Farmer Responses to Weather Shocks and Stresses in Manitoba: A Resilience Approach

Peter Myers

A thesis submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the degree of

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Abstract

This thesis explores the concept of resilience of farmers and agroecosystems to climate shocks and stresses. The objectives were (1) to identify weather-related shocks and stresses that Manitoba farmers have experienced over the past five years; (2) to determine how farmers have responded to these events, and (3) what can be learned from these responses to build resilience and reduce vulnerability to climate change. The work was based on 80 semi-structured interviews (60 with farmers, 20 with organizational representatives) in two Manitoba case study areas, conducted between August 2004 and March 2005. Interviews focused on weather-related shocks and stresses and the subsequent farmer responses in the period, 1999-2005. The findings suggest that farmers were experiencing heightened weather variability, and therefore increased vulnerability – as demonstrated by exposure to excess moisture in areas typified by moisture deficiencies ('Palliser's Triangle' area). Farmers responded to weather stresses in a variety of ways, including long and short term strategies. This response diversity increased the options available when farmers were exposed to unforeseeable future change. For example, reduced tillage, together with shelterbelts, provided complimentary methods for soil and water conservation.

However, long term adaptation was limited by economic pressures and rural decline in both population and services. Low commodity prices and an aging workforce reduced incentives to modify land use practices in ways which foster and protect ecological services. Furthermore, many response strategies where adopted for short-term economics, rather than long-term resilience and systems-orientated thinking. The research reveals that farmers think that the public under-appreciates the farmers' role in food production and environmental stewardship.

Issues of wide-scale attitudinal change and shared environmental responsibility are core issues to building agroecosystem resilience to climate change. This project assessed farmer responses using resilience indicators. These included enhancing flexibility through the creation of options; incorporating local resource management knowledge into farm practices; and incorporating and protecting ecological services into

farm practices. There was evidence of these responses in the study. However, overall farmer responses added up to less than the potential. While farmers diversified in ways that built resilience to weather shocks and stresses, systemic issues, including economic and policy disincentives, inhibited more effective resilience-building.

Acknowledgements

Firstly, I would like to thank the research participants for their valuable time and willing input without which this thesis would not have been possible. Thanks also to my committee members – Fikret Berkes (advisor), Hank Venema, Ian Davidson-Hunt and Steph McLachlan – for their insightful comments which guided me through the writing process. The support from Darren Swanson, International Institute for Sustainable Development (IISD), the Prairie Farm Rehabilitation Administration (PFRA) and my peers was also appreciated.

Thanks to the Climate Change Impacts and Adaptation Directorate (C-CIAD), Natural Resources Canada, for funding this project through a grant to the IISD (H. Venema, principal investigator). To the Resilience Project coordinators – many thanks for having faith in the work of graduate students at the Natural Resources Institute.

Contents

Appendices

List of boxes

List of figures

List of tables

1.0 Introduction

Climate change poses a significant threat to Canadian Prairie agriculture, particularly with regard to increases in weather variability. Whether environmental changes result in variations that exceed historic ranges is important (Berkes and Jolly, 2001). This is especially so when considering agricultural systems that normally operate within certain sets of biophysical conditions. When a surprise event exceeds the normal range of variation, the system will suffer a shock (Figure 1).

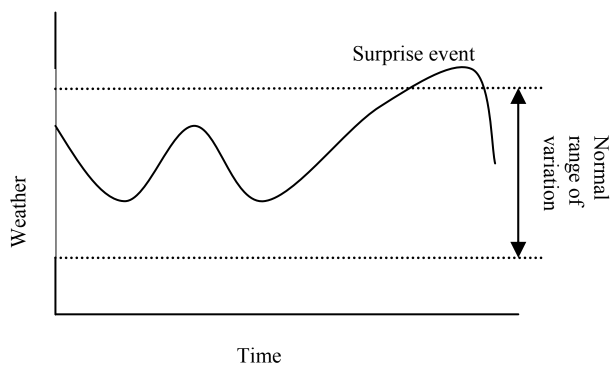

Figure 1: Weather variability and surprise

Further complicating the situation, agricultural systems function on multiple scales – that is, individual farms operate within larger ecological, economic and socio-political spheres which constitute a broader agro-food system. These systems pose their own non-weather related stresses at the farm level, and may interact cumulatively or synergistically with weather stressors. Therefore, a systems approach provides an appropriate theoretical framework for examination of past and present responses of individual farm operations and Regional Agricultural Systems (RAS) to changes in the frequency and severity of water shortages, periods of high temperature, reductions in soil quality and other extreme weather events.

These systems are inherently unpredictable due to their non-linear nature, where changes lead to multiple possible outcomes (Berkes *et al.*, 2003). Systems-thinking simultaneously challenges the logic of a simple, specific solution and endorses, rather, a broader approach that demonstrates flexibility.

Accordingly, some farms and regions seem to be more resilient to climate-related stresses than others. Resilience is *the capacity to absorb disturbances and reorganize while undergoing change so as to retain essentially the same function, structure, identity* *and feedbacks* (Walker *et al.*, 2004). On farms and within agricultural regions, resilience is integrally linked to adaptive capacity- the *ability of actors in the system to influence resilience* (Walker *et al.*, 2004). Institutions, economic resources and equity are some of the ways in which these systems respond to change in manners that do not lead to loss of future options and sustainability (Smit *et al.*, 2003).

To avoid confusion, a note on adaptation is necessary here. For the purposes of this thesis, responses are qualified as either short or long term; strategies which Berkes and Jolly (2001) refer to as coping or adaptive. However, this thesis applies the term adaptation to responses in a stricter sense, closer in interpretation to the work of John Bennett (1969). Adaptive responses are defined beyond their significant temporal investments to include major sunk capital and labour commitments, and/or shifts thereof. Furthermore the phrase 'adaptive management', which refers simply to the notion of 'learning by doing,' is distinct from what is meant by an adaptive response.

Vulnerability is the *degree to which a system is likely to experience harm due to exposure to a shock or stress*, such as climate change (Turner *et al*., 2003). The authors distinguish between shocks (system disturbances with well-defined time frames, short durations and of high intensities) and stresses (system disturbances without well-defined time frames, long durations, and variable intensities). However, vulnerability is registered not by exposure to hazards alone; it also resides in the resilience of the system experiencing the hazard (Turner *et al.*, 2003). This raises the question of whether we can learn from the ways in which agroecosystems respond to shocks and stresses to reduce vulnerability to climate change.

1.1 Project overview and objectives

The proposed thesis is part of a larger collaborative effort including the International Institute for Sustainable Development (IISD), Agriculture and Agri-Food Canada-Prairie Farm Rehabilitation Administration (AAFC-PFRA), and the University of Manitoba (U of M) through the Natural Resources Institute. The project, titled "Adaptation as Resilience Building: A policy study of climate change vulnerability and adaptation on the

Canadian Prairies," consists of three phases including a Vulnerability Analysis, a Resilience Analysis, and an Adaptation Priority Analysis (Venema, 2003).

The University of Manitoba Team is responsible for the resilience analysis phase of the project, including case studies in each of the three Prairie Provinces (Manitoba, Saskatchewan, and Alberta). The thesis includes a measure of farm and regional level stressors and the associated responses with respect to past climate variability in selected communities, a measure of resilience associated with the response findings, and a commentary on prairie agricultural policy influences on the resilience and vulnerability of farms and agricultural regions to future weather shocks and stresses. Two case studies in Manitoba lay the groundwork for future studies in Saskatchewan and Alberta.

The specific objectives of this thesis are:

- To identify climate-related shocks and stresses Manitoba farms have experienced over the past five years;
- To determine how these farmers have responded to these events;
- To determine what can be learned from these responses to build resilience and reduce vulnerability to climate change.

1.2 Thesis approach

The project takes a resilience approach, founded on the concepts of local resource management knowledge, ecological resilience, adaptive management and the systems approach. The systems approach, coupled with ecological resilience, is synonymous with the agroecosystem concept – *complex social-ecological systems, which highlight the linkages between agricultural practices and landscape processes* (Tengö and Belfrage, 2004). Agroecosystems deal with people and the environment together, based on the premise that understanding is gained through examination of interactions between component parts rather than study of the parts in isolation (Berkes *et al.*, 2003). In contrast to the dominant view, complexity is accepted as an inherent property of social-ecological systems and understanding these systems requires a framework that is 'as simple as possible but no simpler' (Einstein, as quoted in Holling, 2001).

System dynamics exhibit a complexity which can be described using Holling's adaptive cycle model. Adaptive management, or 'learning by doing', refers to the process of incorporation of feedback from changes in the environment into local resource management knowledge – particularly during the creative 'backloop' (release and reorganization phases) of the cycle (Gunderson and Holling, 2002). Over time this knowledge accumulates, simultaneously influencing the values of resources users in a way that may differ substantially from the perspective held by outside resource management (Berkes, 2004). Presuming change and diverse value sets are universal in agroecosystems, a management structure modeled on a sharing of power and flexible enough for periodic re-evaluation should be adopted – tenets embodied within the concept of adaptive co-management (Berkes, 2004).

Resilience is highest during the reorganisation and early exploitation phases of complex adaptive cycles, when connectivity between system components and cost associated with experimentation failure is low (Gunderson and Holling, 2002). Human systems, unlike ecological systems, possess the capacities of foresight, communication, and the ability to amplify change via technology (Holling, 2001) – and in this way influence risk and resilience to future shocks and stresses. In social-ecological systems, building resilience includes fostering the development of these traits, which enable the synchronization of key phases in social and ecological processes.

1.3 Methods overview

The larger collaborative effort, "Adaptation as Resilience Building[1]" took a systems approach – dealing with people and the environment together – on how agricultural systems respond to change (Figure 2). The project involved several steps. The stakeholder narratives, which provided the material for the Resilience Analysis, are the subject of the present thesis.

The stakeholder narratives helped investigate the sources of resilience, and involved three stages: case study identification and two interview components (Figure 3). Using available Statistics Canada data, a vulnerability map was generated by the Vulnerability Analysis component of the larger project. This map, showing exposure to

[1] Adaptive capacity, as defined by the overall project, is distinct from the use of the term 'adaption' with respect to response (p. 2).

climate change and adaptive capacity, was used to select the two case study areas for the Resilience Analysis (Swanson *et al.* 2007). Both case studies had high historic exposure to climatic variability but differed in their respective adaptive capacities – one high, one low (Venema, 2003).

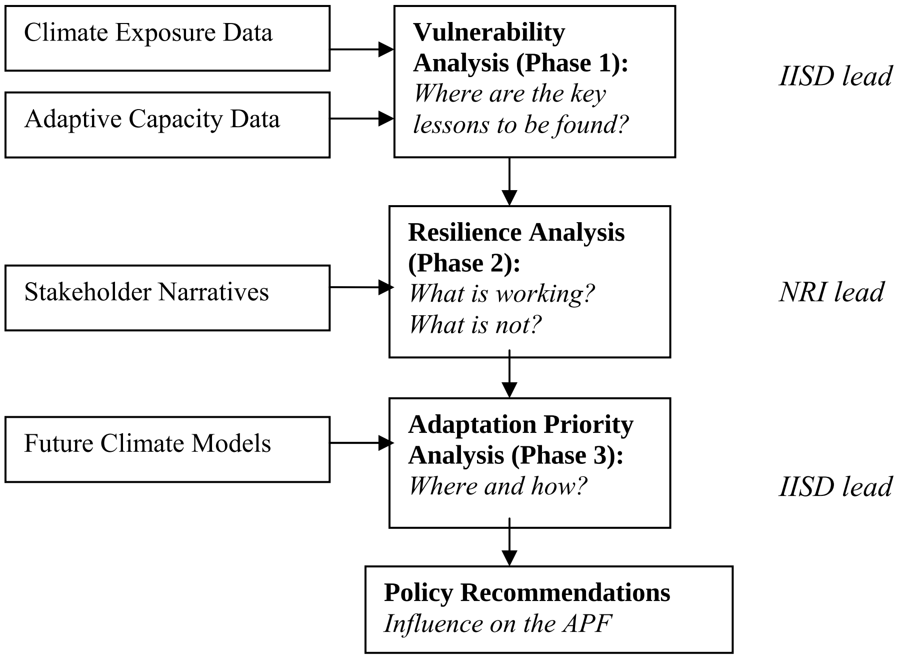

Figure 2: Project phases and chief investigators (from Venema, 2003).

The Resilience Analysis used semi-structured interviews (SSI) to explore shocks and stresses – with emphasis on those related to weather – in the case study areas. In order to engage participants in the research, they required a sense that their input was of tangible value, and it was the role of the researcher to ensure the information gathered was ultimately applied (Stringer, 1996)[2]. The researcher used techniques to:

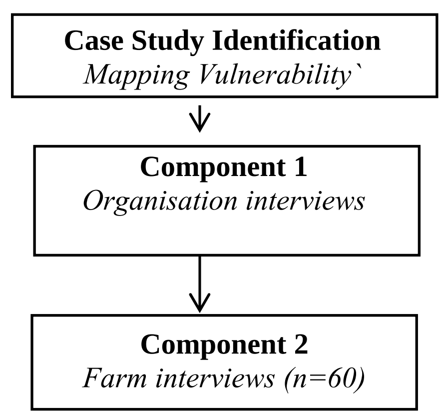

Figure 3: Methods flowchart

[2] Application of data collected was a decision involving multiple partners – including the interviewees, the researcher and the overall project members.

1. Create a 'team dynamic' between the researcher and participants (*e.g.* common goals – influence on policy decisions, changing agricultural practices).
2. Represent heterogeneity within the study area (*e.g.* interviewing different farm types, representation of diverse producer values) (Pretty and Vodouhê, 1997).

The field study had three components: the identification of shocks and stresses, the farmers' responses to the former and the influence of agricultural policy on their responses. Farmers' responses to shocks and stresses provided an indication of their adaptive capacity or lack thereof. This, in turn, helped identify the main sources of vulnerability and resilience.

Interview lines of questioning were as open-ended and free of researcher bias as possible in the interest of conserving the integrity of informant perspective. However, since the researcher could determine key areas of concern in advance, information gathering had the potential of becoming overly lengthy to ensure relevant issues were covered (Pretty and Vodouhê, 1997). The research required expression of threat perception associated with weather and climate as nested within threats in general – on both the farm and regional scales. Since this approach may have diluted the collection of weather and scale-specific data, the research consisted of two components.

Component One – Organisation interviews

- Identification of key regional issues without pigeon-holing, focusing lines of questioning for Component 2.
- Introduction of researcher and project to case study community.
- Focus on policies and programs influencing agricultural practices.

Component Two – Farm interviews

- Identification of farm level weather and non-weather shocks and stresses.
- Identification of farmer responses to shocks and stresses, focusing on those related to weather.
- Identification key aids and impediments influencing farmer responses, including policy and program influences.
- Generation of subsequent interviews through peer referral.

1.4 Research significance

Key lessons learned about resilience contribute to the Adaptation Priority Analysis phase of the overall project, which includes the formulation of agricultural policy recommendations. Major policies highlighted during interviews included the former Canadian Agricultural Income Stabilisation Program, Crop Insurance, drainage regulations and various programs supporting the practice of zero-till. The research findings also may also include implications concerning the emerging Agricultural Policy Framework (APF) for Canada.

Climate change research has historically focused on vulnerability and mitigation rather than on the concepts of response and resilience. This thesis represents a significant contribution towards the practical integration of vulnerability and resilience approaches, shifting the research and policy focus from 'what if' to 'what next'.

1.5 Research limitations

Agricultural systems were scaled for case study, and the project used a modified version of the Regional Agricultural System (RAS) model (IISD and the Environmental Adaptation Research Group [EARG], 1997) to limit the scope, focusing primary on two scales: the farm and Regional Agricultural System levels (Figure 4).

Individual farms are influenced by many exogenous and endogenous forces, where exogenous forces include those beyond the control of individual farmers (biophysical environment, government policy) and endogenous forces are those over which individual farmers have a degree of control (experience, finance, management practices). Combination of these forces result in farm decisions – in this study those made with respect to climatic stress – and the farm interviews focused on this level.

Individual farms combine to form Regional Agricultural Systems (RAS), and multiple, interconnected RAS compose the broader Prairie agroecosystem (PAE). As scale increases, exogenous forces are increasingly relegated to the endogenous sphere. Take policy decisions for instance – while individual farmers are not likely to have an affect, regional interest groups may. These groups exist at the RAS level, and interviews provided data related to formal and informal organisation. This data, coupled with the cumulative set of stress and response results gathered in each case study, provided for the resilience analysis at the RAS scale. The broadest scale – Prairie agroecosystems – contained implications for resilience at other levels, which is included in the discussion. However, defining the boundaries for research using a systems approach is problematic. Climate, ecosystem structure and function, ecosystem services, and managerial institutions vary drastically from one agricultural system to the next (Rosenweig and Hillel, 1998; Carpenter *et al.*, 2001). Following in the footsteps of previous resilience research (Berkes and Seixas, 2004; Tengö and Belfrage, 2004; Bryant *et al.*, 2000), these issues were addressed as best as possible through case study at a local level.

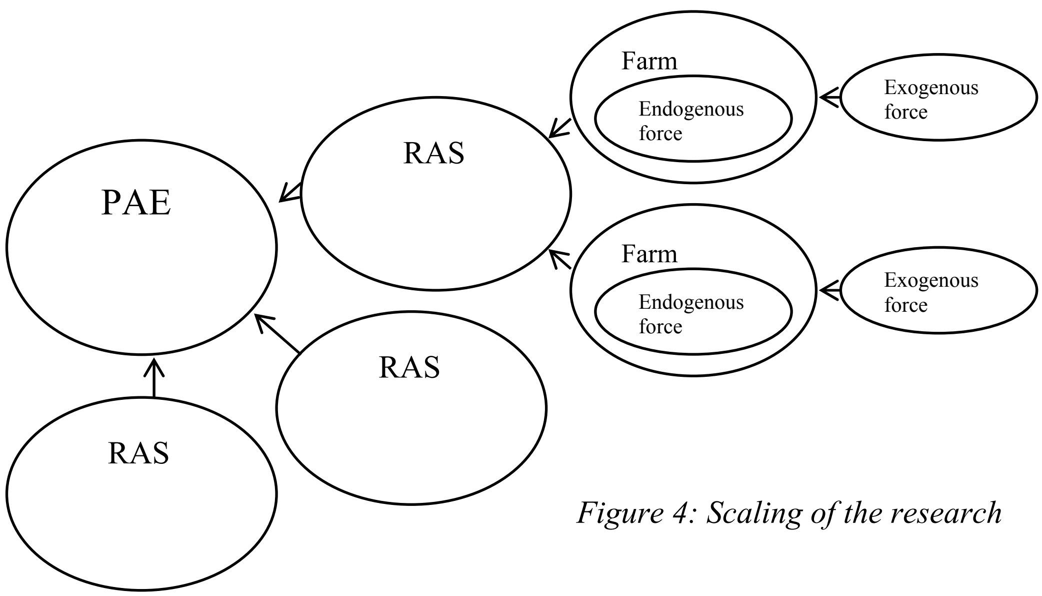

Figure 4: Scaling of the research

A key note should also be made concerning the measure of resilience. In fact, the current resilience of a system cannot truly be measured – resilience is reflected in responses to future shocks or stresses and as such, is forward-looking (Berkes and Seixas, 2004). What were measured were conditions under which a system is likely to be capable of managing risk adaptively, or surrogates of resilience. Given the inherent uncertainty associated with change in agroecosystems, these conditions are described simply as the creation and maintenance of diversity and flexibility amongst and within response options.

Finally, shocks and stresses focused on the period, 1999-2005, though historical responses (whether enacted or considered) were occasionally recorded. Therefore, the data sample is representative of the most recent memory, and results may not necessarily capture the full range of responses possible.

2.0 Research methods

2.1 The participatory approach

The field research, amounting to the interview process of the Manitoba Resilience Analysis, was carried out within a participatory framework. A participatory approach to research involved interviewees in defining and working to solve local concerns, emphasizing local resource knowledge, empowerment and sustainability in management (Chambers, 1997). While participatory approaches have a variety of positive and negative attributes (Box 1), it is widely assumed that the benefits far outweigh the costs (Ira, 1998). Traditional 'extractive' forms of research tend not to involve interviewees in design, and are inefficient since (a) they result in overly lengthy sampling to ensure the issues of interest are covered, and (b) ignore the contextual grounds for understanding and influence the process by prompting with answers (Pretty and Vodouhê, 1997).

Furthermore, outside researchers bring their own way of thinking and seeing problems (Kaplan, 1977), which may not be consistent with the views of the community – often resulting in policies and projects for which communities feel no sense of ownership or obligation (McDade,2002). Researchers gain understanding and appreciation of local perspectives, perhaps reducing their own biases, by residing and work sharing in the community where the research is conducted (Pretty and Vodouhê, 1997). These activities help guide the research process, enhance researcher credibility and help to establish trust and openness between the researcher and subjects. With regard to the latter, encouraging expertise role-reversal throughout discourse – where the researcher takes a learning role – empowers the subjects and encourages teaching and sharing with outsiders (McDade, 2002).

Box 1: Benefits and costs of using participatory methods (source: Ira, 1998)

Benefits

- Increased sense of ownership
- Improved productivity and efficiency
- Increased coverage of impact
- Increased equity and self-determination
- Increased likelihood of project continuation
- Increased cost sharing and effectiveness
- Increased appropriateness and relevance

Costs

- raised expectations
- possible distrust
- increased time and costs
- increased complexity

2.2 Field study methodology

2.2.1 Overview

Eighty interviews were conducted in two Manitoba case study areas, including twenty organisations and sixty producers (Table 1). Organisational representatives interviewed included members from Rural Municipalities, Conservation Districts, Manitoba Agriculture Food and Rural Initiatives, policy-orientated organisations and several community-based organisations. The duration of interviews ranged from twenty minutes to three and a half hours, though they typically lasted approximately an hour. Field study was conducted between August 2004 and March 2005, during which time the researcher resided within the case study areas.

Table 1: Interviews conducted between August 2004 and March 2005

	Organisation	Farmer
North	8	30
Southwest	12	30
Total	20	60

Farm types interviewed (Table 2) included mixed, livestock, grain and several specialty operations (*e.g.* PMU and organic). Sizes of the farms ranged from thirty to three hundred head for livestock operations and seven hundred to five thousand acres for grain operations – mixed farms varied depending on the predominance of either grain or livestock aspects. Farm size was difficult to stratify for several reasons (*e.g.* lack of data related to income and multi-family versus single-family farms).

Table 2: Farm types by case study area

Farm type	**North case study**	**South case study**
Grain and oilseed	9	10
Livestock	8	6
Mixed	11	14
Other	2	0

2.2.2 Case study selection

Two case study areas for the Manitoba Resilience Analysis (Figure 5) were coarsely selected using the vulnerability map produced by the IISD and PFRA in the Vulnerability Analysis stage of the overall project (Swanson *et al.*, 2007). Two layers – climate exposure and adaptive capacity – were combined in a GIS mapping exercise, carried out by the IISD in partnership with the PFRA using Statistics Canada data. Economic resources, technology, infrastructure, institutions, networks, equity, information, skills and management were used as indicators of adaptive capacity (Swanson *et al.*, 2007). Each case had high historic exposure to climatic variability, but differed in their respective adaptive capacities- one judged high, one low. While both case studies differed in their respective adaptive capacities, the researcher was not informed of the Vulnerability Analysis findings prior to the commencement of the Resilience Analysis. This decision was made in an effort to maintain objectivity during the interview period.

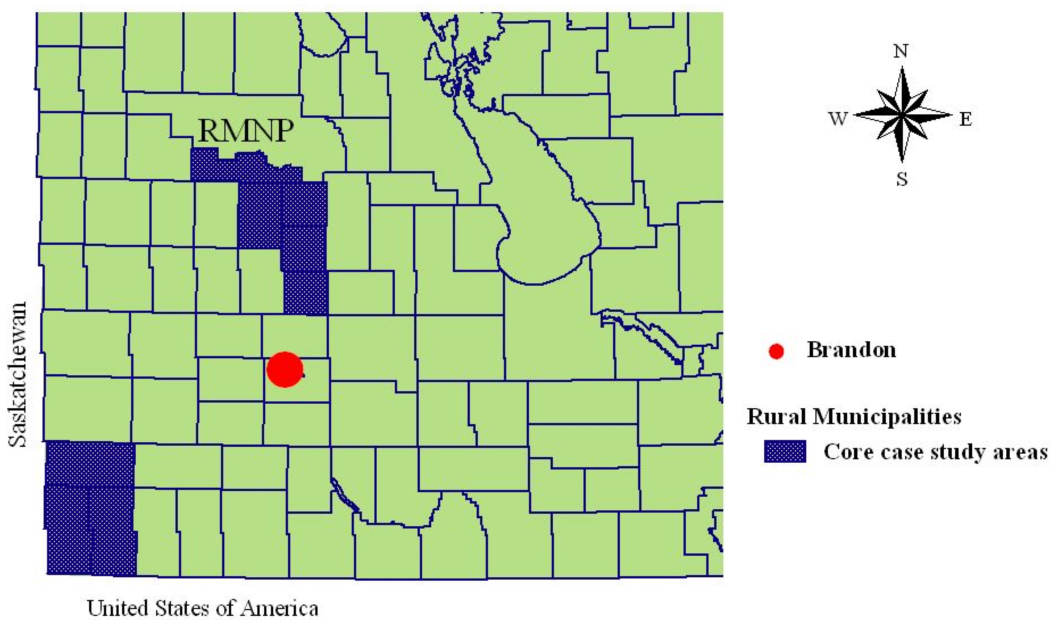

Figure 5: Two case study areas: the 'north case study' south of Riding Mountain National Park and the 'south case study' at the Manitoba borders with Saskatchewan and the United States

2.2.3 Interviewee identification

Letters introducing the study and requesting interviews were sent to Rural Municipality and Conservation District officials (Appendix I). A series of interviews conducted with councilors, reeves and district managers in both case study areas lead to subsequent producer interviews via peer referral. These peer referrals, contacted by phone, were used to generate subsequent interviews throughout the interview process. Each interviewee typically provided the names of one or two other producers and/or individuals involved within the community or local organisation. Several farmers were also interviewed on the basis of the researcher's personal contacts.

2.2.4 Semi-structured interviews and participatory tools

A generalized, flexible semi-structured interview (SSI) schedule was used, where specific lines of questioning evolved through the participatory process. SSI constituted the main participatory tool driving data collection. These interviews provided a vehicle for the use of various other participatory tools, which interviewees used without prompting from the researcher. The following participatory tools, adopted from Pretty and Vodouhê (1997), were employed by interviewees: farm and local area histories, seasonal calendars of activity, diagrams, modeling, and peer referencing. For example, farm and local histories proved useful in establishing local contexts and breaking the ice.

