RIDING THE RISK WAVE:
FARMER KNOWLEDGE AND EXPERIENCE WITH GM CROPS IN THE CANADIAN PRAIRIES

By Ian J. Mauro

A thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfillment of the requirements of the degree of

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THE UNIVERSITY OF MANITOBA

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

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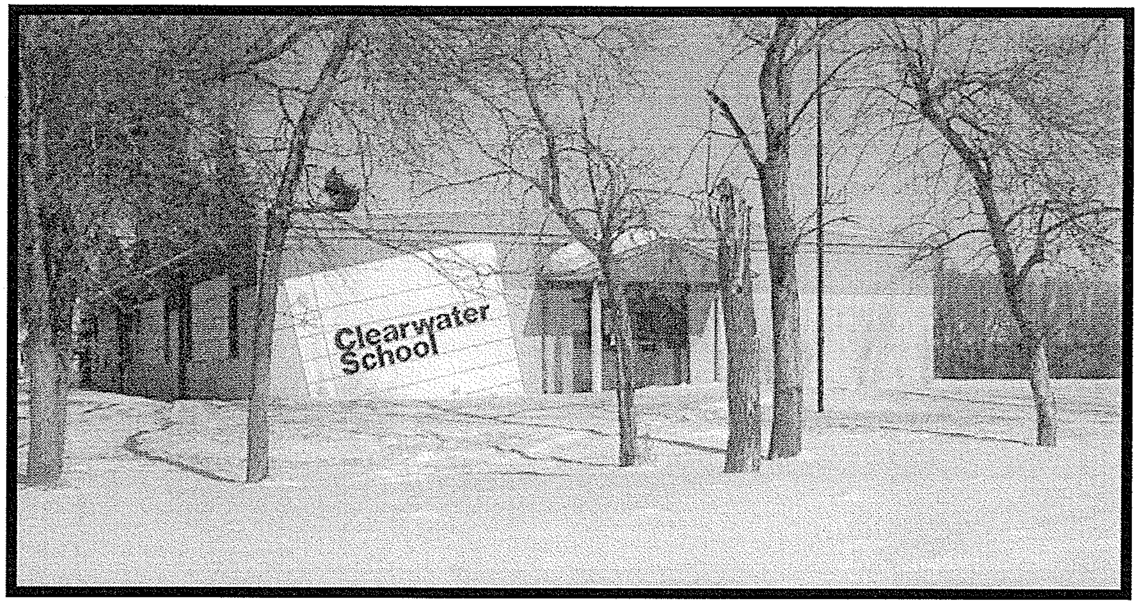

The majority of this thesis was written while living in the Harvest Moon Learning Centre located in the rural community of Clearwater, Manitoba, over the winter of 2007 and 2008. I am indebted to this community for accepting me and sharing their prairie peace, which allowed me to find clarity of mind, context regarding farming, and above all focus.

Due to rural decline this building, the town's former elementary school, was officially closed in 2001. Having the next generation of children leave town for education was a major upset for this community. It was symbolic of the larger prairie-wide "rural crisis" and a seed for change.

In 2002, the year my doctoral research began, a group of agrarians, academics, and activists began the Harvest Moon Society, an organization committed to "healthy land, healthy communities". Shortly thereafter we purchased this building and along with the community began the long process of reanimating it. Six years later, our community-based organization has grown like a weed, and like the phoenix from the ashes, our perennial festival, educational programs, and local food group based out of this school is now a model for rural re-birth and resilience.

Arguably my thesis began in Clearwater and it's fitting that I've finished it in this knowledgeable and generous rural community. The hallways of this school have seen many learners and I follow in their footsteps. Hopefully the ideas generated here – past, present, and future – will play their part in keeping the people and land comprising rural communities healthy and sustainable.

ABSTRACT

Although genetically modified (**GM**) crops have been used in Canada for over a decade, no peer-reviewed study has yet investigated farmer experiences and insights regarding this technology. Farmer local knowledge (**LK**) was documented regarding the benefits and risks associated with GM crops, and the overall impact of this technology on the environment and rural communities across the prairies. Farmer LK was investigated with video-based interviews (n=25), a mail-out survey (n=370) in Manitoba focused on *post-release* experiences with GM canola, and a larger prairie-wide questionnaire (n=1566) related to *a priori* evaluation of GM wheat. Overall, benefits associated with GM canola and GM wheat, which are both herbicide-tolerant (**HT**) crops, were related to easier, better, and simpler weed control. The risks associated with GM canola and wheat were more complex and included contamination, agronomic impacts, corporate control, and market harm. Those using GM canola were at greater risk if they had experienced HT volunteers, operated smaller farms, and grown these crops for longer periods of time. Although farmers had not grown GM wheat, their LK was useful for evaluating potential risks associated with this crop, and was shaped by their distrust in government and corporations and belief in the importance of community and environment. Prairie farmers overwhelmingly rejected HT wheat and did not want to see it commercialized. Overall, those most at risk from GM crops practiced conservation tillage, seed saving, and organic farming. Interviews with farmers engaged in lawsuits with industry over GM crops, specifically the *Monsanto v Schmeiser* and *Hoffman v Monsanto* cases, indicated that the "social fabric" of rural communities was threatened by corporations, patent law, and damage caused by this technology. That regulators have restricted their attention to

"science-based" risks associated with GM crops while ignoring associated impacts on humans systems, has effectively left Canadian farmers "riding the risk wave". It is important that decision-makers acknowledge that "substantial difference" exists between GM and non-GM crops, and undertake a more holistic, rigorous, and farmer-focused approach to risks associated with GM crops in the future.

ACKNOWLEDGEMENTS

I must first thank all the farmers and rural community members that participated in this research, without their contribution this thesis would not have been possible. I consider this document as much theirs as it is mine. In particular, I would like to express my gratitude to Percy and Louise Schmeiser and the organic farmers of Saskatchewan for all the time, knowledge, and kindness they have shared over the years. Your resistance inspires many.

Although not a farmer, my thesis advisor Stef McLachlan has tended the soil of my mind, planting seeds of knowledge, and showering me with support, friendship, and opportunity. Working together has been a truly transformative experience - from the Arctic to agriculture – he has indeed changed my life. His collaborative and student-centred approach, combined with his commitment to social justice and radical politics, is rarity amongst the institution, and arguably is the only reason why I'm here today. Thank you Dr. Detail, the joyous and arduous battles fought are a true testament to the strength of our intellectually creative relationship. Given that we have worked collaboratively throughout this research, I also consider it as much yours as it is mine.

I am incredibly grateful to my thesis committee – Drs. Van Acker, Kenkel, and Walker – for their camaraderie, academic rigor, and support. Rene, weeds of knowledge that is what you have planted, and man have they grown! Thank you for "volunteering" your invaluable experience and insights regarding agriculture, rural communities, and specifically GMOs. Norm and Dave, you two have helped me to better understand the mathematical elegance in nature, the study of ecology as a whole, and how this applies to empirically understanding the human mind. Your challenging questions have always been welcome, although often not easy to answer. Dr. Singh has also played an invaluable role as a guest to the committee. Av, your thoughtful feedback has been critical in shaping this research, and your ongoing work demonstrates that sustainable and community-based agriculture indeed is the way of the future.

Many others have contributed to my graduate work. My colleagues in the Environmental Conservation Lab have been amazing. Specific thanks to Ryan, Troy, Mel, Karen, and Alexis; you've all been beacons in the storm of study. Dave, although life is not just, your contribution was. Peter Kulchyski, Chris Trott and I continue to "rock the tundra" together, and I have learned much from them. Importantly, my Inuit friends of Pangnirtung have deeply enriched my understanding of how local knowledge works in praxis and my appreciation for "the land" in general.

I must thank two amazing artists for their contribution to this thesis. Jim Sander's help shooting and editing *Seeds of Change* has been invaluable and the aesthetic of that film is largely his creation. Dustin Leader's photos – many of which have graced the pages of the *Globe and Mail* – are found on the chapter headings of this thesis.

Like any dissertation, this one has been a struggle, and there are many I need to thank in this regard. Firstly, Jim Turk of the Canadian Association of University Teachers (CAUT) helped keep us safe in one heck of a thunderstorm on the prairies, and I cannot thank him enough for this. Many student organizations, like UMSU and GSA were also important contributors to our success. Nancy Oliveri's support, guidance, and ethical example have been invaluable. And finally, thanks to David Suzuki for his laudable work, as well as his friendship, encouragement, and belief in our research.

Throughout life and study, the unwavering support of my family – Ma, Pa, Andy and Pico - has always been the wind under my wings, and has allowed me to soar to wonderful heights. Perhaps this degree means that I'll finally be leaving the nest!

Nathalie, you have no idea how much support you provided while being so far away in Africa. Thank you for this and making it home alive. Your knowledge of life enriches and humbles me. I look forward to chasing each other to ends of the world. Akulu.

Funding provided by the Social Sciences and Humanities Research Council (SSHRC) and Manitoba Rural Adaptations Council (MRAC) has made this research and my recent livelihood possible. The support of these institutions has made this the first publicly funded study regarding the impact of GM crops on farmers, rural communities and the environment in western Canada.

