extension workers (a service that is no longer offered by Alberta Agriculture), the EFP, provincial agricultural web sites, and agricultural field demonstrations. Information coming from Municipalities or Counties (e.g. the County of Newell in Alberta, or the La Salle-Redboine Conservation District in Manitoba) usually was a result of talking to local employees directly.

Industry

Industry is used to categorize all sources of information that come from seed suppliers and growers, chemical suppliers, as well as companies that distribute seed and chemical packages. Equipment dealers and private agronomists or agriculturalists are also grouped under the industry category. Most producers made a distinction between seed and chemical dealers; however some producers reported receiving information on seed-chemical packages. These packages are often developed by companies using genetically engineered crops so that only their own band of chemicals can be used (Scrinis, 1998). This allows seed-chemical companies to maintain market power by linking seed customers more closely to the chemical product, thereby increasing the dominance the biotech seed and chemical industrial complex (Hayenga, 1998). Scrinis (1998), states that this techno-industrial system locks farmers into a productivity race that does not take into account the ecological damage or short-mindedness of this productivity growth. Occasionally during the interviews, farmers mentioned using these packages, which were recognizable by name (e.g. Monsanto's Round-Up Ready Canola), but simply stated the source of information as being a seed dealer. Only farmers that made the distinction with these seed-chemical packages are noted, but in reality, more farmers are using these systems then this report indicates.

Information coming from chemical, seed, or seed-chemical companies was conveyed using broacher mail outs, internet web sites, test plots, retailers, field agents and agronomists, industry sponsored producer meetings, agricultural shows, and industry research. Information coming from the equipment industry was usually communicated through dealerships or agricultural-shows (e.g. Ag-Days in Brandon, Manitoba or Ag-Expo in Lethbridge, Alberta). In some instances, dealerships would host test trails in which farmers could try out new equipment. In this study, private agronomists or agriculturalists refers to independently operated companies (e.g. Agri-Trend) that consult with, and provide advice to producers. While many producers reported receiving information from agronomists and agriculturalists (i.e. field agents), the majority of these were employed by seed or chemical companies and hence were grouped in that category.

Producers and Conservation Organizations

Producer and conservation organizations are used to refer to Ducks Unlimited Canada, producer organizations, irrigations districts (specifically the EID), and other conservation organizations. Ducks Unlimited, a well-known non-profit conservation organization, conveyed most of their information using land negotiators that engage in one-on-one discussion with producers. Ducks Unlimited also passed along information to producers through broachers, trade shows, and their web site. Producer organizations that were mentioned in the Manitoba study area included Keystone Agricultural Producers, the Manitoba-North Dakota Zero Tillage Farmers Association (MANDAK), and the Organic Producers Association of Manitoba Co-operative. In the Alberta study area, producer organizations that were mentioned included the MANDAK and the Reduced Tillage Linkages (RTL) organization. In addition, separate producer organizations existed for specialty crops (e.g. Potatoes, Edible Beans, and Sugar Beats). Information from producer organizations was conveyed though local meetings, conferences, newsletters, field school demonstrations, and local field agents. The EID[1], which is essentially a farmer's cooperative (EID, 2008), has a Board of Directors that commonly conveys information to the water users in their constituency. Annual meetings and reports are other platforms through which the EID provides information to producers. Other conservation organizations that

[1] The Eastern Irrigation District, which draws its water from the Bow River, was established in 1914 and is Canada's largest operating irrigation district. It was originally financed and colonized by the Canadian Pacific Rail Company, before being handed over to its water users in 1935. In 1968, with the passage of the Irrigation Act, the provincial government and the water users became the principle stakeholders of the irrigation industry in Alberta. Since the passage of this act, the Eastern Irrigation District has progressively enhanced the efficiency of water delivery and distribution; moving from an inefficient, flood dominated irrigation system, to now providing financial incentives for low pressure center-pivot irrigation systems (Klassen and Gilpin, 1999; Raby, 1965).

were mentioned included: Delta Waterfowl, Pheasants Forever, and the Alberta Fish and Game Association.

Social/Experiential Sources

Social/Experiential sources of information included experience and knowledge passed down from both intra- and intergenerational family, neighbours, and other local producers. Information conveyed between producers sometimes occurred from observing the success of a neighbours crops rather than though explicit communication. Personal experience with various soil and water conservation was also cited as being an important source of information among producers. Producer-level information sharing usually occurred in an informal setting such as coffee shops, producer meetings, or roadside conversations.

Media

Media was largely limited to farm publications. Farm publications that were mentioned included: The Western Producer, Country Guide, Grain News, Manitoba Co-operator, Top Crop Manager, Farmer Express, Canadian Cattlemen, and Alberta Beef Magazine. Other sources of media were rare, but included: books, and city newspapers or news web-sties.

Universities/Research Conferences

Some producers independently sought our scholarly research with the goal of improving their farming operation. Sources of information included research conferences, or research done at post-secondary institutions. Research conferences included the Southern Applied Research Association Conference and Farm Tech Conferences. Although these conferences may have some speakers from government and industry, the majority of the research is done independently at universities. Research conferences done by government or industry were grouped in their respective categories. Information obtained from universities was conveyed through research forms, field demonstrations, research papers, and knowledge from past degrees or diplomas obtained by the producers. In the

Manitoba study area, the University of Manitoba was only university that was cited as a source of information. In the Alberta study area, the University of Lethbridge, the University of Idaho, and North Dakota State University were all cited as sources of information.

4.3 Nature of Cross-Scale Linkages

Given the institutional landscape described above, the direction of the cross-scales linkages through which information flows will now be explored. Pretty (2002) suggests five different contexts in which cross-scale linkages can be observed. These include: local connections (between individuals in a community), local-local connections (between groups within a community and among different communities), local-external connections (between local groups and external agencies), external-external connections (between different external agencies), and external connections (between individuals with external agencies).

Since the scope of this research focused on individual producers, cross-scale linkages between, among, and within external agencies and community groups were not explored. Instead, the research focused on local and external connections that take place at the individual level. Local connections or horizontal linkages between individual producers and family members were commonly observed pathways for information to flow. The frequency with which information was conveyed from the producer being interviewed to other individuals and organization is summarized in Table 3. Without exception, these horizontal linkages were two directional. That is, all the producers who were interviewed stated that they both gave and received soil and water conservation information with neighbours, family members, or other producers. This horizontal information exchange occurred both inter- and intra-generationally.

Table 3 – Horizontal and Vertical Information Linkages Observed for 28 Producers

Type of Connection	Number of Farmers Where Connection was Observed	Nature of Connections
Horizontal Linkage	28	- Sharing experience and knowledge with family, neighbours, and/or other farmers
Vertical Linkage	3	- Sharing experience and information with higher-level of organization via information meetings, farm publications, or through producer organizations.

Unlike the two directional horizontal linkages observed between producers, external connections or vertical linkages were overwhelmingly one directional. That is, institutions are almost exclusively providing information to producers and are not an open source for dialogue. Only during three interviews did farmers state that they passed information along vertically to a local groups or external agency. One farmer in the Alberta study area did a presentation at a local zero-till information meeting organized by government and industry. A cattle rancher in the Alberta study area shared his experience of moving to low-external input system of grazing with Grain News, a regional farm publication. While a producer, in Manitoba, stated that he passed information along to Keystone Agricultural Producers, a provincial producer organization. The absence of widespread, two directional, information sharing between individual producers and groups or external agencies indicates information flow is predominantly top-down in Prairie agriculture.

4.4 Frequency of Information Flow and Content the Information Received

In attempting to quantify where producers get information for particular soil and water conservation practices, it is important to keep in mind that a portion of information that any individual reads, experiences, or hears may not be remembered. While some producers indicated that they obtained information that they choose to ignore, the majority of the information that producers recalled receiving involved practices that they have adopted or are considering adopting on their own farms. Therefore, the content discussed here may not be representative of all information that is received by producers. The content is however, what is remembered by producers, and therefore is mostly likely to become an adopted practice.

During the interview process, some farmers stated multiple sources of information pertaining to a given practice, and for some practices they stated that they do not get any information. Although each source of information is identified as a linkage, the existence of a linkage does not indicate the content, usefulness, or applicability of the information. For instance, even though there are many linkages with respect to wetland conservation, most producers reported getting little information in this area that has translated into the adoption of new practices. To account for this limitation regarding the identification of linkages, a discussion on the general content of the information is provided. The discussion will also indicate, in general terms, whether producers have implemented corresponding practices into their operations.

Based on the data from Table 4 each soil and water conservation practice will be discussed below. Each of the eight practices below will identify the primary sources of information and compare the sources of information between the study areas in Alberta and Manitoba. This will be followed by a discussion on the primary messages that producers are receiving. Finally, differences in the content of the information received by producers in Alberta and Manitoba will be explored.

53

Table 4 – Frequency with which 28 Producers Obtain Information for Soil and Water Conservation Practices from Various Sources

	Government			**Industry**					**Produer/Conservation Oranizations**				**Social/Experiential**			**Media**		**Universities/Research Conferences**		
Question Asked:	Federal	Provincial	Municipalities or Counties	Seed	Chemicals	Seed-Chemical Packages	Equipment	Agriculturalist or Agronomists	Ducks Unlimited	Producer Organizatoins	Irrigation Districts	Other Conservation Organizations	Family	Neighbours or Other Farmers	Personal Experience	Farm Publications	Other Media	Research Conferences	Post-Secondary Institutions	Total number of sources of information for a conservation practice regardless of the source of information
Where do you get information regarding tillage practices?	0, 0	6, 4	0, 1	1, 0	4, 2	0, 0	3, 3	1, 0	0, 0	4, 1	0, 0	2, 0	0, 2	11, 12	1, 6	6, 9	0, 0	3, 0	1, 5	43, 45
	0	**10**	**1**	**1**	**6**	**0**	**6**	**1**	**0**	**5**	**0**	**2**	**2**	**23**	**7**	**15**	**0**	**3**	**6**	88
Where do you get information regarding reduced chemical application or alternatives to chemical application?	0, 0	3, 3	0, 0	1, 2	5, 11	0, 2	1, 0	2, 1	0, 0	3, 0	0, 0	0, 0	0, 0	4, 2	1, 1	3, 3	0, 1	1, 0	1, 1	25, 27
	0	**6**	**0**	**3**	**16**	**2**	**1**	**3**	**0**	**3**	**0**	**0**	**0**	**6**	**2**	**6**	**1**	**1**	**2**	52
Where do you get information regarding organic farming?	0, 0	1, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0	4, 2	0, 0	0, 0	0, 1	4, 9	1, 0	5, 7	0, 1	0, 0	0, 1	15, 21
	0	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**0**	**0**	**1**	**13**	**1**	**12**	**1**	**0**	**1**	36
Where do you get information on crop varieties that can cope with a wide range of weather conditions?	2, 0	2, 2	0, 0	11, 4	2, 1	0, 1	0, 0	0, 0	1, 0	1, 1	0, 0	0, 0	0, 0	2, 5	2, 3	2, 3	0, 0	1, 0	1, 1	27, 21
	2	**4**	**0**	**15**	**3**	**1**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**7**	**5**	**5**	**0**	**1**	**2**	48
Where do you get information on how to deal with excess moisture or rain?	1, 0	1, 1	0, 6	0, 0	0, 0	0, 0	0, 6	0, 0	0, 0	0, 0	2, 0	0, 0	0, 2	0, 6	2, 8	3, 0	0, 0	0, 0	0, 1	9, 30
	1	**2**	**6**	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**2**	**0**	**2**	**6**	**10**	**3**	**0**	**0**	**1**	39
Where do you get information on new irrigation techniques, methods, and technology?	1, 0	3, 0	0, 0	0, 0	0, 0	1, 0	10, 0	1, 0	0, 0	2, 0	6, 0	0, 0	1, 0	1, 0	0, 0	2, 1	0, 0	1, 0	1, 0	30, 1
	1	**3**	**0**	**0**	**0**	**1**	**10**	**1**	**0**	**2**	**6**	**0**	**1**	**1**	**0**	**3**	**0**	**1**	**1**	31
Where do you get information regarding wetlands?	3, 2	4,3	0, 2	0, 0	0, 0	0, 0	0, 0	0, 0	10, 1	0, 1	3, 0	0, 1	1, 0	0, 0	0, 1	1, 3	0, 1	0, 0	0, 0	22, 15
	5	**7**	**2**	**0**	**0**	**0**	**0**	**0**	**11**	**1**	**3**	**1**	**1**	**0**	**1**	**4**	**1**	**0**	**0**	37
Where do you get information regarding shelterbelts?	6, 13	3, 4	2, 1	0, 0	1, 0	0, 0	0, 0	0, 0	3, 0	0, 0	9, 0	3, 0	0, 0	0, 1	0, 0	1, 2	0, 0	0, 0	0, 0	28, 21
	19	**7**	**3**	**0**	**1**	**0**	**0**	**0**	**3**	**0**	**9**	**3**	**0**	**1**	**0**	**3**	**0**	**0**	**0**	49
Total number of times a source of information was cited regardless of specific soil or water conservation practice	13, 15	23, 17	2, 10	13, 6	12, 14	1, 3	14, 9	4, 1	14, 1	14, 5	20, 0	5, 1	2, 5	22, 35	7, 19	23, 28	0, 3	6, 0	4, 9	199, 181
	28	**40**	**12**	**19**	**26**	**4**	**23**	**5**	**15**	**19**	**20**	**6**	**7**	**57**	**26**	**51**	**3**	**6**	**13**	380
	Total Government = **80**			Total Industry = **77**					Total Produer/Conservation Oranizations = **60**				Total Social/Experiential = **90**			Total Media = **54**		Total Research = **19**		

First Number = Alberta
Second Number = Manitoba

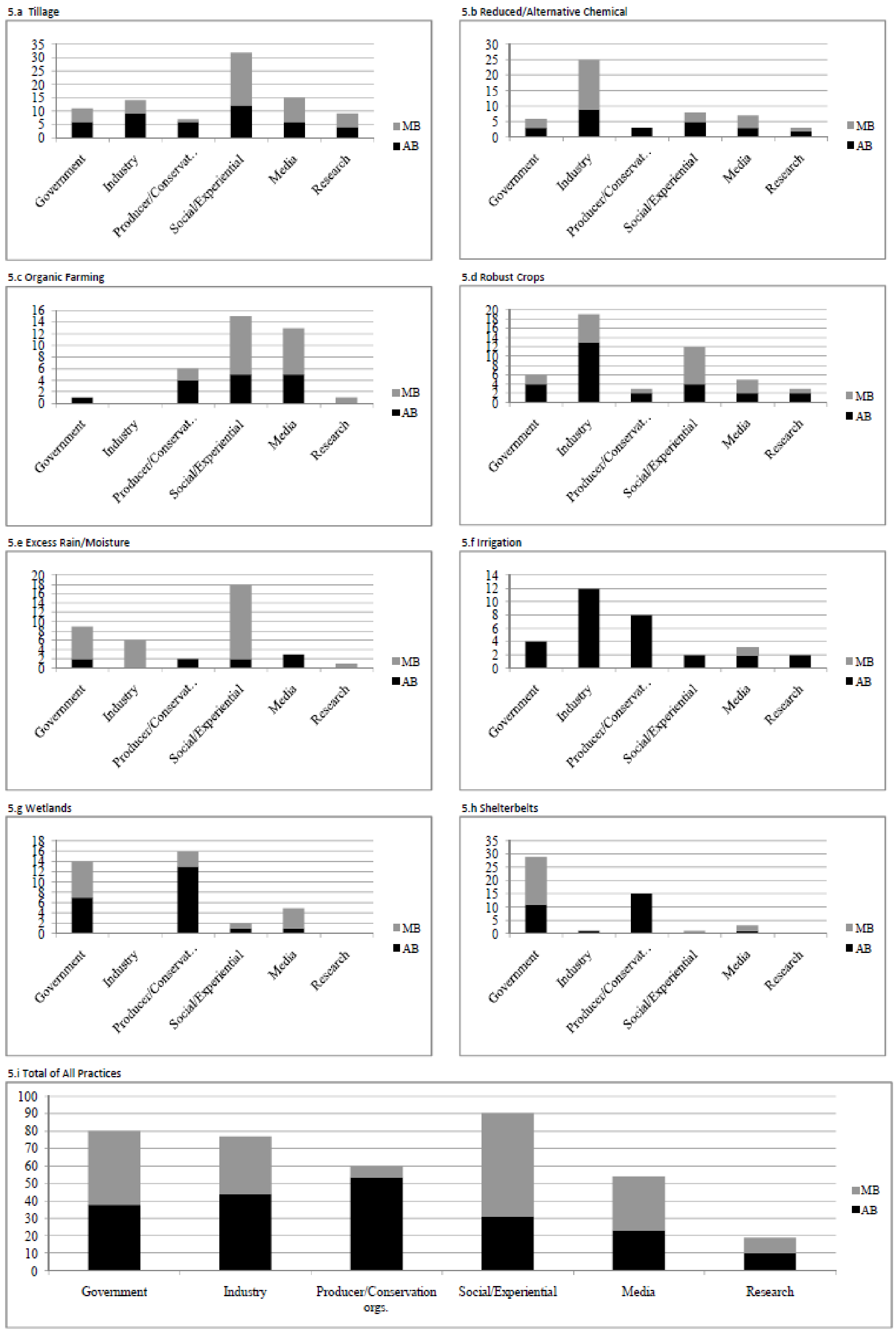
4.4.1 Tillage Practices

Information received by producers regarding tillage practices comes mostly through word-of-mouth from neighbours or other farmers (Figure 5.a). Farm publications and the Provincial Government also play an important role in passing tillage information along to producers. While less commonly cited as an information source, post-secondary institutions conveyed more information regarding tillage than any of the other soil and water conservation practices discussed. When comparing the study areas in Alberta and Manitoba, the information obtained by producers in both provinces came from similar sources. However, in the Manitoba study area, six producers stated that their own personal experience was a source of tillage information compared to just one producer in the Alberta study area. Farmers interviewed in the Alberta referred to producer organizations as an information source more often than the producers interviewed in the Manitoba study area.

While the sources of information between the two provinces are similar, the content of the information is very different. In the Alberta study area, information regarding zero-tillage or reduced tillage was commonly mentioned. Nine of the 14 farmers interviewed in the Alberta study area had moved from a conventional tillage system to some sort of conservation tillage. They cited the benefits of zero-tillage as being: increased retention of moisture, increased organic matter, reduced wind erosion, and preservation of microbes that break residues into nutrients. A system of tillage known as dam and dyking was cited by three specialty crop producers that grew potatoes or sugar beets. Knowledge of this system, in which holes are made at the top of small hill to encourage water uptake by the plant, came from producer organizations associated with the specialty crop.

Like the Alberta study area, producers in the Manitoba study area received information regarding reduced or conservations tillage (cited seven times), but due to the heavy-clay soil in the Red River Valley this information was largely

Figure 5 (a-i) - Frequency with which 28 Prairie Producers Acquire Information for Soil and Water Conservation Practices from Various Sources



ignored. For the most part information received by producers has lead to reduced burning of crop residues and a shift away from conventional tillage. Conventional tillage has been replaced with the adoption of heavy harrows. Heavy harrows facilitate in breaking up crop residues and help to incorporate residues into the soil. According to several of the interviewees, this increases the organic matter in the soil, preserves micronutrients, and allows the soil to warm in the spring allowing for a better quality seedbed. Compared to burning, using heavy harrows also reduces the severity of wind erosion. Seven of the 14 farmers interviewed in Manitoba have moved from a conventional tillage system using cultivators to one that uses heavy harrows. Six of the farmers in the Manitoba study area used other equipment to deal with crop residues either on its own or in addition to heavy harrows as an alternative to burning. Other equipment used to break up and incorporate residues into the soil included a fine-cut straw chopper and a double discer.