The main objective of the organisational interviews was to determine key regional shocks and stresses without pigeon-holing them into those related specifically to weather. Each interview identified and evaluated shocks and stresses separately (Figure 6), both to ensure adequate data coverage and avoid amalgamation of disturbances. The data highlighted key regional issues and allowed the researcher to determine how the risk of weather-related disturbance is perceived by regional management relative to other stressors. This information guided lines of questioning in the second component.

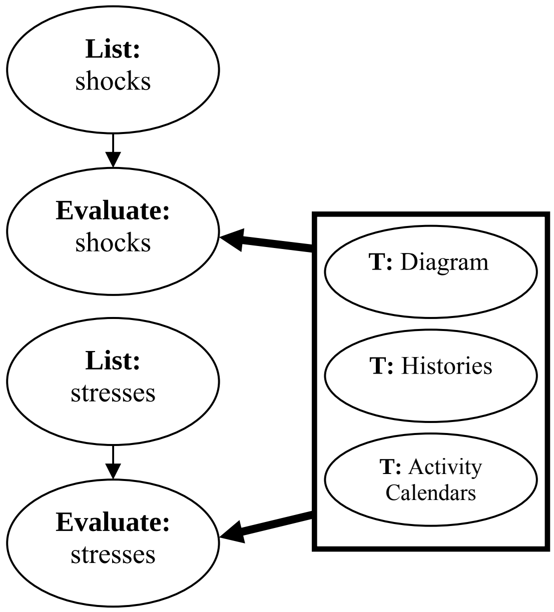

Figure 6: Component One semi-structured interviews

Interviewees were then asked to identify organisational responses to disturbance – particularly in reference to their policies and programs, if applicable. Interviews finished with a request for peer and farm referrals. The key objectives of phase one included the identification of weather and non-weather disturbances and organisational perception of subsequent farm-level response, with specific emphasis on weather disturbances.

Component two differed slightly from the first, with an increased focus on responses to shocks and stresses (Figure 7). Farmers' responses to shocks and stresses provided an indication of their ability to respond or lack thereof. This, in turn, helped identify the main sources of vulnerability and resilience. Respondent were prompted to discuss aids and barriers to their responses. Their answers provided insights into how resilience to future climate disturbance could be improved. Interviewees were also asked to comment on farm-related programs influencing their responses. Interviews ended with peer referencing.

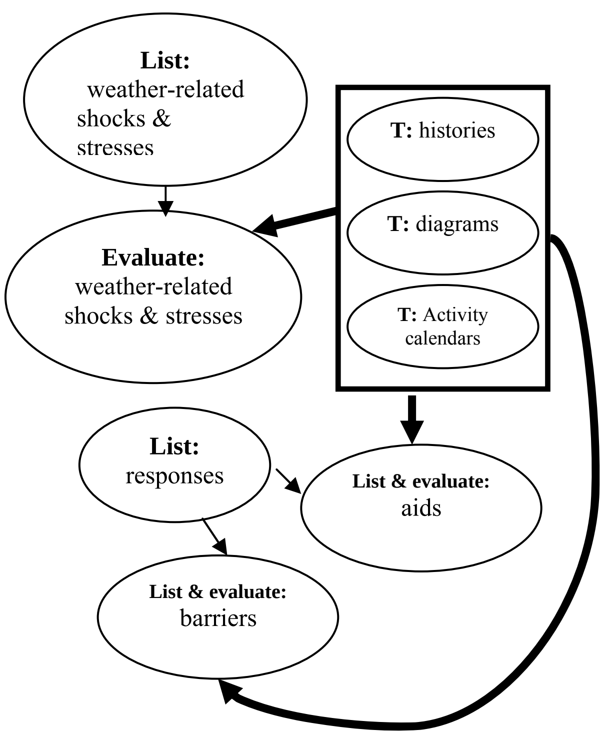

Figure 7: Component Two semi-structured interviews

2.3 Data Collection, Organisation and Reporting

Participants were asked questions according to the producer and organization interview schedules (Appendices II & III). The researcher asked follow up questions in order to prompt expansion on previous responses. Interviews were electronically recorded and notes were taken. All individual interviews were kept confidential *as per* the research consent form, which were signed by all interviewees.

The interview data – including stresses, impacts, responses and program comments – was compiled in multiple spreadsheets using Microsoft Excel™. The raw data was then sorted, filtered and tabulated. Categories were established to cluster the data and generate other tables and figures found in this thesis. These categories were established based on similarities existing within the data (*e.g.* excess moisture in different years, use of various alternative markets) and through hybridization of earlier resilience frameworks. The categories were adjusted according to input received from the thesis advisor and feedback from project partners at the IISD over the course of several workshops held following the research period.

2.4 Methodological Limitations

Participants in this study shared information which was used to formulate policy recommendations and define weather stress within the larger context of agricultural and rural issues. However, the objectives did not involve the development or promotion of social organisation by participants, and no participant was involved in decision-making regarding data application. Certain sections of the research, due to funding and project constraints, required that information be guided to some extent. SSI's were used to gather information on specific topics without spelling out exactly what these topics might be. Levels of participation are not uniform and should not be accepted without qualification. *Participation by consultation* best describes participation in this project, where

> *People participate by being consulted, and external agents listen to views. These external agents define both problems and solutions and may modify these in light of people's responses. Such a consultative process does not concede any share in decision-making, and professionals are under no obligation to take on board people's views (Pretty and Vodouhê, 1997).*

3.0 Literature review

3.1 Climate crises on the Canadian prairies: Historical and future aridity

3.1.1 Biophysical and economic context

Canadian prairie agricultural activity occurs within the Western Interior Basin physiographic region, which is the northern portion of Great Plains Eco-zone (Venema, 2006). The region compromises the north-western extreme of cultivable land in North America, typified by a natural vegetation cover of primary grassland and the fertile soils of the interior plains. Climate regimes of the prairies are classified as cold temperate and sub-arctic – these agricultural regions experience relatively long winters, short summers and low precipitation (Venema, 2006).

Although the annual precipitation for Manitoba (400-600 mm) is considered marginal for agricultural production, most falls in growing season (particularly in June) when crops assimilate it most readily. Furthermore, relatively cooler temperatures on the prairies tend to reduce the effect of evapo-transpiration from the soil. Clear skies and warm temperatures in summer contribute to sufficient growing degree-days (1700-1800 annual GDD in Manitoba) for agriculture (Venema, 2006).

Cropping on the Canadian prairies is historically associated with grain production, and while wheat, canola and barley production remain high, diversification into specialty crop production (*e.g.* mustard, dry peas, lentils) is rising. Establishment of extensive irrigation infrastructure has taken place in regions of moisture deficit, opening land to production which had previously been, and may still prove to be, agriculturally unviable (Venema, 2006).

The coincidence of favourable soils and marginal hydro-climatic conditions has resulted in a large and diverse agricultural economy on the Canadian prairies since European settlement. Canadian agriculture and agro-food sectors combined contribute 8.3% to the national gross-domestic product, with the prairies producing well over half the total value of Canadian agro-food exports (Venema, 2006).

The northern case study includes the core Rural Municipalities (RM) of Clanwilliam, Park (south), Harrison and Minto. The area is characterized by rolling terrain, lakes of various sizes, grasslands, and mixed woodlands. Agriculture is the keystone of the rural economy and activity in the area, and exhibits high diversity – cereal crops, specialty crops, cow/calf operations, feedlots of various sizes, dairy operations, mixed farming, and, more recently, several bison and deer farming operations. Tourism is also an important economic draw for the area given its proximity to Riding Mountain National Park. Hobby farms, guest ranches and outfitting operations are all active in the area given the draw of tourists to the lakes, beaches and other recreational opportunities.

Collectively, the northern case study has an average elevation of 2024 feet above sea level. The region supports a population of 2025 according to the 1996 census (Statistics Canada) and encompasses an area of 1186.19 km^2 (these numbers exclude the RM of Park – no data provided). The average winter temperature is -13.25°C and 24.25°C in summer. The region receives 471.75 mm of precipitation in a year, 360.75 mm falling as rain, 111 mm falling as snow. On average, the area has 98 frost free days.

The southern case study includes the RMs of Albert, Arthur, Edward and Brenda. Agricultural activity includes livestock, mixed operations, specialty crops and, dominantly, grain farming. Major transportation routes in the area, including highways and rail, offer good connectivity to markets in Saskatchewan, the United States and western Manitoba. Feed companies, grain elevators, implement dealers and transportation services are important employers and rate-payers in the region. Additionally, recent development of oil resources in the area has attracted several large companies which are prominent local employers and contribute significantly to the local tax base – accounting for nearly one-third of the RM of Edward's tax revenues, for example.

Collectively, the southern case study has an average elevation of 1578.5 feet above sea level. The region supports a population of 2488 based on the 1996 census (Statistics Canada) and encompasses an area of 2311.05 km^2. The average winter temperature is -11°C and 26.75°C in summer. The region receives 455.25 mm of precipitation in a year, 344.25 mm falling as rain, 111 mm falling as snow. On average, the area has 115 frost free days.

3.1.2 Historical climate and weather stress on Canadian prairie agriculture

The prairies are frequently affected by climate-related disasters, including extreme weather events such as drought, tornado, flood and hail. While no particular area is immune to the vagrancy of weather, frequency and severity of these events are regionally variable. Furthermore, areas which have historically experienced the greatest inter-annual variability in precipitation and temperature roughly coincide with the areas hardest hit by severe drought events (Venema, 2006).

Moisture deficits exist in most regions on the order of 150-400 mm a year. The prairies have historically been punctuated by drought – including those in the years 1906, 1936-38, 1961, 1976-77, 1980, 1984-85, 1988 and 2001-03 (Venema, 2006). In the eighties, drought resulted in export losses, large farm assistance payments, farm income losses and foreclosures. Specifically, in 1984-85 reduced production resulted in a loss of more than a billion in GDP, while in 1988 export losses were in excess of four billion. In the same period farm assistance was in excess of 1.3 billion – yet Manitoba Net Farm Income decreased 50% and an estimated 10% of farmers and farm workers left the agriculture sector in 1988 alone (Venema, 2006). Increasingly, the economic impacts of drought are absorbed by a much larger national economy that has grown less dependent on agriculture – in 1999 2% of the GDP came from agriculture (excluding the agro-food sector).

3.1.3 Climate change impacts: Global Circulation Models and other reports

In November 2003 the Canadian Senate Committee on Agriculture and Forestry released a Report entitled *'Climate Change: We Are at Risk'* – in which they predict increased frequency and widespread drought on the prairies resulting from future climate change. Assessments of agricultural vulnerability to climate change are largely based on Global Circulation Models (GCMs). Scenarios for the North American Great Plains, generated through the use of several principle GCMs all show an increase in temperature and decrease in soil moisture with a doubling of atmospheric carbon dioxide (IISD and EARG, 1997; C-CIAD, 2002).

Published models (Sauchyn *et al.,*2002; Nyirfa and Harron, 2002) both predict increased precipitation, but this gain is offset by increases in temperature which lead to overall loss of soil moisture through evapo-transpiration. While variability exists within GCMs, there is some consensus that the cooler, wetter models merely delay the onset of increased aridity predicted by the hotter, drier models (Wall *et al.*, 2004; Nyirfa and Harron, 2002). The regions of highest predicted moisture deficits roughly correlate with Palliser's triangle – a large triangular area, centrally located in the Canadian Prairies, historically defined as unsuitable for agriculture dating back to government surveys in the mid-1800s (Venema, 2006).

While these models represent the use of the best scientific knowledge, the projected impacts of climate change based on GCMs continue to be contested. Critics emphasize limitations of GCMs, including issues of coarse data and the utility of the information in producer decision-making processes.

GCMs estimate temperature and moisture at a coarse geographical scale, and a 'top down' approach is used to downscale to estimate future change at local and regional levels (Wall *et al.*, 2004). Questions have been raised over the validity of interpolation methods used to predict regional impacts, particularly in those regions with specific microclimates (CCIAD, NRC, 2002).

Unlike the consistent outcomes of large-scale scenarios produced by GCMs, regional and local projections for climate impacts vary widely over scale and farm type due to sensitive social and ecological system variables (Deschenes and Greenstone, 2004; IISD and EARG, 1997; CCIAD, NRC, 2002; Wall *et al.*, 2004). This has resulted in projections that report differences, both positive and negative, for outcomes in production levels, agro-climatic properties, farm systems and regional economies. Certain agricultural regions or sectors may even economically benefit from predicted long term changes in climate (Wall *et al.*, 2004; Nyirfa and Harron, 2002; Deschenes and Greenstone, 2004). These results contradict the popular view of negative welfare outcomes on the Great Plains.

Furthermore, authors have highlighted the usefulness of different types of information in farm decision-making processes (Risbey *et al.*, 1999; Bryant *et al.*, 2000; Basher, 1999). For example, climate change models which emphasize averages in temperature, precipitation and growing season – results which alone are not necessarily helpful in decision-making – are often ignored by farmers (Bryant *et al.*, 2000). Decisions and perceptions are more sensitive to recent weather and climate, including the previous years' conditions in particular, and inter and intra-annual variation are far more influential than annual averages (Risbey *et al.*, 1999; Bryant *et al.*, 2000). Risbey *et al.* (1999) constructed a model showing that Australian producers who plan tactically based on historical climate data are economically outperformed by those who use even moderately successful seasonal forecasts. These results highlight how the attribution of impacts on inappropriate scales can misinform response to environmental change (Risbey *et al.*, 1999).

Finally, the popular focus on 'global warming', often taken as synonymous with climate change, may be overshadowing other significant alterations in conditions associated with climate (Wall *et al.*, 2004). Scenarios have tended to focus on average temperatures and moisture, and factors such as growing season, timing of frost, pests and disease. However, analyses of vulnerability have pointed to variability and frequency of 'non-normal' conditions as the key attribute of climate change impacts (Smit and Skinner, 2002). For example, in a Southern Ontario climate change study farmers referred to moisture extremes (both excess and drought) with far greater frequency than references to growing season lengths or crop yields (Smit *et al.*, 1996). The future frequency, magnitude and extent of extreme weather events remain highly uncertain and represent a multitude of possible outcomes (Wall *et al.*, 2004).

3.2 Complex systems and uncertainty

3.2.1 Framing regional agricultural impacts of climate change

As noted in the previous section, regional projections of vulnerability to climate change produced from GCMs are extrapolations of coarse data gathered at larger scales, under-representing the complexity found at local levels. Assessments of climate risks require regionally specific contextualization to sensitive social and ecological variables, including micro-climatic regimes, interactions between multiple sources of shocks and stresses, risk perception and response measures.

The region known as Palliser's Triangle, mentioned in the preceding section, is projected to experience the highest precipitation variability, and magnitude of variation, on the Canadian prairies (Venema, 2006). Historically, areas experiencing high variability correlate with drought extremes. At the same time, it is expected that the prairies as a whole will soon be returning to drier conditions using proxy-historical records (*i.e.* the cyclical periods of aridity notwithstanding climate change). The timing of cyclical onset of drought, in conjunction with the anticipated climate change impacts, is expected to compound agricultural vulnerability to future transient variability and extreme weather events (Venema, 2006).

Weather and climate stresses influence vulnerability both directly, by increasing weather variability, and indirectly, by exasperating non-weather related issues (Venema, 2005). The prospect of increased frequency and severity of weather events compounds a multiplicity of other physical, economic and social shocks and stresses – stagnant commodity prices, increased input costs (*i.e.* fuel and chemical), closure of the American border to beef export, increased nutrient loads on prairie water bodies and threats to export markets related to genetically-modified crops – all contributing to widespread rural decline (Venema, 2005, 2006). These stresses originate both endogenously and exogenously depending on the scale from which they are viewed (Walker *et al.*, 2004). Many originate outside the farm scale, however, internal attributes of farms, such as personal debt or family breakdowns, influence perceptions of external stimuli, including weather conditions (Bradshaw *et al.*, 2004). As such, response options for climate and weather risks are part of a larger business risk management strategy which varies by farm type and location (Bryant *et al.*, 2000; Wall *et al.*, 2004). Decisions occur in a dynamic 'whole farm' setting where weather risks are nested within the entire suite of risks affecting an operation (Bryant *et al.*, 2000; CCIAD, NRC, 2002; Wall *et al.*, 2004).

Perception of risk by producers is an important factor in assessing climate impacts on agriculture, since farm-level decision-making incorporates these risks into operating strategies to lessen negative impacts (Wall *et al.*, 2004). Perception of climatic risk appears to vary by commodity, and studies have shown cash crops perceive higher risk than livestock producers (Wall *et al.*, 2004). A study by Alberta Agriculture (Stroh Consulting, 2005) recorded a variety of views on climate change, ranging from scepticism to definite observation of changes associated with the phenomenon.

The net impacts of weather and climate events on production and regional economies depend largely on the responses taken (CCIAD, NRC, 2002; Deschenes and Greenstone, 2004). Responses represent more than mere reaction – by taking place before and during perturbation periods, they buffer farm systems and mitigate impacts.

3.2.2 Farmer responses to Previous Climate Stresses

Broadly, the major triggers for changes to farm management strategies are economic. Successful response occurs when the cost of that action is less than the cost of the impact (IISD and EARG, 1997). It is not surprising that Smit and Skinner (2002) conclude most responses are modifications of existing farm practices and public policy processes. For example, Stroh Consulting (2005) found that income stabilisation and changes to crop types and varieties were the most common options deployed in instances where producers were responding to climate alone. From a set of Ontario farms who had 'perceived a noticeable change in climate over the last five years', Wall *et al.* (2004) found participants responded by growing different crop types and varieties, altered tile drainage, reduced tillage, changed the time of planting and enhanced irrigation systems.

A climate response typology, specific to Canadian agriculture, was developed by Smit and Skinner (2002) according to the involvement of different agencies (government, institution and producer); the intent (spontaneous versus planned), timing (reactionary, concurrent or anticipatory), duration (short versus long); spatial extent (local to widespread) and the strategies' relationship to existing processes. The four categories of responses include technological development, government programs and insurance, farm production practices and farm financial management. These categories are 'direct', while other options (*e.g.* participating in the dissemination of information) stimulate, rather than constitute, responses.

Polsky and Easterling (2001) found that farmers in areas which have experienced high variability tend to be less susceptible to variations in climate than farmers in areas of comparatively stable climates. These results support the findings of other researchers. However, the reasons for the apparent vulnerability reduction in this study are unclear. The authors state that responses to climate may actually be associated with unsustainable land use practices – such as increased fuel consumption and irrigation – which may increase exposure to climatic hazards in the long-term (Polsky and Easterling, 2001).

It has also been found that many farmers feel confident technical solutions have, and continue, to mitigate disturbances associated with climate change (Bryant *et al.*, 2000; Wall *et al.*, 2004). However, as Smithers and Blay-Palmer (2001) caution, limitations such as lengthy development periods and 'bundling' of desirable with non-desirable traits in cultivars are ways which may hamper the reliability of future technological developments.

There is no linear relationship between changes in the farm decision-making environment (*e.g.* policy, environmental, market) and farm level response (Bryant *et al.*, 2000). Farm decisions are influenced by a discreet set of key drivers, the geographical scale(s) these drivers influence, how these drivers are perceived by producers and other regional actors, and the cost associated with shifts in farm management practices. Successful response depends on the effectiveness, economic feasibility, flexibility and institutional compatibility within individual contexts (CCIAD, NRC, 2002). Decisions amount to trade offs in short term profits, effects on socio-economic structure or land use patterns and ecological sustainability (Risbey *et al.*, 1999). In summary, farmer responses occur in a complex decision-making environment, and is best examined using a systems approach.

Another typology, developed from an earlier study of resilience, provides a broader and more flexible approach for defining system responses to climate stresses. In their Canadian arctic study Berkes and Jolly (2001) define responses as either short term coping strategies or long term adaptation[3] strategies. Coping mechanisms include 'short

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[3] Recall that while the long term and short term nature of responses is applied to the findings of this thesis, 'adaption' in the sense that it is used here is not (p. 2).

term responses to situations that threaten livelihood systems, which often take the form of emergency responses in abnormal seasons or years', whereas adaptive strategies 'are the ways in which individuals, households and communities change their productive activities and modify local rules and institutions to secure livelihoods.' Furthermore, the authors go on to describe mechanisms through which coping strategies may become adaptive over time. The next section describes and justifies the use of the systems approach to understand response to disturbances, particularly in light of the complexity previously described.

3.2.3 Agroecosystems: Humans, environment and complexity

The systems approach, coupled with ecological resilience, is synonymous with the concept of agroecosystems – *complex social-ecological systems, which highlight the linkages between agricultural practices and landscape processes* (Tengö and Belfrage, 2004). Ecological and human communities are inextricably linked by human dependency on ecosystem services, and the separation of these systems is both artificial and arbitrary (Berkes *et al.*, 2003). Both communities are living systems, and it is this shared trait that validates and justifies the inclusion of humans in the environment (Capra, 1996). These systems operate interdependently, where ecological services provide for human needs while knowledge and recognition of these services promotes their sustainable use (Matson *et al.*, 1997). The rationale for using the agroecosystem approach regarding the question of climate change and agriculture relates to two arguments. One, the uncertainty and unpredictability surrounding future climate change are considered inherent traits of complex social-ecological systems. Secondly, systems theory provides methods for dealing with uncertainty, including processes which enhance biological and socio-economic diversity in agroecosystems.

The rationale for fostering diversity in complex systems is rooted in the flexibility it provides for dealing with unpredictable outcomes. While the exact outcomes of change are difficult to predict, the general outcome is expected to fall within a broader range of variability based on past experience (Tengö and Belfrage, 2004). For instance, a typical annual rainfall in south-western Manitoba ranges between 400-600 mm, but moisture deficits between 150- 250 mm are a reasonable expectation in any given year (Venema, 2005). The diversity strategy is inexact – aiming to provide and maintain a wide subset of options in the face of change. Ecologically, this is built into the system by enhancing redundancy in species with similar ecological function as well as those with keystone roles (Walker *et al.*, 1999). Socio-economically, enhancing a diversity of land use techniques and technologies buffers against stresses. The logic, after Stanford University biologist Paul Ehrlich, is that 'the first rule of intelligent tinkering is to save all the parts.'

While system diversity and complexity are not synonymous, they are strongly related. An increase or decrease in one generally leads to a corresponding increase or decrease in the other. Attempts to simplify agricultural systems through large reductions in diversity, while increasing control of production of food, fibre, fuel and income, undervalues ecosystem services such as nutrient recycling and the control of local microclimates which depend on landscape heterogeneity (Altieri, 1999). For example, Tilman and Downing (1994) suggest that high biodiversity reduces the loss of biomass during drought events and speeds the recovery back to original levels of productivity. Naeem *et al.* (1994) found diverse agroecosystems tend to exhibit higher productivity due to increased respiratory efficiency. One way of enhancing biodiversity includes the creation of edges, or ecotones, which are overlaps of habitat types that contain a mixture of species from each one (Lachler *et al.*, 1999).

However, advances favouring landscape homogeneity – including the growth of farm machinery and some of the technologies which improve input efficiency – have come at a cost to wetlands, uplands, soil and water health and quality. The United Nations Millennium Ecosystem Assessment (MA)[4] identified the acute vulnerability of dryland agroecosystems arising from loss of ecosystem services, particularly in light of climate change. The PFRA released a report in 2000 regarding the health of Canadian soil resources, finding 50% of arable land under annual crop is threatened by erosion and requires intense use of crop residue and permanent cover to maintain soil health. Furthermore, they estimate 14-40% of soil organic matter has been lost from prairie soils since cultivation began.

[4] http://www.millenniumassessment.org//proxy/document.356.aspx

Economic and market forces acting on Manitoba prairie communities have led to the overall reduction of diversity – ecologically, though the removal of shelterbelts and permanent cover, socially through the closure of schools and loss of rural services. The systems approach takes a holistic, process-orientated perspective of climate change and agroecosystems, contributing to a hazard literature which has historically tended towards either physical or human emphasises (Berkes, 2007).

3.3 Vulnerability and resilience

A selection of agricultural vulnerability literature has addressed adaptive capacity with respect to climatic variability (Bradshaw *et al.*, 2004; Smit and Skinner, 2002). On the whole, however, risk and hazard assessment methods have continued to focus on mitigation of shocks and stresses without adequately addressing the ability of actors in a system to influence resilience (Turner *et al.*, 2003).

Given the inherent uncertainty associated with change in complex systems, we seek a set of basic conditions that have allowed systems to effectively cope with change characterized by surprise and unknowable risks (Berkes, 2007). These conditions are described simply as the creation and maintenance of diversity and flexibility amongst and within response options – providing capacity for system resilience.

3.3.1 Defining vulnerability, resilience and concept linkages

Definitions and thinking on resilience are far from homogenous, and different uses of the term have led to diverse sets of conclusions and considerable confusion (Adger, 2000; Gunderson, 2000; Carpenter *et al.*, 2001). We define social-ecological resilience holistically, expanding on the definition introduced in chapter one, as the *capacity of a system to deal with shocks and stresses associated with change through processes of self-organization and adaptive learning, where the system shifts while retaining its basic function, structure, identity and feedbacks* (Walker *et al.*, 2004).

Vulnerability to a shock or stress can be thought of as the inverse of resilience in a way (Holling, 2001; Berkes, 2007), or as *the risk of negative consequences associated with agricultural shocks and stresses which cannot be mitigated through the employment* *of current adaptive measures* (Rosenzweig & Hillel, 1998). As indicated in the definition, vulnerability is registered in two ways: through exposure to a shock or stress and in the resilience of the system experiencing the hazard (Turner *et al.*, 2003). The resilience approach places emphasis on how to deal with hazards, and as such gives insights on how vulnerability can be reduced through an increase in resilience (Berkes, 2007).

As Berkes (2005, 2007) points out, resilience thinking is important to vulnerability in multiple ways, including:

- Provision of an integrated, holistic approach for evaluation of hazards in human-environment systems. This is consistent with the 'all-hazards' trend in vulnerability literature described by Hewitt (2004);
- Placing emphasis on the ability of systems to deal with hazards via response and absorption; and
- Shifting focus onto future shocks and stresses, both uncertain and unknowable, to help guide the development and evaluation of adaptive policy options.

3.3.2 Resilience-building processes in complex systems

Building resilience accounts for multiple possible outcomes of change via responses which enhance flexibility (Berkes *et al.*, 2003) – in this way, a system may either respond to or absorb a disturbance. The surrogates of resilience – including local resource management knowledge, adaptive management, ecological resilience and the systems approach (the latter two discussed in the previous section) – provide the capacity for stakeholders within a system to respond. In other words, resilience provides opportunity for actors in a system to influence shocks and stresses through a diverse set of response options.