For Trail Boss:
Grandfather,
Farmer, &
Poet

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Chapter 1

Thesis Introduction: Objectives, Approach, and Contribution

"You see, I went on with this research just the way it led me. That is the only way I ever heard of research going. I asked a question, devised a method of generating an answer, and got – a fresh question. Was this possible, or that possible? You cannot imagine what this means to an investigator, what an intellectual passion grows upon him"

-Dr. Moreau

The Island of Dr. Moreau by H.G. Wells

INTRODUCTION

"...I am convinced that Natural Selection has been the main but not exclusive means of modification"

Charles Darwin, Origin of Species, 1859

When Charles Darwin wrote these words 150 years ago, he could not have anticipated the reverberations of his ideas, and future application of his theory of natural selection in science, particularly recombinant DNA (**rDNA**) technology that allows alternate "means of modification" and the development of genetically modified (**GM**) crops. Interestingly, Darwin's journals show that his groundbreaking theory, arguably amongst the most successful in the history of science, was informed by local knowledge (**LK**) of Galapagos inhabitants that knew which islands tortoises and finches came from, by their markings and shape, helping the scientist to understand mirco-evolution (Sillitoe, 2007). Furthermore, Darwin's first chapter of *The Origin of Species* is subtitled "Variation under domestication", demonstrating the author's recognition of the important LK that farmers contributed to the creation of biological diversity through millennia of crop selection and breeding (Fowler and Mooney, 1990). In this way, the theory of evolution, history of plant breeding, and development of GM crops are inextricably linked with and informed by LK, particularly that of farmers.

The environmental release and agricultural use of GM crops is controversial and has precipitated a "food fight" of global proportions. The ensuing debate has been acrimonious and largely dominated by rhetoric. On one side, industry promotes GM crops as a panacea that will "feed the world", while on the other environmental groups warn of catastrophe due to these "frankenfoods" (Cook, 2004). Balanced, impartial, and holistic information about the benefits and risks associated with GM crops remains elusive. Regulators worldwide use "science-based" risk assessment to evaluate GM crop safety, as they believe it is an objective decision-making tool, which allows for approval and deployment of this technology based on "sound science" (Nap et al., 2003). However, risk assessment has been criticized for being restrictive in nature, as it does not consider broader socio-economic, cultural, and political impacts that may be associated with GM crops (Abergel and Barrett, 20002). Risk analysis, in contrast, incorporates science as well as public input regarding these broader issues, which some believe allows for a more interdisciplinary and rigorous examination of the impacts of this technology (Auberson-Huang, 2002). Yet most risk analysis is still restricted to consumer attitudes regarding GM crops (e.g. Aerni, 2002; Taylor-Gooby, 2006), and very few studies have explored farmer attitudes toward and experiences with this technology.

Arguably, farmers are the most affected and knowledgeable stakeholders in the GM crop debate, given their decade-long experience with this technology. Worldwide, there are only a few studies where farmers have been meaningfully consulted regarding GM crops, these mostly carried out in the Global South (e.g. Chong, 2005; Soleri et al., 2005). Some have argued that farmers are largely viewed as passive adopters of expert-developed technology (Fliert and Braun, 2002), and correspondingly most research has focused narrowly on farmer adoption and economics related to GM crop use (e.g. Fulton and Keyowski, 1999; Qaim and de Janvry, 2003). While scholars recognize the important contribution that farmer LK can make towards assessing agricultural technology (Moock and Rhoades, 1992) and have called for greater farmer participation in research

(Middendorf and Busch, 1997), this has yet to be carried out with GM crops in North America.

In this study, I have attempted to document farmer LK regarding the benefits and risks associated with GM crops, and the overall impact of this technology on the environment and rural communities across the Canadian prairies. Furthermore, it may be the first to incorporate farmer LK within a risk analysis framework and one of few that uses both quantitative and qualitative social research methods to achieve this.

SCOPE OF THE THESIS

This study focuses on the Canadian farm experience with GM crops, specifically in the prairie provinces of Manitoba, Saskatchewan and Alberta. This is an important study area for a number of reasons: 1) Worldwide, Canadian farmers were amongst the first to use GM crops, specifically herbicide tolerant (**HT**) canola, and therefore they have extensive experience and knowledge regarding the benefits and risks associated with this technology; 2) The world's first GM wheat was field tested across Canada, its proposed introduction was controversial, and prairie farmers had important LK regarding its potential impacts; 3) Saskatchewan-based farmers were embroiled in two internationally renowned lawsuits over GM crops, which exemplified the impacts that this technology can have on non-GM farmers, and rural communities as a whole. This is a long-term research study and has lasted six years, from 2002 to 2008.

THESIS OBJECTIVES

The overall objective of this thesis is to explore the role of farmer LK and experience in the risk analysis of GM crops across the Canadian prairies. More specifically, it will:

- Investigate the use of farmer LK in both a priori and post-release evaluations of GM crops;
- Characterize the benefits and risks associated with GM canola and GM wheat across the Canadian prairies;
- Identify what factors contribute to the risks and benefits associated with GM canola and GM wheat;
- Evaluate the impact of lawsuits over GM crops on prairie farmers, particularly those involved in the *Monsanto v Schmeiser* and *Hoffman v Monsanto* cases;
- Determine how video research might be used to document and communicate farmer LK regarding GM crops; and
- Explore how farmer LK and risk analysis might enrich current regulations regarding GM crops and, more generally, agricultural technology

RESEARCH APPROACH & CONTRIBUTION

This dissertation considers farmer LK important, values its contribution to agricultural biodiversity, and seeks to include it in research regarding the evaluation of agricultural technology, particularly GM crops. This research specifically explores how farmer LK can be used in the *a priori* and *post-release* risk analysis of benefits and risks associated with GM crops.

While the importance of participatory approaches that include farmer LK in agricultural research has gained legitimacy in recent years, attempts to do so have mostly been carried out in the Global South (Chambers et al., 1989). These efforts have increased farmer agency and improved sustainability in agricultural systems in many countries (Moock and Rhoades, 1992). This thesis borrows on this ongoing research and attempts to use these techniques in Canada to investigate GM crops.

This research has been informed by extensive communication and partnership with farmers across Canada. Over the past six years, I have traveled extensively across the prairies meeting with farmers, and they have helped to inform the direction and interpretation of this research. I have poured over many pages of insightful comments that farmers have included in surveys. I have spent years analyzing the quantitative data. Throughout my research and writing process I have strived to remain true to what these farmer experts have shared with me. I hope this thesis does justice to their insights and generosity.

Farmer LK was documented using social research methods, particularly qualitative interviews, quantitative questionnaires, and ethnographic approaches (e.g. farm tours, observing farmers at court, etc). Data collection was conducted iteratively in phases and, for example, interviews informed the development of subsequent questionnaires. Where applicable, results are presented in a mixed methodology approach, which triangulates and affirms both quantitative and qualitative findings.

In parts of this study, I have been guided by an "action research" approach, which mandates collaboration between researchers and study participants, and systematically ensures that action is taken to resolve a specific problem identified by participants (Stringer, 2007). Overall, many participants believed that farmers had been marginalized from the GM crop debate, and considered this a problem. Hopefully this research helps to promote and bring awareness to the important insights that farmers have regarding GM crops.

The interview and ethnographic components of this study were recorded using video, which has allowed for the creation of a research documentary video. This video-based methodology is unique, as farmers were able to speak with their own voices about GM crops, and is "action" oriented. The research video produced *Seeds of Change: Farmers, Biotechnology, and the New Face of Agriculture*, has been screened worldwide to farmers, policy makers, and the public at large. Farmers were particularly excited about this video, given that it was inclusive, but also because it made research results accessible to a larger audience. Arguably, this research video gives back to the farm community for all they have contributed to this study, and has been used as a fundraiser for many farm organizations across Canada. This is the first time that documentary research videos have been included in a doctoral thesis at the University of Manitoba, and to my knowledge, the first anywhere in Canada.

Despite predominately using social science methods, this thesis is very holistic in nature, and has drawn on a variety of disciplines to help inform research questions and contextualize ensuing results. Taking this broad approach was necessary, given that farmer LK is embedded within a complex socio-cultural and agroecosystem matrix, and because of the diverse effects that may be associated with GM crops. In this way, this thesis attempts to synthesize knowledge in the social and natural sciences regarding the impacts associated with GM crops, a process that I will argue resembles the structure of DNA itself.

The theoretical framework used to help synthesize the broad array of disciplines relevant to this study is "risk analysis". Risk analysis is an interdisciplinary approach used to incorporate public opinion within a broader framework that includes science. With respect to GM crops, it has principally been used to assess consumer opinions of GM foods, and to compare and contrast these "lay" attitudes with that of "experts", particularly scientists. The associated literature has played an important role in shaping my thesis and has helped inform my thinking and research approach for involving farmers in the evaluation of GM crops across the Canadian prairies.

This, to my knowledge, is the first study to explicitly incorporate farmer LK within a risk analysis framework. Hopefully this thesis helps to broaden the field of risk analysis beyond the "lay" versus "expert" dichotomy that dominates that literature, and will demonstrate that LK is indeed a form of expertise, which in turn is critical to the evaluation of GM crops. Arguably, this project is the first anywhere in the world to document farmer LK and experience with GM crops over an extended period of time, now lasting six full years (2002-2008).

Ethics has also played an important role in shaping this research. All farmers involved in this study provided informed consent to participate. Furthermore, given the action research approach and participatory nature of this study, farmers were central in guiding its direction and outcomes. When making videos, I engaged collaboratively with farmers and consulted with them about content, and these films were only made public once participants agreed that the final outcome reflected their views. The Joint-Faculty Research Ethics Board at the University of Manitoba approved this research under protocol #J2001:060 and #J2008:001.

RESEARCHER BACKGROUND AND MOTIVATIONS

It is now increasingly accepted that the values of researchers play an important role in shaping their outcomes, and it is important to provide a context for how this information has been analyzed and to expose any biases that might be inherent in this process. Here I present a short description of who I am and how this research has affected me.

I am a man nearing my thirties who grew up and continues to reside in Manitoba, Canada. I have lived most of my life in urban areas. However, at the age of nine, I became disillusioned with city life, and asked my parents to send me to live for the summer at my grandparents' farm in Duffield Alberta. My loving parents recognized what a great opportunity this was, one for me to further my relationship with the farm, but also to give some breathing space for our family, including their two other sons, living in a small bungalow in the suburbs of Winnipeg. I boarded the plane by myself and went off to the farm.