4.4.2 Reduced or Alternative Chemical Application

Information regarding reduced chemical application or alternatives to chemical application came predominately from the chemical industry (Figure 5.b). For the purpose of this research chemicals are used to refer to herbicides, pesticides, insecticides, and fertilizer. A total of 16 of the 28 producers interviewed identified the chemical industry as a source of information for these types of practices. The provincial government, neighbours and other farmers, and farm publications were each cited six times as a source of information for reduced chemical application or alternatives to chemical application.

Producers in the Alberta study area used a variety of different techniques to reduce their chemical use. Three farmers in the Alberta study area mentioned their use of new spraying equipment that requires a lower volume of chemicals and still allows for sufficient coverage. Two farmers reported that zero tillage requires a lower volume of chemicals as the weed spectrum is changed (e.g. no longer need to spray for wild oats). Applying different varieties of chemicals that are less harmful to the environment (e.g. contains lower amounts of phosphorus) was mentioned twice. Two mixed-farmers cited that they are able to eliminate pesticide use by controlling weeds using intensive cattle grazing. These two farmers also mentioned they have eliminated fertilizer use by adding nitrogen-fixing legumes to their pasture mix. Another practice that was mentioned once, involved using a lower volume of chemical per acre than is indicated by the chemical manufacturer’s directions.

In the Manitoba study area on the other hand, there was very little specific information that producers received on reduced chemical application or alternatives to chemical application. Most producers in the Manitoba study area (11 of 14) cited chemical companies as a source of information but did not state specifically what information they received. The most common information passed along from chemical companies included what chemicals to use for a given crop and how to apply them. Only one farmer interviewed in the Manitoba study area stated an explicit reduced chemical application practice. This information came from a crop tour at the University of Manitoba that showed alternative application practices including: spraying during different stage of germination to reduce chemical volume and costs, and using different seeding rates to reduce weed competition.

4.4.3 Organic Farming

Organic farming related information came from two major sources: other farmers and farm publications (Figure 5.c). Talking to other farmers and neighbours who had tried organic farming was mentioned by 13 of 28 producers, while farm publications were brought up 12 times as source of information for organic farming. The content of the information received was similar in both the Alberta study area and the Manitoba study area. Four farmers in the Alberta study area and three in the Manitoba study area stated that they get little or no information regarding organic farming. In the Alberta study area, two producers were considering trying organic farming compared to one in the Manitoba study area.

The majority of the producers indicated that organic farming would not work from their operation (7 in the Alberta study area and 9 in the Manitoba study area). A variety of reasons were given as to why they believed organic farming would not suit their operation. Reasons included: It would not work for their type of crop, it was unsuitable with this type of soil, concern over poor quantity and quality of crop, concern that increased productions costs would not be compensated for despite the higher selling price of the crop, and neighbours have tried it and failed. None of the producers interviewed were currently practicing organic farming, but one of the farmers interviewed in Manitoba had tried going organic and found it was not economically viable.

4.4.4 Climatically Robust Crops

Producers predominately cited two sources for which they obtain information on climatically robust crops: seed dealers and, to a lesser extent neighbours and other farmers (Figure 5.d). Reference to seed dealers was notably higher in the Alberta study area compared to the Manitoba study area (cited 11 times by Alberta producers and just four times in Manitoba). Famer-to-farmer communication was more common in the Manitoba study area, being cited five times compared to two times in the Alberta study area. Personal experience with new crop varieties and farmer publications were also relatively important source of information being mentioned five times in each province.

Producers commonly reported receiving information regarding new, climatically robust varieties of crops that they were already growing. Farmers in the Alberta study area cited this type of information nine times, and farmers in the Manitoba study area four times. Two of the four farmers in the Manitoba study area had contracts with seed companies to grow test plots of some of these new varieties. While less common than the information regarding improvements on existing varieties, two producers in each of the Alberta and Manitoba study areas mentioned that they had moved to completely different types of crops that are better able to cope with a wide variety of weather conditions. In Alberta, these new crops were canola, silage corn, triticale, soybeans, and sunflowers. In Manitoba, the new crops mentioned were sunflowers and soybeans. Five farmers in the Manitoba study area and two in the Alberta study area stated that they receive no information on new crop varieties. In the Alberta study area, some producers stated the reason for the lack of information regarding new crop varieties was due to the protection against drought that irrigation provided.

4.4.5 Excess Rain or Moisture

Dealing with excess rain and moisture was a practice that was mainly limited to Manitoba (Figure 5.e). In general, producers received information regarding this topic from municipalities, equipment dealers, and through their own personal experience. Given the dry conditions of south-eastern Alberta, excess moisture is generally not a problem, and hence producers did not receive this type of information. Eleven Alberta producers mentioned that they received absolutely no information on drainage, stating that their fields are built to drain given the historical predominance of flood irrigation. Two farmers stated that they received information from the county and the EID on this matter, but did not cite any specific information. One Alberta farmer cited the EFP as a source of information on regulations regarding runoff from livestock operations.

In the Manitoba study area, many producers stated that information regarding drainage came from personal experience and the municipalities, but did not provide specific examples as to the content of information. Equipment dealers were also mentioned as source of information. For equipment dealers, producers cited more tangible examples of the content of the information they received. For instance, information regarding Global Positioning Systems, which allow the precise identification of low spots in a field, was mentioned four times by producers. While information regarding the new equipment used for drainage (e.g. rotary ditchers, or laser systems) was brought up six times by the 14 Manitoba farmers interviewed. Aside from equipment related information,

information regarding maintenance of drainage systems ditches maintenance, was cited three times.

4.4.6 Irrigation

Information related to irrigation was obtained almost exclusively in the Alberta study area (Figure 5.1.f) due to the extremely dry condition in the Country of Newell and relatively moist conditions in the Whitehorse Plains Region in Manitoba. Only one farmer in the Manitoba study area claimed to have received any information regarding irrigation, however revealed that close attention was not paid to this information since it would not be used.

All of the 14 producers in the Alberta study area used irrigation on their operation. Nine of the producers had exclusively irrigated crops. Four producers had some sort of irrigated crop in conjunction with a cow-calf livestock operation, and one producer had irrigation along with dry land crops. The main sources of information dealing with irrigation were equipment dealers and the EID, as Alberta producers cited these institutions 10 and six times respectively. All 14 of the producers interviewed reported receiving information on the latest irrigation equipment that is energy and water efficient. Common equipment innovations that were mentioned include: central pivots, drop tubes, and low-pressure systems. Seven of the interviewed participants in the Alberta study area mentioned receiving information regarding water conservation practices. This included: monitoring soil moisture content, water requirements for various crops, collecting irrigation runoff, and water application timing. Two of the Alberta participants cited government and EID sponsored incentive programs as a source of information for new innovations in irrigation equipment.

4.4.7 Wetlands

Information regarding wetlands came mainly from Ducks Unlimited and the Federal/Provincial Government (Figure 5.g). While governmental sources of information were cited equally in the Alberta and Manitoba study areas (seven times each in Manitoba and Alberta), Ducks Unlimited was found to be an information source that is much more common in the Alberta study area (Cited 10 times in Alberta compared to one time in Manitoba). In general, information regarding wetlands was more common in the Alberta study area than the Manitoba study area. This is likely a result of the abundance of marginal land used for cattle grazing in south-eastern Alberta, which is more likely to be sacrificed for wetlands than the productive crop land in Manitoba's Red River Valley.

Of the 14 producers that were interviewed in Manitoba, five stated that they received absolutely no information with respect to wetlands, while six named sources of information, but not the specific content regarding that application. Two producers in the Manitoba study area indicated that they receive information regarding buffer zone regulations for wetland and riparian areas, while one farmer reported practicing wetland conservation by leaving ditches and coulees uncultivated.

Like Manitoba, it was common for producers in the Alberta study area to name sources of information regarding wetlands, but not state specifically the content of the information or actions that have resulted from this information. For seven of the 14 farmers interviewed in the Alberta study area this was the case. Three farmers in the Alberta study area received information regarding buffer zone regulations when spraying or cultivating near wetland and riparian areas. Another three Alberta farmers reported building or restoring wetlands on their land. These wetland areas were often situated at the corners of quarter-section plots in which the pivot irrigation systems do not reach. Only one producer in the Alberta study area stated that he received no information regarding wetlands.

4.4.8 Shelterbelts

Information regarding shelterbelts comes predominantly from the PFRA (Figure 5.h). This branch of the Federal Government administers the Prairie Shelterbelt

Program, a program that originated in response to widespread drought and land degradation in the 1930s. In the Alberta study area, producers commonly cited the EID as a source of information for shelterbelts. The EID's Partners in Habitat Development Program works in conjunction with other conservation organizations to plant and maintain trees and shrubs for landowners. While this program receives its trees from the PFRA, many farmers are unaware of the Federal Government's involvement in the program. While less frequently cited than information coming from the Federal Government, the Provincial Government also came up as source of information for shelterbelts in seven of the 28 interviews.

Information related to shelterbelts that producers in the Alberta study area are receiving dealt with the benefits of shelterbelts, how to plant them, maintenance, and programs that provide free trees. Thirteen of the 14 farmers interviewed, reported receiving this type of information and have planted or maintained shelterbelts on their farms. Information regarding the maintenance of shelterbelts in south-eastern Alberta is especially important since trees do not grow naturally in this area and require irrigation. This maintenance-related information comes largely from the EID. While three Alberta farmers cited the Provincial Government as a source of information, the specific content of the information coming from the provincial government was not provided.

Producers in the Manitoba study area noted receiving information regarding the benefits of shelterbelts, how to plant them, different varieties of trees, and programs that provide free trees. Ten of the 14 the Manitoba study area farmers reported receiving this type of information. The provincial government was cited as a source of information four times, only one farmer however, identified the specific content of the information provided (i.e. a provincial agricultural representative helped a producer to obtain trees from the PFRA). While two producers in the Manitoba study area reported doing nothing with the information they receive on shelterbelts, most producers stated that they have added or maintained some shelterbelts on their land. Most producers reported adding shelterbelts around their yards only and not throughout the rest of the farm however.

4.5 Conclusion: Top-Down and Horizontal Information Exchange

Information sharing is likely a major factor that leads to the adoption of soil and water conservation practices by producers. Twenty-eight interviews with farmers in Alberta and Manitoba revealed that vertical information linkages between producers and organizations are largely top-down and one directional. Given the importance of information flow between institutional levels, the predominance of top-down information sharing that is taking place may increase the vulnerability of the system (Hakim, 2005). This type of centralized approach to agriculture leads to reductionism, the transfer of technology, and results in the exclusion of user participation (Pretty, 1998). Horizontal linkages between farmers however, were a very common pathway for information flow. Although a system that is connected across different levels of organization is ideal, widespread horizontal linkages still allows for a combination of different knowledge systems, which is useful in the management of complex systems (McLain and Lee, 1996). The predominance of horizontal linkages between farmers may also provide opportunities for discourse and learning to take place.

Examination of the sources of information reveals that producers receive soil and water conservation information from many diverse sources. Information comes from government, industry, producer/conservation organizations, social/experiential sources, media, and to a lesser extent universities and research conferences (Figure 5.i). There is not a single source that dominates when looking at soil and water conservation practices as a whole, but when specific practices are examined there are often one or two prominent institutions that dominate the information that is conveyed to producers. The sources from which producers receive information were very similar for the Alberta and Manitoba study areas.

The only major exception was the presence of the irrigation district, which played a prominent role in the Alberta study area only. When the sources of information for all the specific soil and water conservation practices are examined, social/experiential sources of information are the most common, with industry and government with also being relatively prominent. The dominance of social/experiential sources of information may be indicative of the wide spread horizontal information sharing that is occurring. This type of information is likely more reliable and experienced-based than information stemming from profit-driven industries.

Chapter 5 – Producer-Level Learning

5.1 Introduction

Agriculture is a perpetually changing activity. New technology and innovations in equipment, practices, seed varieties, and agrochemicals are continually developed. These innovations allow farmers to cope with slowly changing environmental conditions, as well as with weather variability and unpredictability. Social change may also lead to new farming practices as rules, regulations, and broad changes in collective social ideologies evolve over time. The ever-changing technological, environmental, and social conditions require Prairie farmers to constantly learn to cope and adapt in order to remain financially competitive. While the previous chapter focused on the sources and content of information that producers were receiving, this chapter will address the learning that is occurring among producers. Specifically, the third research objective will be addressed, which is to consider the individual learning that precipitated the adoption of soil and water conservation practices using transformative learning theory.

Most research in the area of transformative learning determines learning outcomes after examining the fundamental assumptions that govern frames of reference (Sims and Sinclair 2008; Kerton and Sinclair, 2009). Conversely, this research starts with learning outcomes (i.e. changes in action) and then seeks to examine in greater depth the drivers behind the change in action (i.e. changes in points of view and habit of mind). Specifically, the focus here is to explore instrumental and communicative learning, and to determine how they relate to the transformative learning process. Communicative learning often involves critical reflection, which can lead to a transformative experience whereby individual perspectives and meaning schemes are altered (Sims and Sinclair, 2008). By examining evidence of critical premise-based reflection, insight into individual transformation regarding thought and action towards farming practices can be gained.

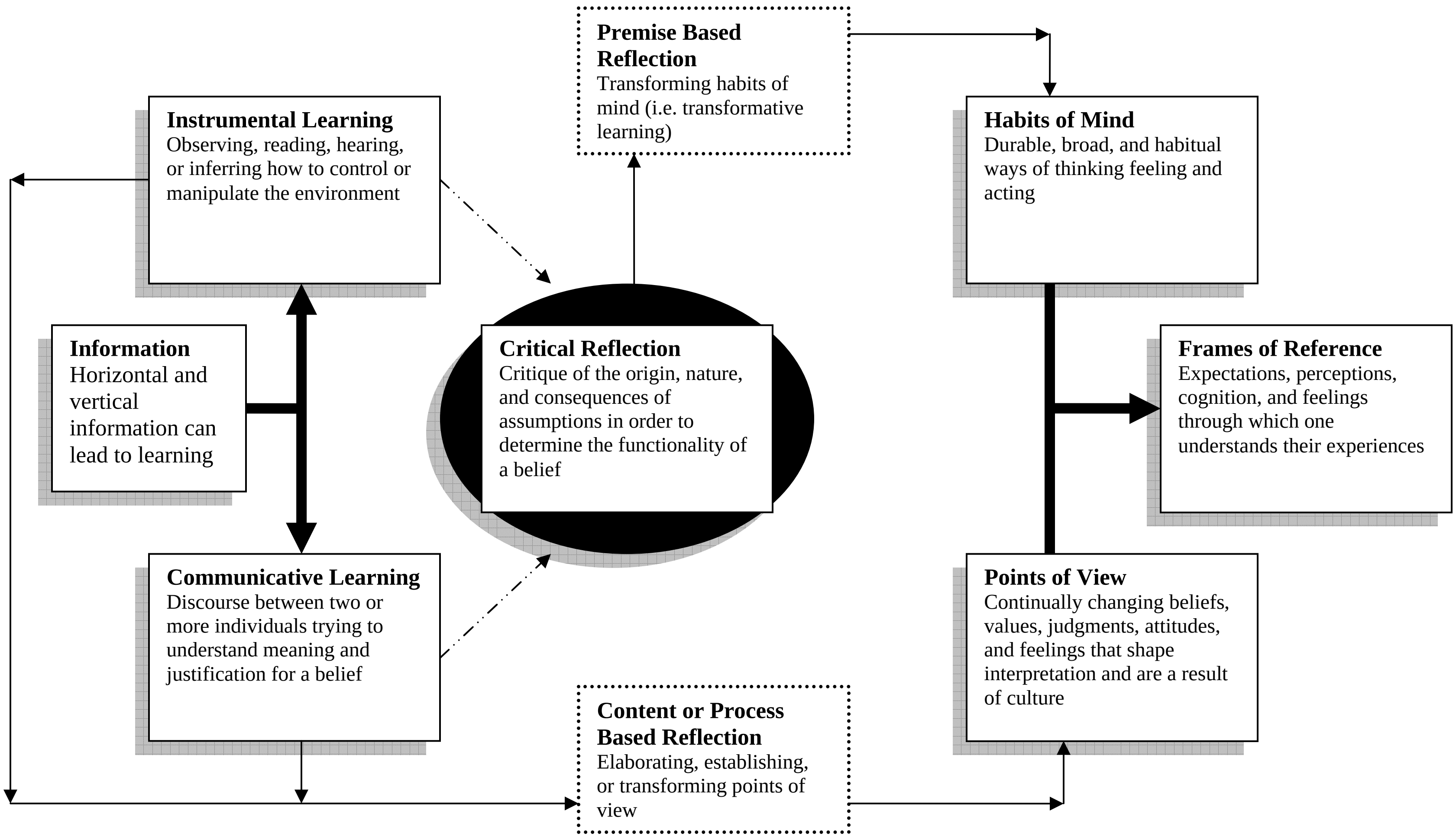
5.2 Transformative Learning as a Theoretical Lens

The learning explored in this research is examined through the lens of transformative learning theory (TLT) (Mezirow, 1994, 1995, 1997, 2000). TLT provides a perspective of informal education that is based on learning at the individual level in adults. The theory focuses on contextual learning, whereby learners interpret and reinterpret their associations, concepts, senses, values, responses and feelings (i.e. frames of reference) that define their world (Mezirow, 1994, 1997).

Transformative learning results in the individual frame of reference to become more inclusive, discriminative, self-reflective, and to be based on experience (Mezirow, 1997). This altered frame of reference then contributes to shaping expectations, perceptions, consciousness, and feelings (Mezirow, 1997). In other words, the ways people think, feel, and act (i.e. habits of mind) are manifested in the way the world is interpreted (i.e. point of view). The way in which experiences are understood (i.e. frame of reference) is a compilation of both the habits of mind and point of view (Mezirow, 1997). Transformation of an individual's frame of reference can occur through a process of “critical reflection and transformation of a habit of mind”, or from an “accretion of transformation in points of view” (Mezirow, 1997: p. 7). Critical reflection involves a “critique of assumptions to determine whether the belief, often acquired through cultural assimilation in childhood, remains functional for us as adults” this is done by “critically examining its origins, nature, and consequences” (Mezirow, 1994: p. 223) (see Figure 6).

Critical reflection takes place within the problem-solving context (Mezirow, 1994). Reflection can be centered on the content (e.g. Does information about tillage in Central Canada apply to me?) and process of the problem (e.g. Is there a better way irrigate my crop?). These types of reflections have the ability to

Figure 6 - Conceptualization of Mezirow's Transformative Learning Theory



transform points of view, which are context dependent and continually changing. Reflection can also be centered on the premise of the problem (e.g. What is my role as a farmer?). Premise based reflection can transform habits of mind, which are more durable and are therefore a more significant change (Mezirow, 1994). Transformations to habits of mind involve being aware and reflective of one's generalized bias towards the way things are perceived (Mezirow, 1997). This type of reflection can be a result of a single significant event or from an accretion of instrumental and communicative learning experiences (Mezirow, 1994; 1997).

Transformation of an individual’s frame of reference, though the reflection of unexamined assumptions that govern habits of mind and points of view, can occur during the process instrumental and communicative learning (Mezirow, 1997). Instrumental learning is problem-based and can usually be resolved through empirical tests (Mezirow, 1994). Communicative learning is not usually amenable to empirical test, but instead involves discourse in which two or more people striving to understand purpose, values, beliefs, and feelings (Mezirow, 1997). In order to understand and validate the content of communication, individuals must engage in discourse to “assess reasons presented in support of competing interpretation, by critically examining evidence, arguments, and alternative points of view” (Mezirow, 1997: p. 6).

5.2.1 Why Transformative Learning Theory?

TLT is an appropriate theoretical lens through which to examine informal adult education in Prairie farmers given that transformative learning outcomes can enhance sustainable practices in resource management (Sims and Sinclair, 2008; Diduck 1999). Using TLT to examine learning allows researchers and resource managers to better understand how to foster learning situations that will lead to changes in the way individuals behave and perceive to world. Transformative learning outcomes can involve beliefs, meanings, justification, and decisions to be based on experience, assessment of context, insight, and informed agreement, making them more autonomous, discriminate, and socially and environmentally responsible (Mezirow, 1995, 2000).