Resilient social-ecological systems exhibit two key properties: the ability to self-organise and the capacity for adaptive learning/management. The coupling of these properties with maintenance of diversity results in sustainability (Berkes *et al.*, 2003). Complex systems respond to shocks and stresses in multiple ways – including absorbing, learning and reorganising after impact (Berkes, 2007). When this occurs, we can learn from shocks or stresses and incorporate the lessons through feedback mechanisms (Figure 8).

Self-organisation incorporates feedback stemming from system memory. Ecological memory includes biological legacies, mobile links, and support areas for those links (Nyström and Folke, 2001). Social memory refers to the long-term communal understanding of the dynamics of system change and the transmission of this knowledge over time (Berkes *et al.*, 2003). It is capable of operating at a much greater pace than ecological memory due to the human traits of novelty, innovation and foresight (Gunderson, 2000). The direction of self-organisation is difficult to predict due to high number of possible recombinations of system components and the differential success and failure of those experiments (Berkes *et al.*, 2003).

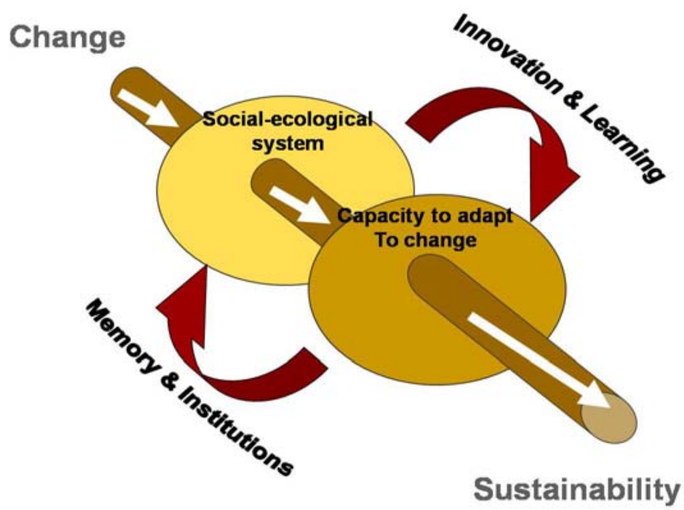

Figure 8: Self-organisation of complex systems undergoing change (from Berkes et al., 2003)

In the context of agroecosystems, a specific form of social memory termed *local resource management knowledge* is of particular interest (Venema, 2003). Local knowledge is 'derived from the direct experience of labour process which is itself shaped and delimited by the distinctive characteristics of a particular *place* with a unique social and physical environment' (Kloppenburg, 1991). People who work directly with resources have intimate knowledge of resource requirements of local conditions. In other words, they are sensitive to context and complexity. This provides the knowledge holder with an ability to practically assess diverse management options. The ability to assess, select and deploy from a variety of management strategies constitutes adaptive management. Ethnoscientists have come to regard farmers as 'keen observers of the environment' (Kloppenburg, 1991) who, through experimentation with new technologies and adaptive management approaches, essentially conduct research as part of their daily life. However, resilience processes must be fostered – they do not operate in an ideal, constant environment – complex, dynamic system variables create barriers to future response.

A Cartesian, agro-industrial approach to agricultural research is widely emphasized. For example, The Council for Agricultural Science and Technology states that 'dependence on case studies reflects a paucity of solid factual information' (as cited in Kloppenburg, 1991). Kloppenburg (1991) characterizes the dominant voice as technocratic and reductionist; a perspective which intensifies the notion of farmers as recipients, rather than producers, of valid knowledge. This offers a potential explanation for widespread dissatisfaction amongst producers with current agricultural problem-solving. The Cartesian approach actively inhibits the holistic perspective necessary for understanding highly variable social and biological systems, and leads to a fragmented understanding of complex systems, shocks and stresses. Busch (1984) recognizes that 'the problem is not that scientific and technical truths are relative, but that they are partial.'

Local knowledge has no credibility without validation by scientists, and the role of case studies is largely one of 'gap-filling' areas where scientific research cannot practically be applied or has yet to be. Cartesian science puts emphasis on trans-locality – the drawing of generalizations to maximize efficiency. Koppenburg (1991) coins these types of understandings 'immutable mobiles', typified by partial understandings of widely dispersed, similar phenomenon. Conversely, local knowledge is preoccupied with production of 'mutable immobiles', where changes in property are inherent and context-specificity links understanding to localities. It is clear on the basis of these two interpretations that different forms of knowledge compliment, rather than exclude, one another. A holistic view is realized through dialogue between diverse knowledge systems.

Experiential knowledge is generally transmitted either orally or through mentorship (Ingold, 2000). In instances where transmission ceases, the knowledge dies with the last generation of users. Reductions in transmission within agricultural communities may be occurring for several reasons. The exodus of farming youth from rural Manitoba may result in future knowledge 'bottlenecks'. Economic limitations, associated with market standards and competition, have contributed to abandonment of numerous farming methods and intensified land use. In an anecdotal conversation with a young organic flax farmer, he recounted how his otherwise Grade 1 flax seed was demoted to Grade 3 – for a financial loss of $1500. The crop was demoted due to 'impurities' from having been intercropped with black medic. The Black Medic was sown as a cover crop which served the dual purpose of fixing nitrogen in the soil and providing browse for his bison following the flax harvest.

The strength of diversification strategies, such as the one described in the example above, is the buffering of business risk, including variability associated with both weather and non-weather disturbances (Bradshaw *et al.*, 2004). While these strategies are identified as potential responses to variability associated with climate change, uptake is not well understood (Bradshaw *et al.*, 2004). Ironically, a closer examination of farmer perspectives on diversification suggests that it might be less a lack of understanding on their behalf and more a lack of attention to what farmers with important diversification experiences are saying. Bradshaw *et al.* (2004) looked at perceived strengths and limitations of diversification strategies to better understand adoption on the Canadian Prairies between 1994 and 2002. The key limitation, unsurprisingly, was a perception amongst producers that an economic benefit is required in the form of lowered production cost, higher return, reduced business risk or some combination of these factors. However, crop diversification divides operations – which reduces the potential revenue in a given year (as compared to operations producing a couple of high priced crops) and decreases the benefits associated with economies of scale. Alternating cropping patterns, such as setting up crop rotations, often involve a trade-off between lower returns and a decrease in business risk. This long term focus of diversification, coupled with high start up costs and the burden of needing to learn to produce and market a new crop, may negatively influence uptake (Bradshaw *et al.*, 2004). As such, ecological services, which provide resilience during major periods of perturbation, are declining in quality and diversity.

Kloppenburg (1991) calls for (a) linkage of local knowledge literature described as 'disparate across time and space' and (b) the need for articulation of partial realities 'to accomplish in conversation what they fail to do in isolation.' This dialogue requires interaction and responses across scale and institution. Inter-scale processes are critical to responses and decisions made at the farm-level for several reasons (Bryant *et al.*, 2000), though literature concerning climate response has focused on the farm community (Burton and Lim, 2005). Firstly, in order for the processes which foster resilience to operate effectively, variability associated with change cannot dramatically exceed historical norms (Nyström and Folke, 2001). Changes related to frequency, magnitude, duration, and spatial distribution of climatic disturbances which exceed these thresholds determined by past experience increase vulnerability (IISD and EARG, 1997). These findings suggest localized responses alone will not resolve climate change issues in agriculture. Secondly, processes of globalisation affect agri-business, highlighting the role of national policy in shaping international political economy. Specifically, adaptation is linked to technological advancement and trade liberalization policy objectives (Burton and Lim, 2005). Technological developments, enhanced production management strategies and financial incentives represent aids to adaptation at the farm scale (Wall *et al.*, 2004).

Resilience building occurs within the system being examined and within what Holling (2001) describes as 'panarchy'. Panarchy refers to the nested nature and composition of systems – smaller subsystems operating within larger contexts (Figure 4, p. 7). Several typologies outline how resilience is built into complex human-environment systems. Collectively, they include:

- learning to live with change and uncertainty, or expecting the unexpected through the establishment of various tools and behaviour (Berkes, 2007; Hewitt, 2004);
- nurturing ecological, social, political, economic and cultural diversity to increase options (Berkes, 2007; Ullsten *et al.*, 2004);
- increasing the range of knowledge for learning and problem solving (Berkes, 2007; Ullsten *et al.*, 2004);

- creating opportunities for self-organisation through local organisations, cross-scale linkages and problem solving networks (Folke *et al.*, 2002);
- planning for changes likely to occur (Ullsten *et al.*, 2004); and
- communicating the societal consequences of recent changes (Ullsten *et al.*, 2004).

Berkes and Jolly (2001) conclude that expectation based on historical climatic variability plays a key role in the development of social-ecological resilience to periodic shocks and stresses, and determines its level of flexibility. Building agroecosystem resilience to the 'wicked problem' of climate variability can be managed to enhance future respondability, through policy and land use management decisions made across scales.

3.4 Policy innovation, complex environments and wicked problems

The possible consequences of climate change for agriculture constitute a wicked problem – *one with no definitive formulation, no stopping rule, and no test for a solution* (Ludwig, 2001). Wicked problems cannot be separated from the issues of value, equity and social justice. The pursuit of objectivity tends to sideline these factors, though they are often the basis of decision making processes (Ludwig, 2001). Conventional scientific approaches, which attempt to reduce the complexity of such problems by dealing with them on a piece-by-piece basis, are unsuitable to an investigation of resilience; complex systems tend to contain diverse perspectives where one rarely proves to hold greater validity than another (Berkes, 2004). In fact, the arbitrary separation of the social and ecological has led to attempts to establish human-dominated systems characterized by technological fixes, economism and command-and-control management (Berkes, 2004; Ludwig, 2001; Jackson and Piper, 1989).

In contrast, complexity is accepted as an inherent property of social-ecological systems and integral to gaining an accurate understanding of these systems (Holling, 2001). Non-linearity, scale, self-organization and thresholds are all traits of complex systems that contribute to an increased complexity which limits certainty and predictability (Berkes *et al.*, 2003; Tengö and Belfrage, 2004). Methods dealing with complexity have emerged in the literature, which promote the inclusion of multiple perspectives, recognition of values and fostering diversity in resource management. These approaches to research create a common language that leads to meaningful dialogue and, in ideal circumstances, may lead to a shared vision (Mitchell, 2002) – helping to understand complexity. The essence of the climate change problem is an emergent property, and lies in the relationships and processes between system components, where solutions are best sought using a systems approach (Jackson and Piper, 1989).

3.4.1 Contextualizing agricultural livelihoods and past policy measures

Many Canadian producers are not in a position to respond to the vagaries of weather or to absorb the costs associated with environmental regulation, such as those associated with greenhouse gas emissions. International policy has focused too heavily on greenhouse gas reduction, while discourse on technology which may foster adaptation has lagged (Burton and Lim, 2005; Basher, 1999). The farm income crises related to stagnant commodity prices and export-orientated agricultural trade policies are strongly correlated to grain, oilseed and hog production (Venema, 2006). These sectors equate with the producers that have taken the hardest economic hit, relative to domestic commodities such as dairy, eggs and poultry (Venema, 2006). While 98% of agricultural operations are still family farms, 73% of household incomes on these operations are generated through off-farm employment (AAFC, 2003). Furthermore, between 1996 and 2001 the number of farms in Canada decreased 10.7% (Martz, 2004). Suggesting family farms can cope with increased weather variability, in light of severe concurrent economic stress, is optimistic indeed.

Past adaptation to cumulative economic and physical stresses occurred during the dust-bowl of the 1930s (a period of drought which affected 7.3 million acres), including the distress migration of a quarter of a million people (Goodwin, 1986). The establishment of the Prairie Farm Rehabilitation Administration (PFRA) and Canadian Wheat Board (CWB) were significant federal policy measures that decreased the exposure to drought and poverty, due to poor land use management strategies and the vagary of international commodity prices for wheat and barley (Venema 2006).

Now, as then, prairie agriculture faces an exhaustion of conventional program options. There is evidence of increased reception to new policy options that expand rural livelihoods beyond traditional prairie agriculture, including energy production and environmental stewardship. Crafting these policies to increase resilience and reduce vulnerability is the challenge. However, subsidies and insurance against climate risks may be leading to farm-level decisions that increase exposure to shocks and stresses by inhibiting resilience-building (McLeman and Smit, 2006). Institutional and political factors have both been criticised for taking a symptomatic approach farm-level risks associated with climate change and variability, possibly increasing the long term vulnerability of Canadian agriculture (Bryant *et al.*, 2000). Agricultural subsidies and insurance provide an appropriate example.

Crop Insurance (CI) compensates producers in below average years for losses incurred due to pests, disease, weather events. In Canada, the program is subsidized 50% by government, on average, while producers pay into a pool for the other half. New Zealand removed multiple subsidies, including CI, resulting in adoption of adaptative response. Prior to CI discontinuation farmers were clearing marginal land for pasture, applying excessive fertilizer and overstocking pastures (McLeman and Smit, 2006). Production intensity, development of new/marginal lands, fertilizer use and cropping of high risk land all decreased when subsidies were eliminated. Furthermore, diversification increased over the same time period. Seeding of lower yielding and more robust varieties, forage seeding, income sources all increased, while concentration of crops in one spatial area decreased. Removal of subsidies reduced three types of hazards according to McLeman and Smit (2006): a *morale* hazard (indifference to loss or risk), a *moral* hazard (a deliberate action that increases risk or is known to be high risk) and the *physical* hazards (the use of unsustainable land use practices).

On the other hand, Bradshaw and Smit (1997) argue that while agroecosystem health in New Zealand may have improved in the short term, both fertilizer use and land development expenditures seem to be rebounding. The increase in individual risk, reduced security and increased economic pressure brought on by tighter profit margins exemplify the complexity of push-pull factors linked to policy and program amendment (Bradshaw and Smit, 1997).

3.4.2 Responding to climate change: Recommended policy directions

The government role in resilience-building includes programs and subsidies for action, provision of information on risk reduction, research programs and Crop Insurance and income stabilisation programs (Wall *et al.*, 2004). However, in assessing these options policy makers must consider the sensitivity of agriculture to different climate variables, who is involved in the response, which options are worth promoting, the likelihood of uptake, where responsibility for costs lay and the influences of change on culture and livelihood (CCIAD, NRC, 2002). In regard to responsibility, for example, Smithers and Blay-Palmer (2001) highlight the importance of government and research roles in the advancement of technology.

However, technological strategies such as development of drought or frost tolerant varieties and supporting practices to conserve soil moisture are not enough. Venema (2006) advances the hypothesis that recent evidence suggests prairie agriculture is not sustainable and requires more aggressive policy innovation. Policy changes advanced by analysts include reform of subsidies to reflect actual risks arising from climate, linking assistance to soil conservation, establishing education programs encouraging sustainable land use, taxation of water by volume for irrigation and regulation of water use for conservation purposes (IISD and EARG, 1997). A two-pronged approach is central to these reformations, including strategies which both mitigate disturbance, and aid response where avoidance was not an option.

Building on the previous criticism of over-simplification (*e.g.* projecting coarse GCM data on regional scales), more complex information needs to be provided to avoid decisions based on limited data – particularly in light of the uncertainty surrounding changes to weather variability (Risbey *et al.*, 1999). The simplification of systems may lead to lack of consideration of cross-scale interactions, misattribution of cause and effect and lack of context, which influence response processes.

Economics also remain the key factor to farmer responses to shocks and stresses – producers expressed the view in an Alberta study that they would not implement change without adherence to a positive influence on their bottom line (Stroh Consulting, 2005). On the other hand, 54% of the farm participants also said climatic changes where a factor in their decisions. With increased information, triple bottom line accounting (*i.e.* calculating the social, environmental and economic costs of responses) might be expected to play a larger role in farm decision making processes. Federal-provincial land and water resource management policies must employ economic instruments that acknowledge the values of ecological services – an area of innovation deemed critical by the MA to reduce agroecosystem vulnerability (Venema, 2006). Assigning value to agroecosystem services are the responsibility of both producers and consumers of agricultural products.

Sustainable management of agroecosystems given probable historical and possible future climate hazards depends on several requirements: responding to the amplitude of climate change and variability (Sauchyn and Beaudoin, 1998), understanding of past and future trends and variability in climate (Sauchyn *et al.*, 2002) and a policy framework to reduce impacts of drought and increased aridity which support adoption of soil and water management practices to climatic variability (Sauchyn *et al.*, 2002). Self-organisation, adaptive management and relevant information help address these requirements, while an adaptive policy approach underpins and supports these processes.

Swanson *et al.* (2007) outline the characteristics of adaptive policy, which are 'devised not to be optimised for a best estimate future, but robust across a range of futures' (Walker *et al.*, 2004). Adaptive policy is akin to adaptive management – both are responsive to new information as it becomes available. Explicit incorporation of a 'learning by doing' component in policy formulation recognizes the inevitability of policy change and requisite incorporation of flexibility. In order for the integration of periodic change to become a part of the larger recognized policy process (*i.e.* to reduce the risk of *ad hoc* decion-making), specific rules and regulations must be in place. There are two means by which a policy can be made adaptive in light of surprise, including increased periodic review and assessment, and by intervening at opportune times during complex adaptive cycles (Gunderson and Holling, 2002).

Hollings' (2001) model of complex adaptive cycles (Figure 9) suggests that complexity is best understood not as a large number of interacting *components*, but through a smaller number of controlling *processes*. Complex systems cycle through the processes of organization, collapse, and renewal depending on the status of three key

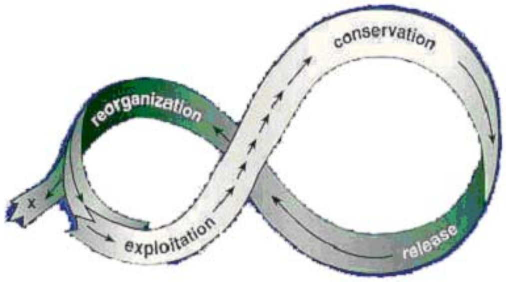

Figure 9: The complex adaptive cycle (from Holling, 2001)

properties: potential, connectivity and resilience (Gunderson and Holling, 2002). As the exploitation phase progresses, potential accumulates through the consolidation, or increased connectedness, of resources. However, as connectedness increases, so does rigidity in the system, which lowers the threshold at which the system is overcome by a surprise event (*i.e.* lower system resilience). Disturbance collapses the system, reducing both potential and connectedness. It is during this release and reorganization phase that a window for innovation occurs – system components recombine in novel experiments, many of which fail. However, at this point in the cycle the cost of failure is low due to the corresponding low connectivity, and system resilience is high. The experiments that survive compliment reorganisation stemming from larger systems cycles. That is, these cycles of 'creative destruction' are influenced by larger cycles within which the system is nested, and by smaller cycles nested within the system – connections across scale referred to as 'panarchy' by Gunderson and Holling (2002). The larger, slower cycle has a stabilizing effect referred to as 'memory' while smaller, faster cycles can cause the larger system to collapse through processes referred to as 'revolts'. In this way, the panarchy is both a creative and conservative concept (Berkes *et al.*, 2003). Importantly, the cyclical nature of the model and the role of the backloop serve a dual purpose: organising ideas on complexity in social-ecological systems, and providing an evaluation tool for policy intervention aimed at increasing system resilience.

The next two chapters examine the results from two Manitoba case studies to assess shocks and stresses over a five year period (1999-2005), evaluate the impacts on these agroecosystems, and to determine what area producers did in response. These results are used to draw conclusions on system resilience in these agricultural regions and guide policy interventions aimed at reducing vulnerability.

4.0 Shocks, stresses and impacts

Weather-related shocks and stresses figured prominently in the results, including five of the eight stresses or shocks mentioned with a frequency greater than or equal to twenty (Table 3). That being said, the interview protocol specifically targeted weather shocks and stresses as well as shocks and stresses in general.

It should also be noted that the quantification of the stresses in Table 3 refer to frequency, and not severity, of each stressor. Although bovine spongiform encephalitis (BSE) is listed fifth in the table, many farmers refer to it as the most prominent stress – particularly in the case of livestock producers. Take the following horse breeder, who said:

> 'Due to BSE the cattle guys stopped buying riding or rodeo stock from us, they're not taking on young horses - when BSE hit, phone calls for ranch horses just stopped - BSE affected more than just cattle guy – it impacted spending in small towns (*e.g.* Coop store) – our cash flow is cut off because a lot of rodeo guys tend to be ranchers' (Respondent 16).

Another producer cited dealing with programs as a stress (Respondent 11), alluding to the political pressure associated with increasing production. Their explanation of the now-defunct Gross Revenue Insurance Plan is found in Box 2.

Box 2: Respondent 11 on production, efficiency and policy

'I've made a good living on a small farm - never had more than 90 head or 600 acres - why is it that a 600 head operation can't make it? – Crop Insurance doesn't cost that much - and if it's too wet, they'll give you $50/acre - you can hold the seed and use it the next year, if you haven't fertilized, you can abort and collect - big guys can't do that - they have constraints such as fall fertilizer application - if the nitrogen's on, they cannot recoup their inputs with $50/acre - the same thing happens in the fall - I can wait for canola to hit 9% moisture, whereas they often cannot - I've only had to dry my grain twice in my life - I don't need aeration/dryers - Mother Nature takes care of it - I might not get rich, but I'll eat - one editorial I read stated that all little farms are inefficient and that they ought to be abolished - I applied for GRIP and didn't get a cent – they said I made enough - so who is inefficient? – it's the big operations that need better coverage - small farms are efficient and don't waste chemical/feed/inputs, we don't have problems getting the crops off - I've had better luck with the weather than any government program.'

Table 3: Frequency of shocks and stresses affecting farms in two case study areas (note: number of stresses may exceed sample size due to multiple occurrences in different years)

shocks and stresses (rank order)	**north (n=30)**	**south (n=30)**	**total (n=60)**
excess moisture	48	60	108
low commodity prices	17	22	39
high input costs (*i.e.* fuel and chemical)	16	19	35
heavy rainfall	17	16	33
BSE	16	15	31
frost	21	6	27
drought (≥ one growing season)	5	15	20
dry period (≤ one growing season)	10	10	20
cold summer temperatures	9	3	12
late snowfall	3	5	8
heavy snowfall	4	2	6
wet fall	2	4	6
weather variability in general	0	6	6
increase in machine costs	2	4	6
warm winter temperatures	4	1	5
hail	3	2	5
rural depopulation	3	2	5
bovine TB	3	0	3
rise in the Canadian dollar value	2	1	3
low buying power	1	1	2
rise in interest rates	0	2	2
collapse of pregnant mare urine	2	0	2
loss of business partner	2	0	2
high speed winds	2	0	2
fire/lightening	1	1	2
American protectionism	1	0	1
health care degradation	0	1	1
conflicts with other local industry	0	1	1
cool spring temperatures	0	1	1
high cost of freight	0	1	1
cost of supporting dependents	0	1	1
market downturn in bison and elk	0	1	1
dealing with programs	1	0	1
Totals	**195**	**203**	**398**

Other respondents found the psychological stress and pressure to increase production the hardest to cope with.

> 'The government is moving in the wrong direction - farming is turning into too much work - the biggest stress is that you are always tied to the operation, there are always things to do – we (my husband and I) cannot travel together to visit relatives in Europe' (Respondent 10).

Respondent 50 summarized the finding that, generally speaking, non-weather stresses have a greater impact than weather stresses: 'non-weather stresses far outweigh weather stresses - we're fourth generation - we've learned to deal/live with the weather - there's no way to deal with these other things - they cause more stress than the weather.'

4.1 Key impacts of weather, non-weather and cumulative stresses

Tables 4 and 5 describe the key impacts associated with the top weather and non-weather stresses. Producers in both case studies highlighted economic depression, community degradation and increased stress as impacts associated with non-weather events. Seasonal issues of lost productivity and disease were key impacts associated with weather stresses. The seasonal nature and perception of weather shocks and stresses supports the findings of several researchers discussed in the literature (Risbey *et al.*, 1999; Bryant *et al.*, 2000), where variability and recent weather outcomes are far more influential than long term trends and averages. The perspective also illustrates that weather events are more an exasperator than direct cause of current social and financial decline in rural agricultural Manitoba.

The participants highlighted two major points concerning the cumulative impacts of stresses, including:

1. That decreased yields and lost inputs *in conjunction* with low commodity prices and high input costs have aggravated the problem of tight economic margins and the ability to finance operations; and
2. That initial weather stresses increase vulnerability to *future* weather events.

Table 4: Top ranking stresses and key impacts (northern case study)

	top stresses (n=30)	top three impacts
Weather stresses	excess moisture (48)	Late sowing or harvest (15)
		unsown acres (13)
		increase in weeds (13)
	frost (21)	lost yield (11)
		lost grade (10)
	heavy rainfall (17)	lost yield or grade (9)
		flooded out acres (8)
		Late sowing or harvest (4)
	dry period (10)	lost yield (4)
		feed shortage, low quality (3)
	cold summer temperatures (10)	immature crops, disease (5)
		lost yield or grade (4)
Non-weather stresses	low commodity prices (17)	tight margins (4)
		cash flow problems (3)
	high input costs (16)	tight margins (5)
	BSE (16)	decreased the value of herd (11)
		increased herd size (9)
		reduced income, cash flow (7)

Table 5: Top ranking stresses and key impacts (southern case study)

	top stresses (n=30)	top three impacts
Weather stresses	excess moisture (60)	increase in weeds (12)
		unsown acres (11)
		lost yield (10)
	heavy rainfall (16)	unsown acres (10)
		flooded out acres (8)
		lost yield or grade (6)
	drought (15)	lost yield (5)
		feed shortages (3)
		insect problems (3)
	dry period (10)	lost yield (5)
		feed shortages (2)
Non-weather stresses	low commodity prices (22)	tight margins (6)
		hurts community (6)
		increased stress (4)
	high input costs (19)	tight margins (6)
		hurts community (2)
	BSE (15)	decreased value (10)
		reduced income (6)
		increased stress (4)

The following narratives highlight the concerns of the first point:

> 'The synergy between the three-fold impact of decreased yields (due to weather) and market prices along with high input costs will really hurt next year when there is no grain to market' (Respondent 7)
>
> 'There were the high fuel and high fertilizer costs – (which were) all input in '05 - then no income (due to flooding)' (Respondent 43)

Holling's (2001) theory of panarchy, or interaction between scales in complex systems, potentially explains how these cumulative effects occur. High input costs and low commodity prices, associated with market pressures systems larger than the farm scale, are compounded by climatic production failures at the farm level. The outcome is an increased vulnerability to tight economic margins.

Regarding the second point, the following narratives exemplify how earlier stresses can exasperate the effects of ensuing shocks and stresses.

> 'Single events can upset cycles so much - for example, a wet fall means spring stubble, which leads to late seeding and immature crops – which are more susceptible to frost - if fall work is delayed to spring, it delays crop development, and every week seeding is delayed equals a reduction in yield' (Respondent 7).
>
> 'The wet spring delayed seeding - that in conjunction with cool summer and early frost had an impact on yield and quality' (Respondent 12).