I did this for two summers. These were critical years in my life. I played in the fields, built forts, drove the four wheel Honda, took up welding, shot lots of gophers, baked and ate lots of cinnamon buns, went fishing, and learned the game of chess. And, oh yes, I helped out with farming where I could. My jobs included taking lunch to my grandfather in the field, driving in the cab with him as he cut hay, and feeding the cattle and other farm animals. My grandparents Les and Marie were my mentors in this new life on the farm. My respect for farming and knowledge of those living on the land had begun. My grandfather was my role model and I was soon called "Little Les". He was keen to pass on his knowledge to the next generation. Unfortunately, he passed away a couple years later, and I was left with a hollow space inside, and a desire to learn more.

Upon graduating from high school, I decided to ride my bicycle to California, and departed Victoria in the fall of 1997 for San Francisco. I rode and camped by myself. I became part of the wilderness. The Red Woods in Northern California blew my mind. I realized then that I wanted to study the environment more formally. I returned and quickly entered the Environmental Science program at the University of Manitoba. I learned about the ecological crisis facing humanity and it was depressing. However, instead of being paralyzed by this information, I became motivated by it. I am convinced that significant change is required to ensure future generations have healthy air, soil, water, and climate. My politics, activism and approach to research have been shaped by this belief. I believe that sustainability can only be achieved by linking human and environmental systems, and I recognize the importance of balance between the two. With this mental framework in place and a yearning to learn more about agriculture, pursuing graduate work on farmers and GM crops seemed perfect.

Although I spent time on the farm as a boy, I approached with research a general naiveté about agriculture, and had to learn quickly. The farmers in this study have been great teachers and, in a way, I feel like our relationship carries on where the one with my grandfather left off. I am very committed to the participants in this study, and in general have approached it with credence that they know what is best for agriculture and rural communities as a whole. It is my belief that farmer knowledge is critical to finding sustainable approaches to agriculture. I am perturbed by the current food system, which devalues the importance of these stewards of the land, and benefits wealthy corporations largely at the expense of family farms. My experience carrying out this research, hearing from farmers across the prairies about their plight and concerns, affirms this belief. It has been galvanizing and I have changed because of it. However, the resilience of these farmers, their families, and rural communities brings me hope, and a desire to promote social change.

THESIS STRUCTURE

The thesis is set up so that individual chapters are autonomous, self-contained, and publishable manuscripts. I begin with a review of the literature related to farmer knowledge, risk, genetically modified crops, and technological change in North American agriculture (Chapter Two). This is followed by a theoretical contribution where I build an argument for holism in risk research, which combines both social and natural sciences into a "double helix of risk" (Chapter Three). I then explore farmer attitudes towards both GM canola and GM wheat using a video-based methodology that is presented in written form (Chapter Four) and presented as the documentary called *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture* (Chapter Five). A mixed-methodological approach combines these interviews with Manitoba-based quantitative survey data to investigate the impact of GM canola across the Canadian prairies (Chapter Six). I then evaluate farmer LK toward the benefits and risks associated with GM wheat, specifically Roundup Ready Wheat, using a prairie-wide survey (Chapter Seven). The experiences of farmers involved in the *Monsanto v Schmeiser* and *Hoffman v Monsanto* lawsuits are then documented with an action research approach (Chapter Eight). In the final chapter, I detail the project's contribution to knowledge, summarize the major findings from the study and present a new theoretical model called the "risk wave", and offer recommendations about how future risk research and regulation on GM crops might be carried out in a more holistic and farmer-centred manner.

REFERENCES

Aerni, P. (2002). Stakeholder attitudes toward the risks and benefits of agricultural biotechnology in developing countries: A comparison between Mexico and the Philippines. *Risk Analysis*, *22*, 1123-1137.

Abergel, E., & Barrett, K. (2002). Putting the cart before the horse: a review of biotechnology policy in Canada. *Journal of Canadian Studies*, *37*, 135-161.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology*, *20*, 1076-1078.

Chambers, R., Pacey, A., Thrupp, L.A. (Eds.) (1989), *Farmer First: Farmer Innovation and Agricultural Research*. London: Intermediate Technology Publication.

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research*, *8*, 617-634.

Cook, G. (2004). *Genetically Modified Language: The Discourse of Arguments for GM Crops and Food*. New York: Routledge.

Fliert, E.V., & Braun, A.R. (2002). Conceptualizing integrative, farmer participatory research for sustainable agriculture: From opportunities to impact. *Agriculture and Human Values*, *19*, 25-38.

Fowler, C., & Mooney, P. (1990). *Shattering: Food, Politics, and the Loss of Genetic Diversity*. Tucson: University of Arizona Press.

Fulton, M., & Keyowski, L. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum*, *2*, 85-93

Lurquin, P.F. (2001). *The Green Phoenix: A History of Genetically Modified Plants*. New York: Columbia University Press.

Middendorf, G., & Busch, L. (1997). Inquiry for the public good: Democratic participation in agricultural research. *Agriculture and Human Values*, *14*, 45-57.

Moock, J.L., & Rhoades, R.E. (1992). *Diversity, Farmer Knowledge, and Sustainability*. Ithaca, NY: Cornell University Press.

Nap, J.P., Metz, P.L., Escaler, M., & Conner, A.J. (2003). The release of genetically modified crops into the environment: overview of current status and regulations. *Plant Journal*, *33*, 1-18.

Qaim, M., de Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. *American Journal of Agricultural Economics, 85*, 814-828.

Sillitoe, P. (2007). Local science vs. global science: an overview. In P. Sillitoe (Ed.), *Local Science vs. Global Science: Approaches to Indigenous Knowledge in International Development*. New York: Berghahn Books.

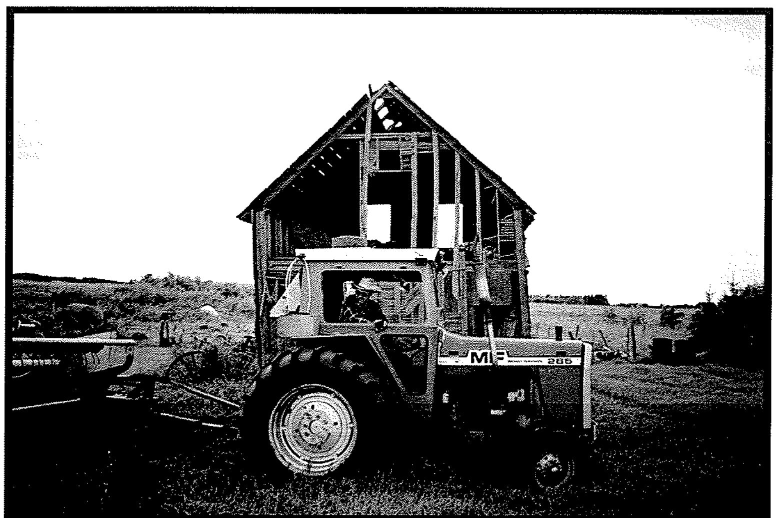
Soleri, D., Cleveland, D.A., Aragon, C.F., Fuentes L. M.R., Rios L. H., & Sweeny, S.H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: Maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research, 4*, 141-166.

Stringer, E.T. (2007). *Action Research, 3rd Edition.* London: Sage Publications.

Taylor-Gooby, P. (2006). Social divisions of trust: Skepticism and democracy in the GM nation? *Journal of Risk Research, 9*, 75-95.

Chapter 2:

Literature Review – Farmers, Risk, and Agricultural Technology in North America



"One man on a tractor can take the place of twelve or fourteen families. Pay him a wage and take all the crop. We have to do it. We don't like to do it. But the monster's sick. Something's happened to the monster"

John Steinbeck

<u>The Grapes of Wrath</u>

CHAPTER SUMMARY

This literature review explores the connections between farmers, risk, and agricultural technology in North America. It begins by showing how North American agriculture was founded with indigenous and farmer local knowledge (**LK**), but in the 20th century shifted towards industrial techniques, which have since had adverse affects on rural communities, human health, and the environment as a whole. Modern agriculture is in crisis and sustainable approaches to food production are desperately needed. Some claim that genetically modified (**GM**) crops will be an integral part of creating a sustainable agriculture. A brief history of GM crops is provided, which critiques the "central dogma of genetics" and concept of "substantial equivalence", and demonstrates that this technology is different from previous plant breeding efforts and may be more risky. The literature on "science-based" risk assessment for GM crops is reviewed, which suggests that this process is inadequate to evaluate the safety of this technology. Despite this, risk assessment was used to approve the release of GM crops, which has caused worldwide controversy largely because the public was excluded from decision-making. The documented benefits and risks of GM crops, particularly those that are herbicide-tolerant (**HT**), are presented largely within a Canadian context, which shows that few studies have examined the impact of this technology on farmers and rural communities. It is argued that agbiotechnology represents a "post-normal science", which would benefit from increased public input, particularly from farmers given their extensive expertise, and risk analysis is offered as a methodology to achieve this.

AGRICULTURE IN NORTH AMERICA

Indigenous farming, prairie settlers, and agbiodiversity

In the lands now known as Canada and the US, prior to the arrival of Europeans, indigenous peoples had sophisticated knowledge and agoecosystems involving squash, beans, sunflower, and corn, which have now largely been destroyed by settler agriculture (Kloppenburg, 2002; Kuyek, 2007). However, in the early days of colonial expansion, Europeans had to rely on these indigenous varieties to sustain themselves, as most of their "old world" crops were not ecologically suited for use in the "new world". Over time, Europeans integrated indigenous varieties into their own systems, while importing and adapting additional crops, which ultimately created the germplasm base for North American agriculture (Kloppenburg, 2002; Kuyek, 2007).