Heighten cognizance, socio-political empowerment, and social change are promoted by dialogue and critical reflection, which are central to the transformative learning process (Mezirow, 2000). Altering ingrained habits of mind and frames of reference through critical reflection can potentially result in the decision maker to increase their environmental awareness. This may ultimately result in social change whereby the collective social consciousness of a community is engaged in achieving sustainable outcomes. According to Sinclair et al. (2008), non-formal education can be used to empower, facilitate participation, and challenge traditional ideologies and practices, creating the potential to ultimately generate social action that enhances environmental sustainability.

5.3 Learning Outcomes

This research sets out to explore the individual learning outcomes of producers. This was done by first selecting a single practice related to soil or water conservation. The producers were asked to choose a practice that they have either recently adopted, is a personal favourite, or works exceptionally well, so that that practice could be discussed in greater detail (Table 5 and 6). While most producers employed several techniques and innovations that were related to soil and water conservation, this research focused on only one of the practices. Of the 28 producers interviewed, only one farmer could not provide a practice to discuss in greater detail. However, this farmer discussed a practice that he was planning on adopting in the near term. Allowing the participants to choose a practice to discuss in greater detail was designed to bring to the fore ideas that the producer spent time deliberating over, thereby making them appropriate pathways to explore transformative learning.

Alberta farmers showed greater diversity in the number of practices they chose to discuss in detail. In total, producers in the southern Alberta study area discussed nine different practices, while Manitoba producers discussed only four different practices. The most common practices that producers in Alberta chose to discuss in detail were new irrigation technologies for the purpose of conserving water, and zero tillage. The most common practices that producers in the Manitoba study area chose to discuss in greater detail included the use of heavy harrows or other equipment used to deal with crop residues, growing new types of crops, and employing equipment to aid in field drainage (i.e. laser ditching and GPS).

Table 5 - Learning Outcomes for 14 Farmers in Alberta

Learning Outcome	Farmers who Cited this Practice
Practicing zero tillage	AB03, AB06, AB07, AB08
Employing water saving irrigation technology	AB02, AB04, AB10
Reducing chemical application	AB01
Practicing reduced tillage	AB14
Creating and conserving wetlands	AB05
Employing holistic grazing	AB09
Soil moisture monitoring	AB11
Dam and dyking cultivation	AB12
Growing new types of crops	AB13

Table 6 - Learning Outcomes for 14 Farmers in Manitoba

Learning Outcome	Farmers who Cited this Practice
Using heavy harrows or other residue management equipment	MB01, MB02, MB07, MB11, MB13
Growing new types of crops	MB03, MB04, MB05, MB08
Using drainage equipment (Laser Ditching, GPS)	MB06, MB09, MB12, MB14
Burning crop residues	MB10

A possible explanation as to why there was much greater diversity in the Alberta study area compared to the Manitoba study area regarding soil and water conservation practices that producers felt were important or work exceptionally well, may be a result of local environmental conditions. Given the heavy, clay soil present in the Red River Valley of Manitoba, the most important soil and water conservation practices dealt with excess water and moisture. As a result of the high soil moisture content, using equipment to incorporating crop residues (which also prevents soil erosion) is especially important. Failing to incorporate crop residues can lead to wind erosion, loss of organic matter, and a poor seedbed in the spring. The moist heavy-clay soil in this area of Manitoba also makes this area ideal for growing predominantly cereal and oilseed crops. Nearly all of the Manitoba farmers interviewed reported growing these types of crops. The County of Newell in Alberta on the other hand, is a very dry area that is mostly under irrigation. As a result of the irrigation, there is a higher diversity in the types of crops grown. This diversity in crops allows for more soil and water conservation options and techniques. The area also has many mixed farming-cattle operations, which contributes to yet even more soil and water conservation practices. While geography and corresponding farm types seems to be an important factor in explaining the differences in variety of soil and water conservation practices, there is likely additional driving factors that explain the difference between Alberta and Manitoba. Although beyond the scope of this research, one such driving factor that can also contribute to the higher diversity in conservation practices producer's chose to discuss, could be the frequency of climate related shocks experience (e.g. prolonged drought).

5.3.1 Sources of Information Driving Learning Outcomes

Examination of the sources of information that lead to learning for single significant conservation practice, reveals that information comes from a broad and diverse set of sources and experiences. While the learning outcomes in the study areas in Manitoba and Alberta were very different, the broad categories in which farmers, the sources of information for learning were quite similar. In general, learning occurred as result of information stemming from government, industry, neighbours, farm publications, producer and conservation organizations, formal education, personal research, and personal experience.

In the Alberta study area, producers who learned to employ water saving irrigation technology generally obtained information from industry (especially irrigation equipment dealers) and producer and conservation organizations (especially the EID). Those producers that were practicing zero tillage learned about this technique mainly from neighbours, personal experience, personal research (i.e. through conferences and universities), the Provincial Government, and producer organisations (i.e. RTL and MANDAK). Of the other seven soil and water conservation practices discussed by producers in the Alberta study area, neighbours and to a lesser extent industry and personal experience were common sources of information that lead to instrumental learning (Table 7).

Producers in Manitoba generally reported fewer sources of information than producers in the Alberta study area. Information regarding heavy harrows or other residue management equipment came predominantly from neighbours, with government (both municipal and provincial) playing a less prominent role. Knowledge of new crops and new crop varieties were reported as coming from mainly neighbours and the Provincial Government. Information that resulted to the adoption of drainage equipment came predominantly from neighbours, personal experience, equipment dealers, and municipalities (Table 8). The narrower range of information sources that lead to instrumental learning in the Manitoba study area may be a result of the homogeneity of farm types in this area, or a greater reliance on farmer-to-farmer information sharing.

5.4 Instrumental Learning

Instrumental learning involves learning to control or manipulate the environment so that new points of view are changed, elaborated on, or established (Mezirow; 1997, 1994). Such learning can potentially transform the beliefs, values, judgments, attitudes, and feelings that shape the individuals interpretation (Mezirow, 1997). Mezirow (1995) refers to three characteristics of instrumental learning. These include learning to obtain skills and information, determining cause and effect relationships, and task orientated problems solving.

For the purpose of this research, instrumental learning mainly occurred with respect to actions that individuals took to increase their economic productivity. This includes

Table 7 - Sources of Information for Learning Outcomes in Alberta

Learning Outcome	Number of Farmers who Cited this Practice	Farmer and Source of Information
Practicing zero tillage	4	AB03 - Zero-till conference, farm publications, family, neighbours AB06 - Neighbour, personal experience, RTL (producer organization) AB07 - Farm Publications, MANDAK (producer organization), Neighbours, Provincial Government, personal experience AB08 - North Dakota State University research farm, research conferences, RTL (producer organization), Provincial Government, industry, neighbours
Employing water saving irrigation technology	3	AB02 - Equipment dealers, Provincial Government, Potato Growers Association, EID AB04 - EID, equipment dealers, personal experience AB10 - Neighbours, EID, seed companies, equipment dealers
Reducing chemical application	1	AB01 - University of Idaho potato school, chemical dealers, equipment dealers, neighbours
Practicing reduced tillage	1	AB14 - Neighbours, Provincial Government, personal experience
Creating and conserving wetlands	1	AB05 - Family, personal experience, neighbours, Ducks Unlimited, EID
Employing holistic grazing	1	AB09 - Farm publications, Grazing Mentorship Program (producer organization)
Soil moisture monitoring	1	AB11 -Industry agriculturalist, personal experience, neighbours
Dam and dyking cultivation	1	AB12 - Neighbours, equipment dealers, specialty crop producer organizations

Growing new types of crops	1	AB13 - Seed dealers, Ducks Unlimited, neighbours, Federal Government

Table 8 - Sources of Information for Learning Outcomes in Manitoba

Learning Outcome	Number of Farmers Who Cited this Practice	Farmer and Source of Information
Using heavy harrows or other residue management equipment	5	MB01 - Municipality, Conservation District, neighbours, personal experience MB02 - Neighbours MB07 - Neighbours, farm publications MB11 - Neighbours MB13 - Provincial Government, equipment dealer, neighbours
Growing new types of crops	4	MB03 - Provincial Government, neighbours, seed companies MB04 - Neighbours MB05 - Provincial Government, University of Manitoba MB08 - Neighbours, personal experience
Using drainage equipment (Laser Ditching, GPS)	4	MB06 - Municipality, neighbours, personal experience, farm publications MB09 - Equipment dealers, municipality, personal experience MB14 - Neighbours, equipment dealers MB12 - Neighbour, personal experience
Burning crop residues	1	MB10 - Personal experience, neighbours, family

practices that are related to increasing or maintaining the economic viability or net return per acre of the farm. Sinclair et al. (2008) identifies four grounded categories of instrumental learning. These include: scientific and technical knowledge, legal /administrative and politic procedures, social and economic knowledge, and potential risks and impacts. These grounded categories of instrumental learning were present in this research data and will be used to discuss the various learning outcomes that contributed to more effective and economical farming methods (Table 9).

Table 9 - Categorization of Instrumental Learning*

Grounded Categories	Specific Learning Outcomes in Alberta	Specific Learning Outcomes in Manitoba
Scientific and technical knowledge	-Use less fuel, equipment, and/or labour (9) -Increase water efficiency (5) -Increase quality of crops (4) -Create uncultivated habitat or wetlands (3) -Expand farm/grow new crops (3) -Conserve soil moisture (3) -Reduce chemical application (2) -Reduce amount of weeds (1) -Diversify operation (1)	-Use less labour/equipment (8) -Enhance quality of soil/ability of soil to grow a good crop (8) -Use a heavy harrows and other equipment to incorporate straw into soil (5) -Save fuel (5) -Enhance drainage (4) -Reduce the amount of weeds (3) -Grow crops that thrive with variable moisture, or cold weather (3) -Stretch out harvest period (2) -Reduce chemical application (2) -Conserve soil moisture (1) -Diversify operation (1)
Legal /administrative and politic procedures	- EID incentives to conserve water (2) -Obtaining water rights (1) -Ducks Unlimited incentives for growing winter wheat (1)	-Guidelines for burning crop residues (4)
Social and economic knowledge	-Maintain economically viability (5) -Maximize net return per acre (4) -Cost of purchasing/operating equipment delays/prohibits adoption (3) -Maintain good relationships with neighbours by preventing soil erosion (1)	-Maximize net return per acre (7) -Maintain economically viability (5) -Cost of purchasing/operating equipment delays/prohibits adoption (3) -Grow a crop that is easier to market (1)
Potential risks and impacts	-Tillage compromises healthy soil and land, and/or causes erosion (6) -Wasting water and energy is an environmental concern (2) -Over irrigation causes salt/alkali build up (2) -Drought and flood impacts are intensified without wetlands (1)	-Not incorporating crop residues compromises healthy soil, land, seedbed, and/or causes erosion (4) -Burning crop residues compromises healthy soil and land, and/or causes erosion (2) - Heavy harrowing can cause

	soil compaction (1) -Sunflowers extract more nutrients from soil than cereals (1)

***** Number in brackets indicates number of producers who cited the specific instrumental leaning outcome

5.4.1 Instrumental Learning Outcomes in Alberta

Instrumental learning outcomes among Alberta producers mainly dealt with learning new skills and technical knowledge. The discussion below focuses on the instrumental learning that set the producer on the path to adopting a new soil or water conservation practice. The quotes given below are selected to highlight the common themes expressed by Alberta producers.

The instrumental learning that occurred largely dealt with specific benefits associated with the practice they chose to discuss in detail. When discussing the adoption of water-efficient irrigation technology (i.e. low pressure sprinklers with drop tubes), producers mentioned that they had learned the importance of water conservation and the resulting lower irrigation costs. Said one producer when asked about his learning with respect to new irrigation equipment:

> We generally learn about those types of things from industry, they have new systems that allows us to reduce the overall amount of energy required as well as making some better use of the water applications itself ... we are changing our systems to get the water applied closer to crop level and reducing the pressure requirements within the systems ... as we need to do work on the existing systems we tend to look at ways that will allow us to reduce both the energy and get better utilization out of the water. -AB08.

Many producers also noted that these irrigation systems could also increase the quality and quantity of their crops and require less labour then older wheel line or flood irrigation systems. Producers noted that these older irrigation systems posed the risk of over irrigation resulting in soil salinity. Some individuals also stated that they had learned of EID financial incentives to encourage the adoption of water-efficient irrigation equipment.

In addition to irrigation technology, the other common practice that producers in the Alberta study area discussed in detail was the adoption of zero tillage. Producers noted learning that excess tillage can reduce the productivity of their land and health of the soil. They also were cognizant of the risk of erosion and soil compaction that exists with conventional tillage. The most commonly observed instrumental learning outcome justifying the adoption of zero tillage, was the decrease in fuel consumption and labour. This likely had a major role in convincing producers to adopting zero-tillage. Farmers also noted zero till requires smaller less costly equipment that is used less and therefore it requires fewer repairs. One producer noted:

> I would watch my neighbour who was a no-till farmer pull by my place at about 5 o'clock in the afternoon. He was headed with his sailboat to the lake and I was working on machinery in my yard, and about 10 o'clock that night, I was still out there and he was coming back from the lake after sailing, and I remember thinking to myself: One of us must be doing something wrong, and I wasn't sure it was him, and if it could work for him, why couldn't it work for me, so once we got the questions answered, we thought it could, and made the change. -AB06

For some producers learning of some benefits occurred only after the conservation practices in question was adopted. These producers often learned of environmental benefits of the practice causing the adoption initially, but only through their first hand experience did they come to learn of secondary benefits. This was particularly common in the move from conventional tillage to zero tillage. One farmer discussed that learning about the reduced wind erosion and increased soil moisture were the initial driving factors behind his move to no till, but states:

> We were quick to discover some fairly significant secondary benefits … that we did not really appreciate the impact that they would have, and that is reduced equipment usage and reduced fuel consumption. -AB08

5.4.2 Instrumental Learning Outcomes in Manitoba

Like the Alberta study area, instrumental learning outcomes among Manitoba producers involved learning new skills and technological information. The instrumental learning that occurred was associated with specific benefits associated with the practice they chose to discuss in detail. Excess moisture and to a lesser extent wind erosion were cited as the major concerns for farmers in the White Horse Plains Region. As a result, the practices that producers discussed in detail were much narrower in scope, but still provided many diverse instrumental learning outcomes.

Several producers instrumentally learned to cope with excess moisture and erosion by adopting of heavy harrows and other equipment to deal with crop residues. Learning of specific benefits, risks, and regulations included: the ability of this type of machinery to incorporate crop residues in the soil, enhancing the quality of the soil and seedbed, growing productive crops, saving fuel, requiring less labour, using less expensive equipment, learning about burning regulations, and reducing erosion and soil compaction. When asked why one producer started using a heavy harrow, he noted:

> I could work the straw into the field better and reduce the number of cultivations, because it is cheaper to run the heavy harrows than it is to run the deep-tiller across the field. And by heavy harrowing you could probably reduce your number of deep-tillage passes by, probably two. And probably use about a quarter of the fuel. -MB11

Another producer who started using a heavy harrow stated that:

> We have to manage our straw somehow, and we have to break it up and get our soil black so that when springtime comes around ... and the ground stays cold, you got to have black ground to warm it up... otherwise things don’t germinate. -MB07

Several Manitoba producers also discussed the importance of the adoption of new crop varieties and new types of crops. Instrumental learning outcomes associated with this practice included: reducing the amount of chemicals used, maintaining productivity under variable moisture and cold weather conditions, conserving soil moisture, stretching out the harvest period, and diversify the farming operation. A producer who switched from growing Spring Wheat to Winter Wheat stated:

> Because you are seeding into standing stubble in the fall, you are saving fuel because you are not working the land that your seeding ... it allows the stubble to stand and stay in the soil, so there are some soil conservation practices there that are of benefit. If you are worried about your land blowing in the winter and fall... it conserves moisture for the following spring, if you are concerned about dry weather ... it reduces the time you spend seeding in the spring, and because of the earlier harvest period, your harvesting a crop when you have more time ... it is a very competitive crop so you tend to use relatively little weed control chemicals. -MB04

The third practice that was common among producers in the Manitoba study area was the adoption of drainage equipment. Instrumental learning associated with the practice included: enhancing the ability of the soil to grow a productive crop, reducing the amount of labour required, enhancing drainage of the field, and learning that the expense of the equipment can be prohibitive. A producer who had recently purchased a laser commented on its importance:

> [Laser-ditching] pays for itself in terms of cost and the amount of work you save ... in our flat area here if you don't have ditch drainage, your land will deteriorate, so it basically improves the land. -MB06

5.4.3 Instrumental Learning Conclusion: Frames of Reference

While all the practices discussed were related to soil and water conservation, the environmental benefits were usually not the only factor driving the change. Some producers stated that the economic benefits were the main reasons for the change in practices, while the environmental benefits were secondary. When asked what the motivating factors behind a producers move to zero-till were, the producer responded:

> One of the biggest motivators was economics ... if I can figure out how to manage my input costs my bottom line is going to be better. Second, you add dust storms every spring ... and you realize it's good to be a no-till farmer... So part environment, mostly economics to be honest. -AB06

Some producers stated that the environmental benefits of a practices were equally important or more important than the economic benefits. These farmers often did not distinguish between environmental and economic benefits, but saw them as being complementary. Said a farmer when asked why he had moved to zero-tillage:

> [It was a] response to the realization that what we were doing wasn't right and did not seem sustainable … and beyond that we were becoming increasingly aware that our bottom lines were being negatively affected on a continual basis, and the only area of control that we had was on our cost side, our input side ... but this was a secondary factor to erosion and moisture retention. -AB08

The perception of seeing environmental and economic benefits as complementary came up again when another farmer was ask why it was important for him as a producer to use heavy harrows. He responded that the use heavy harrows allows for less time and money to be spent on field drainage and fertilizer application, and then going on to say:

> [Heavy harrows allow him] to improve the soil's organic matter and to reduce my costs ... organic matter makes more nutrients available for the next year's crop, and [provides] better internal drainage in the soil, you get more straw and organic matter the water can infiltrate the ground. -MB11

While all producers learned instrumentally to some degree (e.g. experimenting with or reading about new techniques, talking to neighbours), there was a distinction in how farmers framed the problem and their consequent meaning scheme that provided justification and understanding for the instrumental learning that was occurring. Farmers usually had one of two perspectives that shaped their interpretation towards instrumentally learned farming technique. These perspectives were: 1) maintaining economic viability, and 2) maximizing economic return per acre. Farmers themselves often explicitly stated this difference in their points of view. For example, MB09 stated that dealing with excess s moisture is important for "profit" and "maximizing yields", in contrast MB06 stated the importance of "maintaining the health of the land" and the "ability of the land to produce a crop."

For some farmers, such as MB09, economics was the driving motivation for adopting new practices with soil and water conservation benefits. For other farmers, such as MB06, economics was still important, but was not the sole factor in determining farming practices. In other words, the net return per acre was not the only the driving factor for the adoption of soil and water conservation practices. Producers who showed evidence of instrumentally learning under a frame of reference aimed at maximizing their net return per acre were often not as concerned with conservation and environmental issues. When one producer was asked why monitoring soil moisture content was important there was no mention of the importance of water conservation or broader environmental problems. Instead he responded:

> When I start up the pivot it costs quite a bit of money, and when I don't have to do it, I don't want to do it, and I don't want to get water on wrong moments, I want to get it when it needs it to get the highest possible yield. -AB11

Generally, the producers whose learning of new soil and water conservation practices occurred within a frame of reference where maximizing their net return per acre was the primary goal were not as cognizant of the correlation between environmental benefits and economic benefits. This may be due to the fact that many of the environmental benefits may be observable over the long term only (e.g. benefits of organic matter and soil microbes), while economic benefits are more immediately.