4.2 Weather stresses from 1999 to 2005, emphasizing excess moisture

In terms of weather, excess moisture and heavy precipitation have had the most severe impacts on producers in the last five years. Many producers alluded to their lack of experience in dealing with too much moisture (Box 3). Generally speaking, weather shocks and stresses occurred with similar frequencies between case study areas. However, frost and cool temperatures were mentioned with higher frequencies in the north case study area, whereas drought and weather variability were noted more often in the southwest. This might be expected given differences in the geographic contexts of the two case study areas. For example, Respondent 31 describes periods of drought and dryness in the southwest as 'not a surprise,' and frost might be expected to be more of a concern in an area of relatively high elevation where 'even Dauphin (100 kilometres north of this north farm) gets more heat units' (Respondent 9).

Box 3: Producer perspectives on excess moisture

'Over the last six years, excess moisture has been the biggest obstacle - some years it was a matter of annual totals, others it had more to do with the timing, or a combination of the two - historically it has been drought issues' (Respondent 7).

'We're farming for a whole different type of climate the last seven years - in '03 it dried out OK – it was the best crop in 7-8 years, but there were still unsown acres – it was the only normal year in the past eight - excess moisture has been the biggest hurt in Southwestern Manitoba in the last seven years - barring that, we'd probably be twice as profitable – in 2005 we had a normal spring, then 20" of rain in June - that's four times the precipitation we normally receive in a season - we got stuck in harvest too from the spring rain - we're still totally saturated, and if we get a foot of snow, we won't get a crop in this spring' (Respondent 38).

Topography, the timing of weather events and farm type influenced impacts (Box 4). Respondent 49 contrasted excess moisture conditions in different years: '2005 and 2004 were different from 1999 – the crop was sown before it turned wet, after the inputs were in the ground – it hurt worse – though we still lost income in 1999, at least we hadn't spent on inputs.' Respondent 6 discussed farm topography: '(my land) is sandy and rolling, so it mitigates (the impact of) excessive moisture.' Finally, Respondent 39, a mixed farmer, explains why excess moisture is more of a concern for grain operations:

> 'The largest weather stress in the last couple of years has been excess moisture – though it has hit the grain industry worse – it still affected us because we couldn't grow a crop – though it was more of an inconvenience – no crop, but a lot of feed was available.'

Box 4: Respondent 60 regarding topographical influences on excess moisture

'The dryness hurts everyone, but wet weather is worse - guys with high land are OK - you only see one problem area, the low spots - frost hits these low spots too - we dropped 800 acres north of Reston three years ago - over the eight years I farmed it, only 1-2 were productive - you really have to assess the risk factors of tracts of land - there's another 800 acres coming up for sale right at our backdoor - we're better off with the lower risk land, with a better slope for drainage - low basin land either dries out or floods out - we rely on bottom-end draining around here and they're not maintained - the blowing soil in the '70s and '80s plugged the runways - water tends to get land-locked, it doesn't reach the main channels - that's our predicament - we're still renting some high-risk land, but after this year the landlord will have to find someone else - we'll tell them they need to lobby for better drainage with the surrounding producers - it's a capital asset that's going downhill.'

4.3 Perspectives on weather variability

Southern respondents discussed weather variability in terms of unpredictability and described it as a *stress unto itself*. Northern respondents also noted weather variability, but did not commonly refer to it as a stress or as something completely unexpected. In fact, some of the northern commentary surrounding changes in climate or weather patterns alluded to predictability. The following lists are compilations of weather variability comments from each case study, respectively.

South respondents

> ‘There’s wilder swings (wet to dry extremes) than we used to have – in the nine years I’ve been here, there haven’t been two the same – older producers have told me it was more consistent in the past’ (Respondent 32).

> ‘1999 was a wet year and 2000 a dry year – it went from one extreme to the other – although I didn’t have a lot of problems on my operation, the switch from one extreme to the other created conditions farmers in the area were unfamiliar with – we’re used to dry weather, we have historical experience … excess moisture is newer, people didn’t know what to do – after a big rain, we’re usually back on the land after one or two days – wet roads were a problem, you couldn’t move equipment much – it is a big effort to drain fields, there’s financial implications – it’s caused high levels of frustration – I hadn’t experienced worse in 35 years on council – it’s been hard on the psyche, the change in farming methods – this year’s moisture (2005) recalls memories from 1999’ (Respondent 33).

> ‘When I started back in the 1980s, it was drier than hell – no rain at all – now, from the mid-1990s on, we've been fighting wet weather’ (Respondent 42).

> ‘In 40-50 years, we never had a flood – now it’s happened twice in the last five years – there's more extremes – even the late frost is a bit different … extreme weather sums it up – freak snowstorms – I saw my first funnel cloud last year, and I've lived here 60 years … it's scary – you don't know what direction it'll go – weather I can take in stride – it's the extremes we can't handle’ (Respondent 50).

> ‘We’re farming for a whole different type of climate the last seven years – excess moisture has been the biggest hurt in southwest Manitoba – in 2003 it dried out OK … it was the only normal year in the past eight … this year (2005), we had a normal spring, then got twenty inches of rain in June – that's four times the precipitation we normally receive in a season – we got stuck in harvest too, from the spring rain – we're still totally saturated, and if we get a foot of snow, we won't get a crop in this spring’ (Respondent 38).

North respondents

> 'It's the first time in 100 years we were not all sown (due to wetness) – according to my grandfather, we historically don't get highs and lows – the valley sucks moisture in – drought years work best here' (Respondent 1).
>
> 'You cannot depend on the weather like you used to be able to – not necessarily temperature, but wind, precipitation, *etc.*' (Respondent 8).
>
> 'Over the past number of years we don't get snow we used to over winter – in 1959 we had 6 feet – now it's a foot, in a bad year a foot and a half – winters are not as cold as they used to be – the almanac is calling for a foot of snow in May – three or four years ago it was mild too – it stayed cold into spring and we had a foot of snow around May 20th that year – warm winters have improved things because we can seed earlier – snow was the biggest obstacle – it has made a big difference in yields – it's decreased the impact of early season weeds and made a big difference in frost-free days – except for the frost of 2004, killing frosts don't occur until mid-September – they used to be the end of August' (Respondent 11).
>
> 'The weather has changed - when I was little, you could be combining in October - the days could be 22-25 degrees - not anymore, now it snows - things seem to be a month off – the last two years January (now warmer) seems to have flipped with February (now colder) - this is occurring during calving season - plus cold snaps in February only last 3-4 days versus 1-2 weeks which can occur in January - also, May rains seem to be coming in June - July was historically a real good haying month, now it's late July or August – the pattern I've noticed is everything's a month off' (Respondent 24)
>
> 'The 1999 moisture was the most shocking year – talking to old timers, they'd never seen a year like this – there was always a two-week window for both seeding and harvest – we got neither' (Respondent 26).
>
> 'Winters are much warmer now and there is less snow – you can work right through' (Respondent 63).
>
> 'Weather patterns always used to move from west to east – you could expect weather in Alberta or Saskatchewan to show up here 1-2 days later – now that trend doesn't always hold anymore – its harder to predict than in the past' (Respondent 65).

4.4 Comments on climate change and global warming

Though the topic of climate change was not a focus of interviews, the following comments were made regarding the issues of climate change and global warming. In particular, producers focused on whether or not weather stresses could be attributed to the phenomenon.

‘If this weather is due to the greenhouse effect, I’ll enjoy the warmer weather – it’s better for the cattle and gets the golf course going a little earlier in the spring (off - farm work)’ (Respondent 8).

‘If the weather events of the last five years become the norm, a good response would be to increase livestock and reduce grain farming’ (Respondent 21).

‘Whether climate change is happening or not, a clean environment is proactive’ (Respondent 22).

‘We think of both 1999 and 2005 as anomalies – unsown acres have never been common’ (Respondent 25).

‘There was the major snowstorm of 1959 – we were still hauling hay with horses, and the sled wouldn’t move well through the wetness – we’re learning from the past – the 1950s were actually much wetter than 1999 – the horses were up to their bellies in mud’ (Respondent 35).

‘I don't know whether what's happening (excess moisture) is climate change’ (Respondent 52).

‘There's been ups and downs in agriculture for years - look at the 1930s – big rains have occurred before too, washed everything away – 1952 was really wet, and in 1961 it was so dry nothing grew but Russian thistle – there's always been a pattern … 1999 was admittedly bad – it rained and never quit’ (Respondent 53).

‘Is it (weather) more unpredictable? Winters are not as cold as in the past – growing up we were in a drier cycle, it was more consistent – are we settling into a normal cycle or is it more variable? I don't know – the old guys have never seen it like this’ (Respondent 57).

‘There’s a psychological affirmation that abnormal weather maybe not so abnormal – take the wetness of the 1950s’ (Respondent 68).

‘Though we’ve had major weather events – the once in a lifetime rain of July 1st – which repeated itself July 7th – whether it can be attributed to climate change or not is a different issue’ (Respondent 76).

4.5 Summary of stress and impact findings

Farmers in the two case study areas discussed a number of shocks and stresses to their operations in recent history, and those related to weather figured prominently amongst them. Interviewees also made comments pertaining to both climate change and weather variability. General comments included:

1. The suggestion that weather variability seems to be increasing over time. However, opinions on whether extreme weather can attributed to climate change phenomenon were far from homogenous.

2. That the impacts of weather related shocks and stresses are variable depending on the specific topography of the farm, farm type and timing of the weather event.
3. That the cumulative effects of stresses cause bigger problems, and single events can upset farm cycles significantly.

These findings raise the question of whether or not producers have ways in which they respond to shocks and stresses, and if so, whether producers respond to shocks and stresses in manners that build resilience. Farmer responses, including aids and impediments, are the topic of the following chapter.

5.0 Responses to shocks and stresses

Farmers are not passive recipients of shocks and stresses, and respond to them in a variety of ways (Table 6). Responses ranged from temporary modifications of farm practices to major shifts in production methods. The following chapter describes general trends in response strategies, examines linkages between stress and response (Section 5.1), lists the top aids and impediments to key weather responses (Section 5.2) and characterises responses according to their temporal and scalar attributes (Section 5.3). The results in this chapter provide a framework for the resilience analysis – the topic of Chapter 6.

Producers in both case studies responded to shocks and stresses using diverse methods. Furthermore, of the 32 response categories recorded, eighteen were employed with a frequency of ten or more. The diversity of responses to shocks and stresses is an indication of self-organisation, though the direction of self-organisation is hard to predict due to a large number of possible future recombinations and the unknown success or failure of responses (Berkes *et al.*, 2003). Political and economic influences play a significant role in this regard, and we return to this discussion in the next chapter.

While diversity of responses indicates that producers are indeed responding to stresses, the next section of this chapter focuses on how stresses and responses are linked. This includes a discussion of general trends and observations, categorization of responses by triggering stresses (*i.e.* weather, non-weather or mixtures of the two), and an examination of regional response differences associated with weather-related stresses.

5.1 Stress-response linkages

In this section we delineate key stress-response issues as perceived by interviewees (Section 5.1.1); categorise responses by weather, non-weather and mixed triggers, and cross-reference the *top response* categories with the major responses to *top stresses* (Section 5.1.2); and examine several key weather responses highlighting differences between case study areas (Section 5.1.3).

*Table 6: Frequency of responses to farm shocks and stresses in two case study areas (note: number of responses may exceed sample size due to multiple occurrences in different years)**

response (rank order)	**north (n=30)**	**south (n=30)**	**total (n=60)**
modify or employ an existing farm practice for ≤one season	17	33	50
alter a farm cycle (≤one season)	17	18	35
get outside help from within the local agricultural sector	21	11	32
wait out	7	22	29
work longer or do extra work	18	10	28
reduce tillage	8	19	27
Crop Insurance (CI) and other insurance claims	14	11	25
increase buffering capacity	13	11	24
reduce spending, borrowing, or do a job yourself	5	17	22
'work with the weather'	13	9	22
market strategy	9	11	20
reduce seeding or other inputs	2	16	18
alter a farm cycle or practice (≥ one season)	5	12	17
use technological advances	12	4	16
temporarily increase herd size (note: BSE specific)	7	8	15
match land use to agricultural potential	9	5	14
use local associations and support networks	3	10	13
off farm employment (long term)	5	5	10
government aid and programs (outside CI – CAIS, BSE claims)	4	5	9
diversification	4	5	9
out of commodity	4	4	8
destroy inventory	4	2	6
use credit to access loans	1	3	4
increase production to improve margin	0	4	4
increase efficiency	1	1	2
sell at reduced prices	2	0	2
invest in local slaughter capacity	1	1	2
use government aid and programs to alter a management practice	1	0	1
off farm employment (short term)	1	0	1
buy out partner	1	0	1
NGO seed program	0	1	1
farm small	1	0	1
Total	**210**	**258**	**468**

* A breakdown of response groups by specific responses can be found in Appendix IV.

5.1.1 Controllability, stress severity and other response barriers

Interviewees alluded to several important factors influencing farmer responses to shocks and stresses, including:

1. The perception of stresses as external and/or uncontrollable in nature;
2. The synergistic nature of stresses (see Section 4.1);
3. The implications associated with stress severity; and
4. The importance of individual farm contexts, including both commodity and topographical characteristics (see Section 4.2).

Many stresses, whether responded to or not, were described as out of the farmer's control. The reality, as Respondent 31 put it, is that 'weather does rule your life – you have to learn to work with it and around it'. This type of comment was echoed by other producers:

'You can't do anything about the weather' (Respondent 3).

'The weather cannot be controlled, so you shouldn't worry about it, but you do' (Respondent 16).

'Weather is something we have no control over – that's not out of the ordinary' (Respondent 24).

Furthermore, uncontrollable factors listed were not limited to weather stresses and included, notably, market and political forces.

'I like to farm, but farming is high risk – there are many uncontrollable factors, and I can't deal with things beyond my control – programs that deal with disasters and market forces have to ensure a fair return for what we grow – Canada has a cheap food policy and lots of people (in the agro-food industry) are making money – yet the risk is all on the farmer' (Respondent 40).

'The trouble with farming is we can't set the prices to compensate for weather – to pass the expenses on to the consumer – we have no control, there is just no way through the grain companies, *etc.*' (Respondent 47).

'Non-weather stresses far outweigh weather stresses – we've learned to deal with the weather – but there's no way to deal with these other things' (Respondent 50).

'The issue with BSE was the uncertainty – if you knew two years before the border would open, you could manage for it – but it was a few weeks, then a few months, and then you stop listening – you can deal with a problem if you know what it is' (Respondent 59).

Secondly, some stresses can stymie attempts to cope or respond to others, making it difficult to isolate and respond to individual shocks and stresses.

> 'In 2005, wanted to silage again (in response to wet harvests), but the price of fuelling the process (machinery) prohibited that' (Respondent 14).
>
> 'The feed prices went up to $90-100 a ton during the drought, but cattle prices dropped to 8¢ a pound during BSE – that coinciding was the biggest stress – it's very difficult to de-stock your herd, which is the normal response during a drought' (Respondent 27).

Weather extremes and variability, rather than simply the occurrence of surplus or inadequate moisture, create conditions difficult to deal with.

> 'There seems to be a little more adverse weather than there used to be – it's spasmodic (*e.g.* heavy rains, high winds) … you cannot depend on the weather like you used to be able to' (Respondent 8).
>
> '1999 was a wet year and 2000 a dry year – from one extreme to the other – I haven't had a lot of problems with my own operation, but this created conditions farmers in the area were unfamiliar with' (Respondent 33).
>
> 'In 40-50 years, we never had a flood – now twice in the last five years – there's more extremes – even the late frost – it's a bit different, it's not often experienced – extreme weather sums it up – freak snowstorms – I saw my first funnel cloud last year – I've lived here 60 years – it was six to eight miles west of the farm – it's scary – you don't know what direction it'll go – 'weather' I can take in stride … it's the extremes we can't handle' (Respondent 50).

Finally, excess moisture events affect crop-based and livestock-based activities differently. The top impacts of excess moisture (*i.e.* increased weeds, lost yields, unsown acres and delayed seeding/harvesting) reduce the value of cash crops to a far greater extent than crops destined for forage or pasture. The comparative vulnerability of grain producers, as compared to mixed operations, was reflected by response options available to the latter. Mixed operations redirected poor cash crops into silage or green feed. Other livestock producers even reported increases in forage and pasture production in wet years.

> 'We cut the oats early for green feed – it was not marketable as crop – the oats had rust – it's important as a farmer to be able to make the weather work for you – if you'd grown the oats as a straight crop, you'd be in trouble' (Respondent 35).

This producer continued to describe how the rolling topography and soil characteristics reduced the impact of excess water.

> 'The excess moisture of 1999 was good because the land here is light, it led to good amount of forage – the excess moisture in 2005 meant we lost some pasture, but again gained forage elsewhere and the light land here soaks it in quickly, the potholes are full – the native prairie which is hayed was excellent this year – it's not great for crops, but that's OK' (Respondent 35).

> 'The land is sandy and rolling, which mitigates excessive moisture and drown outs – only the low areas are affected in contrast to large tracts being flooded out' (Respondent 6).

These comments on controllability, context, impact severity and the influence of multiple stresses highlight a dichotomy between two general response approaches – decisions to curb production and cut losses versus options that sustain production through crises. The following two examples allude to excess moisture, input costs and the ability to manage 'around' the weather.

> 'We did summer fallow and planted winter wheat in the fall – 2000 was our best crop ever – it did well – we saved on inputs, why mud it in? It was more a weather than a management response – it was raining every morning' (Respondent 46).

On the other hand, others chose to protect inputs which had been invested.

> 'In the wet years, most of the times we got seeding done and tried to keep fields free of weeds – fungus and disease occur late in the year, so it is hard to tell what damage is done – the yield is sensitive – when do you give up? The inputs are heavy in the first thirty days of a crop – there's lots invested, so there is a lot to protect at that point' (Respondent 20).

5.1.2 Responses to weather, non-weather and multiple stresses

The following section breaks out responses by the nature of the triggering stress or stresses, including weather, non-weather and mixed influences. This is followed by a cross-referencing of *top weather responses* with the responses to *top weather stresses*. We begin with a focus on the weather category.

The top three responses to weather stresses (Table 7) included employment of a standard farm practice, altering a farm cycle ≤ one season and hiring outside help. The complete list of responses, however, includes nineteen response categories – twelve of which registered with a frequency of ten or more times. Similar to overall response results, dealing with the weather included a diverse set of options. Furthermore, these results agree with the Smit and Skinner (2002) finding that most weather responses are modifications of existing farm practices and public policy processes – though the use of technology, increases in buffering capacity and longer term alterations to farm practices also appear to be significant.

Table 7: Farmer responses to weather stresses

weather responses	north (n=30)	south (n=30)	total (n=60)
employ a standard farm practice	17	33	50
alter a farm cycle (≤one season)	14	16	30
hiring outside help from within the local agricultural sector	18	7	25
wait out	5	19	24
work longer or do extra work	13	10	23
Crop Insurance claims	13	10	23
'work with the weather'	11	8	19
use technological advances	12	4	16
increase buffering capacity	10	5	15
reduce seeding or other inputs	1	13	14
alter a farm cycle or practice (≥ one season)	3	8	11
use local associations and support networks	1	9	10
market strategy	4	5	9
reduce spending, borrowing, or do a job yourself	1	5	6
reduce tillage	0	6	6
match land use to agricultural potential	5	0	5
destroy inventory	2	0	2
diversification	0	1	1
out of commodity	1	0	1
total	**131**	**159**	**290**

Regarding responses to non-weather stresses (Table 8), increasing herd size (BSE specific), reducing spending or doing a job yourself and employing a market strategy topped the list. The complete list includes 24 response categories – five greater than the weather elicited – but only the top two where employed with a frequency greater than ten. In fact, only the top six had a frequency of five or more. Non-weather options appear more constrained.

There is also very little overlap observed between weather and non-weather response categories. Hiring outside help, waiting out a stress, working longer or doing extra work, use of government programs (outside CI) and altering a farm practice ≥ one season appeared in both Tables 7 and 8, however the frequencies with which they were employed differed significantly (*e.g.* wait out: 24 responses to weather stress, five responses to non-weather stress). Though this finding is intuitive – different stresses and impacts might be expected to elicit different responses – other responses constituted mixed approaches to the cumulative impacts of weather and non-weather shocks and stresses.

Table 8: Farmer responses to non-weather stresses

non-weather responses	**north (n=30)**	**south (n=30)**	**total (n=60)**
increase herd size (note: BSE specific)	7	8	15
reduce spending, borrowing, or do a job yourself	5	8	13
market strategy	5	4	9
reduce tillage	4	4	8
hiring outside help from within the local agricultural sector	3	4	7
wait out	2	3	5
alter a farm cycle or practice (≥ one season)	2	2	4
use credit to access loans	1	3	4
work longer or do extra work	4	0	4
out of commodity	2	2	4
increase production	0	4	4
reduce seeding or other inputs	0	3	3
destroy inventory	1	2	3
use government aid and programs (BSE claims)	1	2	3
insurance and agro-chemical product claims	1	1	2
alter a farm cycle (≤one season)	2	0	2
invest in local slaughter capacity	1	1	2
increase buffering capacity	1	1	2
increase efficiency	0	1	1
sell at reduced prices	1	0	1
use local associations and support networks	1	0	1
match land use to agricultural potential	1	0	1
diversification	1	0	1
buy out partner	1	0	1
Total	**47**	**53**	**100**

In many instances, responses and management practices were adopted to cope with multiple stressors (Table 9). Reduced tillage practices and long term off-farm employment were the two key categories listed by respondents. The complete list includes 22 response categories, though only the top two where employed with a frequency equal or greater than ten. The top six had a frequency of five or more. Notable adaptations included among those responses included the matching of land to agricultural potential, diversification and buffer strategies.

Table 9: Farmer responses to multiple weather and non-weather stresses

response	**north (n=30)**	**south (n=30)**	**total (n=60)**
reduce tillage	4	9	13
off farm employment (long term)	5	5	10
match land use to agricultural potential	3	5	8
increase buffering capacity	2	5	7
diversification	3	4	7
government aid and programs (CAIS, NISA, FIPP claims)	3	3	6
reduce spending, borrowing, or do a job yourself	0	3	3
alter a farm cycle (≤one season)	1	2	3
out of commodity	1	2	3
'work with the weather'	2	1	3
market strategy	0	2	2
alter a farm cycle or practice (≥ one season)	0	2	2
use local associations and support networks	1	1	2
work longer or do extra work	1	0	1
destroy inventory	1	0	1
Use government aid and programs to alter a management practice	1	0	1
increase efficiency	1	0	1
sell at reduced prices	1	0	1
reduce seeding or other inputs	1	0	1
off farm employment (short term)	1	0	1
NGO seed program	0	1	1
farm small	1	0	1
Total	**33**	**45**	**78**

Though the frequencies of these adaptions are low, consideration must be given regarding two factors: (1) these strategies tend to involve large financial and labour investments on behalf of producers and (2) their ability to mitigate impacts are often dramatic and dynamic (*i.e.*multiple benefits).

> 'We adopted zero-till to conserve soil, moisture and labour (single versus multiple passes) – after the 1980s drought, the biggest driver then was moisture – since then I've become a soil conservationist – it's important to long term sustainability – the reduced labour is a bonus – I'd be at 1000 acres or less if I wasn't zero-till' (Respondent 23).

> ‘We've been using a quick rotation strategy the last ten or twelve years – (each paddock spends) three years fenced with hay or grass, then it’s cropped – the objective is to have forage on every acre – from what we've observed, we are convinced of the benefits of forage in rotation – in 2005, two-thirds of the farm at that point had been in and out of forage – (that land) handled the water much better – the acres which had been in crop for twenty-three years were not as good because of poorer internal drainage and soil structure – alfalfa root structure goes down fifteen feet, which allows water to drain – in 1999 we saw it’ (Respondent 22).

5.1.3 Cross-referencing top responses to top stresses

This section identifies the specific weather stresses which triggered the *top weather responses* (Tables 10 & 12), and key responses to *top weather stresses* (Tables 11 & 13). We assess whether the responses correlate between these two data sets. The findings suggest that the top weather response categories strongly agree with the key weather responses to the top stresses, owing largely to the predominance of excess moisture and heavy rain events which occurred over the period of research interest (1999-2005). We examine this finding in each case study area.

In the southern case study area, all top weather responses were primarily elicited by excess moisture and heavy rain, which accounted for 93% of all triggers (Table 10). All the top responses – employing standard farm practices, altering a farm cycle for ≤ one growing season, waiting out a stress and reducing seeding and inputs – were strongly linked to the top stresses of excess moisture and heavy rainfall alone.

A comparison of the top response categories in Table 10 to the major responses to top stresses in Table 11 exhibits a high level of correlation. All four of the top responses in Table 10 are included as major responses in Table 11. Seven of the twelve major response categories in Table 11 are also top weather responses. As a percentage, the correlation increases – 80% of major responses were also top responses. However, drought and dry periods were strongly linked to getting outside help and reduced tillage – a result overshadowed by the predominantly wet-weather during the 1999-2005 period of interest (excess moisture and heavy rainfall mentions outweigh drought and dry periods by a ratio of 4:1, Table 11). As Respondent 7 put it, ‘over the last six years, excess moisture has been the biggest obstacle ... historically it has been drought issues.’

Table 10: Top ranking responses and key triggers (southern case study)

	top responses (n=30)	triggering stress
Weather responses	employ a standard farm practice (33)	excess moisture (28)
		heavy rain (3)
		drought (2)
	wait out (19)	excess moisture (15)
		heavy rain (3)
		dry period (1)
	alter a farm cycle for ≤one season (16)	excess moisture (8)
		heavy rain (5)
		drought (3)
	reduce seeding and other inputs (13)	excess moisture (13)
N-W response	increase herd size (8)	BSE (8)
	reduce spending, borrowing or do a job yourself (8)	High inputs/low commodity (5)
		BSE (3)
		dependents (1)

Table 11: Top ranking stresses and associated responses (southern case study) [5]

	top stresses (n=30)	major responses
Weather stresses	excess moisture (60)	*employ a standard farm practice (28)*
		wait out (15)
		reduce seeding and other inputs (13)
	heavy rainfall (16)	*alter a farm cycle (≤ one year) (5)*
		alter a farm cycle or practice (≥ one year) (5)
		wait out (3)
		employ a standard farm practice (3)
	drought (15)	Reduce tillage (4)
		get outside help from within the local agricultural sector (4)
		alter a farm cycle (≤ one year) (3)
	dry period (10)	get outside help from within the local agricultural sector (3)
		Reduce tillage (2)
N-W stresses	low commodity prices (22)	reduce spending, borrowing, do a job yourself (3)
		increase production (2)
	high input costs (19)	Reduce tillage (4)
		Reduce seeding or other inputs (2)
	BSE (15)	increase herd size (8)
		get outside help from within the local agricultural sector (4)
		reduce spending, borrowing, or do a job yourself (3)

[5] Italicized 'major responses' in Table 11 are also 'top responses' found in Table 10.