With European farmers in control of new world agriculture, extensive networks of farmer-to-farmer seed and knowledge sharing occurred, and this was enhanced by Canadian and US government seed distribution programs that encouraged on-farm research and plant breeding[1]. These farmer-centered programs, predicated on millions of hours of collective labor and knowledge, were highly effective at increasing yields and further strengthening agricultural biodiversity and rural communities in both these nations (Kloppenburg, 2002; Kuyek, 2007). However, much has changed since indigenous peoples and European settlers developed this once largely self-sufficient, family-controlled, and ecology-based food system.

The rise of industrial agriculture

It is largely accepted that the rise of "industrial agriculture" in the 20th century – predicated on mechanical, chemical, and biological technologies - exceeded in magnitude all previous changes in agriculture going back to its birth 10,000 years ago (Paarlberg and Paarlberg, 2000). Governments and industry promoted industrial agriculture, as it was their belief that Fordist principles of manufacturing and large-scale production could be applied to agriculture, which indeed increased labor and land productivity (Troughton, 2005).

Prior to the Second World War, farms in Canada and the US were at their peak number. With the war effort pressure to increase food supply with industrial methods was mounting (Troughton, 2005). It was largely believed that increasing food production would play an important role in winning the war (Paarlberg and Paarleberg, 2000). In Canada, rapeseed[2] (the precursor to canola) was grown broadly for the first time to support the war effort, as the oil made an excellent lubricant for vehicles being used overseas to transport troops (Kneen, 1990). A great number of chemicals were developed in this period including DDT to protect troops from malaria. Scientists found that nerve and mustard gases could be used to develop agricultural pesticides (Horne and McDermott, 2001). As a result, the chemicals developed in this period were subsequently used in agriculture as herbicides, insecticides, and fungicides (Blaine and Powell, 2001) and war veterans were employed as pilots for aerial spraying of these products (Horne and McDermott, 2001). Further linking the World War II with the rise of industrial agriculture, the technology used to produce bombs in this period were subsequently applied to make nitrogen fertilizers for agriculture (Fowler and Mooney, 1990). Post-World War II, governments in North America enacted policies that placed priority on large-scale, technologically intensive, and globally competitive agribusiness, largely to the detriment of small-scale family farms (Kuyek, 2007).

Machinery, pesticides and nitrogen fertilizers became increasingly available to farmers, and were hard to resist given that they increased yields and reduced labour requirements (Lewontin, 2000). Using farm machinery as an indicator, in Canada between 1941 and 1961 combines increased from 3 per 100 farms to 82 per hundred farms (Abell, 1970). The tractor was a symbol of industrialization, it made farm life easier and promised "emancipation from drudgery" (Boyens, 2001). However, these changes allowed agribusiness to control the means of production on farms, and thus was the first step in the loss of farmer autonomy in the "agrifood system" (Lewontin, 2000). Farmers increasingly became viewed as passive adopters of expert-developed technologies (Fliert and Braun, 2002). This was particularly the case regarding scientific plant breeding efforts, which arose from the emerging field of genetics and subsequent industrialization of biology.

Industrialization of biology

In the early 20th century, Mendel's work on biological inheritance was rediscovered (Lewontin, 1991), and this precipitated a major shift in plant breeding efforts across North America. The traditional farmer-to-farmer model of plant breeding was replaced with a one-way scientist-to-farmer technology transfer model (Kuyek, 2007). Early scientific plant breeding efforts developed superior wheat varieties, yield-boosting hybrids in the 1930s, and crops that performed well with newly released synthetic pesticides and other inputs (Lewontin, 2000). In the 1930s, the US Congress also passed a law allowing scientists to claim intellectual property rights over the plants they developed, which ultimately led to "plant breeders rights" legislation in many industrialized countries around the world (Teitel and Wilson, 1999). In this way, biology was being used to further industrialize agriculture, and was becoming increasingly guided by profit motives for agribusiness.

The development of wheat varieties in North America demonstrates how genetics facilitated industrialization, prairie expansion, and the takeover a farmer-directed plant breeding by scientists. In 1842, an Ontario farmer named David Fife imported hard spring wheat seed from a friend in Glasgow Scotland that was rust resistant, early ripening, and with superior milling qualities (Olmstead and Rhode, 2004). This seed, later named Red Fife, was ideally suited for the North American climate, and allowed farmers to grow wheat across the continent where it had previously not been possible (Olmstead and Rhode, 2004). Through farmer-to-farmer seed sharing (Kuyek, 2007), this seed eventually became the premiere wheat variety across North America, and allowed for settler expansion and the growth of prairie agriculture (Olmstead and Rhode, 2004).

Given the success of Red Fife, agribusiness was particularly interested in expanding its use to promote export sales, which prompted the Canadian government to "improve" the variety, particularly its yield potential (Kuyek, 2007). The use of Mendelian genetics was sweeping agricultural research program across North America, and government plant breeders used these methods to cross Red Fife with an Indian variety called Hard Red Calcutta, and created Marquis wheat. Marquis wheat was very popular and by the 1920s, it made up 90% of the wheat grown across the prairies and helped double wheat yields (Kuyek, 2007). In the US, similar research was carried out, and wheat yields increased almost 60%, prompting some scholars to conclude that biology played as large a role as mechanization and chemicals in the industrialization of agriculture (Olmstead and Rhode, 2004).

Some have argued that the development of hybrid corn demonstrates how the science of genetics was used to prevent farmers from reusing their seed, and thus biology was used to promote capitalist ideology (Lewontin, 1991). These new corn varieties had "hybrid vigour" upon being planted, which enticed farmers to adopt the technology, although it did not reproduce true in subsequent years. Thus, farmers began to abandon their age-old practice of seed saving (Kloppenburg, 2002). By the 1960s in the US, hybrid corn accounted for 96% of seeded land, demonstrating the massive transformation away from seed saving (Horne and McDermott, 2001). The Canadian and US governments were strong proponents of hybrids and invested considerable research in this technology, even though these developments largely benefited commercial interests more than those of farmers (Lewontin, 1991). While both governments were proponents of hybrid corn, its introduction in the US increased privatization of agricultural research and development quickly, whereas in Canada public breeding programs were maintained as a priority into the 1980s (Moore, 2002).

Public versus private research in Canada

Canadian farmers did not resist losing control of plant breeding to scientists, and were largely supportive of government and industry research and technology development. For the most part, scientists found solutions to farmer identified problems, and research was generally geared toward benefiting farmers (Moore, 2002), and thus there was widespread support for these programs. Furthermore, Canadian farmers remained largely in control of seed supply, and when breeders released new varieties, it was the farmers that actually grew out, multiplied, and distributed this "certified" seed (Kuyek, 2007). Nearing the end of the 1970s, these certified varieties only accounted for between 25-30% of seed used in Canadian agriculture, enough for about 14% of the land base (Kuyek, 2007). This positive relationship between farmers and scientists is reflected in the early development of canola.

Canadian plant breeding efforts to transform rapeseed into canola – between the 1950s and 1970s – demonstrates how research at that time was being carried out by the public interest (Kneen, 1990). Researchers bred rapeseed for lower erucic acid and glucosinolate levels, which eventually allowed the plant to be used for consumption as edible oil and created a new commodity for farmers (Kneen, 1990). The bulk of this research was carried out collaboratively in the public sector, particularly by Dr. Baldur Stefansson from the University of Manitoba and Dr. Keith Downey with Agriculture Canada (Kneen, 1990). Many regard canola as the "Cinderella story" of Canadian public planting breeding efforts, showing how farmers, scientists, and government worked collaboratively to develop this important crop for prairie agriculture (Kneen, 1990). However, later in the 1980s, this work became increasingly privatized by industry due to the development of hybrids and patented plant breeding processes (Kneen, 1990). That canola was increasingly privatized reflected an overall shift in Canadian agricultural research policy at that time.

By the mid 1980s, Canadian government research programs had become increasingly guided by a neoliberal agenda, which promoted the importance of market-based principles (Moore, 2002). This, in part, was due to fiscal restraints within government, and marked a shift towards a more corporate US model of agricultural research that had begun with the deployment of hybrid corn in the 1930s (Moore, 2002). This shift, some believe, resulted in government resources being used to benefit agribusiness at the expense of the "public good" (Moore, 2002).

While governments largely spearheaded industrial agriculture in North America, predicated on a Fordist ideology, many believe that over the long-term it was agribusiness that ultimately benefited (Troughton, 2005). Throughout the 20th century, corporations were able to amass wealth, control, and power through the marketing of proprietary seeds, pesticides, fertilizers and farm machinery (Evans, 2002). These massive changes in agriculture over the past century have severely altered rural communities, and the environment.

The "technology treadmill" and "farm crisis"

This shift towards industrial agriculture has adverse consequences for farmers and rural communities. Farmers have become beholden to a "technology treadmill" with the rise of mechanical, chemical, and biological innovations, as increases in production depress prices and require that farmers adopt ever new technology to stay competitive (Kloppenburg, 2002). The farmers walk with technology but ultimately get nowhere (Horne and McDermott, 2001). Indeed, they may actually fall further and further behind, as this "boom-and-bust farm cycle" increases overall costs and favours larger farms relative to smaller ones (Buckland, 2004). This creates fierce competition within the farm community for economic survival, increasingly marginalizes or eliminates "family farms", and forces those remaining on the land to resort to shrewd business principles and specialization (Dasgupta, 1988). The common mantra in industrial agriculture is "get big or get out" (Jackson, 2002).