On the other hand, producers who reported that they were looking to maintain economic viability rather than maximize profit often stated the importance of the economic benefits of the practice in question, but also the environmental benefits, showing that instrumental learning is occurring within a sustainability-centred frame of reference. These producers generally expressed a higher degree of concern for the environmental implications of their actions. For the most part, producers that reported their desire to maintain economic viability looked at economic benefits as being dependent on environmental health and sustainability. A producer who was commenting on his constructed wetland conservation area stated that:

> It's hard to separate what piece does what for what reason. We are looking to do a complete job, and its one of the responsibilities of a land owner to provide conservation for nature's sake and for climate's sake, but it does us financial benefit as well. -AB05

All of the producers learned instrumentally to solve problems and become better farmers. However, the way in which producer's framed the problem (i.e. frame of reference stemming from habits of mind and point of view) varied between farmers who were seeking to maximize profits compared to those who were seeking to maintain profits. Framing the problem in such a way that gave less focus to financial issues generally resulted in secondary instrumental learning outcomes that took into account the importance of suitable practices and the correlation between economic and environmental benefits. Emphasis solely on economic return tended to be a barrier to instrumental learning of environmental benefits.

5.5 Communicative Learning

Communicative learning involves trying to understand what someone means, and unlike instrumental learning it is usually not open to empirical tests (Mezirow, 1994). While a farmer can experiment with zero tillage to see if it really does increase soil moisture (i.e. instrumental learning), understanding purpose, values, beliefs, and feelings associated with communicative learning cannot usually be validated through empirical testing. Although learning that occurs through communication between individuals can occur at the instrumental level, communicative learning usually involves two or more individuals trying to understand the justification for beliefs that stem from underlying assumptions (Mezirow, 1997). For example, communicative learning is not about how zero tillage works but assessing the underlying reasons and values for practicing zero tillage.

In order for the learner to validate what is communicated discourse is needed. Discourse involves "dialogue in which we focus on content and try to justify beliefs by giving and defending reasons and examining the evidence for and against other viewpoints" (Mezirow, 1994: 225). The process of discourse where one's judgements are questioned through the assessment of reasons, arguments, or viewpoints required the individual to engage in critical reflection. This type of communicative learning and discourse may eventually set the learner on the pathway to the transformation of normative ideologies (Kerton and Sinclair, 2009).

This section separates the communicative learning that occur among farmers in Alberta and Manitoba. For each of the two provinces, the analysis begins with a description and examples of the sources of information that lead to communicative leaning. The remaining three sections detail evidence that may indicate critical reflection stemming from communicative learning. Communicative learning where farmers engage in dialogue that is critical of beliefs and underlying assumptions is very important, as it is this critical reflection often sets the learner on the pathway to premise-based reflection. Three categories, which may indicate critical reflection, were observed in the research. These include: reflection on interrelationships between practices and the environment, reflection related to the roles and responsibilities, and reflection regarding social norms or normative ideologies. Most of the quotes given below are selected to highlight the general sentiment expressed by producers. Some of the quotes are used to highlight unique or interesting learning outcomes.

5.5.1 Communicative Learning in Manitoba

5.5.1.1 Sources of Information Leading to Communicative Learning

Communicative learning was mainly limited to producer-producer contact, where they set out to understand each other's reasoning and alternative points of view with respect to soil and water conservation practices. This usually involved seeking to understand values and reasons for changing practices. One farmer, who moved to using a heavy harrows to manage crop residues, noted that communication between farmers in conjunction with personal observation is important for learning new information and practices:

> We all watch each other and share what we do, people keep track of what you do and observe what is working, and if your crop comes up terrible the next spring people notice it... We are all running demonstrations to a certain extent, and we are all looking for better ways to do things... If somebody has something new everybody is watching, and we talk about it too, meeting on the road, or the coffee shop or whatever. -MB01

For the most part communicative learning was limited to dialogue between farmers, however, there was small amount of communicative learning that occurred through institutions. In one instance, MB13 mentioned the role that the local farm equipment dealer played in facilitating his decision to purchase heavy harrows to manage crop residues:

> Our local farm equipment dealer would take us to see people who were using various systems. You could talk to them about how they liked it and how it worked for them. -MB13

He went on to state:

> By talking to people who were implementing [heavy harrows] already, you could pick their brains and ask questions, and they were very good about telling us about what was good and what wasn't good, and with that information we went back and made a choice. -MB13

In this case, MB13 seems to show evidence that he had spent time deliberating over the decision to purchase the equipment, which may indicate that critical reflection has occurred. The deliberation process involved both dialogue with other farmers who were already employing the equipment as well as first hand observation of these farmers' crops. While the equipment dealer played an important role in facilitating this discourse and possible critical reflection, the dealership was not in itself directly involved in the dialogue process. As MB13 indicates, the dialogue regarding the implementation of heavy harrows ultimately came from farmer to farmer communication.

5.5.1.2 Reflecting on Interrelationship between Practices and the Environment

In some cases, farmers seemed to indicate that critical reflection may had occurred with respect to the effects that their farming practices had on environmental health and sustainability. This occurred as part of a discourse process that included dialogue with other farmers, as well as instrumental and experiential learning. One farmer, that had purchased a heavy harrow, was asked if there was a single event that precipitated the adoption of this practices, the producer responded "Yep, June 9th 1985. There was a big windstorm and we had to reseed a bunch of crops"-MB01.

The ability of MB01 to name the exact date, of a storm that occurred over two decades ago shows that this event likely had a significant and lasting impact on his frame of reference. It is possible that this single event resulted in critical reflection with respect to his perception of the relationship between tillage practices, soil erosion, and the long-term environmental state of his farm. This single event likely led to his eventual adoption of heavy harrows. The producer went onto express his belief of the importance of residue management and the strong feelings that lead to his change in practice:

> You just absolutely despise to see your soil blowing, it hurts your stomach if you really care for your land, and I just never want that to happen again, and you do everything in your power to stop that from happening again. -MB01

Another farmer also may have engaged in critical reflection with respect to the adoption of heavy harrows. After talking with his neighbour about the benefits of using a heavy harrow to manage straw, MB02 decided to buy the piece of equipment together with his neighbour to offset the high cost. He noted that:

> You watch what’s happening. In general farmers want to get ahead; they want to do the best job they can. So if you see your neighbour doing something that seems to be working, you’re going to try it, you’re going to go talk to him ... -MB02

Upon assessing the reason for buying this equipment, the producer seems to indicate engaging in critical reflection with respect to the importance of soil conservation, his connection to the land, and the effect his practices have on future generations.

> We view the soil as the future. If you think of a person working in Winnipeg, he’s got a job, yeah he’s tied to the job, he’s probably has a pension. But when you’re a farmer, it’s the same land my grandfather farmed, my dad farmed, I’m farming it, now my son is helping me ... so it goes on for generations. You seemed to be tied to it in some ways, so it is probably a little different than a job. Your soil is your future, so you want to take care of it… you want to invest in it. -MB02

5.5.1.3 Reflecting on Roles and Responsibilities

It was common for producers, who seemed to show evidence of critical reflection with respect to the importance of soil and water conservation practices, to indicate that they had also reflected on their roles and responsibilities as a farmer. In learning to understand the purpose and reasons for using a heavy harrow one producer noted “economics dictates, you have to follow the trends and become more efficient and that was just the way it has to go to stay in the farming business”-MB13. However, MB13 goes onto show reflect on his role as a farmer and importance of suitable practices for future generations, stating:

> These extreme winds that we are getting, we see top soil blow that takes a million years to create and in the matter of a couple days or hours we lose the most precious recourse we’ve got, and that scares the shit out of myself and most of the younger farmers out here, that is our resource, that is what we’ll pass onto future generations. -MB13

Another farmer who moved to using a heavy harrow to manage crop residues noted that communication between himself and neighbouring farmers was important for learning of this detail regarding this new practice. He then reflected on is reasoning and beliefs for adopting this practice stating:

> Because we own our land we are looking at the long-term benefits. And just generally we always want to treat our land was well as we can because we are all just temporary caretakers. -MB01

MB01 went on to show evidence of weighing the pros and cons of adopting heavy harrows to manage crop residues and soil health.

> Our residue management is long-term gain and short-term pain. So you have minimize your short-term pain and be around to enjoy the long-term gain...you want to leave the land as good or better than when you got it, and you do whatever you can to accomplish that, and not starve in the meantime. -MB01

This indicates critical reflection may have occurred during MB01’s considered between the increased financial costs in the short-term versus the long-term economic and environmental benefits that can be obtained with proper residue management. MB01 also reflects regarding his responsibility as a farmer by equating his role as being not only a producer of crops, but also a temporary caretaker of the land.

5.5.1.4 Reflecting on Social Norms

Communication that occurred between some farmers regarding conventional farming practices resulted in critical reflection in which normative values and beliefs were brought into question. This critical reflection led to questioning ingrained thoughts and assumption associated with conventional farming practices. MB13 discussed how his feelings regarding high input agricultural practices and long-term environmental sustainability have been altered, leading to the purchase of a heavy harrow:

> It is important to preserve organic matter and keep the nutrients on the land, and we don't want to contribute to greenhouse gases more than we have to... My father's generation never really thought about it, but my generation is a little better educated I guess, and little more understanding of the data that is coming out. And we realize that this isn't some made up thing, it is real and we don't want to be contributing to it... we have some effect on it and we try to be good stewards of the land. -MB13

5.5.2 Communicative Learning in Alberta

5.5.2.1 Sources of Information Leading to Communicative Learning

Like the Manitoba study area, farmers in the Alberta study area indicated that other farmers were the most important sources of information when it comes to dialogue associated with communicative learning. One farmer discussed his experience of moving from conventional tillage to zero tillage and mentioned the importance of communication with other farmers. He noted that this source of information was valuable in understanding, and eventually adopting this practice.

> Most of my knowledge would come from a couple of neighbours, and once we decided to do it then we would take zero till conferences ... but most of it came from a neighbour that said: Hey, you got to do this. This is the only way to go. And eventually he showed me the benefits. -AB03

While AB03 mentioned that he did receive information regarding zero tillage from zero-till conferences (specifically he was referring to RTL conferences), this information came after his decision to change his tillage practices. It was through dialogue with neighbours that resulted in his change in beliefs towards conventional tillage. The tillage conferences on the other hand, acted as a learning platform to convey specific techniques and information for zero tillage farmers. This additional information likely acted to validate his understanding of zero tillage, reinforcing his decision to adopt the practice. AB03 went on to describe his role in now promoting this zero tillage among other local farmers, stating: “We have neighbours that wonder if [zero till] works and I promote it to the end” – AB03.

While the majority of dialogue that results in communicative learning occurs between farmers, this may be a result of recent changes to provincial agricultural extension services in Alberta. One farmer stated the importance of provincially employed District Agriculturalists that no longer exist:

> The district agriculturalist was kind of a consultant who knew a little bit about everything but kind of had specialties in different areas. They were just a close resource that we could drop in and have a chat with at any point in time. -AB08

He points out that the loss of this source of information has forced producers to look elsewhere for information about new practices:

> They sort of disbanded that whole program and so we have been forced to look in other places and that’s were technology really stepped into the gap now that we all have access to high speed internet ... so that has really opened the door to a lot of the information, although it does take a lot of personal effort to do that, when before it was [the District Agriculturalist’s] job to lay it out in front of you and kind of made it a bit easier ... so we still have access to the same type of information, but it takes some personal initiative to access it. -AB08

The abolishment of Alberta’s District Agriculturalists indicates a loss in potential dialogue between farmers and trained agricultural experts familiar with the local area and conditions. The source of dialogue may have been important for producer’s critical reflection process and communicative learning. A shift in information acquisition from the District Agriculturalist to the internet makes dialogue and communicative learning more difficult. While it is still possible to learn from information obtained on the internet, the loss of discourse poses a barrier to communicative learning, making critical reflection regarding traditional practices and habitual ways thinking difficult. Given the loss of District Agriculturalists, some dialogue may be lost, but widespread horizontal linkages indicate communication with neighbours and other farmers may have filled this void.

5.5.2.2 Reflecting on Interrelationship between Practices and the Environment

Like producers in the Manitoba study area, producers in the Alberta study area seemed to show critical reflection regarding their relationship between their farming practices and the long-term health of their land and the sustainability of their farm. An Alberta producer commented on his long-term environmental effects of practicing zero tillage:

> Tilling is hard on our resources. It's hard on our soil. I want my farm to be here a hundred years from now, and if anything, I want it to be healthier. When I'm done with it I can say it's in better shape than even when I started, that's kind of my goal, whether my family continues on or whether the next person continues on. -AB03

Another farmer who practiced zero tillage also seemed to show evidence of critical reflection regarding the long-term health of his farm. He stated: "I want to leave a healthy heritage for my kid or kids if they decide to farm, or whoever takes over the land, we want to leave things in good shape environmentally" – AB06

As evident in both AB03 and AB06, reflection occurred regarding the impact that their decisions as producers have on future generations. AB06 went further in describing how his personal experience, along with information obtained from neighbours, has altered his perspective on zero tillage, provoking him to share this experience with others. He stated that he has shared his positive experience of zero tillage with:

> Everyone who will listen and watch, you bet. A certain percent of the population learns by hearing, the majority learn by looking over the fence and seeing what the neighbours are doing…I enjoy trying to mentor some of the next generation or encourage them. -AB06

Another farmer, who moved to zero tillage, not only seemed to indicate possible critical reflection regarding his relationship to the land, but also reflected on the high input, technology driven approach to agriculture.

> The business aspect of [zero tillage] is essential but beyond that I guess it is the feeling that you want to leave the land in better shape than it came to you ... You do the job for the joy of doing it rather than the monetary return ... we don't know

> a lot about how mother nature works, and sometimes letting some of the natural process occur is a better way to go. -AB08

5.5.2.3 Reflecting on Roles and Responsibilities

Critical reflection regarding responsibilities to future generations was evident in a number of farmers mentioned above who showed concern regarding the environmental implications of their practices and the importance of the long-term sustainability. Other farmers also showed evidence of critical reflection on roles and obligations. Commenting on importance of wetland conservation, AB05 stated: “We are just holders of the land, and need to improve things as we go.” He added, “We owe it the environment, and wildlife, and other users of the land to do a good job of managing it.”-AB05.

Another farmer reflected on his responsibly to prevent wasteful practices and how this relates to economic benefits: “We want to conserve water and energy to do things cheaper, the environment is also a concern, you don’t want to over irrigate.” He went onto add “waste is no good ... we have to be stewards of the land.” -AB02

Many of farmers implied that they have an obligation to take care of the land and soil for future generations. Other farmers mentioned how their role as a farmer was shaped by feelings and values that drove a change in practice. Critical reflection regarding values and feelings seemed to be evident as AB08 assessed his reasoning for practicing zero-tillage:

> It is very rewarding to adopt a practice that has all the good things going for it ... That is the one thing that you remember all the time is that it sort of feels good to do something that you have a better feeling for its sustainability than the practices that you had before. -AB08

The positive feelings that AB08 associated with zero tillage align with his sense of responsibility to employ sustainable practices. Now convinced of the benefits that zero tillage provides, AB08 mentioned his involvement in promoting the practice with other local farmers, stating that he “did a sort presentation as a local zero-till information meeting...other than that it’s just bugging the neighbours who are still doing full tillage.”-AB08

One farmer, who moved from a high-input cattle operation to a less intensive gazing system after engaging in dialogue with the Grazing Mentorship Program, seemed to show indications of undergoing critical reflection regarding his responsibility to preserve wildlife and practice sustainable grazing practices. When asked why it is important to him to practices this low input grazing system he responded he has an "interest in having the farm more in grass, more in permanent cover, more sustainable…" he added, "and I like the way the farm looks, you got more wildlife habitat, everything just seems nicer."-AB09

One farmer discussed his experience of moving from conventional tillage to zero tillage in instrumental terms, but then expressed the importance of family, questioning not only his role as a farmer but also as a family member. When asked what motivated his adoption of zero tillage he responded:

> It required less labour, less fuel, less machinery, less fertilizer, there were lots of different benefits... My family was a motivation too. I could spend more time with my family that was also important to me, rather than sitting in a tractor all fall tilling and working it up, now when I pull the combine out I'm done. -AB03

5.5.2.4 Reflecting on Social Norms

Critical reflection with respect to social norms based on entrenched habitual ways of thinking can result in decisions that challenge the conventional wisdom and traditional farming practices. AB06 recalls how his decision to move to zero tillage was a not in line with typical practices, and how this has led to a fundamental change in the way other local farmers view zero tillage.

> Probably between me and [two neighbours] we were the first ones to change in our community, and guys told us for a lot of years that it couldn't be done, but more and more are doing it all the time now. -AB06

Another farmer who had recently immigrated to Alberta from Zambia bought new knowledge regarding tillage practices for irrigated crops to the local community. This knowledge challenged the conventional wisdom that zero tillage was not a viable option for irrigated crops. AB07 recalled that "nobody no-tilled here at all, and I had actually done some when I was working for a couple of guys in Zambia." Upon moving to Canada he noted, "it looked like the ideal thing to go into right way, but I found a really hard time finding any information at all on it." -AB07

AB07 went on to describe how another farmer had started practicing zero tillage around the same time as him. They meet through Alberta Agriculture, which recruited other producers in the area who were interested in zero tillage, and arranged for a meeting to take place. This meeting provided the opportunity for discourse as it allowed producers to "exchange ideas and talk about [their] experiences and it grew from there." –AB07

The dialogue that took place between these producers involved discussion "on the equipment itself, and then it gradually became how you plough the fertilizer in at the same time ... what is best for spraying, and harvesting ... lots of equipment stuff to talk about"- AB07. Using this information ultimately resulted in the farmers to engage in autonomous decision-making and depart from the status quo. While nearly all the farmer-to-farmer communication in the study occurred informally, in this case the dialogue that led to communicative learning was facilitated was by the Provincial Government, as they provided a platform the communication to occur. This communicative learning, along with first hand observation, has since lead to a fundamental shift in local sentiment towards sustainable tillage methods.

> Initially people were really sceptical saying that it wouldn't work on irrigation, but then when they saw that it did work, and worked pretty well, then everyone started asking me. Then the county actually got a drill that they would rent out and it became so much in demand that they couldn't really keep up, and so I was doing a lot of custom seeding for people. -AB07

This case shows how the communication and dialogue that occurred between AB07 and other producers interested in zero tillage, resulted in the questioning of traditional farming methods and normative ideologies. This change resulted in learning not only at the individual level, but may have also brought about learning at the community level as evident by the County of Newell's involvement. Among most farmers in the area the notion of conservation tillage seemed to be altered from a practice done for environmental benefits at the expense of productivity, to a practice that could sustain a productive crop and provide significant economic and environmental benefits.

Another producer in the local area gave an account of his own critical reflection stemming from the farmer-to-farmer communication that drove his decision to move to zero tillage.

> The question was always in my mind as I was going around doing that recreational tillage is: why are we doing this? Do we have to? And the prevailing wisdom had always been … if you are in irrigation you've got to plough and deep-till, and rip, and do all this stuff. We just happened to have district agriculturalist at the time, who put on an information day, and found that [zero till] could be done in irrigation… -AB08

AB08 goes on to describe his subsequent deliberations, showing evidence that his decision to move to this unconventional practice may be a result of critical reflection stemming from dialogue and experiential learning. He also explains how an outsiders' point of view was helpful in bring about this change to the local community.