Table 12: Top ranking responses and key triggers (northern case study)

	top responses	triggering stress
Weather responses	get outside help from within the local agricultural sector (18)	excess moisture/heavy rain (12)
		dry period/drought (5)
		frost (1)
	employ a standard farm practice (17)	excess moisture (13)
		heavy rain (4)
	alter a farm cycle (≤one season) (14)	heavy rain (6)
		excess moisture (4)
		drought (4)
	Crop Insurance (13)	excess moisture/heavy rain (8)
		frost (3)
		hail (2)
	work longer or do extra work (13)	excess moisture/heavy rain (11)
		frost (1)
		cold summer (1)
N-W responses	increase herd size (7)	BSE (7)
	reduce spending, borrowing, or do a job yourself (5)	high input costs (3)
		low commodity prices (1)
		BSE (1)
	employ a market strategy (5)	BSE (4)
		high input costs (1)

Table 13: Top ranking stresses and associated responses (northern case study)[6]

	top stresses (n=30)	major responses
Weather stresses	excess moisture (48)	*employ a standard farm practice (13)*
		work longer or do extra work (6)
		get outside help from within the local agricultural sector (10)
	frost (21)	market strategy (3)
		Crop Insurance (3)
		'work with the weather' (2)
	heavy rainfall (17)	*alter a farm cycle (≤one season) (6)*
		work longer or do extra work (5)
	dry period (10)	*get outside help from within the local agricultural sector (4)*
		increase buffering capacity (3)
		'work with the weather' (2)
	cold summer temperature (9)	*alter a farm cycle (≤one season) (2)*
N-W stresses	low commodity prices (17)	Reduce spending or reduce tillage (2)
	high input costs (16)	Reduce spending or reduce tillage (5)
	BSE (16)	increase herd size (7)
		Market strategy (4)
		get outside help from within the local agricultural sector (3)

[6] Italicized 'major responses' in Table 13 are also 'top responses' found in Table 12.

In the northern case study area, similar to the south, all top weather responses were also elicited primarily by excess moisture and heavy rain, which accounted for 77% of all triggers (Table 12). Most top responses – employing standard farm practices, altering a farm cycle for ≤ one growing season, and working longer or doing extra work – were strongly linked to excess moisture and heavy rainfall. Only getting outside help and Crop Insurance exhibited some degree of application amongst weather stresses, including excess moisture, drought, dry periods, frost and hail. A comparison of the top response categories in Table 12 to the major responses to top stresses in Table 13 exhibits a high level of correlation. All the top responses in Table 12 are included as major responses in Table 13. Eight of the twelve major response categories in Table 13 are also top weather responses. As a percentage, the correlation increases – 83% of major responses were also top responses. However, dry periods and frost were strongly linked to increasing buffer capacity, 'working with the weather' and market strategies. Similar to the south case study, this result was overshadowed by the predominantly wet-weather during the 1999-2005 period of interest (excess moisture and heavy rainfall mentions outweigh dry periods, frost and cold temperatures by a ratio of 3:2, Table 13).

Both case studies share a central theme – the issue of excess moisture and the over-whelming response to it. However, they also exhibited important differences with regards to the methods employed for dealing with the impacts of excess moisture. The south exhibited a tendency for waiting out the moisture and reducing seeding and other inputs, while the north opted for working longer or doing extra work and getting outside help.

5.1.4 Key weather responses and differences between case study areas

Table 14 includes the collective top weather response categories of both case study areas. Notable differences between the case study area responses included the employment of standard farm practices, hiring of outside help, waiting out a stress and reducing seeding and inputs. While both case studies shared the employment of standard farm practices as the top response option to excess moisture, the breakdown of this response category into specific responses tells a different story (Table 15). Drainage accounts for the difference between north and south with regards to the 'employment of standard farm practices' category (Table 15).

Table 14: Top responses to weather stresses

weather responses	north (n=30)	south (n=30)	total (n=60)
employ a standard farm practice	17	33	50
alter a farm cycle (≤one season)	14	16	30
Hiring outside help from within the local agricultural sector	18	7	25
wait out	5	19	24
Work longer or do extra work	13	10	23
Crop Insurance claims	13	10	23
reduce seeding or other inputs	1	13	14

Table 15: Specific responses of the 'employ a standard farm practice' category

	specific response	north (n=30)	south (n=30)	total (n=60)
standard farm practices	make a chemical application	9	11	20
	drain the land	0	11	11
	cultivate the soil	1	7	8
	burn the stubble	4	0	4
	maintain the existing drainage system	1	3	4
	summer fallow	2	1	3
	total	***17***	***33***	***50***

Two different explanations for higher drainage and cultivation in the southwest have already been mentioned – the higher proportion of grain farmers and the influence of the topography on local hydrology. Excess moisture, all else being equal, would flood out a larger area in the south due to its lower elevation relative to surrounding regions and flatter topography relative to the north. Both cultivation and drainage efforts were in effort to reduce soil moisture to create conditions necessary for seeding.

Other, less frequently employed, long term adaptations are also significant, as previously mentioned, and differences exist between case studies. In the south, the predominance of grain production and historical experience with drought led to a stronger conservation tillage response in that case study area.

Table 16: Other important responses to weather stresses

weather response	north (n=30)	south (n=30)	total (n=60)
reduce tillage	8	19	27
Alter a farm cycle or practice (≥ one season)	5	12	17
use technological advances	12	4	16
use local associations and support networks	3	10	13
increase production	0	4	4

5.2 Response aids and impediments

Interviewees were asked about influences which either aided or impeded their responses to shocks and stresses. This section considers key overall aids and impediments, followed by those pertaining specifically to weather stresses.

Response aids and impediments are listed in Table 17 and 18, respectively. Top aids include flexible attitude, experience, technology, neighbours, political will and participation in a variety of farm groups or clubs.

Table 17: Response aids

Response aid	north (n=30)	south (n=30)	total (n=60)
flexible attitude, no delaying reaction	22	29	51
experience and knowledge	18	28	46
available technology	13	11	24
neighbour's help	14	6	20
program aid and political will	2	16	18
organisation/participation in farm interest group	1	17	18
market opportunities, consumer response	4	9	13
ability to outsource for help	11	0	11
product availability, affordability	6	4	10
cooperative weather, luck	1	5	6
border constraints/decreased value	5	0	5
employment opportunities	2	2	4
on-farm buffer capacity, diversity	2	2	4
good credit history, low interest, low debt	1	2	3
improved property	0	2	2
Reduced work load	0	1	1
small size	0	1	1
reduced tillage practices - earlier access	0	1	1
Feed production	0	1	1

Key impediments include cash flow problems, lack of political will, variable returns on investments, rigid attitudes and inexperience.

In terms of responding to weather stress, networking amongst farmers and organisations, operational flexibility and the availability of technologies were important aids in both case studies (Tables 19 & 20). Key impediments included increased levels of stress and workload, inexperience and a lack of predictability, additional expenses, uncooperative neighbours and political will and regulations.

Table 18: Response impediments

Response impediment	**north (n=30)**	**south (n=30)**	**total (n=60)**
additional expenses and cash flow	14	28	42
policy impediments, non-participation and political will	7	33	40
unpredictable return and difficult markets	15	16	31
Rigid attitude, delayed reaction and inexperience	1	20	21
additional workload and stress	5	6	11
topographical/seasonal limitations	3	4	7
issues with a neighbour	1	4	5
reduced tillage practices - moisture trap	0	4	4
local service limitations	2	1	3
operational limitations	1	1	2
reduced quality of commodity	1	1	2
monopoly in crediting agencies	1	0	1
available product poor quality	1	0	1
cumulative effects	1	0	1
continued moisture	0	1	1
stakeholder infighting	0	1	1
monopoly on chemical products	1	0	1

Table 19: Top weather response aids and impediments (southern case study)

	top responses (n=30)	aid (top 3)	impediment (top 3)
Weather responses	employ a standard farm practice (33)	organisation amongst farmers (6)	political will and regulations (15)
		participate in organisation (3)	additional expense (12)
		flexibility of operation (3)	problem with neighbours (6)
	wait out (19)	small size (1)	inexperience with stress (3)
		reduced tillage (1)	reduced tillage (2)
		flexibility of operation (1)	Unpredictability (1)
	alter a farm cycle for ≤one season (16)	neighbour's help (2)	poor quality commodity (1)
		market options (2)	difficult market (1)
		flexibility of operation(1)	
	Reduce seeding and other inputs (13)	buffer capacity (2)	regulations (2)
		flexibility of operation (2)	reduced tillage (2)
		experience and attitude (2)	

Table 20: Top weather response aids and impediments (northern case study)

	top responses (n=30)	aid (top 3)	impediment (top 3)
Weather responses	get outside help from within the local agricultural sector (18)	good neighbours (5)	Increased stress level (3)
		recognize need to outsource (3)	Increased work load (2)
		experienced labour (2)	additional expense (2)
	employ a standard farm practice (17)	recognize need to outsource (8)	unpredictable outcome (8)
		available technology (8)	
		no hesitation (4)	
	alter a farm cycle (≤one season) (14)	knowledge available (1)	short growing season (3)
		flexibility (1)	
		good neighbours (1)	
	Crop Insurance (13)	knowledge of claims (1)	drainage regulations (1)
	work longer or do extra work (13)	knowledge of constraints (2)	
		good neighbours (1)	

5.3 Responses: temporal and scalar considerations

The following section revisits overall responses, and groups responses into categories including ‘increasing options’, ‘decreasing or mitigating costs’ and ‘doing nothing’. These groups are further categorized on the basis of temporal and scalar attributes (Table 21). Temporally, responses have been categorized as either short term or long term.

Short term strategies were heavily favoured over long term ones (Table 21). The question of why seasonal or temporary modifications to operations were employed with over twice the frequency of semi-permanent adaptations includes several possible explanations. Adaptations, associated with higher financial and labour costs, are long term responses since large investments generally require more time to break even[7]. Responses which include the incorporation of new technologies, infrastructure and major landscape amendments are examples of such investments.

Insofar as responding to weather stresses are concerned, several problems with initiating long term responses arise. As pointed out by Risbey *et al.* (1999) and Bryant *et al.* (2000), farm decisions are more sensitive to recent weather and climate, including the previous years' conditions in particular, and inter and intra-annual variation are far more influential than annual averages. Respondent 32 describes the 'wilder swings (extremes) than we used to get – from wet to dry – in the nine years I've been here, there hasn't been two the same.' Furthermore, the uncertainty inherent with change in complex climatic systems, including surprise and unknowable risks, greatly influence experimental failures and successes (Berkes, 2007).

Lack of experience with excess moisture was also a factor –creating conditions farmers were unfamiliar with. Coupling the short term focus on weather with a lack of predictable outcomes does not provide an environment condusive to investment. That being said, experimentation with strategies at small scales may lead to eventual adaptation. For example, Conservation Districts leverage reduced tillage uptake in some regions. 'We're into zero-till … our experience has been successful – the local soil management groups in the early 1990s changed things totally - through their programs and using their equipment, it didn't cost anyone anything, and benefited the environment' (Respondent 22).

Farmer responses are also characterised by their external or internal qualities, relative to the Regional Agricultural System (RAS) model introduced in Chapter 1 (IISD and EARG, 1997).'Increasing options' is sub-categorised by linkages internal and external to farm operations For example, 'reduced spending' or 'doing a job yourself' indicate responses within the farm itself and exhibit a self-reliant nature.

[7] While all adaptions are long term responses, not all long term responses constitute adaptation.

Table 21: Response categories by duration and linkages between scales

temporal response category		qualitative response categories	response	north (n=30)	south (n=30)	total (n=60)
temporal response category	short term responses	increase options (internal*)	modify or employ an existing farm practice for ≤one season	17	33	50
			alter a farm cycle (≤one season)	17	18	35
			'work with the weather'	13	9	22
		subtotals		47	60	107
		increase options (external**)	get outside help from within the local agricultural sector	21	11	32
			Crop Insurance (CI) and other insurance claims	14	11	25
			market strategy	9	11	20
			temporarily increase herd size (note: BSE specific)	7	8	15
			government aid and programs (outside CI – CAIS, BSE claims)	4	5	9
			use credit to access loans	1	3	4
			off farm employment (short term)	1	0	1
		subtotals		57	49	106
		decreasing or mitigating costs - addressing tight margins	work longer or do extra work (e.g. cleaning up)	18	10	28
			reduce spending, borrowing, or do a job yourself	5	17	22
			reduce seeding or other inputs	2	16	18
			destroy inventory	4	2	6
			sell at reduced prices	2	0	2
		subtotals		31	45	76
		do nothing	wait out	7	22	29
		subtotals		7	22	29
		short term totals		**142**	**176**	**318**
	long term responses	increase options (internal*)	increase buffering capacity	13	11	24
			alter a farm cycle or practice (≥ one season)	5	12	17
			use technological advances	12	4	16
			match land use to agricultural potential	9	5	14
			diversification	4	5	9
			farm small	1	0	1
			Buy out partner	1	0	1
		subtotals		45	37	82
		decreasing or mitigating costs - addressing tight margins	reduce tillage	8	19	27
			out of commodity	4	4	8
			increase production to improve margin	0	4	4
			increase efficiency	1	1	2
		subtotals		13	28	41
		increase options (external**)	use local associations and support networks	3	10	13
			off farm employment (long term)	5	5	10
			invest in local slaughter capacity	1	1	2
			use government programs to alter a management practice	1	1	2
		subtotals		10	17	27
		long term totals		**68**	**82**	**150**
		total responses		**210**	**258**	**468**

*increasing options internally refers to responses which are implemented within the operation itself.
**increasing options externally refers to responses which are contingent on institutions outside the operation itself - these responses operate either horizontally (e.g. arrangements made between multiple farms) or vertically (e.g. markets of the larger agro-food system and various levels of government) across scales.

> 'I don't flip my machinery much – I make due – I keep my machinery in decent shape with less invested … I've always operated with the mindset of keeping costs down – my cultivator and tractor are from 1987 – they're the last machinery I bought – I've got a combine and my tractor does all the seeding, cultivating and combining – on one engine – most farmers won't operate like that anymore' (Respondent 45).

Conversely, responses such as 'getting outside help' or 'using local associations and support networks' depend far more on external factors and actors within the RAS. Respondents 16 and 31 described hauling and purchasing feed outside their operation; while the latter goes on to discuss the importance of available labour to expansion efforts.

> 'My neighbour has a trucking business – what used to take me two or three days he can do in one – it saves time and fuel … during hay shortages, I buy from reasonable guys – bump the price up enough to keep them happy, (while keeping it) affordable for me' (Respondent 16).

> 'Economics have forced the size of operations up – the limiting factor, however, is the ability to find the labour required, good farm help – the job is dirty, has bad hours, there is often too much time off – it's not attractive – one guy can take care of 25 cattle, but not 400 – most of the help you find are the older, retired farmers – which means problems in the present and future … as the operation gets bigger, we're more and more dependent on a good feed source – we either have to go farther to get it, or reduce the herd' (Respondent 31).

The response attributes discussed in this chapter – general trends, stress-response linkages, temporal considerations and transactions between operations and organisations across scale – frame farmer responses for resilience analysis. Chapter 6 reviews the conditions that foster resilience building and applies these system traits to several central examples from the findings.

6.0 Response and Resilience-Building

The resilience analysis draws on the weather response findings discussed in the last chapter. Several farm management practices are examined, illustrating case study differences in vulnerability and resilience-building to future weather stresses. As stated in the introduction, resilience *is the capacity of a system to deal with shocks and stresses associated with change through processes of self-organization and adaptive learning, where the system shifts while retaining its basic function, structure, identity and feedbacks* (Walker *et al.*, 2004). Furthermore, resilience is integrally linked to adaptive capacity and vulnerability. In agroecosystems, this amounts to *the ability of actors in the system to manage resilience* (Walker *et al.*, 2004). Vulnerability is *the degree to which a system is likely to experience harm due to exposure to a shock or stress* (Berkes, 2007; Turner *et al.*, 2003).

We assess weather responses using resilience indicators, or surrogates, after factors identified by authors cited in the literature review. These include farmer responses which:

- Enhance flexibility through the creation of options;
- Employ adaptive approaches to management (Berkes *et al.* 2003);
- Incorporate local resource management knowledge (Nyström and Folke, 2001; Gunderson, 2000; Berkes *et al.* 2003; Kloppenburg, 1991);
- Incorporate and protect ecological services (Holling and Meffe, 1996);
- Create network opportunities across scale (Berkes, 2007 and 2004; Ullsten *et al.*, 2004; Smit *et al.*, 2003; Folke *et al.*, 2002);
- Communicate the societal consequences of recent changes and plan for changes likely to occur (Ullsten *et al.*, 2004).

With respect to increased weather variability, this amounts to learning to live with change and uncertainty, or expecting the unexpected, through the establishment of tools and behaviours which build resilience (Berkes, 2007; Hewitt, 2004; Berkes and Seixas, 2004). Diversity provides the general foundation for resilience by increasing the number of options available (Ullsten *et al.*, 2004; Berkes, 2007). Ecological, social, political, economic and cultural factors of diversity operate across a variety of scales.

We assess resilience from an agroecosystem perspective, defined as *complex social-ecological systems, which highlight the linkages between agricultural practices and landscape processes*. The systematic and scalar natures of agroecosystems translate into complex research environments, posing a problem to measurements of resilience and diluting findings to an overly simple suite of general conclusions. In order to assess resilience it is necessary to adequately define both the system state and stress being examined (Carpenter *et al.*, 2001).

Regarding shocks and stresses, we focus on the increased uncertainty, and lack of experience, associated with weather variability. Take the following examples:

'Extreme weather sums it up … it's scary – you don't know what direction it'll go … 'weather' I can take in stride … it's the extremes we can't handle' (Respondent 50).

'There have been wild intra-annual swings, five records being set in 2002-2003, including both the hottest and coldest temperatures' (Respondent 67).

'There seems to be little more adverse weather than there used to be – you cannot depend on the weather like you used to be able to – this area is a barometer of spasmodic weather' (Respondent 8).

'It's hard to plan year-to-year – nature pulls the sheet out from underneath you – we're reliant on weather patterns' (Respondent 60).

These observations, in conjunction with climate models and analyses predicting increasingly variable and extreme weather, are cause for concern. Variability and extremes increase vulnerability to a much greater degree than changes to long term averages (Runnalls, 2007; Canadian Climate Impacts and Adaptation Directorate [C-CIAD], 2002). The following discussion focuses on two opposite moisture extremes (excess and deficiency) associated with an increasingly variable climate.

Excessive moisture, which represents the largest data cluster of stresses, provides an excellent example of this growing lack of predictability. Projections forecast 3-4°C increases in Manitoba summer temperatures by 2080 – fingering excessive heat and moisture deficiency as probable future limiting factors to prairie agriculture (Nyirfa & Harron, 2002). However, the following quotes suggest otherwise.

‘Over the last six years, excess moisture has been the biggest obstacle … historically it has been drought issues’ (Respondent 7).

‘The excess moisture of 1999 was the one you remember most – it’s always been dry, but not in the last five years … wetness is memorable because it's an anomaly’ (Respondent 55).

‘We had seven inches of rain in one day – I've never seen that before’ (Respondent 12).

‘The 1999 moisture was the most shocking year – talking to old timers – they’d never seen a year like this – there was always a 2-week window for both seeding and harvest – we got neither’ (Respondent 33).

6.1 Resilience and excess moisture

The impacts of excess moisture included lost production due to flooding, increases in weeds and delayed seeding and harvesting. Farmers responded predominantly by waiting, altering drainage, getting outside help, working longer, making insurance claims, altering production cycles and reducing inputs. Producers also used various combinations of these responses, which resulted in overlaps. For example, farmers who waited out the moisture were largely focused on reducing the risk of lost inputs.

> ‘We waited for it to dry out, shut things off and stayed in the yard – with regards to the wheat, a lot was not sprayed because the crop was already under water and cool temperature stress – spraying only sets the crop back farther, so I let the weeds grow’ (Respondent 34).

I examine several aspects concerning resilience and excess moisture, including the waiting option, drainage practices and strategies involving the incorporation of buffers. These stories include comments on case study differences, touching on relevant social and political influences.

6.1.1 Waiting out moisture and Crop Insurance

The wait out response was employed in the southwest at a 3:1 ratio relative to their northern counterparts. Combinations of inexperience, topography, a focus on grain production and timing of the moisture were major response drivers. Many producers perceived excess moisture events as discrete, and temporary disturbances – ‘we think of both 1999 and 2005 as anomalies’ (Respondent 26). Other respondents who opted to wait referred to a lack of predictability and inexperience with wet weather, or simply cited that it was not physically possible to get on the land.

> ‘I don't really mind the dry years – I knew how to handle them better than the wet years – I don't know how to adjust to the wet weather’ (Respondent 52).
>
> ‘In 1999, there was two months before you could spin a wheel’ (Respondent 41).
>
> ‘There was just no access – the wetness in 1999 was different than in 2005 – even on high ground you'd sink to your ankles – no matter what equipment you had, you couldn't turn a wheel, you couldn’t get off the approach’ (Respondent 42).
>
> ‘There was nothing a guy could do – you can dig drains, but it's so flat – there’s nowhere to drain to – it's slough to slough’ (Respondent 47).

The wait out option was also strongly tied to compensation for un-seeded acres due to flooding, through the Crop Insurance program. Compensation and insurance help buffer farms operating under conditions where the ‘ideal environment is rare (and the) margins for a bumper crop are very narrow – 34 degrees is bad for a crop and so are weeks with 4-5 inches of rain – you cannot manage for ideal conditions’ (Respondent 7). It is perceived, unlike other programs, as a useful tool for decision-making. ‘Weather is unpredictable, and CI is the only option … they need to keep those options – CI is predictable, you know your level of coverage, what you're getting it for – you can go ahead and move forward – *ad hoc* payments are OK, but unpredictable’ (Respondent 59). In a scenario where financial aid is sought infrequently, to compensate for rare climatic and market circumstances, waiting out a stress represents a common-sense approach which reduces the risk of lost inputs.

However, in the context of increasingly variable weather, swinging ‘from one extreme to the other’ (Respondent 33), reliance on waiting out wet conditions and insurance claims serve to increase vulnerability to future climatic extremes. One, by providing a disincentive to adoption of other response options (McLeman and Smit, 2006), which increase flexibility. Secondly, compensation programs only partially reimburse losses – ‘the maximum you can buy up to is 85% of your long term average’ (Respondent 22). Successive claims result in declining coverage, and the program eventually economically collapses. Of those producers who cited Crop Insurance as a response, over half made more than one claim between 1999 and 2005.

During the wet periods of 1999 and 2005 the government made two key amendments to the Crop Insurance program that influenced the wait out response. First, the extension of sowing deadline dates later into the spring was negatively perceived by many producers. They referred to likely increases in claims related to lower yields and the vulnerability of immature crops to frost impacts. ‘The wet spring delayed seeding - that in conjunction with a cool summer and early frost had an impact on yield and quality’ (Respondent 12).

> ‘Crop Insurance drove some of the poor decisions made in the spring of 1999 – the late seeding deadline led to recklessness, and the coverage afterwards doesn't cover the costs incurred … they need to stop extending the seeding deadline – here, it is craziness to seed beyond and sets you up for a total wreck in the fall’ (Respondent 22).

> ‘Cumulative effects have been a factor … for example, a wet fall means spring stubble, which leads to late seeding and immature crops, which are more susceptible to frost – if fall work is delayed to spring, it delays crop development, and every week seeding is delayed equals a reduction in yield’ (Respondent 7).

Second, the government increased provisions for flat-rate compensation of unsown acres due to flooding. Farmers applauded the extension of coverage for un-seeded acres and other premium options. On one hand, Respondent 22 described this adjustment as an adaptive policy measure, discouraging late seeding in 2005. ‘We knew the $50 an acre was there – we became better aware of how the program worked – the $50 can be used in decision-making – the program has improved since 1999.’ By improved, Respondent 22 stated ‘there was no coverage for un-seeded acres (in 1999) so you had to do (seed) it all.’ On the other hand, the coverage for unsown acres may provide a disincentive to adaptive changes on farms where conditions are appropriate. As Respondent 75 stated ‘CI is important – it’s the producer’s first management tool for mediating risk – but it’s also important to try by diversifying crops and spreading their land base to reduce income instability and variability.’

The strong linkages between the wait out response and CI programming possibly reduce uptake of alternative measures, suggesting a lack of transformation in an environment where change is, and will be, required. However, in some instances waiting is inevitable, due to flooding related to both natural and anthropogenic drainage patterns. Some producers were forced into waiting out wet conditions because of the drainage practices of upstream neighbours. ‘After the wetness of 1998 I had a neighbour with a blocked runway holding up water on my land – the year prior to that my neighbour upstream flooded me badly by draining *ad hoc*’ (Respondent 52).

6.1.2 Drainage, licensing and watershed planning

After chemical applications, drainage responses were a large component of the ‘employment of standard farm practices’ group – which also included cultivating, burning stubble and summer fallow (Table 15, Section 5.1.4). These responses were mentioned with particular emphasis on response to excess moisture (Tables 10 & 12). The rationale behind drainage is related to the key impacts of excess moisture – unsown acres, lost yield or grade and flooded-outs.

Respondents in the southern case study area employed the drainage response strategy with far greater frequency of their northern counterparts – drainage accounting for 14 of the 33 ‘standard farm practice’ responses in the southwest case study as compared to *one* of the 17 responses in the north case study. Explanations for the higher rates of drainage in the southwest include a higher proportion of grain farmer participants and different geographical contexts. Excess moisture, all else being equal, would flood out a larger area in the south due to its lower elevation to surrounding regions, flatter topography and poor drainage infrastructure relative to the north.

> ‘The low basin land either dries out or floods out – we rely on bottom-end draining around here (ditches) – they're not maintained – the blowing soil in the 1970s and 1980s plugged the runways – water tends to get land-locked, it doesn't reach the main channels’ (Respondent 60).

> ‘We tried to improve our drainage, but it is difficult without provincial drains to take it away once it is off the field – with those, there'd be less issues with neighbours … the province spends lots of money on drainage of “provincial waterways” which don't exist here – here you have to do it yourself – not even the culverts or drains in ditches on provincial highways are maintained here, and the natural runways are filled with debris and silt as a result of cultivation and erosion during the 1980s drought … during the flood of the century, the Red River Valley had a drainage system in place – they still seeded … that type of system is not in place here –here, you miss an entire crop year … the province never would take action … we’re not treated the same here as the Red River Valley … now it’s more heavily regulated … none of us want to drain and hurt our neighbour – we could do it and be civil about it out here’ (Respondent 38).

Farmers who drained touched on problems associated with inexperience and added expenses.