Farmers face enormous financial pressures in part due to the transition to industrial agriculture. Over the last 60 years, Canadian farm income has steadily dropped despite the widespread use of mechanical, chemical, and biological agricultural technology (NFU, 2003). Analysts believe Canadian farmers are now in the worst "farm crisis" in history, and report how over the past twenty years farmer net income has been near or below those of the Great Depression, while agribusiness has garnered record profits (NFU, 2005). Increasingly, farmers must assume farm credit to support industrialization, in order to pay for tractors, fuel, pesticides and hybrid seeds (Giangrande, 1985), which further changes social relationships, and makes farmers reliant on banks and industry (Aball, 1970). In 2007, it was estimated that Canadian farmers total farm debt was $57 billion (NFU, 2007)

High input costs associated with industrial agriculture are largely viewed as the number-one obstacle to farm profitability. Since 1975, farm input costs have increased four-fold, and have pushed many farmers into bankruptcy (Boyens, 2001). Some suggest that agribusiness has "predatory pricing", whereby they vary prices for inputs such as fertilizer and seeds to capture farmer profit based on the commodity market (NFU, 2003). This is further compounded by the chronically low margins that farmers receive for their products (Boyens, 2001), which forces farmers able to compete back onto the treadmill to operate at larger scales and with more technology (Weis, 2007). This has had devastating consequences for the structure of rural communities.

In Canada, over this same 60 years, rural populations have declined from over 30% of the total population to less than 2% (Skogstad, 2005). With fewer farmers on the land, the sense of community in rural areas is undermined, and associated services (e.g. hospitals, stores, etc) have become difficult to maintain (Sim, 1988). Furthermore, research shows how these economic pressures can adversely affect farm family psychological, social, and spiritual wellbeing (Buckland, 2004). Yet, in rural communities, there is a certain amount of status and prestige associated with technology adoption, which continues to pressure farmers to use industrial methods despite associated financial and social costs (Francis, 1994). The environmental costs of industrial agriculture are also placing enormous pressure on human and ecological systems.

Environmental erosion

Rachel Carson's publication of *Silent Spring* in 1962 exposed the world to the extent that chemicals, primarily those used in agriculture, were compromising environmental and human health. Worldwide, the use of pesticides has grown since World War II and now approximately 2.5 tons are used annually at a cost of about $20 billion (Pimentel, 1996). Globally, these pesticides poison over 1 million people and cause about 20,000 deaths each year (Pimentel, 1996). Those most affected are the farm workers themselves (Horne and McDermott, 2001). In the US, the yearly number of diagnosed cancer cases related to pesticides ranges from 6,000 to 10,000, and other adverse human health effects such as neurological damage may be associated with these chemicals (Pimentel, 1996). Studies show that almost half of US ground and well water may be contaminated with pesticides (Pimentel, 1996). Pesticides also harm a wide variety of wildlife, including microorganisms, fish, birds, and mammals, through direct or secondary environmental exposure (Pretty, 1995). This chemical pollution from agriculture costs approximately $100 billion each year in human health and environmental damage worldwide (Pimentel, 1996).

Soil health is critical for agriculture (Pretty, 2005) and has also been damaged by industrial agriculture due to increasing farm specialization, ever-larger farms, and monoculture-cropping practices (Altieri, 2000). Some estimate that when settlers first came to the North American prairies, the topsoil depth averaged ten inches, but after mechanization and chemical use about half of this soil, on average, has eroded away (Horne and McDermott, 2001). With fertilizer use, the natural organic matter of the soil is not replenished (Horne and McDermott, 2001), and despite chemical substitutes soil has lost its productivity and is now causing major yield decreases (Soule and Piper, 1992). This soil blows off the land contaminating waterways with pesticides and nutrients, causing build up of sediments in lakes, streams, and rivers and increases the risk of floods (Pretty, 2005). Some argue that excessive soil damage has caused the downfall of past civilizations and may indeed be the downfall of the modern era (Montgomery, 2007). Monocultures have also led to the spread of disease and pests.

Some argue that industrial agriculture demands monoculture and genetic uniformity, as "economies of scale" require simpler systems that cater to larger farms, and agribusiness desires for grains and other produce that are standardized for food processing (Kneen, 1999). That only two potato varieties were used in Ireland in the 19^{th} century, these susceptible to blight caused by *Phytopthora infestan*, caused the "potato famine" and stands as the most dramatic example of the dangers of genetic uniformity (Fowler and Mooney, 1990). However, with the rise of Mendelian breeding, scientists did not learn from potato blight, and increasingly sought to "weed out" unwanted traits and promote genetic uniformity and monocultures for industrial purposes (Fowler and Mooney, 1990). More recently in the Red River Valley – a highly productive agricultural region that includes parts of Manitoba, Saskatchewan, North Dakota, South Dakota, and Minnesota – monocultures have made wheat susceptible to the fungus *Fusarium graminearum* (wheat scab), and cost farmers $4.2 billion (USD) between 1992 and 1998 (De Vore, 2002). Expensive and highly toxic fungicides were used to combat the problem. This additional expense, in part, caused approximately one-fifth of farmers in 1997 to quit farming in the Red River Valley (De Vore, 2002).

As farmers ramp up their use of pesticides, some insects, weeds, and fungi evade being controlled, and as a result they evolve resistance (Soule and Piper, 1992). As a result, pesticides no longer work on over four hundred species of pests (Fowler and Mooney, 1990). Once these species become "pesticide resistant", the changes to these "superpests" are irreversible, leading some to conclude that chemicals actually create greater pest problems than they solve (Soule and Piper, 1992). Ironically, chemicals often kill beneficial organisms that might control unwanted pests thus throwing nature off balance, which further increases farmer dependency on agribusiness to develop new pesticides (Altieri, 2000). This problem is further compounded by overall loss of genetic diversity in agriculture.

To overcome "superpests", plant breeders increasingly wish to use genetic materials from locally adapted non-industrial varieties, as these traditional "landraces" often have natural pest resistance (Soule and Piper, 1992). However, with the development of Mendelian breeding, many of these landraces were domesticated, and their genetic diversity has been irrevocably lost (Fowler and Mooney, 1990). That professional breeding of "improved varieties" has replaced landraces is the most significant reason for the loss of agricultural biodiversity, and is now recognized as a major global problem (Fowler and Mooney, 1990). These problems associated with industrial agriculture are further compounded by industrialized society itself, particularly its worldwide reliance on fossil fuels.

In an era of global warming and depleting fossil fuels, agriculture is increasingly recognized as being very energy inefficient, and arguably is its "Achilles' heel" (Horne and McDermott, 2001). This form of agriculture requires external energy inputs in the form of fossil fuels for tractors and irrigation, petrochemical derived fertilizers to increase yields, and massive energy requirements to transport food globally (Pretty, 1995). In the US, industrial agriculture consumes 20-120% more energy than low input systems like organic methods (Pretty, 1995). Globally, industrial agricultural uses approximately twelve times the energy compared with food production in less-developed countries (Horne and McDermott, 2001). Analysts predict that in the near future fossil fuels will be cost prohibitive for use in industrial agriculture, and these price increases will likely bankrupt more farmers (Horne and McDermott, 2001).

The crisis of industrial agriculture and agbiotechnology

It is increasingly recognized that industrial agriculture is negatively affecting the environment, public health, and rural communities (Tegtimeier and Duffy, 2005). The problems associated with industrial agriculture have in part been attributed to the inadequacy of risk management, which until the 1970s was entirely reactionary, and no attempts were made to predict and avert potential problems with technology, particularly chemicals (Tait and Levidow, 1992). In an era of environmental awareness and concern, industry, government, farmers, and the public largely agree that "sustainable agriculture" is desirable. However, sustainability is a contested term, and how it is to be achieved remains elusive, if not controversial. Some argue that agroecology – the application of ecosystem thinking, cultural knowledge, and appropriate technology – to increase sustainability, yields, and farmer profitability is best (Gliessman, 2005). Methods incorporating agroecology include organic farming, permaculture, low input agriculture and others (Pretty, 1991). However, others claim that these methods will not meet the food requirements of the 21st century, and advocate a new wave of industrial agriculture based on advances in biotechnology, which they believe will make farmers more profitable, increase yields, reduce pesticide use, and overall promote sustainability (Conway, 1998). Agbiotechnology represents the latest wave in the tsunami of change that industrial agriculture has caused for farmers, society, and the environment as a whole.

GM CROPS, RISK ASSESSMENT, AND CONTROVERSY

Discovery of DNA and agriculture's transformation

As we have seen, industrial agriculture began motoring away shortly after the end of World War II, about the same time the mother molecule of life was discovered. In 1953 - building on the work of Darwin, Mendel, and others - Watson and Crick made public their model of deoxyribonucleic acid (**DNA**): the iconic "double helix". With the structure of DNA established, studies began on its properties and in the early 1970s scientists had found a way to create recombinant DNA (**rDNA**), which allowed them the unprecedented ability to cross genes between species (Lurquin, 2001). These methods were highly controversial, led to a short-term moratorium on their use, and precipitated the Asilomar Conference in 1975 where the first biological containment strategies were developed, which ultimately set the groundwork for science-based risk assessment and the future commercialization of products derived using rDNA (Rifkin, 1998).

In 1977, scientists found that a soil bacterium *Agrobacterium tumefaciens* could infect a plant cell and transfer genes that cause crown gall disease, and this stimulated research on how this bacterium might be used to incorporate genetic materials from other species into plants (Halford, 2006). By the early 1980s, scientist began routinely using *A. tumefaciens* to transfer desirable genes into plants, and these "transformations" were incorporated into every plant cell, were active, and were thought to act stably (Halford, 2006). Additional gene transfer methods have also been developed, most notably the biolistic method that uses a "gene gun" to fire DNA coated pellets into the nucleus of a cell, which has also allowed for plant transformation (Jones, 2007). Plants "transformed" in this way have been called transgenic, genetically engineered (**GE**), genetically modified (**GM**), and genetically modified organisms (**GMOs**) (Halford, 2006). In agriculture, products derived from these processes are often referred to as "agbiotechnology".

As indicated throughout this literature review, farmers have been modifying plants since the dawn of civilization, and in the past century scientists have increasingly been involved in plant breeding efforts using Mendelian genetics. Many believe that GM crops simply represent an extension of these previous breeding efforts (Bud, 1991). However, others argue that GM crops represent a fundamental transformation in agriculture, as their development allows for the crossing genes between species, and may present new and potentially dangers risks for society (Teitel and Wilson, 1999). This debate about how comparable GM crops are to their non-GM counterparts has led to contentious debate in genetics and has significant consequences for the practice of risk assessment.