> I had a neighbour that moved into the area from Zambia ... and he kind of came over with a clean slate... no preconceived notion, no dad looking over his should saying no-no you got to do it this way ... he and another fellow were the very first one in the area to adopt zero-tillage of anyone...and they bought a zero till seeder that I was able to rent from them for a couple of years to give this a try ...that kind of brought it right to home. -AB08

5.5.3 Communicative Learning Conclusion: Indications of Critical Reflection

Communication in both the Alberta and Manitoba study areas was largely limited to farmer-to-farmer dialogue. While it may be presumptuous in some cases to state definitively that critical reflection is occurring without more in-depth data, many participants showed evidence of questioning underlying assumptions that govern farming practices. These types of thought processes, where individuals are challenging the assumptions on which habits of mind or points of view are based, is indicative of critical reflection (Mezirow, 1997). In the Manitoba study area most of the communicative learning that took place occurred in farmers that had adopted the use of heavy harrows. Other learning outcomes (i.e. enhanced drainage and new types of crops) that were discussed in detail with Manitoba farmers were more instrumental in nature. That is, learning involving enhanced drainage techniques and new types of crops are essentially ways of enhancing farm productivity within an individuals existing point of view. The adoption of heavy harrows on the other hand involves a more fundamental change. This change seemed to cause farmers to be critically reflective of purpose, values, reasons, and feelings associated with the practice. Similarly, in the Alberta study area, questioning of underlying assumptions was especially evident in farmer who had move from convention tillage to zero tillage. Critical reflection was also seemed apparent for other Alberta producers who moved to a holistic grazing system, constructed a large wetland conservation area, moved to reduced tillage, and grew new types of crops. In general however, these practices did not result in critical reflective outcomes as commonly as did changes in tillage practices.

In both provinces, producers showed evidence of reflecting on interrelationships between practices and environmental outcomes, the roles and responsibilities of a farmer, and social norms. Fundamental changes in practices involved farmers to engage in discourse in order to validate the justification for adopting a new farming technique. The discourse involved the individual to be critically reflective of dialogue with other farmers. In addition to discourse, first hand observation and experience as well as the producer undertaking further research regarding a new farming practice contributed to the critical reflection process. In the Alberta study area, an individual from outside the local community initiated the adoption of zero tillage. This idea led to discourse, communicative learning, and change in the local community. This finding, that individuals considered to be outsiders of the social system as those that initiate new innovations, is consistent with other research (Granovetter, 1983; Gerber and Hoffmann, 1998; Folke, 2003).

Consistent with research done by Sims and Sinclair (2008), the learning in this study combined both instrumental and communicative aspects. The learning pattern that was commonly observed involved communicative dialogue in the initial stages as farmers validated and understood the evidence that a new farming practice is more effective.

However, reflection was not limited to dialogue, as first hand observation and experiential learning (i.e. instrumental learning) played an important role in farmer's validation of truth claims. In essence, many producers empirically tested knowledge conveyed during communicative learning with other producers. These empirical tests, based on first-hand experience and observation, are ways of instrumentally learning and critically reflecting. Dialogue still played an important role in the reflection process, but most critical reflection involved examining evidence and justifying of beliefs at the individual level. This combination of instrumental, experimental, and dialogical reflection is part of individual discourse, which is inherent to communicative learning. The next section will explore how some of the learning discussed above was part of, or showed aspects of a transformative learning process.

5.6 Transformative Learning

Transformative learning involves contextual learning, critical reflection of underlying assumptions, and validating meaning by assessing reasoning (Mezirow, 1995). Through critical reflection and transformation of habits of mind or points of view, an individual's frame of reference can be transformed (Mezirow, 1997). Mezirow (1994) identifies habits of mind stemming from three sets of psychocultural codes that shape "sensation and delimiting perception, feelings, and cognition" (p. 223). These codes are sociolinguistic codes, which include social norms, ideologies, and theories; psychological codes, which include personality traits and ways of feeling and acting; and epistemic codes which include focusing on the concrete over the abstract and leaning styles.

The focus of transformative learning is on the premise of the problem rather than the content or the process (Mezirow, 1994). Reflection on the premise of the problem may lead the individual to ask question such as: Why have we not looked at more sustainable farming methods in the first place? What is the fundamental purpose or reason for farming? What are the broader consequences of my actions for future generations? What is my role as a farmer and a steward of the land? This type of premise-based reflection can transform the individual habitats of mind through critical reflection of one's generalized biases (Mezirow; 1994, 1997). Transforming habitats of mind is more significant and more difficult to achieve than elaborating, establishing, or transforming points of view (Mezirow, 1997).

While transformative learning can result when soil or water conservation practices are adopted, not all changes in farming practices are a result of transformative learning. Some producers described the reason for their change in practices to be a result of an altered point of view (i.e. resulting from content or process based reflection). While this type of change may still be important in achieving sustainable outcomes, viewpoints are continually changing and are not based on ingrained ways thinking, feeling, and acting (Mezirow, 1997). For the change to be considered transformative learning the learner must show evidence that habits of the mind and ingrained behaviours have been transformed. Evidence of altered habits of mind will be discussed with reference to the above mentioned psychocultural codes. The categories mentioned below do no necessarily confirm the presence of transformative learning. They are instead designed to provide an indication as to where premise-based reflection or transformative learning could possibly: occur, be in the process of occurring, or has occurred in the past.

5.6.1 Indicators of Transformative Learning

5.6.1.1 Questioning Roles and Social Norms

One way in which an individual's habits of mind can be altered, and hence transformative learning occurs, is through critical reflection of sociolinguistic codes. One's reflection of the impacts of agriculture and their roles as a farmer shows a transformation in habits of mind. This research shows that this type of transformation usually resulted in a shift to more sustainable practices that take into consideration soil and water conservation. The process of critical reflection leading to this transformation occurred as a result of discourse during the communicative learning process and is discussed is that section. The process of questioning roles and social norms was often expressed as cognizance and concern for the environment, soil, and future generations and one's roles as temporary caretakers of the land. This outcome indicating transformative learning was relatively common. In total, three producers in the Manitoba study area (MB01, MB02, MB13) and six producers in the Alberta study area (AB02, AB03, AB05, AB06, AB08, AB013) noted that the importance of their role in fostering sustainability through their agricultural practices. The apparent transformation in their habits of mind seemed to be a driving factor in their change in practices.

Other producers seemed to be critically reflective of social norms and conventional farming techniques resulting in the adoption of new practices. Again, this reflection often occurred as a result of discourse during the communicative learning process. These potential transformations were often expressed as departing from traditional practices as a result of knowledge gained through instrumental or communicative learning. For example in Alberta, widespread learning from an immigrant from Zambian who brought a unique frame of reference resulted in change at the community level. In total one producer in the Manitoba study area (MB13) and five producers in Alberta (AB06, AB07, AB08, AB09, AB14) seemed to indicate a transformation in their habits of mind by questioning normative practices.

Tradition farming practices are social norms that stem for sociolinguistic codes that determine perceptions, feeling, and cognition (Mezirow, 1994). According to Sims and Sinclair (2008) transformative learning occurs when individuals critically reflect on the underlying assumptions of their habits of mind and points of view and develop a more functional frame of reference through enhanced instrumental and communicative competence. Often farmers identified the transformation of normative ideologies as moving from the traditional way of doing things to new a practice that was different, innovative, and more practical under present day conditions. These transformations, which act to challenge social norms, may have lasting changes on the way individuals think about sustainability for their farm.

5.6.1.2 Enhanced Instrumental Competence

By moving away from the traditional ways of doing things (ingrained in sociolinguistic codes or more specifically social norms) and questioning their role as a farmer, some producers seemed to exhibit critical reflection. This reflection often caused farmers to gauge the success of new practices by examining the evidence surrounding new practices, even if this was not consistent with traditional ways of doing things. Challenging traditional practices marks a transformation stemming from epistemic codes in which the individual shifts their focus from abstract normative ideologies to concrete, experience based ways of thinking (Mezirow, 1994). In this way, producers enhance their instrumental competence through which to gauge evidence for and against new practices (Sims and Sinclair, 2008). This new frame of reference often involved cognizance of the environmental sustainability of practices.

In some cases, enhanced instrumental competence lead the producer to look for information in a variety of different sources. For example, AB13 noted how he looked for information as to how he could prevent soil erosion from a federally run research centre, and discovered the benefits of planting Winter Wheat. MB01 noted actively seeking out information regarding heavy harrowing from demonstrations organized by the local Conservation District. In making the decisions to move to zero tillage, AB03 showed evidence of increasing his instrumental competence by seeking more information about the technical details of the practices by attending zero tillage conferences. He stated: “Once we said yep we’re going to do this, then we would take zero till conferences and stuff like that, and just constantly learn.” -AB03

AB03’s decisions to enhance his level of knowledge regarding zero tillage by enrolling in these conferences may have been a result of a transformation in his habits of mind during a critical reflection process. This producer’s ability and desire to seek out reliable and diverse sources of information could translate to future adoption of other sustainable practices. Similarly, AB08 also showed enhanced instrumental competence resulting from a possible transformative learning experience, as he noted acquiring research information regarding zero tillage from universities. This type of information acquisition was not widely observed, and involves a high degree of personal initiative and open-mindedness. Knowledge-seeking action of this type may be indicative of premise based reflection that can set the learner on the path of altering habitats of mind and developing a frame of reference that is more experience-based, factual, and autonomous.

5.6.1.3 The Learner is set on a Pathway for Further Premise-Based Reflection

Undergoing transformative learning may cause the individual to engage in future discourse as new evidence, argument, or points of view are encountered (Mezirow, 1994). According to Kerton and Sinclair (2009), communicative learning and discourse may then set the learner on the pathway to the transformation of normative ideologies. Persistent normative ideologies can prevent individuals from adjusting habits of mind that influence farming practices. Transformative learning has a more lasting impression on the learner than does other types of learning as it alters ingrained beliefs and behaviours thereby impacting future experiences (Kerton and Sinclair, 2009). AB03 shows that his decision to adopt zero tillage, has acted as a catalyst for future change as he is now considering other sustainable practices in his operation.

> We still do spray quite a bit of chemicals. We spray more than what we would like to. I don’t like to but it seems to be a necessity. I think we spray better chemicals, chemicals that aren’t so hard on the environment...We would love to get rid of [chemicals] if we could. -AB03

Questioning the use of agrochemicals may arise from a heightened awareness of environmental issues. This may stem from a transformation in his individual habit of mind. Participants would need to be studied over a longer time period however, to confirm if this is indeed a transformation that will lead to future sustainable changes.

5.6.1.4 Enhanced Communicative Competence and Social Change

Questioning normative ideologies can lead to transformation that results in not only enhanced instrumental competence but also enhance communicative competence (Sims and Sinclair, 2008). A transformation in habitats of mind can provoke consideration for future sustainable practices at the individual level as with AB03, but also may lead more effective means of communication. One effective vehicle for sharing information reported by AB08 was to do “a short presentation at a local zero-till information meeting... I had some documentation in terms of digital photographs of what we were doing"- AB08. In this way AB08 was able to share his experience with a large number of people and provide observational evidence regarding the benefits of the practices to other producers.

Another producer, who possibly underwent a transformative learning experience noted that rather than simply telling other farmers of the benefits of his wetland construction he shows them directly how the wetland drainage system functions through a tour, stating: "I share this experience up to point; I'm not out teaching course or anything. But if someone is interested we certainly would take them on a tour"-AB05. Similarly AB07 seemed to indicate enhanced communicative competence by helping to initiate zero tillage meetings and demonstrations in the local community. By these means, information sharing is likely more effective and may ultimately result in transformative learning among other producers.

Since all producers indicated that they shared information with their neighbours, this in itself is not indicative of transformative learning. However some producers that seemed to undergo a transformative experience were more effective in sharing information and experiences. This indicates that transformative learning may result in more constructive farmer-to farmer communication. Widespread communicative leaning of this type may eventually result in community level mobilization and social change.

5.6.1.5 Gaining Insight into One's Own Learning Style

While transformation of habits of mind stemming from sociolinguistic codes was the most commonly observed, AB06 showed evidence of critical reflection stemming from epistemic codes, specifically gaining insight into his learning style. When describing his move from conventional tillage to zero tillage, one producer reported:

> We went from maximum tillage to zero tillage in one swoop… I was first introduced to the idea of no till and where it could work by talking to a neighbour and watching him do it year after year on his farm, then when I got all the piece figured out and put together in my mind then I was able to take the step myself… That's the type of learner I am; it has to fit in my mind first and once that has happened then the physical stuff is easy. -AB06

He went on to mention:

> I'm the kind of guy who researches and I have to have all the questions answered and once the questions are answered then I make a decision and go with it, and I probably spent years getting answers to the questions and once the answers satisfied me then we did the step. -AB06

This indicates the premise-based reflection likely occurred, resulting in the individual to gain this type of insight. This type of epistemic reflection in which the learner gains insight into his learning style was not commonly observed. However, this type of reflection may be important for the individual in order for further learning and adoption of innovations and practices to occur.

5.6.2 Examining Transformative Learning as a Process

The section above outlines specific outcomes that may provide indications of transformative learning. While these may be important for indicating where the transformative learning process may be occurring, they alone cannot confirm the existence of transformative learning. This section will provide a more comprehensive examination of transformative learning as a process. The transformative process involves a combination of instrumental and communicative learning along with premise-based critical reflection. Looking at one individual producer (AB06) the process of learning that he underwent in making the decision to move from conventional tillage to zero tillage will be explored. Some of the quotes used in this section are repeated from the preceding sections in order to establish the chronological learning process the individual underwent.

AB06 felt like zero tillage was the most important water conservation practices that he has undertaken on his operation and chose to discuss the transition from conventional to zero tillage in more detail. He was first introduced to the idea of zero tillage approximately 12-15 years ago. He states that he made the decision to move "from maximum tillage to zero tillage in one swoop." When questioned about where he first learned of the practice he states:

> The question was where do we get information on no till and the answer was [Reduced Tillage Linkages], but where I was first introduced to the idea of no till and where it could work by talking to a neighbour and watching him do it year after year on his farm, then when I got all the piece figured out and put together in my mind then I was able to take the step myself.

This statement shows that discourse with another farmer was an important factor in changing AB06's point of view towards tillage. This change in viewpoint is likely a combination of both communicative and instrumental learning. While the producer organisation, RTL, played an important role in providing information about the specific techniques and practices associated with zero tillage, its was interaction with his neighbour that initially changed his mind to adopt this new practice. He went on to explain how learning of advancements in the equipment industry also played a role in driving this change:

> I think a portion of it too was that we kind of specialized in growing grass and alfalfa, and I didn't own big horse power equipment … back about the time when Flexi-Coil came out with a good disc drill that was the year we started no-till because all of a sudden I had something I could pull that would work in all our conditions … so the equipment being available and the understanding of the process … I had ordered a big disc ripper from John Deer and I ended up cancelling that order, trading in my whole line of machinery and buying no till equipment … and it was that quick we were into it completely.

After explaining some of the factors that were helpful in precipitating this change, AB06 goes onto offer insight into his learning style, stating: "That's the type of learner I am; it has to fit in my mind first and once that has happened then the physical stuff is easy"- AB06. The statements above show how deliberation, critical reflection, and evaluating the evidence were more important to the adoption of the practices than was the actual physical adoption. Although convinced of the benefits of zero tillage, AB06's demonstrates openness to alternatives, stating: "Your next step from full tillage would be some kind of reduced tillage as an intermediate step, and possibly we did a little of that, but basically the step was just right to no till."

He went on to provide further details as to how his change in tillage practices was an accumulation of deliberative consideration, until a threshold was reached in which the understanding translated into action.

> I'm the kind of guy who researches and I have to have all the questions answered and once the questions are answered then I make a decision and go with it, and I probably spent years getting answers to the questions and once the answers satisfied me then we did the step.

In describing why he decided to make the transition to zero tillage, AB06 states that the decision came from a combination of two major factors. Although he describes the adoption was a result of "a slow learning process", the first and most important factor in driving the change was economics. He states: "One of the biggest motivators was economics." He then explained that he had "little control over what things go off my farm for, the selling price ... but I do have full control over the input costs." He goes onto to state:

> If I can figure out how to manage my input costs my bottom line is going to be better. Second, you add dust storms every spring ... we started doing no till and we would get a hurricane of a wind …and you realize it's good to be a no-till farmer... You couldn't see anywhere and yet our fields weren't moving at all. So part environment, mostly economics to be honest.

This statement shows that while economics was the major driver in causing the adoption of this new farming practice, environmental issues were also considered. Unlike many other farmers who mentioned economics being the most important driving force behind the change, this point did not prevent secondary instrumental learning regarding environmental benefits in AB06. Given the importance role that soil plays in yielding a productive crop, it may be implied in the statement above about soil erosion that AB06 sees environmental and economic issues as being mutually dependent. This finding is consistent with other farmers who seemed to show aspects of transformative learning. Nevertheless, his explication mention of the role that environmental issues played in his decision to adopt zero till likely indicates reflection on the importance of environmentally sound practices. The acknowledgement of the importance of environmental issues (i.e.

erosion prevention) may be related to mindfulness of broader ecological issues and his responsibility or role as a farmer. Another important factor that seemed to drive this change seemed to be reduced labour and increased leisure time.

> I would watch my neighbour who was a no-till farmer pull by my place at about 5 o’clock in the afternoon. He was headed with his sailboat to the lake and I was working on machinery in my yard, and about 10 o’clock that night, I was still out there and he was coming back from the lake after sailing, and I remember thinking to myself: One of us must be doing something wrong, and I wasn’t sure it was him, and if it could work for him, why couldn’t it work for me, so once we got the questions answered, we thought it could, and made the change ... So it was a little bit of looking over the fence, and watching it happen and thinking if he can do it why can’t I.

In order to gain insight into AB06's reflection process, he was asked to describe how, in addition to the information obtained from other farmers and RTL, he came to believe that adopting zero tillage would be a desirable practice. He replied: “The good evidence point towards [zero tillage] and you weigh out all the facts and see what’s truth and kind of go with that.” He went on to state:

> Probably between me and [two neighbours] we were the first ones to change in our community, and guys told us for a lot of years that it couldn’t be done, but more and more are doing it all the time now, but the vanguard needs to be crazy for a while.

In this was AB06 implies that while much of his decision was based on careful deliberation and searching for evidence, there was still risk involved. AB06 seemingly sees himself as an innovator in this regarding becoming an early adaptor of this practice, despite some unknown consequences. This idea of risk taking is likely and inherent personality trait that stems from what Mezirow (1994) describes as p*sychological* codes. The progression of AB06 to adopt this adaptation may indicate a substantial transformation, if this venturesome behaviour is incongruent with the individual’s typical demeanour.

In order to gain insight into AB06's assessment of the action of moving to zero tillage, he was questioned why it is important to him that he engage in this practices on his farm, to which he replied: "I think it goes back to the same two reasons economic reasons and environment reasons." He went onto to state that he wants to:

> Leave a healthy heritage for my kid or kids if they decide to farm, or whoever takes over the land we want to leave things in good shape environmentally … and I've got to make enough money to get to the future without going broke.

This seems to provide evidence of critical reflection with respect to his role as a farmer and the importance of sustainable practices for future generations. This type of reflection and concern for the environment and future generations may be indicative of premise-based reflection.

When asked about sharing his positive experience regarding zero tillage with others, AB06 indicated that he shared with "everyone who will listen and watch." He then went further in describing how "a certain percent of the population learns by hearing, the majority learn by looking over the fence and seeing what the neighbours are doing." In terms of whom AB06 shared this information with; he stated that it is mainly with other farmers. He went onto say:

> As far as no-till that [information sharing] has to be other farmers. They are the only ones that have that option or do that practice …I enjoy trying to mentor some of the next generation or encourage them, by taking special time out to do that.

This idea of trying to mentor future generations provides further evidence demonstrating cognizance of environmental issues and the long-term impacts of farming practices. Given all the indications of transformative learning in this individual it is likely that premise-based reflection has occurred, specifically with respect to environmental consequences and the welfare of future generations. The transformative learning process as described for AB06 involves a combination of instrumental and communicative learning, deliberation, and reflection. However, the process is highly variable and dependent on context and personal behaviour, making is difficult to quantify.

5.6.3 Transformative Learning Conclusion: The Link with Information

Transformative learning in individual farmers is a means for achieving sustainable practices in the face of environmental uncertainty. Transformative learning cultivates autonomous decisions making in individuals, which is needed for making morally sound choices that are in line with sustainable environmental development (Mezirow 1997). According to Sinclair and Diduck (2008: 416) individual participation in environmental decision-making can evoke feelings of empowerment that is "conducive to broad-based individual and social learning that could enable the transition to sustainability."