> 'We're used to dry weather, that's our historical experience – excess moisture is newer, people didn't know what to do – after a big rain, we'd usually be back on the land after one or two days – there was a big effort to drain fields, and there's financial implications in that – it's led to high levels of frustration – the change in farming methods has been hard on people's psyche' (Respondent 33).

> 'I don't know how to adjust to the wet weather – I could increase drainage, but then the water just becomes the neighbour's problem – I'd prefer not to do that' (Respondent 52).

The question of resilience and drainage in response to excess moisture is a variable one, with gradients and water supply central to the matter. Respondent 68 stated that 'the (provincial) drainage ditches now in place allow water to flow past natural catchments – that being said, without these ditches there would be no agriculture or communities in vast sections of the jurisdiction.' Providing the right balance of drainage can enhance resilience to moisture variability, through the provision of water in drier periods and the ability to regulate excesses in wetter periods. At the same time, economic drivers have encouraged *excessive* drainage – increasing exposure to future moisture extremes. For example, low commodity prices have led to a 'mining of the soil … farming on volume, not price' (Respondent 71).

> 'It's (drainage) being aggravated by the way farming has gone – a side effect of having to have more acres in production – so on the other hand, it's hard adding more rules when there are already so many other things making farming difficult – big operators don't want to go around sloughs, even when in some cases they use up more resources then if they just left them alone – years ago this would not have been an issue – we'd leave the sloughs in grass, and when the water was gone in June, cut it for feed – small farms in the day were still able to use all their acres' (Respondent 78).

> 'Ditching season is coming up, but as one producer said, "we are only 60 days away from drought" – with wet weather though, there will be a lot of ditching even though it can move from wet to dry quickly – we should be focusing on a functioning watershed, emphasizing the long term over the short term; not letting the extremes dictate what gets done out there – the land conversion lowers buffering capacity to the extremes' (Respondent 73).

> 'There's no respect for water – people have forgotten the basic water cycle – we need trees, but they tilled them under across the road' (Respondent 55).

Excessive drainage of this nature is a threat to neighbouring properties and regional water quality, particularly in the southwest. As such, drainage licensing and watershed management in Manitoba were major topics addressed by producers and organisational interviewees. Licensing authorities are variable – including the provincial government and, in some instances, Conservation Districts (CD). Administration of drainage by CDs was generally perceived positively, by providing clear standards, representative boards and the protection of ecological services. For example, CD board representation crosses scale, combining producer, municipal and provincial membership – leading to decision-making representative of multiple perspectives.

> 'After the wetness of 1998 I had a neighbour with a blocked runway holding up water on my land – I approached the CD and in consultation with my neighbour, they deepened the runway – it was the year prior to that my neighbour upstream flooded me badly by draining *ad hoc* – that's when I approached the CD about what happened the following year' (Respondent 52).

> 'The funding provided by municipalities ensures representation on the District Board and gives a sense of ownership and participation (in the planning process) – it's good to have a CD present in the Rural Municipality (RM), it helps protect riparian areas in particular' (Respondent 63).

> 'You might ask me how I can be against drainage when I do it myself – I'm on the CD board, as well as the sub-district – in 1998 most people had a good year – not us, we took on their water – it's so flat and level here – we lost acres due to flooding from that type of drainage – so I'm happy about the law for zero to twelve-inch openings – I've learned about water flow capacity through the area – it helps define problem areas which helps address the problem – there are more and more tools to do this – I have an understanding of the Water Stewardship/Water Rights Act surrounding drainage … the CD also helps coordinate RMs, identifies hotspots regardless of boundaries – though some are gung-ho and others don't want to be involved (*i.e.* issue three years ago where a municipality diverted water three miles but wouldn't maintain the drain) – it (the drain) grew in – we went in and did the work last fall because the Emergency Measures Organisation funded a bunch of it – the municipality itself wasn't into doing it – that's why the CD is good – for pointing the finger … the CD response used to be limited by funds available – now you can access money through different mechanisms – they have the capacity now to do $25,000 maintenance work – a very small amount is covered by the CD, but with the RMs you can "stack" funding – use multiple funding sources to address the problem areas' (Respondent 60).

> 'Lots of drainage took place, some guys were cutting paths and passing the problem onto the next guy – planning is part of the license application – it ensures how and where it is drained too, whether it will cause problems downstream' (Respondent 74).

> 'I've been involved in on-site meetings since 2001, including farmers and their neighbours within a two-mile radius – in the past a producer applied for a licence, received it six to twelve months later, and maybe approached neighbours at the end of the process – the licences allow drainage to occur, but also ensure certain controls, such as sediment traps, pipes at the end of ditches, grassing of ditches, *etc.*' (Respondent 68).

CDs often work in partnership with other regional authorities and government branches, which can enhance flexibility. For example, Respondent 68 pointed out that 'government cannot strive for solutions that are not 100% effective, whereas CDs can go after projects that work 70-80% of the time.' Furthermore, CD boards possess practical experience which is not necessary held by employees from other regulatory branches of government. Interestly, Rural Municipality (RM) representatives attributed higher costs and longer time frames associated water management activities to outside government agencies and their lack of experience in the prairies.

> 'The policies and regulations are not working … the Department of Fisheries and Oceans (DFO) could mean culvert requirements may cost a municipality four to five times as much as they would if they (DFO) were not involved' (Respondent 67).

> 'The replacement of large culverts couldn't be done by the RM – we had to do it through Manitoba Conservation – the province and the DFO had "tied our hands" with regards to replacing culverts, which has led to setbacks – too much permitting and red tape – the process needs to be sped up' (Respondent 63).

> 'The province didn't impede *per se*, but financial aid (Disaster Assistance) comes with strings attached – for example, culverts which were put in without a drainage licence would be paid for only if they were dug out, licensed, and put back in – as for the DFO, the licensing and red tape from the Fisheries Act and Navigable Waters, I encouraged the neighbouring reeve to not bother and act with a culvert installation – they'd put in a teeny culvert which will washout in the next flood – if we do it, they (DFO) wouldn't even know otherwise – DFO has been around since 1882, now they're moving into prairies (not really their domain), but we need to work with them – they can significantly increase the cost of a project – we had two bad bridges which were an added cost to farmers who have to divert route – the bridges were dry in spring and could have been repaired but no work was allowed until after June 15th – it was wet by then' (Respondent 71).

Producers made similar comments related to licenses, including: lengthy processing times, regional inequities, over-regulation, under-enforcement and lack of farmer participation – culminating in considerable *ad hoc* drainage.

> ‘Licensing needs to be more controlled – it’s OK if it’s a bit of water – but if the area is flat and without cattail, they’re affecting the water table without realising it – it all drains down into the Souris river, and some producers have been flooded out by drainage practices upstream – people up top get rid of their water and dump it downstream – draining onto neighbour’s doesn’t work so well’ (Respondent 78).

> ‘The procedure to get a licence is heavily regulated and it’s tough to gain permission – it’s regulated by people who are not involved in farming … we applied for a licence, and were told it would take two weeks – it took two years, with a lot of harassment’ (Respondent 38).

> ‘Drainage is top down - they (authorities) are not consulting farmers … there’s a double standard too – it’s OK for the Local Government District to pump onto us, but we need that ability also’ (Respondent 11).

> ‘Licensing seems to be getting tighter and tighter when we really need them to be freer - we have started cleaning up our existing drains, and next fall plan on working on new ones’ (Respondent 20).

> ‘Drainage permits and licensing are not being enforced, so farmers are not even bothering with them’ (Respondent 67).

> ‘The province needs to be much more proactive concerning the drainage going on – they need to increase their role as an intervening body between landowners who have drainage conflicts’ (Respondent 72).

> ‘Licences for drainage need quick turn around times, might take too long to get … governments aren’t prepared to act quickly’ (Respondent 74).

Most producers who mentioned *ad hoc* drainage also discussed consultation of their neighbours. On one hand, this is an indication of self-organisation amongst producers. On the other, it indicates a lack of confidence in water governance – owing to a perceived lack of political will.

> ‘Drainage issues need to include neighbours - we're working it out between ourselves, not necessarily on licensing level – license is more involved than it needs to be, there’s supposed to be permission but we go ahead, it only brings up more problems’ (Respondent 37).

> ‘Farmers got fed up with politics of it, with Manitoba Conservation – we drain on our own, working together – it's illegal, and it’s not much fun knowing that, but there is no choice - admittedly, some drainage is done improperly, but the majority is done in good faith … if it rains here and floods the shed, before I take a shovel of dirt, I need a licence or I could be reported … with respect to the government approach, we don't need more policemen, we need someone who can show you how drainage should be done’ (Respondent 38).

Comments on neighbours included more than just individuals, and surrounding jurisdictions were also a concern. The southwest case study shares provincial and international borders with both Saskatchewan and the United States – neighbours which do not necessarily play by the same rules.

> 'Southeast Saskatchewan has been draining more than they have before, which means more water on the Manitoba side – in 1999 that led to damage to infrastructure (*e.g.* washouts) – if it stays wet, drainage can be expected to increase even more' (Respondent 33).

In these instances, the role of regional authorities and cooperation amongst them is important. Manitoba RMs and CDs have joined the Saskatchewan watershed authority to form the Three Creeks Watershed Association – uniting the watershed for drainage, water quality and management issues. However, CDs are not universally supported by RMs.

> 'Not all CDs have changed to watershed boundaries yet – some RMs haven't joined the CD and ratepayers wonder if they are getting their money out of it – though CDs are the way it should've been organised in the first place' (Respondent 78).

The amalgamation of drainage licensing authority with the watershed planning body (*i.e.* CDs) builds resilient. It helps regions respond to excess drainage and moisture through the provision of information on local hydrology and best management practices. Watershed plans reduce exposure to future moisture extremes, since they remove the guesswork associated with the following type of statement: 'they're moving water off wet land, hopefully to someone else who needs it' (Respondent 71). However, limitations to information, knowledge, finances and political uncertainty are significant barriers to watershed planning.

> 'We (CD) have pushed for watershed management plans the last two years … this provides a tool to take action for flooding and drought. The designing happens at the watershed scale – it's about the big picture, not on the individual municipality or farm basis. We look at what will happen from top to bottom … we have conducted survey and GIS work to alleviate flooding (*e.g.* size of culvert required) – we make use of available technology – our GIS technician has produced work which has led to better planning, higher awareness of ecosystem function, better communication of ideas and faster results – but there are also technological and information limitations – we've used ten-year-old aerial photos, there is a reduced number of water monitoring stations because of government downsizing – we even have to rely on water data generated at operating flow stations outside the CD boundary' (Respondent 67).

> 'Drainage was an action item that resulted from the watershed plan last summer and winter – are we for it or against it? Not much could have been done regarding drainage problems in 1999, but we should have learned more from then to deal with this year (2005)' (Respondent 74).

While improvements to drainage are important, this alone will not solve the problems caused by excess moisture. ‘Excess water comes from extremes, nine out of ten farmers might say it needs to be gotten rid of, or that they don't care who it affects – the fact is, you cannot build enough infrastructure to deal with extremes’ (Respondent 42). As indicated in Chapter 5, farmers respond to weather extremes, including excess moisture, in a variety of ways, and this diversity in response is the foundation of the resilience approach. These responses included strategies which incorporate natural and anthropogenic heterogeneity, reallocate tracts of land prone to flooding to other uses, use technologies to overcome obstacles and/or provide mediation of soil drainage properties.

6.1.3 Alternatives to waiting or draining: buffers and technology responses

Some farmer responses helped reduce exposure to excess moisture by spreading risk – through improved internal drainage, diversification of commodities and end products and increased technological capacity. The following examples represent buffers which enhanced operational flexibility to moisture extremes, though producers acknowledged the extra work required to do so.

Producers buffered themselves against excess moisture by improving internal drainage on parcels of their land by amending soil properties through rotational practices, manure management or altering cultivation strategies. For instance, Respondent 28 stated, ‘the pasture takes the moisture OK, particularly with manure incorporation’ (Respondent 28).

> ‘This spring when the land was wet my husband went out, pulled an old plough out of the bush, and worked the land until the water was gone – the young guys just sat around waiting for it to dry up – some of the big outfits simply have so much invested they become rigid, they lose their flexibility in how things are done’ (Respondent 63).

> ‘We've been using a quick rotation strategy the last ten to twelve years – for three years it’s fenced with hay or grass, then cropped – the objective is to have forage on every acre – from what we've observed, we are convinced of the benefits of forage in rotation – in 2005, two-thirds of the crop had been into and out of forage – it handled the water much better – the acres which had been in crop for twenty-three generations were not as good because of poorer internal drainage and soil structure – the alfalfa root structure goes down fifteen feet, which allows water to drain – in 1999 we saw it’ (Respondent 22).

Other producers evaluated risk and adapted by exchanging tracts of property prone to failure or altered production to suit typical conditions.

> 'We dropped acres north of Reston three years ago – over the eight years I farmed it, only one or two were productive – you really have to assess the risk factors of tracts of land – there's another 800 acres coming up for sale right at our backdoor – we're better off with the lower risk land, with a better slope for drainage' (Respondent 60).

Several grain producers changed cultivars or crop types, planted multiple crops and setback seeding to fall.

> 'We planted crops which handle moisture better – less flax, more wheat and barley on the drier land' (Respondent 23).
>
> 'We did summer fallow and planted winter wheat in the fall – 2000 was our best crop ever – it did well – we saved on inputs, why would we mud it in?' (Respondent 46).
>
> 'We plant canola, flax, sunflowers, oats, barley, rye, hard wheat and peas – often all in one year – hopefully two or three of them pay decently at the end of the year – it spreads the risk – however, diversification equals more work – it may balance things in the short term better than a single-commodity operation transition into next, but in the long run those should average out too – you just need to be able to survive a five year string of poor performance in a single commodity' (Respondent 59).

Mixed operations were better equipped to manage adaptively, by allocating poor cash crops to feed or converting vulnerable acres in crops to forage and pasture. In these cases, production of silage increases the feed value of poor cash crops and even weeds. The conservation and use of wetlands and weedy species are an indication of local resource management knowledge and a novel application of ecosystem services.

> 'We cut the oats early (in October) for green feed – it wasn't going to be marketable as a crop, the oats had rust – if you'd grown the oats as a straight crop, you'd be in trouble – we also cut bulrushes for feed in the spring, the protein content was 18% (same as alfalfa)' (Respondent 35).
>
> 'We sowed oats in July 1999 – it went to green feed … in the end the crops were light – but the ability to grow feed was tremendous – the quality was down, but there was great production – if we'd have been set up like we are today, the oats, *etc.* would have made great silage – that triggered our move into cattle – in 2005 with our alfalfa, we didn't have a water problem – we'd shifted – the switch to silage helped in wet years – we let volunteer weeds grow and turned it all into feed with the forage harvester – we put silage up at high moisture – things like foxtail, that cause lumps in cattle, were not an issue (degraded)' (Respondent 54).

> ‘We couldn't put up hay, so we moved into silage – it makes for super good feed and weeds can be silaged too – the unsown acres of 1999 went to weeds – these were silaged which reduced their seeds’ (Respondent 56).

Many producers opted for technological responses, including the addition of dryers and heaters to bins for harvesting wet grain, or larger machinery capable of travelling over muddy terrain. ‘Getting stuck and rutting the fields is dependent on equipment – we've had upgrades since 1999, with wetness in mind’ (Respondent 42). ‘It was difficult to combine crops with moisture – now we can take it off at seventeen or eighteen-percent moisture, even up to 25 percent – without the fans, it’s difficult to harvest properly – this year only the canola and a third of the wheat were taken off dry’ (Respondent 6).

Reduced tillage was also perceived as an aid to mobility in wet conditions, which is somewhat of a surprise, since the practice was largely adopted for moisture conservation and cost reduction during water-deficient conditions. This result is an example of buffering against unknowable change and uncertainty.

> ‘It makes it easier to sow early – if you had a field half ploughed and half not, which would you drive on? Early seeding is the critical thing, and the best defense against frost, wetness and drought – zero-till is critical to what we do here – it’s easy and works for wet and dry’ (Respondent 22).

However, this point of view was not shared by everyone. ‘The moisture trap created by direct seeding is a double-edged sword – it compounded excess moisture problem’ (Respondent 34). ‘With excess moisture there is not a significant difference between zero-till and conventional tillage’ (Respondent 30).

These alternative responses (adaptations in particular) are subject to a host of aiding and impeding influences, including the additional costs associated with transition, technology and labour. ‘The transition was wildly expensive – $400,000 for the chopper, $100,000 for the swather – plus it’s big labour’ (Respondent 56). ‘In 2005, I wanted to silage again, but price of fuel for the process prohibited it’ (Respondent 14). ‘With two sides to the operation, there's more stress and no off-season’ (Respondent 59). Large shocks and stresses can also make it difficult to maintain both sides of a mixed operation.

‘We thought we'd get into canola, wheat and barley – after the frost in 2004, we were right out again’ (Respondent 13).

Producers also discussed the Canadian Agricultural Income Stabilisation (CAIS) program, which many thought provided a disincentive to mixed farming and silage production.

> ‘I’m hoping to qualify for (CAIS) in 2005, I don't know yet – you're encouraged to use these programs, but when payments are to be made, you're better off not participating –because of our diversification we don't fit the mould – if you feed the grain to yourself (cattle), they don't consider it lost income because it's not being sold commercially – it depresses the payment’ (Respondent 44).

> ‘Our BSE program support is tied to CAIS – if we don't qualify in 2004, they’ll want the money back – I’m expecting a bill – also, the farm inventory counts as income – so silage counts even though it is for feed, not resale’ (Respondent 14).

> ‘It’s (CAIS) not working for diverse or mixed farmers – it doesn't cover for individual disasters, but treats them as one (*e.g.* BSE programs were good and helped them survive, but makes their incomes look stable to CAIS) … GOPP (grain and oilseed program) is OK for straight grain – it's based on reference margins from CAIS – we're waiting, afraid we won't qualify because of advances received for cattle during BSE, or that they'll want the CAIS advance back – I don't know for a given year whether we're eligible or not’ (Respondent 49).

> ‘2004 was our worst year all things considered, but feed inventory (silage) was up $25,000 – but how would we sell the silage out of the bunker pit? It’s not intended for sale – the program lacks common sense – the cost put into making the silage, as well as the cost of land rental, on the other hand, are not considered an expense … something is wrong there – it seems you need to use and abuse the program to make it work – what good is that?’ (Respondent 28).

Cost-sharing, the presence of contractible services and rental opportunities in these regions helped reduce economic thresholds. Furthermore, producer’s referred to flexible attitudes, open-mindedness and the ability to prioritize as key aids to these responses.

> ‘You have to be able to step back, remember what’s most important, and take some time for yourself – take things in stride – multiple generations can be a drawback because of a sense of responsibility to keep everything in the family – it leads to decisions based on emotion rather than sound business sometimes, for example, failing to downsize, or buying up “family land” you cannot afford’ (Respondent 31).

Experience, knowledge and participation in local clubs and program opportunities were also important response aids. These responses are more than alternatives to waiting or draining, representing proactive approaches to soil and water issues and a shift away from production-oriented land use.

> ‘We now practice rotational, swath and bale grazing – it spreads the manure that way – we rotate cattle in forty to fifty-acre paddocks – my son took a rangeland management course in Lethbridge and has been making adjustments on the farm … we take part in Grazing Club which meets periodically at Conservation District office’ (Respondent 35).

> ‘Our programs provide an alternative to drainage, so people get something out of their wetlands, compensation for *not* draining and seeding wet areas – some think it’s enough, others will never bite – to curb drainage by these people, regulation is the only answer – they will only be stopped by an iron-clad law’ (Respondent 72).

A Conservation District manager discussed periodic evaluation of programs, prioritising activities relative to economics and the changing needs of the region – an excellent example of adaptive policy at the regional level.

> ‘The Conservation District board differs from the staff perspective – they’re of the frame of mind that more water storage will help mitigate flooding – that’s not a guarantee – in 2005, in the lowest area in the watershed, it was still three feet deep, plus one foot deep on the upstream end - the staged release works with slight water flows, but the extremes simply exceed the present infrastructure and doesn’t mitigate damage … the periodic review of programs and policies to evaluate suitability with respect to their provision for the district’s goals are measured against their cost’ (Respondent 68).

6.2 Resilience and moisture deficiency

As previously mentioned, the period of research interest (1999-2005) was predominated in the two case studies by excess, rather than deficient, moisture. Never-the-less, historical exposure to drought resulted in lengthy discussion of the topic by interviewees. ‘Historically it has been drought issues’ (Respondent 7). ‘It's always been dry, but not in the last five years’ (Respondent 55).

Drought experience was particularly evident in the southwest case study – demonstrated the frequency with which they discussed the stress (twenty-five in the southwest, fifteen in the north). Drought impacts – including lost yields, insect outbreaks and feed shortages – exposed grain, cattle and mixed operations alike. However, producers stressed an ability to cope with aridity, due in large part to their historical experience.

> ‘Drought runs in a 10-year cycle so you should prepare for it, though the extent and severity cannot be known’ (Respondent 27).
>
> ‘Growing up we were in a drier cycle, it was more consistent …we're well conditioned to drought so it's not as catastrophic’ (Respondent 57).
>
> ‘Dealing with dryness is not a surprise - weather problems are dealt with through my built-up experience, while drawing on the wealth of experience from older farmers and neighbours in the area – they have a far greater ability to adapt’ (Respondent 31).

Major responses to aridity included reduced tillage, getting outside help, altering cycles for less than one year, increasing buffer capacity and ‘working with the weather’. Several of these responses to drought are linked into multiple stresses, indicative of a systems approach to farming. Furthermore, both long and short term responses were employed, which is also an indication of resilience, working across temporal scales. Importantly, coping strategies may become adaptive over time (Berkes and Jolly, 2001).

Coping strategies included getting outside help and temporary alterations to farm cycles. A good knowledge base, coupled with creativity, helped Respondent 27 alter feeding cycles during drought. However, the coincidence of multiple stresses can make altering cycles during drought difficult. Respondent 27 discussed how the BSE crisis impeded the ability to temporary ‘de-stock’ in response to high feed prices.

> ‘As for feeding during drought – I know how to change feed resources/formulas (holds a PhD in agriculture) – I bought more straw and made the proper contacts – even so, the costs were ten percent higher than normal over winter – you have to think outside the box to get around problems, you have to calculate that into your management plan …the feed prices went up to $90 or $100 a ton during the drought, but cattle prices dropped to eight cents a pound during BSE - that coinciding was the biggest stress – it is very difficult to de-stock the herd, which is the normal response during a drought.’

Many produces cited strong business relationships and resource sharing arrangements as essential in the reduction of cost associated with getting outside help from within the local agricultural sector (*i.e.* buying hay from off the farm, labour and equipment pools, local abattoirs and transport services). Contracting work and purchasing commodities outside the farm can increase efficiency.

> ‘We hauled straw fifty miles for feed, due to dryness and large herd retention from BSE - it was the first time in 100 years we had to buy feed – we bought feed from Dauphin area where they actually received lots of rain in 2003’ (Respondent 35).

> ‘My neighbour has a trucking business – what used to take me two or three days, he can do in one – it saves time and fuel … During hay shortages, I buy from reasonable guys … I’ve been dealing with the same guys for hay over twelve years – they’re pretty good about not taking advantage of one another – there is recognition that our livelihoods hinge on one another in the long term – these good business relationships are key’ (Respondent 16).

> ‘As the operation gets bigger, we're more and more dependent on a good feed source – we either have to go farther to get it, or reduce the herd – back in the day, mixed farms provided options – but they have lots of negatives too’ (Respondent 51).

These responses are a prime example of self-organisation amongst producers. Furthermore, self-organisation is occurring both amongst producers and across organisational scales. Networks between farmers and organisations on different levels influence adaptive capacity and reduce vulnerability (Berkes, 2007). Respondent 27 discussed the potential of cooperative ventures involving farmers and industry.

> ‘We need to make different types of feed resources available to farmers, and potentially alternative feeds (*e.g.* bi-products of grain industry) – grain and cattle guys could work together in drought years – create some revenue for grain producers by fencing off and allowing cattle onto crops it might not be economical to harvest – often a great feed crop gets written off, but is never baled up for cattle – it would be a tremendous, but difficult, solution – during drought, there’s always feed in area which doesn't get used (Respondent 27).

Respondent 35 discussed how they ‘take part in Grazing Club which meets periodically at the Conservation District office.’ Skills-training programs can also augment capacity in these communities.

> ‘The Canadian Agricultural Skills Service program was run and administered by the Parkland, and the information was available at the agricultural office – if your income is below a set level they subsidize training – myself and my wife received $16,000 each as a grant – I'm doing my Class 1’ (Respondent 36).

Adaptive strategies to deal with drought conditions included the establishment of buffers and long term amendments to various farm cycles. Farmers incorporated buffers to spread risk by spreading property over space, producing below carrying capacity and diversifying production methods and commodities. Simply put, ‘the key is not to operate in a “be-all-end-all” fashion – the bills always come and you need to have the money to fall back on' (Respondent 8). Some buffering strategies, as the word implies, work equally well for moisture excesses and deficiencies.

> 'Our land goes fifteen miles north to south, and two miles east to west – the climate moves west to east …we're self-insured' (Respondent 19).
>
> 'We spread our land out – we're north and west of Melita – we run across soil types and weather changes – at home here, it's gravel – last year it wasn't too bad, but in dry years it's opposite – this helps spread risk – when you're in business with the weather, you assume things will be average and then hope for cooperation' (Respondent 59).
>
> 'With drought there's not much you could do – hay wasn't too bad, but there was no second cut – the pasture further south was better off – I have pastures within a thirty mile radius of the farm – when it's dry, all you can do is be ahead with feed, have extra pasture – you can't make it grow – you need more land or stacks, or you reduce your herd number' (Respondent 57).

The allocation of land to extra forage, rotational systems, altering varieties and soil amendments helped buffer operations during droughts.

> 'I sowed a lot of marginal acres to grass, started rotational grazing, and get water from the pipeline while reducing my usage of dugouts and creeks' (Respondent 51).
>
> 'In drought years you don't get quantity, but the quality of the grass that does grow is high – we have lots of bush on property and grass does well in there in drought years' (Respondent 13).
>
> 'Weather-wise, the bad thing about cattle is wet or dry, the number of head you can support changes a lot – I have a bit of extra pasture so as not to overgraze, to deal with the uncertainty of weather' (Respondent 57).
>
> 'We wouldn't wait for event to happen to react … we have hay, early and late maturing crops which compensates for weather-related patterns' (Respondent 19).
>
> 'I added manure from feedlot which has benefited our soil – we're building back what was lost in the 1930's – that increases our land value' (Respondent 54).

Producers adapted to drought by altering calving, grazing and seeding cycles, highlighting how alternative markets and regional infrastructure build adaptive capacity, and increase options, for farmers.