Shattering of the "central dogma" paradigm

Since the discovery of DNA and rDNA technology massive changes have taken place in the field of genetics. Arguably, genetics is undergoing a "paradigm shift" (Kuhn, 1962) and conventional scientific understanding (what Kuhn calls "normal science") is likely inadequate for explaining phenomena related to genetic technologies, particularly GM crops. Kuhn (1962) believes that when normal science breaks down, scientists engage in intense intellectual battle for the new conceptual and methodological framework (i.e the new paradigm) that will govern a discipline. The scientific battle for a new paradigm regarding biological inheritance and gene regulation seems well underway.

The foundation of genetics has been built upon "the central dogma", a concept promoted by Francis Crick that argues that DNA is the exclusive means for inheritance in living beings (Commoner, 2002). Essentially, the central dogma hypothesizes that a DNA gene codes for a phenotypic trait, and that there should be a one-to-one relationship between genes and proteins (Commoner, 2002). Viewing DNA as a linear system, scientists developed GM crops under the assumption that single gene insertions corresponded with single trait expressions, and many conclude that these products are similar to conventional crops except for the new gene (Murray, 2003). It is often stated that transgenesis is simply an extension of traditional breeding methods (Teitel and Wilson, 1999), and scientists and industry further claim that transgenesis is a very precise and safe procedure (Larkin and Harrigan, 2007).

However, the Human Genome Project found that humans only have around 30,000 genes and over 100,000 proteins, which some believe proves the one-to-one ratio of the central dogma false (e.g. Commoner, 2002). Some have argued that this "destroyed the scientific foundation of genetic engineering and the validity of the biotechnology industry's widely advertised claim that its methods of genetically modifying food crops are 'specific, precise, and predictable' and therefore safe" (Commoner, 2002).

Recent research further demonstrates the deficiencies of the central dogma. Studies show that "transformations" using *A. tumefaciens* and biolistic methods have deleted, scrambled, and rearranged the DNA of GM plants (Latham et al., 2006) and may lead to pleiotropic (unintended) effects in host organisms that are cause for concern regarding biosafety and current approaches to risk assessment (Wilson et al., 2006). Furthermore, scientists investigating gene regulation in plants using an epigenetic approach have found that environmental factors may affect gene expression (Moch, 2006), and that genes may actually work in synchrony with each other to produce phenotypic traits (Vaucheret et al., 1998).

Although industry claims transgenesis is precise, the way that they create GM crops demonstrates otherwise. While transgenesis does indeed allow for the crossing of genes between species (i.e. "transformation), the exact mechanisms for how these genes recombine is not well understood (Jones, 2007). Furthermore, industry recognizes that transgenesis causes gene silencing, genetic rearrangements, and other pleiotropic effects, and when developing GM crops they generate a number of plants and test for "single-copy events" (Jones, 2007). One study shows the imprecision of this approach, documenting how over four million *Arabidopsis* plants had to be transformed to find one plant that properly incorporated the desired gene (Hanin et al., 2001). A more conservative industry assessment indicates that "usually well over 100 plants" must be produced and carefully screened to create a proper single copy GM crop (Devine, 2005). Critics believe that because of this imprecision "genetic engineering it should not be considered a science because its central processes are still not understood (Teitel and Wilson, 1999).

Some have argued that society is now in a "postgenomic" future, as genetics has proven too reductionistic and linear, and has not appreciated the true complexity of living organisms (Fujimura, 2005). To deal with this "biocomplexity", which is overlooked by the central dogma, some state that "systems biology" is required, as it considers "gene networks, cells, organs, and organisms as systems interacting with each other and with their environments" (Fujimura, 2005). While a Kuhnian paradigm shift towards systems biology seems imminent, GM crop regulation and risk assessment is still largely based on the outdated principles of genetics based on the central dogma.

"Science-based" risk assessment of GM crops

World over, regulators have approved GM crops using "science-based" risk assessment with the goal of gauging the "possibility, probability, and consequences of harm" prior to the commercial release of these products (Nap et al., 2003). The Canadian system of GM regulation is based on this model (Yarrow, 1999). According to Conner et al. (2003), this science-based approach is governed by an empirical definition of risk:

Risk = probability x consequence
= likelihood of event x (negative) impact of

While risk is considered the likelihood of an adverse impact, a hazard is defined as the actual impact itself (Wachbroit, 1991). Many in the scientific community argue that risk assessment provides objective information about potential hazards (Smyth and Phillips, 2006). This practice allows regulators to set "risk thresholds" for GM products that allow acceptable products onto the market while rejecting those deemed too risky (Phillips, 2006). That regulators view science as being "value neutral" allows them to legitimize decision-making based on "facts" regarding the highly controversial and politically charged issue of GM crops (NRC, 2002).

However, what hazards are identified as being important is considered a subjective and potentially contentious process (NRC, 2002). Risk assessment for the most part only considers hazards that are scientifically quantifiable and predictable (Jensen et al., 2003). The obvious implication of this is that experts and scientific elites dominate in hazard identification and risk assessment (Isaac, 2006). While this effectively means that public input is excluded from risk assessment, some argue this is necessary to maintain the efficacy and objective nature of regulation (Phillips, 2006). This approach to risk assessment is based on the normative assumption that technological progress is beneficial to society (Isaac, 2006). To scientifically assess potential hazards, risk assessment requires "reference scenarios" that use non-GM crops as a baseline to evaluate safety (NRC, 2002).

Risk assessment considers GM crops "substantially equivalent" to non-GM crops, allowing scientists to compare novel crops to conventional ones with a history of safe use, and generally assumes that recombinant DNA technology is harmless (Mayers et al., 2002). This means that GM products (i.e. phenotype) and not the process of transgenesis (i.e. genotype) is the focus of risk assessment (Nottingham, 2002). Essentially, selected chemical and ecological characteristics are compared and if they are relatively the same and no major changes have occurred with GM plants, they are considered safe and more rigorous testing is not required (Anderson, 1999). As Yarrow (1999) states, "This analysis of familiarity and substantial equivalence of novel traits is really the crux of the Canadian safety-based regulatory approach".

A number of federal departments oversee the regulation of GM crops in Canada, although the Canadian Food Inspection Agency (**CFIA**) plays the lead role (RSC, 2001). The CFIA is "Canada's largest science-based regulatory agency", with over 5000 employees across the country, and reports to the Minister of Agriculture and Agri-Food Canada (CFIA, 2007). The CFIA assesses the impact of GM crops on the environment and biodiversity and is responsible for overseeing all field trials (RSC, 2001). Developers of GM crops can only apply to the CFIA for field trial permits after their product has shown utility and stability over a seven-year period of greenhouse or laboratory experiments (Phillips, 2006).

Worldwide, field trails are central to risk assessment (Nap et al., 2003), as decision makers consider them the most appropriate tool to determine agronomic safety of GM crops prior to their release (Conner et al., 2003). Some scientists also believe that field trial data can be scaled up mathematically to allow for predictions, both spatially and temporally, at the landscape level (Hails, 2002). Only GM crop developers, their agents, and regulators know the location of field trials in Canada (Phillips, 2006). According to Yarrow (1999) the CFIA's environmental assessment is based on five main criteria:

- The potential for the plant to become a weed
- The potential for gene flow to wild relatives
- The potential for the plant to become a plant pest
- The potential to affect non-target organisms
- The potential impact on biodiversity

The CFIA does no independent testing and industry is responsible for submitting data on these five criteria (Yarrow, 1999). The CFIA considers these "paper reviews" to be adequate and claim that company data is equivalent to peer-reviewed science and the process is a "standard scientific method of evaluation" (CFIA, 2008a). In addition to data provided by industry, the CFIA consults peer-reviewed literature and expert advice through advisory panels and technical workshops (CFIA, 2008a). That GM crops are considered substantially equivalent and assumed to be safe means that mandatory labelling is not required for foods containing GM materials (CFIA, 2008b). However, many have disputed the claim that risk assessment is based on "sound science", and the use of this practice to approve GM crops remains contentious.

Unscientific nature of risk assessment

Critics, on the other hand, claim that GM crop risk assessment is based on "unsound science" and "ideology" (Levidow and Carr, 2000). They further argue it has been designed to convince the public of safety, through claims of objectivity and predictive capacity, despite high levels of uncertainty associated with new technologies like GM crops, this in order to advance science and industry goals (Jasanoff, 2003). Critically evaluating how substantial equivalence has been used in risk assessment seems to give credence to these claims.

That risk assessment uses substantial equivalence has also been extensively criticized for being "pseudoscientific" (Millstone, 1999). Some believe that comparing chemical composition does not reveal anything about the potential toxicity of these new GM plants when consumed (Millstone, 1999). It has been alleged that substantially equivalence is a political concept promoted by industry and governments, which allows for GM crops to be released without proper toxicity or ecological studies on their effects, in order to save companies time and money (Millstone, 1999). In Canada, the Royal Society of Canada (2001) severely criticized the federal government for their use of substantial equivalence, and stated: "...those who are responsible for the regulation of new technologies should not presume its safety unless there is reliable scientific basis for considering it safe".

That risk assessment is focused on physical properties (i.e. phenotype) and does not consider potential hazards associated with the process of transgenesis (i.e. genotype) has also been criticized (Nottingham, 2002). In effect, the epigenetic and pleiotropic issues associated with GM crops are not considered in risk assessment (Wilson et al., 2006). This concern seems corroborated by evidence suggesting that transgenes insertion may cause adverse effects (Clark, 2006). Studies have found that both GM soybean (Sanogo et al., 2000) and GM cotton (Colyer et al., 2000) are more susceptible to disease and pests, respectively, than their "substantially equivalent" non-GM counterparts, and the authors of these reports conclude this was likely due to the transgenic process itself. As some indicate, risk assessment is based on science rooted in the central dogma of genetics, which makes the regulatory concept of substantial equivalence outdated, and arguably dangerous (Commoner, 2003). Recognizing this problem, the Royal Society of Canada (2001) further recommended that the CFIA move away from the assumption that genetics is a linear and that transgenesis is "precise", suggesting a more holistic approach that seeks to understand the biocomplexity of GM crops.