Transformative learning can be a long and varied process. One individual's transformative learning experience may look very different from another's. The process for one such producer (AB06), outlined above, shows how the process is highly dependent on external context and individual behaviour (e.g. psychocultural codes). The process involves a mixture of instrumental and communicative learning. These two types of learning can result in critical reflection with respect to the functionality of one's beliefs, causing a transformation in the individual's habitual way of thinking, feeling, and acting (i.e. transformative learning) (Mezirow, 1994, 1997). This type of process or at least aspects of this process seem to be present in AB06 as his decision to move from conventional tillage to zero tillage is explored.

This research has brought forth examples of other producers who seem to show aspects of transformative learning. While these indicators of transformative learning do not provide definitive evidence that transformative learning is in fact occurring, they do act as an guide indicating where transformative learning could possibly occur, or where is may be in the process of occurring. These indicators include: questioning roles and social norms; enhanced instrumental competence; the learner is set on a pathway for further premise-based reflection; enhanced instrumental competence; and, gaining insight into one's own learning style. Overall, questioning roles and social norms was the most common indicator of premised-based reflection that occurred. Enhanced instrumental and communicative competence was observed less frequently, while further premise-based reflection and gaining insight into one's own learning style were only observed once each.

Based on the results from Chapter 4, nearly all the information exchange that occurs in the Prairie agro-ecosystem is top-down or from producer to producer. Given these means of receiving information, it is important to explore how the number and type of information sources is related to transformative learning indicators in farmers. Table 10 below makes this link between indicators of premise-based reflection and information sources. The degree with which a producer indicates premise-based reflection was determined as strong, moderate, some, or none based on the number of types of premise-based reflection indicators observed. The total number of information sources as well as the main information source or sources as stated by the farmer is also given.

When linking indicators of transformative learning with the main sources of information used by the individual producers for adopting soil and water conservation practices, there seems to be a trend in the information sources used. The main sources of information were neighbours. Seventeen of the 28 producers interview indicated that neighbours or family were their main source, or one of their main sources, of information when it came to adopting a particular soil or water conservation practices. The prominence of neighbours as main information sources was especially widespread in Manitoba as 10 of the 14 producers (compared to just 6 of 14 producers in Alberta) indicated this was the major information sources. However evidence that horizontal information sharing was used as the main information source by most producers is not necessarily related to indicators of transformative learning.

The types of information sources that seem to be most strongly correlated with indicators of transformative learning as those that involve an interactive or experiential process. These may or may not be related to horizontal information. For example, AB06 indicated that he communicated closely with one particular neighbour who convinced him (through conversation and demonstration) of the benefits of zero tillage. Similarly AB03, AB05, and AB13 stressed the importance of a single close neighbour, family member, or group

Table 10 - Linking Indicators of Transformative Learning to Number and Type of Information Sources

Producer	Indication of Premise-Based Reflection	Type(s) of Premise-Based Reflection	Farmers' Information Sources	Main Source(s) of Information as Described by the Producer
AB01	None		4	-University of Idaho potato school
AB02	Some	-Questioning role as a farmer	6	-Equipment Dealers -Provincial Government
AB03	Strong	- Enhanced instrumental competence - Enhanced communicative competence -Questioning role as a farmer - Set pathway for further premise-based reflection	4	-Neighbours
AB04	None		3	-Eastern Irrigation District
AB05	Moderate	- Enhanced communicative competence -Questioning role as a farmer	4	-Family
AB06	Strong	-Gaining insight into his learning style -Questioning social norms -Questioning role as a farmer	3	-Neighbours
AB07	Moderate	- Enhanced communicative competence -Questioning social norms	5	-Farm publications -MANDAK crop tour
AB08	Strong	- Enhanced instrumental competence - Enhanced communicative competence -Questioning social norms -Questioning role as a farmer	6	-Neighbours -North Dakota State University research farm
AB09	Some	-Questioning social norms	2	-Grazing mentorship program
AB10	None		4	-Neighbours
AB11	None		3	-Industry agriculturalist
AB12	None		3	-Equipment dealer
AB13	Moderate	- Enhanced instrumental competence -Questioning role as a	4	-Neighbours

		farmer		
AB14	Some	-Questioning social norms	3	-Neighbours
MB01	Moderate	- Enhanced instrumental competence -Questioning role as a farmer	3	-Conservation District
MB02	Some	-Questioning role as a farmer	1	-Neighbours
MB03	None		3	-Seed Companies
MB04	None		1	-Neighbours
MB05	None		2	-Provincial Government
MB06	None		4	-Municipality -Neighbours
MB07	None		2	-Neighbours -Farm publications
MB08	None		2	-Neighbours
MB09	None		3	-Equipment dealers
MB10	None		2	-Neighbours
MB11	None		1	-Neighbours
MB12	None		2	-Neighbours
MB13	Moderate	-Questioning social norms -Questioning role as a farmer	3	-Equipment dealers -Neighbours
MB14	None		2	-Neighbours

of neighbours that provided the information, or demonstrated with their own crops, thereby convincing them to change their farming practices. On the other hand, AB07, AB08, MB01, and MB13 indicated that their main information was obtained via vertical information exchange (or a combination of vertical and horizontal) from sources where they could learn through first-hand observation. Such sources included crop tours, visiting universities research, and demonstrations by the Conservation District or equipment dealers. Overall, information (conveyed both horizontally and vertically) that gave producers the ability to observe and interact seemed to be a strongly correlated with indicators of transformative learning.

Examining how indicators of transformative learning is related to the number of different information sources a producer accessed for a particular soil or water conservation practices reveals that in general, that the greater the diversity of information sources the more likely a producer is to shows indicators of transformative learning (see Table 11).

Table 11 – Volume of Information Sources for Various Groups of Producers

Producer Groups	Number of Total Information Sources in Group	Number of Producers in Group	Ratio of Sources to Producers
- Producers with a moderate or strong indication of transformative learning	32	8	4.0
- Producers with at least some indication of transformative learning	44	12	3.6
- Producers with no indication of transformative learning	41	16	2.6
- Manitoba producers	31	14	2.2
- Alberta producers	54	14	3.9

To analyze this phenomenon, producers were divided into three different groups based on the degree to which they showed indications of premise-based reflection. These groups include: producers with a moderate or strong indication of transformative learning; producers with at least some indication of transformative learning; and, producers with no indication of transformative learning. The analysis shows that generally the higher the degree to which the producer showed indications of premise-based reflection, the greater the number of sources of information they accessed for the single farming adoption in question. Producers in Alberta on average showed accessed a greater number of information sources than those in Manitoba.

The finding that learning is related to having access to a high diversity of information sources is an idea is supported by the literature. A high diversity of information is noted as being important for building platforms for social learning (Roling and Jiggins, 1998), support structures groups and networks (Fisk et al., 1998), adapting to environmental uncertainty and long-tem environmental change (Berkes, 2002), resilience building (Folke et al., 2003), and adaptive co-management (Olsson et al., 2004). However, it is important to keep in mind that quality and not just quantity of information is also important. This research outlines in detail the learning process undergone by AB06. This producer seems to strongly indicate undergoing transformative learning, however only cites three information sources used in making the decisions to adopt zero tillage. This example indicates that few good sources of information may be more effective in achieving sustainability-centered learning outcomes than an abundance of sources. This research shows that such sources usually involve some type of observation or experimentation. The importance of gaining information though an experiential source is an idea that is stressed in the literature (Somers, 1998; Dietz et al., 2003). Ideally, producers in the Prairie agro-ecosystem would have access to a large number of diverse information sources (both vertical and horizontal) that involved first hand observation and experimentation.

5.7 Learning Summary

The results in this chapter show how transformative learning theory can be applied to learning that is occurring with the Prairie agro-ecosystem among individual producers. All participants experience some degree of instrumental learning. This learning usually involved learning new skills and information, which allowed for more effective farming methods and a better net return per acre. Instrumental learning usually occurred within one of two frames of reference: maximizing profits or maintaining economic viably. The former often acted as a barrier to secondary instrumental learning of environmental benefits while the later often resulted brought about awareness of the mutual benefits between sustainable practices and long-term financial benefit.

In many cases, producers were found to combine elements of instrumental and communicative learning. This finding is consistent in other studies (Sims and Sinclair, 2008) and with transformative learning theory (Mezirow, 2000). In these cases, information was often communicated between local producers to the exclusion of most other organizations and institutions. The information received by producers was then validated through discourse and reflection. The reflection process was different for every producer. Some participants read about the information or attended conferences and seminars, others experimented with new practices, some reported communicating with neighbours to understand the benefits of the practices, while others simply watched to see if neighbours were successful with the new practices. In most cases however, there was some combination of instrumental and communicative learning that lead to validation of the information and the eventual adoption of the practices related to soil and water conservation.

The discourse process associated with communicative learning often caused producers to questioning underlying assumptions thereby showing indications of transformed governing habits of mind. These habits of mind usually stemmed from sociolinguistic codes (i.e. questioning roles and responsibilities and questioning normative practices) and in some cases resulted in enhanced instrumental learning competence as producers set out to collect research in order to make decisions or communicate experiences more effectively with other farmers. This result is consistent with Sims and Sinclair (2008) who suggest that changing farming practices and questioning normative ideologies associated with conventional farming, can lead to individuals having a sense of responsibility to educated others regarding their convictions. In this study producers who showed aspects of transformative outcomes tended to use more effective methods of sharing information and experience compared with producers did not show any indication that habits of mind may be transformed. In one case, a producer showed evidence of gaining insight into his learning style, indicating that perhaps transformation in habits of mind stemming from epistemic codes had occurred. In general, indications of the transformative learning process seemed to be most strongly correlated with producers who underwent critical, dialogical, observational, and experimental processes with a diversity of information sources.

Chapter 6 – Conclusions

6.1 Revisiting the Objectives

The first objective of the this research was to identify the horizontal and vertical linkages that connect individual producers to information regarding soil and water conservation, as this type of information is believed to be important for helping climate change adaptation. Interviews with 28 producers in Alberta and Manitoba revealed that information comes from a variety of sources including government, industry, producer/conservation organizations, social/experiential sources, media, and to a lesser extent universities and research conferences. Exploring the information flow revealed the dominance of top-down information (predominantly from government, industry, producer/conservation organizations, and media) and horizontal information sharing (from neighbours, family, or personal experience). All farmers indicated that they received information from one or more of these top-down sources, and both provided and received information through horizontal channels with other farmers.

The second research objective was to determine the frequency with which information flows from these sources and the content of the information received by producers. There was not a single source that dominated the information received by producers when looking at soil and water conservation practices as a whole, but when specific practices are examined there are often one or two prominent institutions that dominate the information that is conveyed to producers (see Table 4). For example information regarding tillage practices came predominantly from social and experiential sources, while both government information and information from producer and conservation organizations dominated the information flow regarding wetland conservation. When the sources of information for all the specific soil and water conservation practices are examined, social/experiential sources of information are the most common, with industry and government with also being relatively prominent. When comparing Alberta and Manitoba, information sources were very similar with the exception of the irrigation district, which played a prominent role in the Alberta study area only.

The third objective of this research was to consider the individual learning that precipitated the adoption of soil and water conservation practices using transformative learning theory. This was done by considering the process that lead to the adoption of a single farming practice related to soil or water conservation. Sources of information driving the single change in farming practices related to soil or water conservation were less diverse in Manitoba. This might be explained by more variation in the farm types in Alberta as a result of geographic conditions (e.g. topography, soil variation, irrigation), by exposure to past shocks and stresses, or this might also be explained by more reliance on communication between neighbours in Manitoba.

Learning was discussed in three dimensions: instrumental, communicative, and transformative. Instrumental learning was common, and observed in all 28 interview participants. Four grounded categories of instrumental learning were identified, including: scientific and technical knowledge, legal /administrative and politic procedures, social and economic knowledge, and potential risks and impacts. There was noticeable and often explicitly stated difference in the frames of reference in which instrumental learning took place in producers. The difference involved the idea of maximizing profits versus maintaining economic viability. Farmers who indicated the desire to maximize profits expressed the importance of a productive farm, often with a short-term outlook. Those farmers who indicated the desire to maintain economic viability expressed the importance of a sustainable farming, often thinking long-term.

The second category of learning that was examining was instrumental learning. In terms of the sources of information that led to communicative learning, it was found that other farmers and neighbours acted as the dominant source. Communicative learning that involves critical reflection of beliefs and underlying assumptions was focused on. Three types of critical reflection stemming from communicative learning were observed: 1) reflection on interrelationships between practices and the environment, (e.g. MB01 identified the date June 9th 1985, when a wind storm struck his farm provoking motivation to take action to prevent soil erosion while also expressing cognizance for future generations and mutual dependency of economic and environmental benefits); 2) reflecting on the roles and responsibilities (e.g. Several farmers express their role as temporary holders or stewards of the land. This manifested in sustainable actions such as conservation tillage or preventing irrigation waste.); and 3) reflection regarding social norms or normative ideologies (e.g. AB06 came from Zambia, bringing with him innovative and unconventional knowledge which eventually lead to the widespread adoption of zero tillage. This knowledge brought about a fundamental shift away from traditional ways of farming that were ingrained in the social conscious). Exploring critical reflection stemming from communicative learning in this way is important as it may indicate the possibility of transformative learning.

Transformative learning is difficult to quantify as it can be lengthy and highly variable. It is best thought, not as an outcome, but as a process that involves a mixture of instrumental and communicative learning. This process was explored for one farmer, AB06, who seemed to engage in critical, premised-based reflection. While it is difficult to definitively confirm transformative learning, five indicators were found that may suggest where transformative learning might be occurring, or indicates the foundation where transformative learning could occur. These indicators include: questioning roles and social norms; enhanced instrumental competence; the learner is set on a pathway for further premise-based reflection; enhanced instrumental competence; and, gaining insight into one's own learning style. Overall, questioning roles and social norms was the most common indicator of premised-based reflection that occurred. Enhanced instrumental and communicative competence was observed less frequently, while further premise-based reflection and gaining insight into one's own learning style were only observed once each. By relating transformative learning indicators to sources of information, it was found that the number of sources of information driving the adoption of the single soil or water conservation practice in question was positively correlated with the frequency of observed transformative learning indicators observed in an individual (see Table 11). In addition, of the main sources of information used to drive the decision to adopt a single conservation practices, those sources that allowed for observation and interaction were correlated with a higher number of transformative learning indicators (see Table 10).

The fourth and final research objective was to explore some of the implications for adaptive policymaking and resilience building based on the findings of this study. This research objective will be discussed below.

6.2 Implications for Adaptive Policymaking and Resilience Building

With concern regarding the sustainability of agricultural practices in the face of environmental uncertainty, a suitable approach to this problem may involve adaptive policymaking. Climate change is inherently unpredictable, and natural systems are often too complex to fully understand. As climate change continues, shocks such as floods and long-term stresses such as persistent drought will be further exacerbated (Barg et al., 2006). Given this uncertainty, it is important for policies to be able to adapt to changing conditions (Swanson and Bhadwal, 2009). This in turn allows individuals to increase their capacity to adapt to changing conditions and ultimately build resilience (Barg et al., 2006).

Sustainable agriculture involves learning, incorporating of natural processes, reduction of external inputs, and the full participation of farmers in a process that is more equitable, self-reliant, and experiential (Pretty, 1998). The concluding ideas presented below are based on the ideas of promoting sustainable agriculture in the Prairie agro-ecosystem while drawing on the concepts of resilience building, adaptive policy-making, and adaptive co-management. The conclusions below set out to further strengthen positive aspects of the system that were observed and improve on potential weaknesses of the agro-ecosystem to adapt under a changing climate.

1. Strengthen horizontal information sharing
2. Foster learning, especially experiential learning
3. Establish two-way, vertical information pathways

In order to clearly make the link between the conclusions of this study with adaptive policy making and resilience building, it is necessary to break the two concepts down into their parts and explore how they contribute to information sharing and learning in the Prairie agro-ecosystem. It is also useful to explore how the conclusions put forth in this study can contribute to establishing a system of adaptive co-management. Table 12, explores the links between the three conclusions of this thesis set forth to foster sustainable agriculture in the Prairie agro-ecosystem and the theoretical components that support these specific conclusions.

Table 12 - Linking Theory to Thesis Conclusions for Building Sustainable Agricultural System

Conclusions for this Thesis*	**Adaptive Policy-Making (Swanson and Bhadwal, 2009)**	**Resilience Building (Folke et al., 2003)**	**Adaptive Co-Management (Olsson et al., 2004)**
Strengthen horizontal information sharing (A5, A7, B2, B4, C2, C5, C7) Foster learning, especially experiential learning (A3, A4, A5 A7, B1, B3) Establish two-way information pathways (A4, A6, C1, C4, C6)	*Adapting to anticipated conditions:* A1) Automatic policy adjustment A2) Integrated and forward looking analysis A3) Multiple-stakeholder deliberation *Adapting to unanticipated conditions:* A4) Formal review and continuous learning A5) Enable self-organization and social networking A6) Decentralization of decision-making A7) Promoting variation	B1) Learn to live with change and uncertainty B2) Nurture diversity for reorganization and renewal B3) Combine different kinds of knowledge sources for learning B4) Create opportunities for self-organization	C1) Legislation needs to enable participation and power sharing C2) Funding can facilitate self-organization C3) Monitor natural feedbacks to enhance leaning C4) Enhance information flow through social networks C5) Combine diverse sources of information C6) Make sense of various information C7) Create platforms for sharing information and learning

* Letter-number in brackets indicates the theoretical concepts that support the specific conclusion.

6.2.1 Strengthen Horizontal Information Sharing

The literature suggests that farmer-to-farmer communication or horizontal information sharing is important for the adoption of new farming practices. Roling and Van Be Fliert (1998) state that farmer-to-farmer training is as effective as training farm extension workers, and is the most promising multiplier for implementing sustainable programs. Findings by Koutsouris and Papadopoulos (1998) indicate that given their ability to experiment with new techniques in farming systems, individual producers are the most fitting people to develop new management practices. According to Roling and Jiggins (1998), the emergence of new farming techniques requires the support of non-formal education and farmer-to-farmer extension, which allows for information to percolate throughout the community.

In this study, horizontal information sharing among producers was widespread in both Alberta and Manitoba study areas. This finding, which is stressed as being crucial for adaptation, is a positive one for the Prairie agro-ecosystem and confirms the finding that these two areas have a potentially high adaptive capacity to deal with climate change (Swanson et al., 2007). In all cases, producers stated that the sharing of information with other farmers and neighbours is two directional. While information resulting in instrumental learning comes from a plurality of sources, communicative learning (the type of learning that can lead to critical reflection and transformative learning) was largely a result of horizontal information sharing between farmers, to the exclusion of other information sources. Given this finding, it is important to foster conditions that continue to enable or enhance producer-level dialogue and information sharing to allow for communicative learning.

Enhancing horizontal information sharing is supported by some of the concepts of adaptive policy making (i.e. enabling self-organization and social networking, and promoting variation), resilience building (i.e. nurturing diversity for reorganization and renewal, creating opportunities for self-organization) and adaptive co-management (i.e. providing funding to facilitate self-organization, combining diverse sources of information, and creating platforms for sharing information and learning). This research showed an excellent example of how self organization led to the widespread adoption of zero tillage in the Alberta study area. When AB07 moved from Alberta to Zambia, he helped to organize a meeting for famers interested in adopting zero tillage. The exchange of information that took place at this meeting eventually resulted in the widespread adoption of zero tillage by nearly all of the local farmers. When individuals are given platforms to meet and discuss, they are exposed to diverse information that may result in their questioning of current ways of thinking, thereby promoting learning and the adoption of new farming practices.

Given the importance of creating platforms for self-organization, and information exchange, horizontal information exchange may be encouraged by organizing regular meetings for farmers at the sub-district and distract levels, and by arranging technical workshops in which farmers can share experiences (Roling and Van Be Fliert, 1998). However, it is important to note that not all-local knowledge is consistent with sustainable agriculture (Koutsouris and Papadopoulos, 1998). There is a need to insure that information exchanged at the producer level is consistent with sustainable goals. By promoting the type of information that is consistent with sustainable farming practices, policy makers, working within a framework of adaptive co-management, can increase producer level cognizance regarding sustainable and increase long-term resilience.