> 'The value of grass and legume in rotation is phenomenal – we struggled to incorporate it for the health of the land – tracts are rotated through a continuous cropping program, and the alfalfa was marketed to an alfalfa dehydration plant – unfortunately the plant did not survive – we seeded and rented tracts in pasture to cattle folks after that – the addition of fencing was considered an investment – the land use can be varied – the grazing has been equal too, or better than, the grain grown' (Respondent 30).

> 'I changed the calving season to late spring – it means less feeding of hay and more time on pasture – I planted crops to extend the grazing season, reducing the labour and overhead of over-wintering (with cattle indoors) … we bale graze on the hay land, on the land which could use the fertilizer – manure spreading is not an issue – it simplifies the operation, makes it more efficient – before it was seven dollars to bale, five dollars to haul it to the yard, plus the cost of manure spreading afterwards – this way, it saves me twelve dollars a bale – I'll still buy hay though, and graze the hay land, if buying is cheaper than growing – bought hay has two nutrient values – one as feed, the other as fertilizer – I'm importing fertilizer' (Respondent 39).

Organisational interviewees mentioned measures and programs designed to buffer regional water supplies. Respondent 73 discussed the use of small dams to trap surface run-off, while Respondent 74 added the need to fund research for water exploration in the Pierson Buried Valley – money for water supply enhancement programs. Respondent 68 discussed the 1997 policy related to water storage for major use, making clear how and why regulated water supply helps ensure common-pool resources are not usurped by upstream users.

> 'In 1997 the province developed a policy on water storage for major use, relying heavily on the recommendation of the Conservation District – there are a few spring-fed waterways from the western escarpment, but not enough to irrigate – water storage for major use, therefore, cannot be "in-channel" (*i.e.* water cannot be freely pulled off creeks or the provincial drainage system) – there is no allocation of flow except during spring runoff, a period of high flow – the problem with "in-channel" storage is that it fills up and creates water deficit for others – meaning producers have to build reservoirs for storage – between seven to ten eighty-acre/foot reservoirs have been built since 1999 – this costs a producer three thousand per acre/foot – at a hundred acre/feet, that equals three hundred thousand dollars.'

6.2.1 Reduced tillage

The widespread adoption of reduced tillage practices in recent decades has been due to various drivers, including response to drought, high input costs, low commodity prices and combinations of these stresses. As a drought response, reduced tillage conserves moisture by reducing the rates of evapo-transpiration and erosion. Some farmers described the reduction of costs.

> 'It's strictly economic – with savings in input costs and labour, making fewer trips and only working (cultivating) low spots for drainage – the days of recreational tillage are over – we can straight cut rather than swath too (one less pass) – it saves you money in inputs' (Respondent 50).

> 'It's an economic thing – there's fewer trips across the field, it prevents erosion, crops get in earlier, it uses the same amount of fertilizer and a bit more pesticide' (Respondent 19).

Roughly half of the producers who cited reduced tillage as a response linked it to both economic and environmental factors. Reduced tillage, and other responses which span shocks and stresses, demonstrate a systems approach.

> 'The rational for zero-till was drought-driven – we were minimum till prior to that because it reduced manpower, equipment and fuel costs' (Respondent 42).
>
> 'I'm in reduced tillage to conserve soil, moisture and labour costs – after the 1980s drought, the biggest driver then was moisture – since then I have become a soil conservationist – it's important to long term sustainability – the reduced labour is a bonus – I'd be down to 1000 acres or less if I weren't zero-till' (Respondent 23).
>
> 'Erosion was the trigger, but it was more to conserve moisture, to reduce inputs – you use a third of the fuel – you still use chemicals, but they're cheaper' (Respondent 48).

The southwest demonstrated more advanced uptake and development of reduced tillage relative to the northern case study, due to differences in historical exposure to drought and geophysical conditions. The southwest case study is geographically situated in the extreme south eastern corner of the drone-prone region known as Palliser's Triangle, which Palliser described as unsuitable for agricultural development. True to form, the region has experienced greater historical exposure to drought and its impacts, including the dust-bowl of the 1930s.

> 'Lots of marginal land has been converted to forage or zero-tillage – the land doesn't blow like it used to, it maximizes moisture' (Respondent 74).
>
> 'I'm minimum as opposed to zero-till – we have to do some discing before seeding – there's two reasons why I'm not zero-till – one, the sand hardens with moisture – two, the black soil warms up faster' (Respondent 11).

Barriers to the incorporation of reduced tillage include factors such as time, experience and money.

> 'Zero-till took awhile to learn to use – the first year I seeded too deep – it is trial and error' (Respondent 52).
>
> 'There are initial benefits to zero-till, and then a lot more – there's a lag when you are still spending the same amount of money controlling weeds in the shallow zone, and then you're on top of it' (Respondent 48).

> ‘I knew at the start it would come at a cost – but inputs were increasing and we had to do something’ (Respondent 41).
>
> ‘When I made the initial commitment to zero-till, I needed glycol-phosphate – Monsanto had the patent – it was priced out of the range a farmer could afford – it took until five years ago (the patent expiry date) for the soil conservation strategy to grab hold in Western Canada – patent rights and corporate greed seem to trump social benefits’ (Respondent 30).

Presence of early adopters in the southwest case study has provided the region with a history of advocacy and practical knowledge, which helped surmount these barriers to uptake. Respondent 30 described the early days of conservation tillage in the southwest and the challenges pioneers faced, including community scepticism and technological limitations.

> ‘I was an early adopter of zero-till in late seventies – you don't learn it quickly, it comes with experience and observation – the biggest criticism of zero-till was that I'd have to apply more pesticide – that in itself is not a true statement – I use different pesticides, and probably use less per acre than many conventional guys – now we are witnessing a huge swing to zero-till.’
>
> ‘We started experimenting with minimum till in 1979 – we tried different machines, we wanted to be able to do things in one pass – I found a double-shoot drill (fertiliser and seed in separate holes) – I built a prototype with the boot I wanted to reduce disturbance – we did a one-year trial with Atom Jet Industries in Brandon – I made the boot for a third of what it was worth – experimentation over time helped – at first we hired guys to seed with single shoot drills (fertilizer and seed in one hole) – the crop was burnt by the fertilizer’ (Respondent 41).
>
> ‘In the 1980s there were a handful of guys who were good at it, had a knowledge base – I followed them – at first I had doubts in my head – perceptions of people around you who think you're crazy – but now it's 99% of farms around here – that (early perception) didn't impede me – I couldn't get in fast enough … there were equipment issues, but those were mostly for the pioneers – guys designing things in their backyard shops – when we got into it, manufacturers were into it, making better, more reliable equipment’ (Respondent 42).

Pioneers provided the impetus for the study and promotion of reduced tillage programs by regional soils and water conservation groups. ‘Farmers began the reduced tillage and single-pass movement – the research followed – it’s hard to get more efficient than that’ (Respondent 76). Organisations increase learning opportunities and reduced uptake costs through tillage programs, helping producers surmount barriers.

> ‘It was through the “Farming for Tomorrow” program offered five years ago – the Conservation District provided an air-seeder for this purpose, which they rented to us to try out – we have since bought our own air-seeder’ (Respondent 35).

> ‘Local soil management groups in the early 1990s changed things totally – through their programs, and using their equipment, it didn't cost anyone anything and benefited the environment’ (Respondent 22).

> ‘At the time the first winged air-seeders came in, around 1993, it was a great thing – it saved a lot of time in moving from field to field – I rented one for a year through the Conservation District, then purchased one’ (Respondent 52).

> ‘The Manitoba-North Dakota Zero-till Association was a local group set up 20-25 years ago - there were 20-25 guys per meeting then, but by the mid 1990s thousands of guys were wanting to know more about it – the PFRA, Manitoba Agriculture, Bill Poole from Ducks Unlimited all backed the movement’ (Respondent 42).

> ‘It was the Sandi-lands Soil and Water Conservation group – they had the foresight to go to the dealer, who in turn dealt with the manufacturer – they gave the group a 28 foot air-seeder for free, so farmer's could give it a run – it was advertising for a company out of Saskatchewan – it was met with scepticism, but it was free – they've ended up with huge sales … our production went up 25% right away, 50% over time – the whole thing was farmer-driven and controlled – the money was being used well’ (Respondent 56).

Widespread adoption of reduced tillage across the prairies bodes well for the northern case study, particularly in light of future variability. Respondent 63, a northern producer who grew up in the southwest, relayed how her mother remarked that dry, high winds near Minnedosa were ‘like the dust-bowl in Deloraine.’

While reduced tillage is a resilience-building response, single strategies alone are not likely to completely buffer producers from the extremes. ‘Weather I can take in stride – zero-till allows for growth in droughts with as little as four or five inches of rain – it’s the extremes we can't handle’ (Respondent 50). ‘If the land is not being farmed properly it doesn't matter if you have shelterbelts – it'll erode anyways’ (Respondent 11). Reducing vulnerability to future extremes requires a suite of practices which buffer moisture variability. Reduced tillage, permanent covers and, more historically, the planting of shelterbelts all function to capture moisture and reduce erosion.

6.2.2 *Resilience and diversity*

Combinations of reduced tillage, permanent covers and shelterbelts build resilience through redundancy, which is important for multiple reasons. First, the conservation of soil and water through several different, independent processes provides insurance in the event one method proves ineffective or insufficient on its own. The greater gross water deficiencies, associated with extreme drought events, require larger buffers, cumulatively provided through redundant methods.

Secondly, moisture conservation methods provide multiple functions that do not overlap. Shelterbelts and other covers help buffer forage resources, create refuges for livestock and stimulate biodiversity. ‘There’s lots of bush on the property, and the grass (feed) does well in there in drought years’ (Respondent 13). While reduced tillage was important to water conservation, shelterbelts are ‘still good for canola swaths, they keep them from blowing’ (Respondent 46). Shelterbelts were also used in conjunction with strategies for watering cattle: ‘I planted strips to help trap snow around the dugouts, it has helped’ (Respondent 39).

Thirdly, different methods reduce vulnerability by providing surprise benefits to unforeseeable shocks and stresses, which is particularly important in light of the uncertainty associated with climatic models alluding to both increased frequency and severity of weather extremes (Runnalls, 2007). As mentioned in the last section, zero-till ‘makes it easier to sow early … it’s easy and works for wet and dry’ (Respondent 22). ‘You can stand on it better - some guys think it retains moisture - I don't go for that’ (Respondent 42). Beyond increasing mobility in excessive spring moisture, Respondent 37 translated time and money saved into expansion efforts: ‘we’re slowly growing as machinery improves – we doubled our acres in 1998 when we made the move to zero-till’.

Producers have a long standing history, with shelterbelts and the Shelterbelt Tree program. The PFRA has partnered with CDs in coordinated programming.

> ‘We plant for producers, using their trees (PFRA) – we have a stand alone program for this purpose, including our own mulch and plastic – these cost producers $200 a mile and the CD $3000 a mile – we plant and maintain the belts for two or three times a year for three years –the plastic increases the cost to plant but saves weeding and promotes growth’ (Respondent 68).

Most operations had participated in the planting of shelterbelts at one time or another, though in some cases they were not necessary due to the natural presence of trees.

‘There’s enough bush on the land here to begin with, so wind erosion is not an issue’ (Respondent 20). ‘Shelterbelts have limited application here, it’s not wide open country – in most cases natural strips of poplar and wetlands occur on twenty acres of each quarter section’ (Respondent 50).

However, a trend towards shelterbelt reduction, in areas where broad establishment has occurred, mirrors the uptake of reduced tillage. Shelterbelts were perceived by some farmers as a solution of the past, the role of which has since been replaced by conservation tillage. Production aimed at increasing margins means elimination of redundancies to save costs (Box 5).

> ‘We don't personally need strips, zero-till and the stubble takes care of that’ (Respondent 23).
>
> ‘The program is alright, but since the uptake of zero-till, it has run its course’ (Respondent 42).
>
> ‘With zero-till they (shelterbelts) are not an issue, they’re more of an obstacle’ (Respondent 48).

Box 5: Production pressures and declines in covers and shelterbelts

‘The CD has put 1600 miles of shelterbelts in place to reduce erosion, *etc.* – farmer’s have a short memory – we used to do 100 miles of shelterbelts a year, now it’s twelve to fourteen miles, while losing 40 miles a year – this is because it has been wet in recent years, but there was major drought through the 1980s – farmers are less likely now to want to cultivate around, or incorporate, wetlands, shelterbelts or bluffs -producers are happier giving the CD large blocks of land, rather than in conserving two acres on 80 – the old attitude was to leave the land in better condition than you got it in – now farmers are not passing down the farms anymore, leaving a legacy, involving their sons – this has lead to a mining of the soil – there used to be ridges built up between ¼ sections with grasses and trees – these are disappearing – farms are getting larger and gearing towards maximizing returns per acre – the specialization and reduction in mixed farming has impacted grassed runways along watercourses – they used to be fenced and hayed for cattle – now operations are in straight grain with no cattle, there’s too few head to give runways value, which means a reduction in buffering capacity – the runway starts to look more like a drainage ditch than a grassed runway – this is economically driven, rather than by weather’ (Respondent 68).

Redundancy, while resilience-building, represents more work and additional costs in the short term. Many producers alluded to difficulties establishing the trees, or find them a nuisance due to changes in farming methods.

> ‘I planted belts to the north and west – they’re working good now after twenty years, but they were a lot of work to establish’ (Respondent 29).
>
> ‘They (technologies) act as a driver that makes it more efficient to travel in straight lines … it doesn’t take a rocket scientist to see the increase in efficiency by driving through low spots’ (Respondent 26).
>
> ‘I participated in the shelterbelt program in the early 1990s – now I’m more into taking them out, they don't fit well in the middle of field – they helped with erosion in the 1930s, but they're not there for that reason anymore – the maintenance every year includes blow downs, cutting it back – they’re tough with the bigger machinery’ (Respondent 58).
>
> ‘I don’t know how it (shelterbelts) fit in now – farm methods have changed, so erosion is controlled – strips are now a nuisance because of larger equipment – there’s lots of rip-outs and burning going on’ (Respondent 69).
>
> ‘We've got zero-till now – the chemicals which are required for zero-till, the drift (chemical) hurts them (shelterbelts) – in the pasture we tried planting green ash, which grew slowly, so we used bale stacks in tripod shape for shelters’ (Respondent 56).

Producers also highlighted the lack of adequate incentives and poor design regarding programs for the establishment of other permanent covers. Respondent 73 discussed the Green-cover program, a federal incentive aimed at converting marginal land in cultivation into perennial cover.

> ‘They offer incentives which are not high enough, or which do not make sense – for example, the Green-cover Canada program – there was not much incentive to leave previously unbroken land pristine, but there was money to rehabilitate it once it’s broken and it proves unproductive.’
>
> ‘We do not qualify (for the Green-cover program) because we have already incorporated the principles on our farm – it covers planting trees too, but the incentive is too low’ (Respondent 10).

Trade-offs, or elimination of redundancies, indicate linear-thinking and reductionist management approaches. Perception of response functions as one-to-one (*e.g.* conservation tillage and shelterbelts) leads the removal of components from social-ecological systems – limiting options and thereby hijacking the processes of self-organisation (Berkes *et al.*, 2003). This is a distinctly maladaptive behaviour, increasing vulnerability and exposure to possible increases of non-linear environmental change (Millenium Assessment, 2005).

Program incentives are weighed against the ‘rising costs associated with overhead and downward market – which forces farmer’s to cultivate every inch’ (Respondent 73). Some cover programs have been improved by accessing federal funding allotted for carbon sequestration projects, which was important to uptake in several cases.

> ‘I have used the shelterbelt program – I planted two belts, a quarter mile each – the one across the road was also done with the Soil Management Group in a study bid to access money from Kyoto initiatives and carbon credits – it was through the Covering New Ground program – there was money for things like established woodlots’ (Respondent 18).

> ‘We developed this yard site ten years ago, we put in 1000 trees – the PFRA comes in and designs it – they do it cheaply – there are eight rows across a half-mile total – it is a super program’ (Respondent 17).

> ‘I did the yard site on the farm I grew up on – I heard of a Manitoba Hydro program to do with trees, though the Conservation District – I planted five foot trees versus little sticks (quicker establishment) – the district manager and I talked about it, he assessed and filled out the forms, and sent in the application’ (Respondent 24).

7.0 Conclusions

This chapter reviews the objectives, including identification of weather-related stresses, responses, examples of resilience-building for the two case study areas during the 1999-2005 period, and comments on vulnerability to future climate shocks and stresses with emphasis on social and economic pressures limiting response capacity.

7.1 Identification of climate-related shocks and stresses (1999-2005)

Weather stresses (excess moisture, cool summer temperatures, droughts and dry periods) and shocks (heavy precipitation, frost and hail) figured prominently amongst all stresses for the period of interest (1999-2005), including those related to economic and social issues. Producers also discussed increased weather variability and an associated decrease in predictability during those five years. Impact severity and levels of experience were important themes which emerged, including that stresses and impacts often link to one another in synergistic fashion. Vulnerability and exposure to weather extremes were far more important than climatic events of moderate severity. Furthermore, excess moisture dominated the five year period of interest – a perturbation with which farmers have relatively little historical experience as compared to drought. Increased weather variability, coupled with a lack of experience with excess moisture, are important to agroecosystem resilience. The unexpectedness of too much moisture highlights uncertainty inherent to complex systems.

7.2 Farmer responses to weather events

Producers responded to weather stresses from 1999-2005 in diverse ways, including strategies internal to the operation or linked to external sources (*i.e.* neighbours, contractors and organisations). Responses also ranged temporally, and by levels of required economic and labour investment.

Some response methods linked linearly to specific stresses. Improvement or expansion of drains, for example, reduced flooded out areas or lowered soil moisture content. On the other hand, some strategies spanned shocks and stresses. Spreading an operation over larger areas reduces the risk associated with many weather shocks and stresses, owing to the spatial heterogeneity of impacts. Other responses functioned as one of multiple options, amounting to overlapping approaches. Shelterbelts, reduced tillage and permanent covers all deal with moisture deficiency, via stand-alone mechanisms.

Farmer responses depended on issues of context across scale, including considerations at the operational, regional and national levels. Cattle producers, for example, noted improvements to pasture and forage during wet periods, while grain producers suffered reductions in both crop yields and quality. Issues linked to rural decline also influence the capacity for response throughout the Canadian West – producers in both case studies alluded to an inability to control exposure to weather stresses in light of tight economic margins, population declines and loss of regional services.

7.3 Determination of what can be learned from these responses to build resilience and reduce vulnerability to weather variability

The lack of predictability and surprising nature of weather events in the 1999-2005 period of study are not proof of climate change. Rather, the results provide a window on a period marked by variability in the two case study areas. However, producers also referenced historical experiences with weather variability such as the dust bowl of the 1930's and excess snowfall in the 1950's. These previous historical experiences, along with the lack of a sustained, observable and unprecedented trend in climatic extremes on the Prairies – such as that witnessed in the Canadian Arctic – mean that farmers are not prepared to attribute weather variability solely to climate change. Furthermore, the political ramification of the term 'weather variability' is different from the term 'climate change'. There is a sense amongst farmers that weather extremes have historically led to compensatory measures such as Crop Insurance, whereas climate change raises suspicion of regulatory action. However, the questions posed by this thesis are less about the linkage of shocks and stresses to climate change, than how to build resilience to deal with weather variability. Reducing exposure to future variability amounts to enhancing system resilience.

Building resilience requires increasing both diversity and redundancy across scale. Diversity in agroecosystems amounts to enhancing ecological and social heterogeneity (*e.g.* beneficial insect species, clubs and interest groups) which increases options. A variety of responses to 1999-2005 disturbances were found to be resilience-building, while others constituted non-resilient responses – some which increase exposure to future weather variability.

Resilience-building responses exhibited certain universal properties, including increased flexibility. Producers responded to both excess and deficient moisture by enhancing buffering capacity – increasing their options to future weather variability. Rotational strategies, manure incorporation, manure, grazing strategies, diversification of crops and varieties, use of certain technologies, transition from single-commodity production to mixed farming and even cultivating the soil using a hand-driven plough are some of the examples of resilient responses.

Adaptations require 'sunk' capital, including both labour and money. In cases where these strategies were employed, perceived benefits, both actual and future, outweighed the cost. That is, producers who incorporated resilience-building strategies placed emphasis on the savings associated with the fostering of ecological services and adaptive management approaches. A smaller subset of farm interviewees, with strong local knowledge and a systems perspective of food production, persist – not-with-standing market and political pressures which favour increased specialisation and reliance on economies of scale.

On the other hand, producers often respond to moisture variability in reactive fashions that increase exposure to future moisture variability. This was particularly true of grain producers during wet periods, where major responses included either waiting out the moisture or reliance on excessive drainage to circumvent field saturation. Waiting out excess moisture was strongly linked to Crop Insurance claims, which may lead to economic failures of both the program and operations consistently reliant on it. Assistance payments do not build adaptive capacity when they discourage alternative responses or no response at all.

Drainage efforts can aggravate water deficiency problems during dry periods, or create problems for neighbours in wet periods. Here, economic considerations trump ecological and social values important to the long-term sustainability of agroecosystems. This type of command-and-control approach, which seeks to reduce the range of natural variability in an attempt to increase their stability or predictability (Holling and Meffe, 1996; Peterson *et al.*, 1998), increases the vulnerability of farm operations to disturbance. The elimination of system diversity or redundancy, such as shelterbelts, are examples of Cartesian approaches.

These solutions create reliance on off-farm inputs to cope with variable weather and market conditions, such as overuse of fertilizers and pesticides rather than ecosystem services including nutrient cycling and biological controls (Rhoades and Nazarea, 1999). Turner *et al.* (2003) cautions against omission of a systems approach in dealing with vulnerability, pointing out that these types of responses often lead to unintended outcomes and heightened uncertainty. The remainder of the chapter includes a discussion of systems-wide agricultural trends and attitudes which are considerations for enhancing the future resilience of agroecosystems.

7.3.1 Managing for resilience: perceptions and values of agroecosystem actors

Since the direction of self-organisation is hard to predict – due to the large number of possible future recombinations associated with differential successes and failures (Berkes *et al.*, 2003) – resilience-building objectives are reference directions rather than specific targets. A prerequisite to fostering resilience, on any scale, requires learning to live with change and uncertainty. However, the adoption of resilient options depends on the attitudes and values of actors within agroecosystems. Public and government perceptions of environment, farm livelihood and food have important implications for encouraging resilience-building responses and vulnerability reduction to future climate stresses.

Producers spoke at length about rural-urban divides, a lack of appreciation for food origin and the public perception of a ‘divine right to cheap food’. For example, Respondent 80 used an analogy to demonstrate that returns on empty beer bottles are worth more than farmers receive for the barley it takes to produce the beer in the first place. Some took this further, suggesting that assistance often conjures an unflattering image of farm livelihoods.

> 'The rivalry between the urban and rural … needs to be dealt with – urbanites don't realise where their food comes from' (Respondent 40).
>
> 'There's no support financially … urban people don't understand our importance to everyone's lifestyle – do they plan to import all their food in the future?' (Respondent 55).
>
> 'If production income is consistently small and the government payout large, than it is a social program to keep people on the land and no longer agricultural relief … with regard to public money – there's an implication when receiving a payment – there's a public perception not to live too highly' (Respondent 7).
>
> 'Farmers are not looked upon well by society – we're not seen as food security, but as a tax burden – that's part of the reason for cheap food policy' (Respondent 54).
>
> 'In Canada, the least amount of income (per capita) is spent on food as anywhere else in the world – there's a lot of government and societal complacency – people don't appreciate it' (Respondent 50).
>
> 'Everyone we support is making a great living – you put time and money into barley and get nothing out of it – it's out of our control – inputs are increasing, prices are decreasing, and on the grocery shelf the prices still go up' (Respondent 55).

Regarding the environment, farmers alluded to a public perception of producers as polluters, rather than stewards. 'People see farmers as polluters, why we get cancer, *etc.* – but chemical is expensive – I spray at right time and rate to be efficient' (Respondent 11). 'As a steward, it should be obvious that I want to care for the land's health – we've got horses, but what about wildlife scat and boating? It's hypocritical' (Respondent 16). Furthermore, Respondent 48 pointed out that environmental issues are largely societal responsibilities. 'These (environmental concerns) are not farming issues, these are societal issues – if society wants them, you gotta pay for them – there are a lot of laws – if society wants it, they can compensate.' Regulations aimed at reducing environmental contamination from agriculture are perceived as an unfair off-loading of responsibility onto farmers – which also keeps the cost of raw agricultural commodities lower. Lack of public and government will, in light of the perceptions discussed above, is also reflected in the paucity of incentives for several environmental programs.

‘We need more initiatives to not “push bush” – it would be nice to see the municipality offer money or tax breaks to farmers who maintain their tree stands – the municipality would need to have more support from the province … we need better enforcement on road allowances (Crown land until developed by municipalities) are often farmed – they are cleared illegally’ (Respondent 63).

‘The nutrients problem in Lake Winnipeg has unfairly targeted agriculture … the biggest polluter in the area is the town of Erickson – urbanites use five times the fertilizer, per acre, than farmers on their lawns – now they are forcing soil testing – are they doing the same for lawns and golf courses?’ (Respondent 21).

‘The Riparian Tax Credit program – it’s a joke, the amount of money they are offering is not compensation – the value (feed) of grass is ten times the tax break and fencing it off costs money too – the incentive is so low it is not worth bothering’ (Respondent 27).

‘The new phosphorous regulations might affect my ability to apply manure – I'm not sure the regulations are wrong, I'm just not sure how it should be implemented – I'm curious of the phosphorous load generated by cities – it shouldn't be either-or – it’s all of us’ (Respondent 39).

Farmers also relayed the sentiment that there is a general lack of political will, and lack of participation by producers in policy and regulatory processes.

‘Politicians are loath to mention drainage – it's politically incorrect’ (Respondent 7).

‘I don’t see a (environmental) problem, but some people do – yes there are issues, but it is overkill’ (Respondent 16).

‘We used to be our own bosses – now we are such a minority in politics – we have no voice’ (Respondent 21).

Culmination of these factors erodes trust. ‘We cannot produce below cost – that's when the government comes in and wants to offer support – with support comes control, without them looking bad – they end up with more information about farms than they actually pay for’ (Respondent 54).

7.3.2 Rural decline – demographics, economics and self-organisation

Rural decline may be thought of as a reduction in quality of life due to change in population and regional economics. These trends also threaten resilience processes – demographically, networks break down, economically, options become unaffordable. Though rural populations are broadly declining, for many the exodus of youth is the most troubling. Furthermore, while 98% of farms remain family owned and operated, 73% of income on the average family farm is generated off the farm (Venema, 2005).

> ‘My son and another fellow are the only young guys farming around here now – when I was their age, ninety percent of us went back to the farm’ (Respondent 53).
>
> ‘My son wants to farm, but I discourage him – he feels far from home, but he is making money in Alberta’ (Respondent 25).