While field trials are an important part of risk assessment, they have also been criticized for their small-scale and short-term nature, which may reduce statistical power (Marvier, 2002) and compromise predictions of ecosystem effects such as landscape level gene flow and potential invasiveness (NRC, 2002). That field trials do not represent the environment as a whole, has led some to conclude that they may not anticipate different climatic and extreme weather events (e.g. hurricanes, strong wind, etc) that may spread pollen, seeds, and plants in unpredictable ways (Rissler and Melon, 1996). Furthermore, natural disasters like floods may disrupt field trials and allow for unapproved GM crops to be released into the environment, a problem that has already occurred (Nottingham, 2002).

Another opprobrium of risk assessment, particularly in the Canadian context, is that it does not require post-release monitoring of long-term effects associated with commercialized GM crops. The CFIA (2007) states "that..genetic modification does not necessarily introduce unique risks, the potential for long-term effects...is not necessarily different than that for conventional products". As Andree (2002) points out, if the CFIA required post-release monitoring of long-term effects, they would effectively be admitting that GM crops are not "substantially equivalent" to non-GM crops, and thus would contradict the foundation of risk assessment. For some, that the CFIA assumes there will be no post-release hazards associated with GM crops is in itself unscientific (Clark, 2006). However, the importance of post-release monitoring is increasingly recognized as being critical to proper risk assessment, as it allows for validation of pre-commercialization decisions, recording of trends related to predicated effects, and the detection of impacts not anticipated by *a priori* testing (NRC, 2002). The importance of post-release monitoring is affirmed by the recognition of leading Canadian experts that *a priori* risk assessment failed to anticipate hazards associated with contamination, weed problems, and market harm (Krayer von Krauss et al., 2004).

Some believe that it is inappropriate that industry is responsible for performing all tests related to the a priori risk assessment of their own products. Erwin (2001) points out that the primary motivation of agbiotechnology companies is to increase profits for their firms and that they cannot be expected to address risk fully. It is well documented that science conducted by industry is carried out in a way that reinforces their priorities and arguably is far from neutral or objective (Rampton and Stauber, 2001). After evaluating the CFIA's regulatory approach, the Royal Society of Canada (2001) concluded that much of the data industry submits about its own products is not made public, and is protected by confidential business information (**CBI**) provisions. The CFIA maintains that this is important to support industry research and development, a view that has been criticized for putting the agency in a "conflict of interest" as both a promoter and regulator of biotechnology, which ultimately undermines scientific transparency and integrity as well as public confidence in the overall regulatory system (RSC, 2001). Further, critics argue that basing GM crop regulation on "corporate science", which is guided by profit motives and business secrets, is "tantamount to flying blind" and does not allow society to make good decision that are in the public interest (Nader, 1999).

To-date, the public has largely been locked out of regulatory decision-making, and this is exacerbated by the fact that risk assessment does not consider non-scientific social, economic, and ethical issues arising from GM crop use (Abergel and Barrett, 2002). The lack of public input in risk assessment has caused considerable backlash for regulators and industry (Frewer et al., 2004), undermined public confidence in science (Phillips, 2006), and has prompted scientists themselves to call for greater public participation in the regulation of GM crops (RSC, 2001; NRC, 2002). As we have seen, risk assessment is a highly contested methodology for evaluating potential GM crop hazards, and that it has allowed the environmental release of GM crops is in large part responsible for the ongoing global controversy.

Environmental release and global controversy

The use of GM crops by farmers is global. Since their release in the mid 1990s, they have been planted in 23 countries covering approximately 114.4 million ha of land (James, 2007). Globally, the main crops that have been transformed, in decreasing order of importance, include soybean, maize, cotton, and canola (James, 2007). The main traits that have been introduced into these crops include herbicide tolerance (~70%), insect resistance (~15%), and combinations of these (~15%) (James, 2007). Transgenic herbicide-tolerant (**HT**) crops made up 60% of soybean, 28% of cotton, 18% of canola, and 14% of corn planted worldwide in 2005 (Beckie et al., 2006). Canada was one of the first countries to commercialize GM crops, and is now the fourth largest user of this technology, preceded by the US, Argentina, and Brazil (James, 2007). At present, Canada grows approximately 7.0 million ha of GM crops annually (James, 2007) and the majority of this is HT canola (Beckie et al., 2006).

Canadian farmers rapidly adopted HT canola following its release in 1995. Three varieties of novel trait HT canola have been introduced: Roundup Ready (**RR**), Liberty Link (**LL**), and Clearfield (**CF**), these tolerant to glyphosate, glufosinate, and imidazolinone herbicides, respectively (Lawton, 2003). At present, they represent 96% of the 5.25 million ha of canola grown in Canada; approximately 50% of these being RR, 32% being LL, and 14% being CF (Buth, 2006). It is important to point out that both RR and LL have been created using transgenesis and are therefore considered true GM products. However, CF canola was developed using mutagenesis – a chemical induced transformation that does not cross genes between species - and is therefore not considered a true GM product. Thus, approximately 82% of the canola grown in Canada is considered GM (Beckie et al., 2006).

The release of GM crops has become an international controversy and has provoked acrimonious debate amongst scientists, industry, consumers, and environmentalists (Falkner, 2007a). These groups increasingly seek to influence governments to adopt their positions (Newell, 2007). The debate is often dominated by rhetorical and hyperbolic truth claims - that some call "genetically modified language" - by the stakeholder groups, particularly industry (Cook, 2004). It is largely accepted that industry has had tremendous influence over how governments construct and interpret GM crop regulation, which has led risk assessment to focus on science-based priorities at the exclusion of broader social, ethical, moral and religious issues (Newell, 2007). Industry's push for science-based risk assessment, based on "substantial equivalence", has been in part to harmonize regulations internationally so that companies can expand their markets for GM crops (Newell, 2007). That risk assessment excludes public input has prompted some to call it the "biotechnologizing" of democracy (Levidow, 1998). Industry fears that the inclusion of these broader social determinants will slow regulatory approvals, which will increase costs associated with developing agbiotechnology (Clapp, 2007). However, increasingly consumers, activists and environmental groups have played a central role in how this technology has been regulated after its release.

Protests have emerged globally regarding the use of GM crops in agriculture and food, which has further politicized the GM debate and made it increasingly difficult for regulators to move forward with safety approvals (Levidow and Murphy, 2003). Antiglobalization activists have singled out GM crops as a symbol of corporate hegemony and imperialism and often use innovative street theatre demonstrations to make their concerns evident (Jasanoff, 2006). Some have argued that GM crops are a proxy for activist concerns about industrial agriculture, trust in government, and environmental issues as a whole (Dale, 2005). Protesters worldwide have attacked and destroyed field trials claiming that they pose unacceptable risks for the environment (Jasanoff, 2006). Larger international environmental advocacy groups like Friends of the Earth and Greenpeace have facilitated these kinds of activities in many countries (Bernauer and Aerni, 2007). For the most part, anti-biotech environmental activists have had more success in the Europe than in North America (Levidow, 2007). This vocal

European protest has led many food retailers to remove GM ingredients from their products (Murphy and Levidow, 2006) whereas in North America, approximately 70% of processed foods have GM ingredients that are not labelled (Phillips and Corkindale, 2002). The public controversy over GM crops has caused a fault line in international governance over this technology (Weis, 2007).

Most notably, GM crops have created a “transatlantic conflict” over agbiotechnology, which has caused significant difference is how North American and the European Union (**EU**) countries regulate this technology (Murphy and Levidow, 2006). Prior to GM crop commercialization, in the 1980s, both North American and European governments had similar regulations that promoted a flexible and deregulated approach, largely based on “substantial equivalence” (Falkner, 2007b). However, upon commercialization, North America began shipping GM crops to Europe, which caused heightened consumer awareness and concern over this technology, and prompted a coordinated European-wide public campaign to block further imports of these crops (Falkner, 2007b). By 1998, many EU countries had heeded to public concern and imposed national bans on the growing or importing of GM crops, and this forced the European Commission to enact a *de facto* moratorium on all regulatory approvals (Falkner, 2007). As a result, except for approximately 50,000 ha of GM corn in Spain and a few field trials in other countries, these crops are not really grown in Europe (Tiberghien, 2007). The EU is committed to exploring a “precautionary approach” to regulation that mandates public input, restores confidence in government, promotes rigorous use of science, and recognizes uncertainty exists regarding GM crop impacts that requires caution (Murphy and Levidow, 2006).

The EU's precautionary approach has led to regulation that is less dependent on "substantial equivalence" as a decision-making threshold and predicated on the more thorough use of science to evaluate risk (Murphy and Levidow, 2006). This shift was influenced by the European public's belief that GM crops are categorically different from their non-GM counterparts, and also because of the high profile Puzstai affair (Murphy and Levidow, 2006). Arpad Pusztai conducted rat-feeding trials of GM potatoes and found negative effects on the stomach and intestines of these test animals, which the researcher attributed to the process of transgenesis itself (Ewen and Pusztai, 1999). After speaking openly about these controversial findings, Pusztai was fired from his prestigious appointment at the Rowatt Institute in Scotland, which further galvanized public concern over adverse health effects associated with GM foods and increased support for better and more inclusive regulation (Rampton and Stauber, 2001).