6.2.2 Foster Learning, Especially Experiential Learning

According to Roling and Jiggins (1998) sustainability in agriculture must be facilitated through learning. The transformative learning process is especially important for promoting the type of information sharing that is consistent with sustainable farming practices since this research shows that producers who seem to exhibit changes in ingrained habits of mind were often more cognizant of environmental issues. By fostering conditions that are conducive to learning, especially the type of learning that results in premise-based reflection, farmers would likely be more open to new ideas and practices that promote sustainability in the face of environmental change.

6.2.2.1 Conditions for Learning

According to Mezirow (1994) there are six ideal conditions for learning: 1) accurate and complete information, 2) freedom from coercion, 3) openness to alternative perspectives, 4) ability to reflect critically upon presuppositions, 5) equal opportunity to participate, and 6) ability to assess arguments in a systematic manner and accept a rational consensus as valid. This results of this study show, that for the purpose of developing a frame of reference that is conducive to the adoption of farming practices that are sustainable in the face of change, certain ideal learning conditions may be crucial than others. It is also useful to consider ideal learning conditions alongside attributes that determine the rate of adoption of a new farming practices. Somers (1998) list five of these attributes that predict the rate of farm-level adoption. These include: relative advantage, compatibility, complexity, trialability, and observability.

Relative advantage (e.g. moving to zero-tillage strictly because of fuel savings) compatibility (e.g. not practicing organic farming given the soil type) played a role in farmer's rate of adoption, but was more instrumental in nature, and were not typically associated with questioning of underlying assumptions and critical reflection. Trialability and observability on the other hand, did playing an important role in promoting conscientious reflection regarding sustainability. Mezirow's (1994) conditions of openness and the ability to reflect were also important for farmers who seemed to show indications of transformative learning. The following discussion explores these conditions that were important for learning and adoption of sustainable farming practices for Prairie farmers.

Openness and the Ability to Reflect Critically

Openness to be critically reflective on underlying assumptions that govern one's way of thinking, feeling, and acting usually results in the transformation of ingrained thoughts and behaviours. Participants, who seemed to undergo critical reflection, questioned their relationship to the environment, their roles and responsibilities as a farmer, and social norms or convention farming practices. With respect to adaptive policymaking, Swanson and Bhadwal (2009) state that the ability to reflect critically may be an outcome of multi-stakeholder deliberation. This type of critical reflection was driven by a combination of instrumental and communicative learning, but required a certain degree of openness before such reflection could take place. While it is beyond the scope of this research to determine what factors contribute to an individual's openness to consider new ideas and practices, it is clear that this factor played an important role in the adoption of sustainable farming practices.

In the Alberta study area, AB03, who made the decision to move to zero tillage, is an excellent example of an individual with a high level of open mindedness towards revising practices and finding betters ways of farming. AB03 showed the openness to seek out information regarding the technical details of zero tillage, by attending zero tillage conferences and "just constantly learn." -AB03. This idea of always looking for new information and better ways of running one's farm involves a high degree of openness and the ability to critically reflection on current practices. This type of behaviour is conducive to fundamental shifts in an individual's way of thinking and behaving and may be important for farming in readily changing environmental conditions.

With regards to resilience building in the context of climate change, the idea of learning to live with change and uncertainty is consistent with the idea of openness towards new ideas and practices. If a farmer expects variable and unpredictable climatic conditions, then there might be a greater openness towards new farming practices that allow him to cope. Policymakers should bear in mind the importance of encouraging individual openness and the ability to critically reflect. Somers (1998) suggests that leaning about sustainable agriculture may be achieved by influencing the deep cultural layers that influence action. However, a simpler solution may be to encourage farm-level experimentation. These research shows that experiential leaning may ultimately result in critical reflection and individual transformation.

Trialability and Observability

Research by Somers (1998) suggests that using visible indicators of environmental problems and field observation are important for a farmer's learning process. Somers goes on to state that a positive experience with one aspect of sustainable agriculture can result in motivation to try new aspects, resulting in a gradual learning process characterised by shifting goals and perceptions This is also consistent with findings by Weperen et al. (1998), who found that farming practises that had a large visual impact were reported as being the most rewarding for Dutch farmers, and suggests that these types of practices should be used as a starting point for achieving sustainability in farming. According to Swanson and Bhadwal (2009), observability is an important factor for promoting variation, as well as for formal review and continuous learning.

Given the import role that trialability and observability play in promoting learning as suggested by the literature, it is not surprising that these factors were found to be an important factor for changing ingrained habits of mind among the farmers in this research. Like Kerton and Sinclair (2009) who found that transformative learning was best achieved through experiential learning, producers in this study who showed strong indications of transformation in normative ideologies, commonly cited the importance of experience in driving change (either with their own crops, by watching a neighbour, or observing a farm demonstration) (see Table 10).

The mechanism of learning by observing and copying behaviour seemed to be crucial for an individual's premised-based reflection. MB03, a farmer who showed moderate indications of transformative learning, noted that when it comes to new farming practices “we all watch each other and share what we do; people keep track of what you do and observe what is working”. He goes onto state that “We are all running demonstrations to a certain extent … If somebody has something new everybody is watching”. This idea of watching, while a new farming practice is being implemented before adopting the practice for one’s own farm, was common for the farmers in this study. These findings suggest that individual learning in farmers may be enhanced by offering incentives for implementing soil and water conservation practices at a small observable scale. This may lead to full-scale adoption of the practices in the future, as familiarity grows and long term benefits can be observed. In addition, learning may be fostered by encouraging farmers to offer field tours and demonstrations within the community as a way of enhancing sustainable practices.

6.2.2.2 Barriers to Learning

While openness, the ability to reflect, observability, and trialability were found to be important factors that contributed learning and the adoption of sustainable practices, some factors were commonly identified as being deterrents to learning. There are many factors that can deter learning; these include human constraints such as technological, financial, cognitive, behavioural, social, as well as cultural constraints, knowledge gaps for adaptation, and impediments to flows of knowledge (Adger et al., 2007). However, actions taken to reduce vulnerability to climate change are ultimately determined by two factors: the perception of impacts and the cost of the adaptation response (Adger et al., 2007). These two deterrents were commonly brought up by the participants in this research and are discussed below.

Cost of Inputs

Prairie farmers in this study commonly identified cost as being a barrier to the adoption of farming practices consistent with soil and water conservation. This finding is consistent with Smit and Skinner (2002) who found that farmers often cite the lack of adequate financial resources as an important factor that constrains their use of adaptation measures. Bradshaw et al. (2004), notes that long term benefits of climate change adaptation may be hidden or deemed trivial, when producers are faced with significant short-term expenses or financial crisis. Prohibitive cost of entry regarding soil and water conservation practices may limit experiential learning among farmers, thus preventing opportunities for transformative learning which is important for continuous adaptation in the face of change.

The prohibitive cost of equipment required for the adoption of soil and water conservation practices lead to the farmers in this study to delay the purchase of equipment, or disregarded the adoption of such practices. In the Alberta study area, farmers mentioned more efficient chemical application equipment and low-pressure central pivot irrigation systems as having a prohibitive cost. In the Manitoba study area, farmers cited heavy harrows and laser ditching equipment as having a prohibitive cost.

These findings demonstrate the need for policies that provide financial support for sustainable farming practices. According to Smith (1997) when considering any adaptation policy; the benefits should exceed the costs so that the policy is economically justified. Perhaps this could be achieved through a reallocation of government subsidies to farmers. Rather than encouraging high external input agricultural practices through subsidies (e.g. fuel), financial incentives could instead be provided for equipment that allows farmers to better cope in the face of climate change (e.g. heavy harrows, no-till seeders). By creating lower entry costs for equipment consistent with sustainable farming, opportunities for trail, observation, and potentially premised-based reflection can be gained.

Farmer Perceptions

The way in which individuals perceived the problem of farming with persistent climatic shocks and stress could also be a barrier to the type of learning that resulted in the adoption of sustainable practices. The perception of Prairie farmers was often affected by by two factors: cognition and social context. According to Adger et al. (2007) cognitive barriers may arise as a result of a farmer’s perceptions of risk, vulnerability, and adaptive capacity. Bradshaw et al. (2004), suggests that heterogeneity between producers in terms of their decisions to undertake an adaptive responses to cope with climate change is highly variable and the result of very unique circumstances (e.g. debt, family crisis, or access to off-farm income). However, cognitive barriers are particularly difficult to study since knowledge of climate change and possible mitigation solutions may not lead to adaptation (Bennett and Howlett, 1992).

Cognitive barriers may explain why some Prairie farmers did not seem to engage in critical reflection with respect to underlying assumptions that govern their actions and farming practices. Many farmers indicated that they grew up on a farm and had been farming most of their life, and while this experience and local knowledge can act as a source of adaptability, it may also result in ingrained habits of mind that are resistive to change and unable to adapt under changing environmental conditions. Resistance to changing one's ways of thinking, feeling, and acting conflicts with the idea of learning to live with change and uncertainty which is fundamental to resilience building (Folke et al., 2004)

Individual cognition is also influenced greatly by the social context in which the individual exists. According to Adger et al., (2007) barriers to adaptation may arise as a result of broader social and development initiatives, since adaptation to climate change is usually not done in a stand-alone fashion. Even though individuals may be concerned and well informed about environmental issues, the social context in which they are embedded can offset the appropriate behavioural response (Folke, 2003). As a result of persistent social norms, it may take outsider to change ingrained ways of behaving. These innovators are the first people to adopt a new technology or practices, and usually a less integrative into the social system (Granovetter, 1983).

The idea of someone from outside the social setting initiating change is exemplified in the case of the farmer from Zambia (AB07) who brought with him innovative new knowledge and experience regarding zero tillage under irrigation. Given the financial benefits, and reduced labour of this new practice, it eventually spread throughout the community. The idea of a widely adopted practice having multiple benefits is consistent with the idea purposed by Bradshaw et al. (2004) that farmers do not make decisions based on climatic indicators alone. Higher returns, lower risk, and lower production costs all play a role initiating changes among producers (Zentner et al., 2002). In this research, the widespread adoption of new tillage practices for irrigated crops may have lead to transformed habits of mind for some producers, thus establishing the groundwork for widespread change at the community level.

6.2.2.3 Co-learning among Farmers

Consistent with findings from Sims and Sinclair (2008) and Diduck (1999), participants in this study who showed indicators of transformative learning exhibited enhanced awareness of sustainable practices. In some cases these individuals also showed evidence of enhanced instrumental and communicative competence stemming from premise-based reflection. According to Sinclair et al., (2000) this type of premise-based reflection can ultimately empower individuals, facilitate participation, challenge traditional ideologies and practices, and generate social action that enhances environmental sustainability. In the research, AB07's participation and initiation of a zero tillage meeting acted as a learning platform where individuals could exchange information and thoughts, and co-learn. This co-learning provoked some individuals to challenge traditional ideologies and farming practices and adopt zero tillage. In some cases this resulted in a transformed individual frame of reference that was more conscious of sustainability and environment concerns.

Co-learning involves widespread horizontal information sharing, self-organization and social networking, multiple-stakeholder deliberation, and promoting variation by combining different kinds of knowledge sources making it consistent with resilience building and adaptive policy making (Folke et al., 2004; Swanson and Bhadwal, 2009). Furthermore, Somers (1998) notes that co-learning can raise consciousness, stimulate individual and collective reflection, lead to experimentation with new methods, and bring about acceptance of new norms and behaviours. Given the importance of experimentation found in this research, co-learning may also result in the transformation of persistent habits of mind resulting in the adoption of sustainable farming practices. Relates to adaptive policymaking wrt self-organization and social networking; promoting variation

6.2.3 Establish Two-way, Vertical Information Pathways

The final insight gained from this research, to establish two-way, vertical information pathways, stems from the lack of bottom-up information sharing that is occurring in the Prairie agro-ecosystem. This type of information flow, in which insights gained at the producer level are shared with organizations and policymakers, is an important factor for making adaptive policy-making and adaptive co-management. In examining the information exchange that is occurring between farmers and institutional levels, the flow is almost exclusively top down. This may presents problems when considering the long term resilience of agriculture in the face of change. Agricultural innovations are not achieved through the top-down transfer of technology, but through the interactions between actors within the agro-ecosystem (Roling and Wagemakers, 1998). According to Pretty (1998), the participation of farmers in problem solving and the use of local knowledge contributes to sustainable agricultural systems that are adaptive to change.

In order for policies to promote producer-level resilience in the face of environmental change, polices themselves need to be able to adapt to both anticipated and unanticipated conditions (Swanson and Bhadwal, 2009). The ideas of formal review and continuous learning as well as the decentralization of decision-making are components of adaptive policy-making that support the two-way information flow. If policymakers within the agro-ecosystem are leaning from a variety of sources (including an ongoing dialogue with producers) and providing producers with the opportunity to participate in decision-making based on their knowledge of local conditions, policies will be more able to adapt to rapidly changing environmental conditions. This concept is very similar to components of adaptive co-management, which stresses that legislation is needed to enable participation and power sharing, information flow through social networks needs to be enhanced, and that making sense of various information is important (Folke et al., 2003).

The lack of two-way information sharing is a phenomenon that has only been perpetuated in past years with the loss of provincial agricultural representatives. AB08, described the role of the District Agriculturist's in Alberta as a "close resource that we could drop in and have a chat with at any point in time" – AB08. Now that this resource no longer exists, AB08 states that it takes "a lot of personal effort" to find the same kind of information that he was getting before. The loss of the District Agriculturalist's in more than just the loss of an information source. The District Agriculturalist acted as recipient information and not just a source. Producers could provide specific information regarding their soil type, crop, and resources and receive information tailored to their needs. The loss of the District Agriculturalist is indicative of a general shift away from government extension in agriculture. One consequence of this is that completely new climate change practices may have high probability of rejection in the absence of extension and capacity building. Under changing climatic conditions, promoting producer-level information sharing and learning and also making specific provisions for information exchange between producers and government is crucial for effective farm-level adaptation and adaptive policies.

Gathering multiple perspectives from a range of stakeholders is an integral part of complex adaptive systems management (Holling, 1978) and is thought to be applicable for making policies adaptive (Tyler et al., 2006). In this way producer-level information, which is currently going largely ignored could be incorporated into policy-making, resulting in a more adaptive and resilient agro-ecosystem. This type of system of adaptive co-management would allow for continuous learning and information sharing between producers and policy-makers. Increasing the level of interaction between farmers and government may enhance long-term sustainability by reducing producer-level reliance on industry-based sources of information, whose main focus is profit, rather than sustainable agricultural.

6.3 Final Remarks

Adaptive co-management increases opportunities for information sharing and individual learning. When this results in individual habits of mind to become altered, transformative learning occurs. This type of learning may help to alter the way farmers perceive problems, and their openness to critically reflect on solutions. Transformative learning outcomes ultimately increase cognizance of environmental outcomes resulting in a system of agriculture that is more sustainable in the face of environmental change.

With respect to the initial conceptualization of the relationship between information sharing, learning, adaptation and resilience (Figure 1), this research show that barriers to information flow (lack of two-way information sharing) and learning (prohibitive costs, resistant cultural norms, inability to engage in critical reflection) may hinder adaptation and resilience building in the face of climatic change and uncertainty. While actions that build capacity to climate change are being taken by all farmers, the way in which they are understood by farmers is often indicative of short-term reactions necessitated by financial survival, rather than a strategy for long-term resilience building. By promoting information exchange and learning through an adaptive co-management context, ways of understanding problems may be transformed so that challenges are interpreted in a fundamentally new and sustainability-centered way. In addition, there is a need for policy to address prohibitive costs facing producers and the importance of experience and observation, as these factors are crucial for individual learning and the eventual adoption of sustainable farming techniques.

Given these findings, policy-making systems that act adaptively in the face of change and encourage linkages across and between levels of organization would likely contribute to increasing producers' access to relevant information. This would improve awareness climatic challenges. Policy with the mandate of promoting individual and cross-scale information sharing would likely increase the frequency of the type of learning that can lead to the adoption of sustainable practices. If this producer-level learning results in premise-based reflection regarding conventional norms or sustainability, individual transformation, lasting change may be achieved. However individual transformation is occurring in the context of declining numbers of family farms and rural depopulation. Under this business-as-usual scenario, horizontal interactions may be impaired because of declining numbers of farmers actively on the land.

Policy with the mandate of learning in an adaptive context that makes provisions for regionally-specific knowledge and unexpected environmental conditions requires a fundamental shift in the management of agricultural systems. Such a shift would require that farmers have a role in informing agricultural policy through two-way dialogue .

References

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., and Takahashi, K. 2007. Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J,. and Hanson, C.E. (eds.). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK.

Adger, W.N. 2001. Scales of Governance and environmental justice for adaptation and mitigation of climate change. Journal of International Development.13: 921-931.

Adger, W.N. 2000. Social and ecological resilience: Are they related? Progress in Human Geography. 24: 347-364.

Agriculture and Agri-Food Canada (AAFC). 2007. An overview of the Canadian agriculture and agri-food system. Online: http://www.agr.gc.ca/pol/index_e.php. Last Accessed: January 19, 2008.

Agriculture and Agri-Food Canada and Prairie Farm Rehabilitation Administration (AAFC-PFRA). 2003. Analysis of agricultural water supply issues - Prairie provinces national water supply expansion program. Available Online: http://www.agr.gc.ca/pfra/water/natsupply_e.htm. Last Accessed: March 10, 2008.

Alberta Agriculture and Food Canada (Alberta Agriculture). 2008. Programs and services for all audiences. Available Online: http://www.agric.gov.ab.ca/app21/rtw/index.jsp. Last Accessed: February 21, 2008.

Armitage, D., Berkes, F., and Doubleday, N. 2007. Introduction: moving beyond co-management. In: Armitage, D., Berkes, F., and Doubleday, N., (eds.). Adaptive co-management: collaboration, learning and multi-level governance. University of British Columbia Press, Vancouver, British Columbia, Canada.

Barg, S., Bhandari, P., Drexhage, J., Kelkar, U., Mitra, S., Swanson, D., Tyler, S., and Venema, H.D. 2006. Introduction. In: Designing policies in a world of uncertainty, change, and surprise. International Institute for Sustainable Development, Winnipeg, and The Energy Resources Institute, New Delhi.

Bennett, C.J. and Howlett, M. 1992. The lessons of learning: Reconciling theories of policy learning and policy change. Policy Sciences. 25: 275-294.

Berkes, F. 2008. Chapter 8: Climate change and indigenous ways of knowing. Sacred Ecology, Second Edition. Routledge, New York.

Berkes, F. 2007a. Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. Natural Hazards. 41: 283-295.

Berkes, F. 2007b. Adaptive co-management and complexity: Exploring the many faces of co-management. In: Armitage, D., Berkes, F., and Doubleday, N., (eds.). Adaptive co-management: collaboration, learning and multi-level governance. University of British Columbia Press, Vancouver, British Columbia, Canada.

Berkes, F. 2007c. Community-based conservation in a globalized world. Proceedings of the National Academy of Sciences. 104: 5188-15193.

Berkes, F., Armitage, D., and Doubleday, N. 2007. Synthesis: Adapting, innovating, evolving. In: Armitage, D., Berkes, F., and Doubleday, N., (eds.). Adaptive co-management: collaboration, learning and multi-level governance. University of British Columbia Press, Vancouver, British Columbia, Canada.

Berkes, F. 2004. Rethinking community-based conservation. Conservation Biology. 18: 621–630.

Berkes, F., Colding, J., and Folke, C. (eds.). 2003. Navigating social and ecological systems. Cambridge University Press: Cambridge, UK.

Berkes, F. 2002.Cross-scale linkages: Perspectives from the bottom up. In: The Drama of the Commons. Committee on the Human Dimensions for Global Change. Division of Behavioral and Social Sciences and Education. National Academy Press, Washington, DC.

Bernard, R.H. 1988. Research methods in cultural anthropology. Sage Publications Newbury Park, California.