Decline leads to reduced networking – lowering the levels of skilled services and knowledge-holders. Less time spent on the farm may lead to deterioration of local resource management knowledge as a result.

> ‘The exodus from farming is due to low commodity prices, economics – not weather stresses – we're missing a generation now – the twenty to thirty-five year olds are not around, and they're the ones with energy and ideas – without that group, apathy is bad …there's a rural exodus of youth and elderly to cities – the middle-aged people are staying – the old folks need care and the kids are in university – agriculture is a big door of opportunity and we need to reverse the flow of those two groups – we're exporting our best resource, our kids – we need to reverse the flow of youth’ (Respondent 56).

Respondent 44 described how their decision to keep the farm in the family was aggravated by hard economic pressures. ‘My son is trying to take over, and it's frustrating – we're not making money or building equity – now we have an additional family to support which has increased stress.’ Respondent 51 described how high interest rates and drought in the 1980s made the issue one of simply surviving. ‘We stopped our expansion – we went broke – there was no growth, we went backwards – we didn't have the equity at the time to hold on any longer – we just took payments from some *ad hoc* programs and adjusted our lifestyle.’

Tight margins and fewer youth favours production based on economies of scale rather than in social-ecological capacity. Furthermore, it discourages the processes wherein short-term coping strategies become adaptive over time – particularly if the cost of investment is long term or spans generations. Respondent 26 discussed the stress associated with the increasing pressure for creative responses to ever-tighter margins. ‘If you are not getting paid for production, you need to be more inventive and find ways to be more efficient – it can be frustrating.’ Landscape homogeneity often goes hand in hand with farming based in economies of scale. As Respondent 1 remarked regarding the shelterbelt program, 'I don't think I'm into it – I'm more into bulldozing mode than giving up more acreage.'

> 'The money in specialty crops has led to conversion of pasture and permanent cover, even though the soil is light – there's been no impact yet, but it will be felt in upcoming cycles (*i.e.* erosion) – this is because it has been wet in recent years, but there was major drought through the 1980s – clearing trees, leveling ($400/acre) and tile drainage ($400/acre) means in some instances $1100/acre is being invested on marginal land for increased production – is this progress? Perhaps, but is it sustainable?' (Respondent 68).

From a vulnerability perspective, these strategies indicate a reduction in ecological resilience linked to losses in landscape heterogeneity. Farm expansions and an increasingly homogeneous agricultural landscape mean fewer options are available to producers, which in turn impede the processes of self-organisation. Economic drivers have led to a suite of solutions which at best do not build resilience, and at worst, increase exposure to future weather stresses.

7.3.3 A policy challenge: Values, responsibility and decisions across scale

Farmers and other actors in agroecosystems are holders of diverse, and often divergent, values. On farms with high capital costs and large debt loads implementation of long term adaptive strategies are simply not affordable.

> 'Capital costs are a problem for young people who are trying to get into farming – it costs millions of dollars and is virtually impossible – no young guys are getting in and the operations just get larger – there's no incentive, and besides that, even if you had a million, who would choose to put that into a farm?' (Respondent 31)

On the other hand, some producers operate in ways that reflect the environmental economy, saving costs by working within ecological thresholds and employing ecological services. However, producers also made it clear that while ecological services played a role in farm decision-making, they are only one of multiple considerations within larger production strategies.

> 'Why not let Mother Nature do what chemical companies want to do for you? If you've got a bug that eats the pest, that's good technology – there's the cost (pesticide) and you don't have to spread poison on the plant – as for fertilizers,

> nitrogen comes just as easily from a cow pie as a commercial fertilizer – I have to look at environment against economic feasibility' (Respondent 11).

> 'I have thought about it (shelterbelt program) – it hasn't happened yet – I'm weighing production versus conservation values – the tree lines are a liability for modern farming practices – I have to weigh the liability versus asset' (Respondent 36).

Resilience-building responses often provide multiple benefits. These benefits fit well within the sustainable livelihoods theme in rural development, which weights social, health and cultural issues along with economic factors (Ellis and Biggs, 2001). The benefaceries of sustainable agricultural land use include individual farms and regional to national interests, which raises the question of responsibility. For example, incentives to farmers or subsidies for municipalities are ways the public can ensure widespread water quality concerns are addressed.

The government role in managing conflicts between environmental and economic interests (Gibbs, 2003). The author advocates an 'ecological modernisation' approach as the most pragmatic way of redirecting environmental policy making, which involves a transition from an industrial society towards an 'ecologically rational' mode of production. This position on the environment, unlike others, recognises the notion of profitable production – thus it has wider appeal amongst different stakeholders. From a resilience perspective, supporting responses which reflect multiple values, along with equitable cost-sharing arrangements, represent the ideal policy direction. The following section examines current examples of agricultural programs which reflect partnership, public and farm awareness, systems thinking and reasonable incentive.

Comments were made regarding the Alternative Land Use Services Program (ALUS) and Environmental Farm Plans (EFP), reflecting environmental values and heightened awareness of response options.

> 'The drainage and bush-pushing going on around here bothers me, it (ALUS) might help keep producers from using every acre, though they may grow less' (Respondent 28).

> 'I'm participating (EFP), it identifies risks – I did the plan and had high, medium and low risks mentioned. It (the process) helped increase awareness – of tracts of soil and assessments for chemical application; of drainage and its effects' (Respondent 60).

Similarly, as previously discussed, watershed planning and drainage licensing – when conducted together – raise awareness of systems-wide and cross-scale alteration of flow. Furthermore, partnerships between different agencies and authorities are important networks. Management regimes and programs built around networks contribute to the stabilisation, control, self-reliance and complexity associated with community economic development.

The rising popularity of Conservation Agreements[8] is a testament that incentives are, for some producers, enticement enough. As one Conservation District manager put it, 'there are landowners who want to see their land remain in a natural state. They want future generations to enjoy the land like they do.' Partnerships have played an important role in the success of easement programs (Ramsay and Walberg, 2001) particularly in light of 'economic conditions facing prairie farmers (which) ultimately hinder altruistic concerns about wildlife habitat.' One the other hand, there are those who remain unconvinced. Respondent 6 plainly stated, with regard to a habitat program, 'I investigated a program, and only a small parcel qualified – the incentive did not outweigh haying it.'

Once again, uptake of programs such as conservation easements require investiture, which depends farmer, public, and government will. Deepening public understanding and appreciation of farms and their role and responsibility as stewards is important in this regard. Farmers, on the other hand, must recognise the influence of their activities on common-pool public resources. Through gained mutual understanding, a clearer sense of fair distribution of responsibility may result.

Interviewees alluded to the potential for other initiatives which could enhance agroecosystem resilience. Producers discussed the idea that certain social and ecological aspects of the rural landscape remain undervalued.

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[8] Producers enter into contractual agreements to set aside areas of ecological significance (*i.e.* wetlands, native prairie, habitat for species at risk, *etc.*) under contract with a variety of conservation organisations, generally for a predetermined one-time payment. The agreements are legislated through the *Conservation Agreements Act* in Manitoba.

> 'The poplar stands are increasingly being sold to big forestry, and the rural municipality has no control over logging – on the other hand, the aesthetics of the bush, of the nice waterways, is relied on for their recreational value' (Respondent 63).

Gorman *et al.* (2001) examined the Rural Environment Protection Scheme (REPS) in Ireland. The program provides a clear example of a systems approach to environmental protection. The REPS program, borne out of reforms to the EU Common Agricultural Policy, highlights the multifunctional nature of agricultural practices. Reforms to CAP recognise societal demands for protection of both the environment and cultural landscapes. The European Commission took an important additional step in the Cork Declaration of 1996, recognising the requirement that society purchase these environmental services from the farmers. This approach seeks to enhance rural viability and livelihoods through a broadening of assets available to farm families – proper incentives to act as custodians of the collective environment and agricultural landscapes.

Respondent 30 described the untapped potential of alternative markets, but draws attention to political and educational barriers to changes in the agricultural sector.

> 'There is potential for new products (*e.g.* nutriceuticals) – scientific advances are opening up the next revolutions which should be pursued with enthusiasm … we rarely change until there is a problem, it's reactionary – we need to look at our track record and make some major changes – if political courses stymie development, it'll push us towards catastrophe – knowing about change means we must also change (*e.g.* alternative energy trends) – we need to learn about nature, use science as tool to blueprint it – we need to look at historical policies and tax structures and suit them to encouraging change – the only way these types of changes can really be implemented is through education, it's a long term process.'

7.4 Final thoughts on resilience and climate variability

While weather stresses figured highly in farm management for the 1999-2005, they are one of many factors in a complex decision-making environment. In regards to this research, market pressures and topographical limitations often superseded climate disturbances, and certainly outweighed expert premonitions associated with climate change. Notably, the uniform topography and prominence of grain production in the southwest case study means they are not in a position to deal with any increases in the frequency and severity of excess moisture. That is, there is less opportunity to redirect failed cash crops to feed or silage on their own operations or to other farms within the region. Furthermore, natural drainage patterns were sufficient in alleviating most of the flooding in the north during periods of excess moisture. In the southwest this was certainly not the case, and excess drainage was the only real alternative. This might be important in light of the fact that one of the interviewees, a recent immigrant to Canada, was told by the old timers in the Melita area that he'd no longer have to worry about the disease and fungus he'd had to deal with in Ireland. Such has not been the case to date. Topographical determinism holds equally true in the northern case study, however, the topography is diverse, which has translated into operations of various size and commodity, and mixed farming methods are much more common.

Aggravating the problem of excess moisture is the relative inexperience of the Department of Fisheries and Oceans in Manitoba, who have recently taken an increased interest in drainage practices as they relate to fish habitat and alterations to fish bearing waters and the riparian habitat. This is an excellent example of how public interest in environmental quality is coming at a cost disporportionately borne by the producers. In other words, regulatory approaches seem to be favoured over alternatives such as programming and financial incentives.

The pre-dominance of grain in the southwest also means a disproportionate amount of green feed would be produced in wet years if this response option were exercised. While certain responses may be a good thing, they are only so in moderation. For example, too much of a certain commodity may lower the likelihood of finding buyers within the region, or with whom they have closer personal ties. Lack of demand increases the cost of transportation and simultaneously lowering the product value. Trade arrangements and local networks are important in both case study areas with respect to adding value to farm commodities. Furthermore, while rural decline is a global issue threatening networks and relationships between actors in agroecosystems, a larger emphasis on farm expansion in the southwest may be driving people out faster. This is likely reducing potential for trade relationships and self-sufficiency in this case study. Many producers made the point that they were exporting their most important resources – the old, who are the holders of experience, and the young, who possess the eagerness to learn. While the potential for networks seemed to be greater in the north case study, another interviewee spoke at length about how trade between grain and cattle farmers, particularly during droughts, could be improved. While he could not surmise exactly why their was not more cooperation between producers, his hunches included issues of debt, contractual obligations and currency preferences of cash over goods. In both case studies, informal clubs and other agencies have provided forums for learning networks. These networks play an important role in building resilience by buffering farms and adding redundancy.

Examples of strategies which increase buffering and redundancy came from both case studies. The main factor seemed to be more a question of worldview – some producers include ecological services in their accounting, while others do not. Examples included responses such as the use of cattail or weedy species in silage, incorporating rotations and mixed farming. Similarly, some producers include redundancy as part of their risk management strategy, while others see them only as economic liabilities. For example, some producers used manure incorporation to reduce the costs of chemical fertiliser inputs, while others had specialised to a degree where this was no longer a viable option. The linkage between uptake of reduced tillage and the subsequent elimination of shelterbelts is another important example. While the reduced tillage response is stronger in the southwest (*i.e.* earlier and more widespread uptake) it relates both to the prevalence of grain farming in that region *and* to the point above. The major drivers may reduce exposure to moisture variability and reductions in fuel costs, but it does not indicate valuation of redundancy.

As such, tighter margins, a global concern amongst producers, is probably the most prevalent threat to resilience of Manitoba farms to future weather shocks and stresses, the latter becoming the proverbial 'straw that breaks the camel's back.' Farmers seemed to respond to this problem by saving costs in one of two ways: by expansion of there operations or by finding more cost-effective alternatives to unreliable markets and external inputs. The southwest seems to be placing a larger emphasis on expansion efforts rather than small farming – which is generally favoured amongst northern producers. The question of who is more efficient relates to major difference in mentalities, those who approach farming as a lifestyle versus a business. Of course, most interviewees possess mixed attitudes in this respect. However, the southwest was somewhat more businessorientated in an external sense, relying and focusing more on markets outside the local rather than on regionally internal alternatives.

In conclusion, Manitoba farms respond to weather stresses between 1999-2005 in a variety of ways – both resilient and non-resilient. The diversity in response represents future options for dealing with future weather variability. Heightened economic pressure, declines in population and increasingly specialisation may lead to a decrease in these responses. Furthermore, the distribution of responses is not equal. Drainage and waiting heavily outweighed buffering strategies in periods of excess moisture. Historical experience with drought and the uptake of zero-till, both positive indications of resilience, are off-set by the removal of shelterbelts. Program comments highlighted how economic pressures, coupled with inadequate incentives, encourage responses which increase exposure to climate stresses (Appendices V & VI). Also, no strong correlation exists regarding perceived increases in weather variability, climate change and cumulative impacts with responses that target multiple stresses and impacts (Appendix VII). This suggests resilience building may be more an artifact of economic, rather than weather, drivers. Public and farm perceptions of responsibility, regarding environmental stewardship and food values, are key components of policy directions which can enhance resilience and reduce vulnerability to future climate variability.

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Appendix I: Abstract and Cover Letter

Climate Change and Agroecosystems of the Canadian Prairies: A Resilience Approach

Some Manitoban agricultural regions seem to cope with weather extremes better than others. This raises the question of whether we can learn from the ways in which farmers and producer groups respond to these extremes to increase the capacity of farmers to cope and adapt to weather extremes throughout the Prairie Provinces.

This research is part of a larger project entitled, "Adaptation as resilience building: a policy study of climate change vulnerability and adaptation on the Canadian Prairies", a collaborative project of the International Institute for Sustainable Development (IISD), with the Prairie Farm Rehabilitation Administration (PFRA), and the Natural Resources Institute, University of Manitoba. This portion of the research takes a resilience approach, composed of four key tenets:

1. Local resource knowledge: people working directly on the land possess practical experience.
2. Ecological resilience: ecological processes can help negate the effects of extreme weather.
3. Adaptive management: 'learning by doing', refers to the capacity of producers to alter land management practices.
4. The systems approach: vulnerability to extreme weather cannot be well understood in isolation – we need to link it to the 'big picture'.

The participation of people working directly on the land is an essential component of this research. Interviews focus on the identification of extreme weather events, and the subsequent farm and regional-level responses to them. This information will be used to develop a suite of policy interventions aimed at reducing agricultural vulnerability to weather extremes by enhancing farm management options.

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NRI Natural Resources Institute

(Insert interviewee address)

September 12, 2008

To Whom It May Concern:

I am a graduate student at the Natural Resources Institute at the University of Manitoba, working in partnership with the International Institute for Sustainable Development and Prairie Farm Rehabilitation Administration on a study entitled, "Adaptation as Resilience Building: A policy study of climate change vulnerability and adaptation on the Canadian Prairies." The purpose of the study is to understand how farmers have coped with weather extremes, and how policies and programs might enhance farm management options to deal with weather extremes.

A portion of the (insert RM/town/CD) was identified through a mapping exercise as having experienced high historical exposure to weather fluctuations. As part of my contribution to the study I would like the opportunity to interview you and/or producer groups and farmers within your jurisdiction which you feel may have a significant interest in this research. I have attached a summary of my project for further clarification.

I will follow up with a phone call to discuss the willingness of you and your community to participate and to perhaps arrange a short presentation of the research in your community.

Thank you very much for your time, and please feel free to contact me regarding any questions or further information you may require.

Sincerely,

Peter Myers

IISD lead: Dr. Henry David Venema, phone: (204) 958-7706
PFRA lead: Jarret Powers, phone: (204) 984-8881

Appendix II: Organisation Interview Questions

1. *Please briefly describe the agricultural operations of your region (define case study area).*

2. *Have there been any large changes to farm operations in the last five years?*

3. *List any weather extremes which have impacted the region in the last five years. (probe when it occurred, how long it lasted, how often it happened if necessary).*

4. *List any other events which have impacted the region in the last five years. (probe when it occurred, how long it lasted, how often it happened if necessary).*

If the interviewee wishes to discuss events that occurred more than five years ago, it will be recorded as it may capture historical and traditional ecological knowledge.

Also: if the interviewee discusses climate change or uses climate change to explain the frequency of extreme events it will be recorded (use of the term "climate change" will not be used in the interview).

Questions 5-9 repeated for each extreme event.

5. *Please describe how (insert event) impacted the region and quality of farm life in general.*

6. *How did your organization respond to (insert event)?*

7. *What aided you in your response?*

8. *What impeded you in your response?*

9. *What measures and policies would be useful for improving your ability to respond to the weather events we have discussed?*

10. *Have you heard of the (insert policy/program*)? If so, has your organization played a role in its application/considered a role in its application?*

**see list of appended policies and programs*

Appendix III: Farm-level Interview Questions

1. *Please briefly describe your operation including both type and size.*

2. *Have there been any large changes to your operation in the last five years?*

3. *List any weather extremes which have impacted you in the last five years. (probe when it occurred, how long it lasted, how often it happened if necessary).*

4. *List any other events which have impacted you in the last five years. (probe when it occurred, how long it lasted, how often it happened if necessary).*

If the interviewee wishes to discuss events that occurred more than five years ago, it will be recorded as it may capture historical and traditional ecological knowledge.

Also: if the interviewee discusses climate change or uses climate change to explain the frequency of extreme events it will be recorded (use of the term "climate change" will not be used in the interview).

Questions 5-9 repeated for each extreme event.

5. *Please describe how (insert event) impacted your operation and quality of life in general.*

6. *How did you respond to (insert event)?*

7. *What aided you in your response?*

8. *What impeded you in your response?*

9. *What measures and policies would be useful for improving your ability to respond to the weather events we have discussed?*

10. *Have you heard of the (insert policy/program*)? If so, did you apply, or consider applying?*

**see list of appended policies and programs*

Appendix IV: Clustering of specific responses into response categories

response category	specific response
wait out the stress	wait out the stress
alter a farm cycle or practice (≥ one season)	incorporation of grazing strategies (*e.g.* mobile pen rotations)
	incorporation of soil-building strategies (*e.g.* crop rotation)
Reduce spending, borrowing, or do a job yourself	reduce spending in general
	do a job yourself (*e.g.* mechanical repairs)
	reduce borrowing
Reduce tillage	reduce tillage
Reduce seeding or other inputs	reduce seeding
	reduce inputs including fuel, fertilizer and/or pesticide
increase efficiency	reduce chemical overlap by driving in a straight line (includes field leveling, bush clearing and drainage practices)
	test the soil to maximize the benefit of fertilizer applications
market strategy	market crop as feed
	sell customer direct
	market commodities early
	use alternative markets (*e.g.* trucking grain to other elevators)
	use futures
	other market strategies (*e.g.* hold off selling until markets improve)
sell at reduced prices	sell cattle as usual during BSE and the ensuing fall out
	reduced price for bales
use government aid and programs (outside CI)	use government aid and programs (outside CI)
Use Crop Insurance and other insurance claims	CI
	make an insurance claim outside CI
use credit to access loans	use credit to access loans
employ a standard farm practice	cultivate the soil
	drain the landbase
	burn the stubble
	make a chemical application
	allow the field to stand idle for the growing season
	maintain the existing drainage system
alter a farm cycle (≤one season)	put cattle on feed early
	put cattle to pasture early
	grain feed cattle later into the spring
	sow crops late
	sow varieties with a shorter growing season

	over-winter the cattle using feeding formulas to reduce hay consumption
work longer or do extra work	work longer
	do extra work
	cleanup
increase herd size (BSE specific)*	increase herd (BSE)
destroy inventory	shoot stock (BSE)
	discard commodity
get outside help from within the local agricultural sector	hire local help
	import local feed
	use local abattoir
use local associations and support networks	use local associations (*e.g.* grazing club, marketing club)
	use support networks (*e.g.* reciprocation, neighbour's help)
	join lobby efforts
Invest in local slaughter capacity	invest in local slaughter capacity
increase buffering capacity	spread out your land base
	stockpile hay
	rotate crops
use technological advances	use technological advances (*e.g.* purchase/install machinery)
'work with the weather'	alter final use (*e.g.* silage cash crop)
	harvest wetland for hay
Match land use to agricultural potential	switch to a lower risk landbase
	fence off less productive acres for grazing
	suit land to function (*e.g.* plant varieties suited to soil and drainage characteristics)
diversification	diversification (*e.g.* changing from a grain to a mixed operation, investing in other agricultural ventures)
out of commodity	out of commodity (*e.g.* change from grain to forage production)
increase production	increase production (*e.g.* increase bushels grown per acre)
off farm employment (short term)	off farm employment (short term)
off farm employment (long term)	off farm employment (long term)
buy out partner	buy out partner
farm small	farm small (*e.g.* no expansion of operation over time)

Appendix V: Commentary on programs associated with weather stresses including excess moisture, heavy rain, drought and dry periods (southern case study)*

program	comments
Crop Insurance (25)	coverage inadequate - inputs (12)
	unseeded good (9) - but had to lobby for it (3)
	premiums/options good (*e.g.* unsown acres) (4)
	whole-farm averaging poor (3)
	based on low commodity prices rather than inputs (3)
	should cover flood-outs as well as unseeded (3)
	coverage/deductible should not decrease with successive claims (2)
	need the program (2) - it's predictable (3) and timely (1) unlike other programs (1)
	no option of premium (2)
	government inaction (1)
	extended deadline bad idea (1)
	forced you to sow to collect (1)
	rates have not changed recently (1)
	could be improved at the expense of other programs (1)
	premiums too high (1)
	counted as advance on AIDA (1)
	coverage dropping based on land classification (1)
Drainage regulations (7)	no provincial drainage system in place (1) - lots spent on RRV (2)
	ad hoc drainage is detrimental (2)
	good that CD is involved (3) - more money for programs farmers can use to do work (1) - can 'stack' money with RM (1)
	ditches and culverts not maintained well (1)
	need mentoring not policing (1)
	conservation is prioritized over livelihoods by MB Conservation (1)
	licensing heavily regulated and hard to access (1)
	regulators are not farmers (1)
	licence waits long (1)
	no 'Right to Farm' like Ontario (1)
	drainage can be a soil conservation measure (1)
	often drain illegally (1) in good faith with neighbours (1)
CAIS (4)	NISA better (3)
	lumps disasters/programs together rather than treating individually (3)
	access unpredictable (3)
	too complex, difficult filing (2) - and need an accountant (2)
	payments unpredictable (1)
	olympic average system poor (1)
	as we draw, it is worth less and less (1)
	a lot of bookkeeping (1)
	long waits (1)
	treatment of inventory questionable (1)
	need the program (1)

Hay relief (1)	had to lobby province (1)
	straight payouts without stipulations (1)
	need farmer input in program design (1)
DU seed program (1)	restrictions are a problem (1)
GOPP (1)	feeding damaged grain supresses payment (1)
Jury program (1)	applied to RRV in '97, but we received nothing in '99 (1)
Water Stewardship Act (1)	manure regulation implementation needs to be done fairly (1)

*Numbers in brackets indicate the total number of specific program mentions and comments in response to the question, *'What measures and policies would be useful for improving your ability to respond to the weather events we have discussed?'*

Appendix VI: Commentary on programs associated with weather stresses including excess moisture, frost, heavy rain, drought, hail and late snow (north case study)*

program	**comments**
Crop Insurance (25)	inadequate coverage (6) - won't carry you through series of poor years (1)
	deadline extension for sowing a bad idea (3)
	premium options for unsown good (3) - though expensive (1), closer to cost of abandonment (1)
	whole-farm averaging poor (3), but hail insurance covers isolated damage, which is good (1)
	should go up as much in good years as down in poor years to be fair (2)
	coverage/deductible decreases too much with successive claims (2)
	deadline extension - if ok in a bad year, good year should count too (2)
	unseeded good (2) - can make the call not to sow earlier now, can be used in decision-making (1)
	better premium options would help (1)
	first time claim, and coverage was good (1)
	one of the better CI programs in Western Canada (1)
	program is triggered when damage occurs (1)
Drainage regulations (4)	licensing getting tighter at a time we need them looser (1)
	hurting ability to clean existing drains/expansion efforts (1)
CAIS (2)	shouldn't protect inefficient farm management, poor bookkeeping (1)
Variety development (3)	universities/researchers need to develop varieties for this area (2)
Alternative markets (1)	need different feed resources made available to farmers (1)
	develop access to alternative feeds (1) - cooperation between grain and cattle farmers needs to be stimulated (1)

*Numbers in brackets indicate the total number of specific program mentions and comments in response to the question, *'What measures and policies would be useful for improving your ability to respond to the weather events we have discussed?'*

Appendix VII: Perceived increases in weather variability, climate change and cumulative impacts with responses targeting multiple stresses (producer numbers in bold indicate at least one positive response in each the first two and last two columns).

respondent (n=60)	perceive increased weather variability/ attribute changes in weather to CC	impacted by cumulative stresses	≥20% of responses are to multiple stresses	≥50% of responses are to multiple stresses
1	**yes**	no	no	no
7	no	**yes**	**yes**	no
8	**yes**	no	no	no
10	no	no	**yes**	no
11	**yes**	no	**yes**	**yes**
12	no	**yes**	no	no
14	no	**yes**	no	no
15	no	**yes**	no	no
17	no	no	**yes**	no
18	no	no	**yes**	**yes**
19	no	no	**yes**	no
21	**yes**	**yes**	**yes**	**yes**
22	no	no	**yes**	**yes**
23	no	**yes**	**yes**	no
24	**yes**	no	no	no
25	no	no	**yes**	**yes**
26	**yes**	**yes**	**yes**	no
27	no	**yes**	no	no
30	no	**yes**	**yes**	**yes**
31	no	no	**yes**	no
32	**yes**	no	**yes**	no
33	**yes**	**yes**	no	no
34	no	no	**yes**	no
35	no	no	**yes**	no
36	no	no	**yes**	no
37	no	no	**yes**	no
38	**yes**	no	no	no
39	no	**yes**	no	no
41	no	no	**yes**	no
42	**yes**	no	**yes**	no
43	no	**yes**	**yes**	no
44	no	**yes**	**yes**	no
47	no	**yes**	no	no
48	no	no	**yes**	no

49	no	no	**yes**	no
50	**yes**	no	no	no
54	no	no	**yes**	no
57	**yes**	no	no	no
58	no	no	**yes**	no
59	no	no	**yes**	no
60	no	no	**yes**	no