Bradshaw, B., Holly, D., and Smit, B. 2004. Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian Prairies. Climatic Change. 67: 119-141.

Brooks, N., Adger, W.N., and Kelly, P.M. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change. 15: 151–163.

Campbell, A. 1998. Fomenting synergy: experiences with facilitating Landcare in Australia. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Capra, F. 1996. The Web of Life. Anchor Books Doubleday, New York.

Carpenter, S.R., Walker, B., Anderies, J.M., and Abel, N. 2001. From metaphor to measurement: resilience of what to what? Ecosystems. 4: 765–781.

Chamala, S. van den Ban, A.W., and Roling, N. 1980. A new look at adopter categories and an alternative proposal for target grouping of farming community. Indian Journal of Extension Education. 16: 1–16.

Cohen, S.J. 1991. Possible impacts of climatic warming scenarios on water resources in the Saskatchewan River Sub-basin, Canada. Climate Change. 19: 291-317.

Creswell, J.W. 1994. Research design: Qualitative and quantitative approaches. Sage Publications, Thousand Oaks, California.

Dale, V. H., Brown, S., Haeuber, R.A., Hobbs, N.T., Huntly, N., Naiman, R.J., Riebsame, W.E., Turner, M.G., and Valone, T.J. 2000. Ecological principles and guidelines for managing the use of land. Ecological Applications. 10: 639–670.

Daley, B.J. 2001. Learning and professional practice: a study of four professions. Adult Education Quarterly. 52: 39-54.

Diduck, A.P. 1999. Critical education in resources and environmental management: Learning and empowerment for a sustainable future. Journal of Environmental Management. 57: 85-97.

Dietz, T., Ostrom, E., and Stern, P. 2003. The struggle to govern the commons. Science. 302: 1907-1912.

Easterling, W.E., Chhetri, N., and Niu, X. 2003: Improving the realism of modeling agronomic adaptation to climate change: simulating technological substitution. Climatic Change. 60: 149-173.

Easterling, W.E. 1996. Adapting North American agriculture to climate change in review. Agricultural and Forest Meteorology. 80: 1–54.

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: 23-62.

Eastern Irrigation District (EID). 2008. Alberta irrigation districts. Available Online: http://www.eid.ab.ca/Alberta_Irrigation_Districts.htm. Last Accessed: March 10, 2008.

Eastern Irrigation District (EID). 2009. Official Brooks Aqueduct Home Page. Available Online: http://www.eidnet.org/local/aqueduct/formeid.htm. Last Accessed: January 5, 2009.

Fisk, J.W., Hesterman, O.B., and Thorburn, T.L. 1998. Integrated farming systems: a sustainable agriculture learning community in the USA. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Folke, C., Hahn, T., Olsson, P., and Norberg, J. 2005. Adaptive governance of social-ecological systems. Annual Review of Environment and Resources. 30: 441-473.

Folke, C. 2003. Social-ecological resilience and behavioural responses. In:Hansson, B., Biel, A., and Mårtensson, M., (eds.). Individual and structural determinants of environmental practice. Ashgate, UK.

Folke, C., Colding, J., Berkes, F. 2003. Synthesis: Building resilience and adaptive capacity in social-ecological systems. In: Berkes, F., Colding, J., Folke, C. (eds.). Navigating social–ecological systems: Building resilience for complexity and change. Cambridge University Press, Cambridge, UK.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., Bengtsson, J. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations. Ambio. 31: 437-440.

Fritz, R.B. 1990. Computer analysis of qualitative data. In: Lambert, E.Y. (ed.). The Collection and Interpretation of Data from Hidden Populations. National Institute on Drug Abuse. NIDA Research Monograph 98: 31-43.

Gan, T.Y. 2000. Reducing vulnerability of water resources of Canadian Prairies to potential droughts and possible climatic warming. Water Resources Management. 14: 111-135.

Gardner, B.L. 1992. Changing economic perspectives on the farm problem. Journal of Economic Literature. 30: 62-101.

Goodman, L.A. 1961. Snowball sampling. Annals of mathematical statistics. 32: 148-170.

Granovetter, M. 1983. The strength of weak ties: A network theory revisited. Sociological Theory.1: 201-233.

Gunderson, L.H. 2003. Adaptive dancing: interactions between social resilience and ecological crises. In: Berkes, F. Colding, J. and Folke, C. (eds.). Navigating social–ecological systems: Building resilience for complexity and change. Cambridge University Press, Cambridge, UK.

Hakim, K. 2005. Dealing with overlapping access rights in Indonesia. In: Colfer, C.J.P (ed.). 2005. The equitable forest: Diversity, community, and resource management. Resources for the Future: Washington, DC.

Hamilton, G. 1998. Co-learning tools: powerful instruments of change in Southern Queensland, Australia. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK**.**

Hartig, K.E., Grozev, O. and Rosenzweig, C. 1997. Climate change, agriculture and wetlands in eastern Europe: vulnerability, adaptation and policy. Climatic Change. 36: 107-121.

Hayenga, 1998. Structural Change in the Biotech Seed and Chemical Industrial Complex. The Journal of Agrobiotechnology Management and Economics. 1: 43-55.

Heimlich, R.E., Weibe, K.D., Claassen, R., Gads,y D., and House, R.M. 1998. Wetlands and agriculture: private interests and public benefits. Resource Economics Division, USDA, Agricultural Economic Report 765.

Holling, C. S. 1978. Adaptive Environmental Assessment and Management. Chichester, New York.

Holling, C.S., Berkes, F., Folke, C. 1998. Science, sustainability and resource management. In: Berkes, F. and Folke, C. (eds.). Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press, UK.

Huq, S., Rahman, A.A., Konate, M., Sokona, Y., and Reid, H. 2003. Mainstreaming adaptation to climate change in least developed countries (LDCS). International Institute for Environment and Development, London.

IISD and TERI. 2006. Designing policies in a world of uncertainty, change, and surprise. International Institute for Sustainable Development, Winnipeg, and The Energy Resources Institute, New Delhi.

IPCC. 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. Cambridge University Press: Cambridge, UK.

Kerton, S. and Sinclair, A.J. 2009. Organic agriculture: A pathway to transformative learning. In Press.

Kiptot, E., Franzel, S., Hebinck, P., and Richards, P. 2006. Sharing seed and knowledge: farmer to farmer dissemination of agroforestry technologies in western Kenya. Agroforestry Systems. 68: 167-179.

Klassen, S and Gilpin, J. 1999. Alberta irrigation in the old and new millennium. Canadian Water Resources Journal. 24: 61-70.

Koutsouris, A. and Papadopoulos, D. 1998. Extension function and farmers' attitudes in Greece. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Kovan, J.T. and Dirkx, J.M. 2003. Being called awake: The role of transformative learning in the lives of environmental activists. Adult Education Quarterly. 53: 99-118.

Krupnik, I, and Jolly, D. (eds.). 2002. The earth is faster now: Indigenous observation of Artic environment change. Artic Research Consortium of the United States, Fairbanks, Alaska.

Kvale, S. 1996. Interviews: An Introduction to Qualitative Research Interviewing. Sage Publications, Thousand Oaks California.

Lapp, S., Byrne, J., Townshend, I. and Kienzle, S. 2005. Climate warming impacts on snowpack accumulation in an alpine watershed. International Journal of Climatology. 25: 521-536.

Lee, K.N. 1993. Compass and gyroscope: Integrating science and politics for the environment. Island Press, Covelo, California.

Levin, S. 1999. Fragile dominion: complexity and the commons. Perseus Books, Reading, MA, USA.

Levin, S., Barrett, S., Aniyar, S., Baumol, W.,Bliss, C., Bolin, B., Dasgupta, P., Ehrlich, P., Folke, C., Gren, I.M., Holling, C.S., Jansson, A.M., Jansson, B.O., Mäler, K.G., Martin, D., Perrings, C., and Sheshinski, E. 1998. Resilience in natural and socio-economic systems. Environment and Development Economics. 3: 222–235.

McNamara, C. 1999. General guidelines for conducting interviews. Authenticity Consulting, LLC, Minnesota.

Manitoba Agriculture, Food, and Rural Initiatives (MAFRI). 2008. Soil management guide. Available Online:

http://www.gov.mb.ca/agriculture/soilwater/soil/fbe01s09.html. Last Accessed: March 3, 2008.

Marland, G., Pielke Sr., R.A., Apps, M., Avissar, R., Betts, R.A., Davis, K.J., Frumhoff, P.C., Jackson, S.T., Joyce, L., Kauppi, P., Katzenberger, J., MacDicken, K.G., Neilson, R., Niles, J.O., Sutta, D., Niyogi, S., Norby, R.J., Pena, N., Sampson, N., and Xue, Y. 2003. The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Climate Policy. 3: 149-157.

McIntosh, R.J. 2000. Social memory in Mande. In: McIntosh, R.J., Tainter, J.A., and McIntosh, S.K. (eds.) The way the wind blows: Climate, history, and human action. Columbia University Press, New York.

McLain, R., and R. Lee. 1996. Adaptive management: promises and pitfalls. Journal of Environmental Management. 20: 437-448.

Mezirow, J. 2000. Learning as transformation: Critical perspectives on a theory in progress. Jossey-Bass, San Francisco.

Mezirow, J. 1997. Transformative learning: theory to practice. New Directions for Adult and Continuing Education. 74: 5-12.

Mezirow, J. 1995. Transformation theory of adult learning. In: Welton, M.R. (ed.). In defense of the life-world. State University of New York Press, Albany.

Mezirow, J. 1994. Understanding transformative theory. Adult Education Quarterly. 44: 222-223.

Miller, B.D., VanEsterik, P., and VanEsterik, J. 2004. Cultural anthropology. Pearson Education, New Jersey.

Miller, G.D. and Dingwall, R. 1997. Context and method in qualitative research. Sage Publications, London.

Morse, J.M., Barrett, M., Mayan, M., Olson, K., and Spiers, J. 2002. Verification strategies for establishing reliability and validity in qualitative research. International Journal of Qualitative Methods, 1(2): Article 2.

Moser, S.C. and Dilling, L. 2004. Making climate hot: Communicating the urgency and challenge of global climate change. Environment. 46: 32-46.

Motha, R.P. and Baier, W. 2005. Impacts of present and future climate change and climate variability on agriculture in the temperate regions. North America. Climatic Change. 70: 137-164.

Myers, P. 2008. Farmer responses to weather shocks and stresses in Manitoba: A resilience approach. Master of Natural Resources Management Thesis: University of Manitoba, Winnipeg.

Olsson, P., Berkes, F., and Folke, C. 2004. Adaptive co-management for building resilience in social-ecological systems. Environmental Management. 34: 75-90.

Olsson, P., and Folke, C. 2001. Local ecological knowledge and institutional dynamics for ecosystem management: A study of Lake Racken watershed, Sweden. Ecosystems. 4: 85-104.

Ostrom, E., Dietz, T., Dolsack, N., Stern, P., Stonich, S., and Weber, E.U. 2002. The drama of the commons. Committee on the Human Dimensions for Global Change. Division of Behavioral and Social Sciences and Education. National Academy Press, Washington, DC.

Ostrom, E. 1999. Institutional capacity and the resolution of a commons dilemma. In: McGinnis, M. (ed.). 1999. Polycentric Governance and Development: Readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.

Pacala, S. and Socolow, R. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. Science. 305: 968-972.

Pahl-Wostl, C. and Hare, M. 2004. Processes of Social Learning in Integrated Resources Management. Journal of Community and Applied Social Psychology. 14: 193-206.

Pearce, K. 2009. Living with change: How Prairie farmers deal with weather variability. Master of Natural Resources Management Thesis: University of Manitoba, Winnipeg.

Pomeroy, R.S. and Berkes, F. 1997. Two to tango: The role of government in fisheries co-management. Marine Policy. 21: 465-480.

Pretty, J.N. 2002. Social and human capital in sustainable agriculture. In: Uphoff, N. (ed.). 2002. Agroecological Innovation: Increasing Food Production with Participatory Development. Earthscan Publications Limited, London.

Pretty, J.N., and Ward, H. 2001. Social capital and the environment. World Development 29: 209-227.

Pretty, J.N. 1998. Supportive policies and practice for scaling up sustainable agriculture. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Pretty, J. N. 1995. Participatory learning for sustainable agriculture. World Development. 23: 1247–1263.

Pyke, C.R. and Andelman, S.J. 2007. Land use and land cover tools for climate adaptation. Climatic Change. 80: 239-251.

Raby, S. 1965. Irrigation development in Alberta. The Canadian Geographer. 9: 31-40.

Riebsame, W.E., 1991. Sustainability of the Great Plains in an uncertain climate. Great Plains Research. l: 133-151.

Roberts, L.A. and Leitch, J.A. 1997. Economic valuation of some wetland outputs of Mud Lake. Agricultural Economics Report No. 381, Department of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University.

Roling, N.G. and Jiggins, J. 1998. The ecological knowledge system. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Roling, N.G. and Wagemakers, M.A.E. 1998. A new practice: facilitating sustainable agriculture. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Rosenberg, N.J., McKenney, M.S. and Martin, P. 1989. Evapotranspiration in a greenhouse-warmed world: a review and a simulation. Agricultural and Forest Meteorology. 47: 303–320.

Royer, A. and Gouin, D.M. 2007. Potential contribution of payments for ecological goods and services to farm income. Prepared for Agriculture and Agri-Food Canada. Available Online: www.agr.gc.ca/pol/index_e.php. Last Accessed February 21, 2008.

Runnalls, D. 2007. Adapting to climate change. IISD commentary: Opinions and insights for the International Institute for Sustainable Development. October, 2007. Available Online: http://www.iisd.org/pdf/2007/com_adapting_climate.pdf. Last Accessed March 8, 2008.

Savitch, H.V. 1998. Global challenge and institutional capacity: Or, how we can refit local administration for the next century. Administration and Society. 30: 248-273.

Scheraga, J.D. and Grambsch, A.E. 1998. Risks, opportunities, and adaptation to climate change. Climate Research. 10: 85-95.

Schmitz, A., Just, R.E., and Furtan, H. 1994. Crop insurance in the context of Canadian and U.S. farm programs. In: Hueth, D.L. and Furtan, W.H. (eds.). Economics of Agricultural Crop Insurance: Theory and evidence. Kluwer Academic Publishers, Boston.

Scrinis, G. 1998. Colonizing the Seed. Arena Magazine. 36: 41-44.

Siemens, G. 2005. Connectivism: a learning theory for the digital age. International Journal of Instructional Technology and Distance Learning. 2: 3-9

Sinclair, A.J., Diduck, A.P., and P. Fitzpatrick. 2008. Conceptualizing learning for sustainability through environmental assessment: Critical reflections on 15 years of research. Environmental Impact Assessment Review 28: xx-xx.

Sinclair, A.J. and Diduck, A.P. 2005. Public Participation in Canadian Environmental Assessment: Enduring Challenges and Future Directions. In: Hannah, K.S. (ed.). 2005. Environmental Impact Assessment: Practice and Participation. Oxford University Press, Oxford, UK,

Sinclair, A.J. and Diduck, A.P. 2001. Public involvement in EA in Canada: A transformative learning perspective. Environmental Impact Assessment Review. 21: 113-136.

Sims, L.C. and Sinclair, A. J. 2008. Learning through participatory programs: Case studies from Costa Rica. submitted to Adult Education Quarterly. 58: 151-168.

Smit, B. and Skinner, M.W. 2004. Adaptations options in agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change. 7: 85–114.

Smith, J.B. 1997. Setting priorities for adapting to climate change. Global Environmental Change. 7: 251-264.

Somers, N. 1998. Learning about sustainable agriculture: the case of Dutch arable farmers. In: Roling, N.G. and Wagemakers, M.A.E. (eds.). Facilitating Sustainable Agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, UK.

Spreen, M. 1992. Rare populations, hidden populations and link-tracing designs: what and why? Bulletin de Methodologie Sociologique. 36: 34–5.

Statistic Canada. 2001. Total area of farms, land tenure and land in crops, by province (1981-2001 Censuses of Agriculture). Available Online:

http://www.statcan.ca/english/freepub/95F0355XIE/quality.htm. Last Accessed: February 21, 2008.

Swanson, D.A. and Bhadwal, S. (eds.). 2009. Creating Adaptive Policies: A Guide for Policymaking in an Uncertain World. The International Institute for Sustainable Development, The Energy and Resources Institute and The International Development Research Centre. Forthcoming Book, Sage, New Delhi.

Swanson, D.A., Hiley, J.C., Venema, H.D., and Grosshans, R. 2007. Indicators of adaptive capacity to climate change for agriculture in the Prairie region of Canada: An analysis based on Statistics Canada's Census of Agriculture. Working Paper for the Prairie Climate Resilience Project, International Institute for Sustainable Development, Winnipeg.

Taylor, E. 2007. An update of transformative learning theory: A critical review of the empirical research (1999-2005). International Journal of Lifelong Education. 26: 173- 191.

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: 109–123.

Turvey, C.G. 2001. Weather derivatives for specific event risks in agriculture. Review of Agricultural Economics. 23: 333-351.

Tyler, S., Kelkar, U., Barg, S., Venema, H.D., Swanson, D., Bhandari, P., Drexhage, J., and Mitra, S. 2006. Synthesis and Conclusions. In: Designing policies in a world of uncertainty, change, and surprise. International Institute for Sustainable Development, Winnipeg, and The Energy Resources Institute, New Delhi.

Unger, P.W. 1990. Conservation Tillage Systems. In: Dryland Agriculture: Strategies for Sustainability. Advances in Soil Science, Volume 13. Springer-Verlag, New York.

Van Meter, K.M. 1990. Methodological and design issues: Techniques for assessing the representatives of snowball samples. In: Lambert, E.Y. (ed.). The Collection and Interpretation of Data from Hidden Populations. National Institute on Drug Abuse. NIDA Research Monograph. 98: 31-43.

Venema, H.D. 2006. The Canadian Prairies: Biophysical and socio-economic context. In: Designing policies in a world of uncertainty, change, and surprise. International Institute for Sustainable Development, Winnipeg, and The Energy Resources Institute, New Delhi.

Zentner, R.P., Wall, D.D., Nagy, C.N., Smith, E.G., Young, D.L., Miller, P.R., Campbell, C.A., McConkey, B.G., Brandt, S.A., Lafond, G.P., Johnston, A.M., and Derksen, D.A. 2002. Economics of crop diversification and soil tillage opportunities in the Canadian prairies. Agronomy Journal. 94: 216 - 230.

Appendix A: Guide for Semi-Structured Interviews

Synopsis of Interview Questions

General Information:

1. Please briefly describe your operation including both type and size.
2. How long have you been farming in this area?

Information Exchange:

3. For the following categories (a-i), please describe: Where you would find this type of information? What information have you actually received?

   a) Tillage practices
   b) Reduced chemical application or alternatives to chemical application
   c) Organic Farming
   d) Drought resistant crops
   e) How to deal with excess moisture or rain
   f) New irrigation techniques, methods, and technology
   g) Wetlands
   h) Shelterbelts

Identifying Adaptive Actions:

4. Do you practice any of the actions listed above in your farming practices? Is so, which ones?
5. Do you use any other soil or water conservation actions into your farming practices? Is so, which ones?

Learning (looking at only one action from above):

6. Is there one soil or water conservation practice that you have recently adopted? Or, if no recently adoptions: Is there one soil or water conservation practice that you like best? Or, is there one soil or water conservation practice that you works particularly well?
7. When did you adopt this practice?
8. How did you come to know of this practice?
9. Were there other practices that you considered as an alternative? How did you learn of these alternatives?
10. Why did you decide to pursue this particular action?
11. What motivated the change in your actions? What was the idea that drove this change?
12. Was there a particular event or program (i.e. social or biophysical context) that precipitated this adaptation?

13. How did you come to believe the information that motivated your action?
14. Why is it important to you that you (insert adaptive practice)?
15. What were your standards for gauging the success of this adaptive practice?
16. Have you shared your experience with others? If so, how?