Including public input has been an important part of the EU's precautionary approach to GM crop regulation. Citing consumer concern, the EU has implemented mandatory labelling for products containing GM ingredients (Andree, 2007). While largely regarded as a victory for European consumers, some question if consumer choice alone is truly reflective of democratic participation (Newell, 2007), while others warn that it actually neoliberalizes activism (Roff, 2007). In fairness to these countries, extensive public consultations have been conducted to increase input regarding on GM crops, as evidenced by the EU-wide Eurobarometer survey on GM food (Tiberghien, 2007). Overall, the EU has demonstrated that GM crop regulation can be flexible and evidence-based, and accommodate public concern (Levidow, 2007). However, the EU's precautionary approach that includes both scientific and broader societal policy determinants has recently come under attack.

In 2003, the US, Canada, and Argentina – three of the four main GM crop producing countries in the world - challenged the EU's precautionary approach at the World Trade Organization (**WTO**) arguing that the de facto moratorium was an illegal barrier to global trade (Murphy and Levidow, 2006). These GM crop-producing nations hoped to use the WTO dispute mechanisms to force the EU to adopt agbiotechnology and argued that the moratorium was a form of protectionism (Falkner, 2007b). In early 2006, the WTO agreed that the EU's precautionary approach was in breach of international trade rules, which some believe demonstrates the conflict between national environmental protection initiatives and globalization (Isaac and Kerr, 2007). Other expressed disappointment that the WTO would overrule the EU's democratic decision making processes and try to force GM foods onto a skeptical public (Murphy and Levidow, 2006). Yet, given the intense public debate in Europe over GM crops, many believe it is unlikely that the EU will move away from its precautionary approach (Isaac and Kerr, 2007). Ultimately, the long-term implications of the WTO case are difficult to discern, but some conclude that the global contest over legitimate regulatory models for assessing the benefits and risks of GM crops will continue (Murphy and Levidow, 2006).

Benefits and risks of GM crops

Carrying out a literature review on the benefits and risks of GM crops is complex. First, there are many different varieties of GM crops (e.g. corn, canola, etc), which often have different introduced traits (i.e. herbicide-tolerance (**HT**), insect resistance (**IR**), and stacked systems that include both). Secondly, the literature is replete with studies dealing with the GM crop issue at different scales, spanning genomics, proteomics, physiology, ecology, agronomy, etc. For the most part, this review will focus on the farm-level benefits and risks associated with GM crops, and will include relevant agronomic, ecological, socioeconomic, political, and legal issues. To the degree possible, the following literature will focus on GM crops with HT traits, particularly canola and wheat, and will use Canadian examples.

Industry promotes HT crops for their weed control efficacy, as they can resist the application of selective herbicides (Devine, 2005). A number of crops have HT traits, including corn, soybean, canola, sunflower, rice, and wheat (Devine, 2005). Studies confirm industry claims and show that HT canola varieties provide better weed control and reduced dockage (e.g. less weed seeds and chaff in final product) when compared with non-HT varieties (Harker et al., 2000). Research suggests that better weed control increases yield for HT canola (Harker et al., 2000) and HT wheat resistant to glyphosate (Blackshaw and Harker, 2002; Howatt et al., 2006). It is believed that Canadian farmers have rapidly adopted HT canola because it improves weed control and yields (Devine and Buth, 2001), which further simplifies weed management and has allowed farmers to manage larger areas more efficiently (Beckie et al., 2006).

Furthermore, some suggest that HT crops may provide important environmental benefits, as they are often linked with more benign herbicides (e.g. glyphosate), may require less frequent herbicide applications, and facilitate reduced tillage because soil incorporated herbicides have been replaced (Devine, 2005). While research confirms that HT canola relative to non-HT canola has reduced overall herbicide use per hectare, the exact amount of this reduction varies by study, and a precise figure remains elusive (Beckie et al., 2006). While herbicide use has decreased between HT and non-HT canola systems, since 1998 in Canada it has remained constant, as farmers often use HT canola to “cleanup” weedy fields and hope to reduce herbicide use in following years (Beckie et al., 2006). However, research indicates that herbicide use (particularly in HT soybeans in the US) may actually increase, and some contend that industry claims of environmental benefit associated with these products may be overstated (Benbrook, 2001). That HT crops facilitate minimum tillage practices, which requires fewer passes across fields, may increase soil health and carbon sequestration, while reducing soil erosion and fuel consumption (Van Acker et al., 2004). Research suggests that HT canola has indeed reduced fuel consumption, which mitigated approximately 94 million kg of carbon dioxide emissions between 1996 and 2004 (Brookes and Barfoot, 2005). It is suggested that these environmental benefits are yet another reason why HT crops continue to be adopted by farmers worldwide (Devine, 2005).

To date, only two studies have investigated the farm-level impact of GM canola on Canadian farmers, although they have not been peer-reviewed. The Canola Council of Canada commissioned telephone surveys with prairie farmers in 2001 and 2004 that focused primarily on the agronomic and economic impacts of GM crops. The results of these surveys suggest that GM cultivars provided better weed control, yielded about 10% higher, and increased net return per acre by $5.80 when compared with non-GM cultivars (CCC, 2001). Fuel consumption decreased by 31 million liters due to fewer field passes and there was an overall decrease in herbicide use and cost (CCC, 2001). It was determined that GM cultivars can outcross and contaminate non-GM farms and become weeds (i.e. volunteers) that require additional chemical and mechanical control measures (CCC, 2005). Overall, these studies suggest the agronomic and economic benefits of HT crops outweigh risks associated with HT crop volunteers (CCC, 2001; CCC, 2005). However, a number of limitations exist with these studies. For example, the sampling protocol relied on GM crop developers providing list of participants, the methodology excluded small farmers, and broader social, cultural, and political issues were not considered. More research on risks associated with this technology is clearly needed.

One of the major criticisms of GM crops is that they are not containable (Clark, 2004). GM crop traits may escape via gene flow, which can be defined "as the exchange of genes between different, usually related, populations through pollen transfer" (Legere, 2005). Gene flow from GM crops is cause for concern, as it may affect neighbouring fields (both GM and non-GM), volunteer populations, and weedy relatives, which in turn might irreversibly impact farming and ecological systems (Baker and Preston, 2003). While gene flow is a natural process, the introduction of GM crops in agriculture has stimulated research in this area, which has facilitated a more comprehensive understanding of how crops and related species hybridize and the geographical scale for which this is possible (Dale, 2005).

It is important to recognize that gene flow is crop-specific. For example, canola is largely open-pollinated by wind and insects (Smyth et al., 2002) whereas wheat is largely self-pollinating (Waines and Hedge, 2005). Therefore, out-crossing rates differ between canola and wheat, and range between 12 to 55% (Legere, 2005) and 0.1% and 10.1% (Brule-Babel et al., 2006), respectively. Regardless of being classified as being open or self-pollinating, both canola and wheat out-crossing can have large-scale geographical effects. Gene flow studies on canola show that HT crops can hybridize with non-HT crops up to 3 km from the pollen source (Rieger et al., 2002). In wheat, depending on the variety, gene flow has been reported between 27 (Hucl and Matus-Cadiz, 2001) and 300 m (Matus-Cadiz et al., 2004) from the pollen source. Risk assessment had largely failed to predict the impact that this gene flow, particularly in canola, might have for farmers (Ramsey, 2005).

A major issue is that GM canola has extensively contaminated non-GM canola across the Canadian prairies. On average, one in four fields is seeded with canola, and therefore very few regions across the Canadian prairies are isolated from GM canola (Beckie et al., 2006). Canola produces lots of volunteers due to extensive seed shattering before and after harvest (Beckie et al., 2006), which can become dormant in the seed bank for four to five years, and remain a weed problem for farmers into the future (Legere, 2005). Volunteers have now been documented that have three-way trait stacking (Hall et al., 2002) and although single and trait-stacked volunteers can be controlled with additional chemicals (Beckie et al., 2004), costs and liabilities have increased for conventional, minimum tillage, and organic farmers (Smyth et al., 2002). Feral populations canola along roadsides and ditches are also trait-stacked, and likely outcross with in-field populations (Knispel et al. 2008).

Minimum tillage farmers now have to use additional and more costly herbicides to control some HT canola volunteers, as these plants are often resistant to glyphosate, which is the chemical that replaces tillage for weed control in these systems (Van Acker et al., 2004). Since organic farmers do not use chemicals some have attempted to sue GM crop developers (i.e. Monsanto and Bayer) seeking damages for GM canola volunteer cleanup costs (Bouchie, 2002). That government failed to introduce multi-scale stewardship plans when GM crops were introduced has likely exacerbated the problems associated with GM canola volunteers (Beckie et al., 2006). While GM plants may contaminate a farm via gene flow, studies now suggest that contaminated seed may also be a vector.

Gene flow has contaminated non-GM pedigreed seed stocks in Canada, as evidenced by two studies carried out in the country. Friesen et al. (2003) documented that 27 non-GM seedlots had been contaminated by GM traits, with 78% containing Roundup Ready traits and 96% containing either Roundup or Liberty Link, and overall 52% of the samples were above the 0.25% frequency required for certified seed. Another investigation found that of 70 pedigreed non-GM canola seedlots tested 46% contained Roundup Ready traits, while 59% contained either Roundup Ready or Liberty Link traits (Downey and Beckie, 2002). In the US, soybean, corn, and canola have also been extensively and irreversibly contaminated by GM a traits, which prompted harsh criticism of regulators (Mellon and Rissler, 2004).

Many suggest that Canada's previous experience with GM canola contamination may be used as a lesson regarding what might happen with GM wheat should it be introduced (Van Acker et al., 2004). Although GM wheat, particularly HT wheat resistant to glyphosate, was deferred from commercialization in 2004 amongst controversy (Stokstad, 2004) there has been renewed calls for its introduction to stimulate production and economic returns for farmers (Dyck et al., 2007). Research indicates that GM wheat will likely contaminate non-GM wheat through seed and pollen movement, and varieties that are Roundup Ready will stimulate the proliferation of volunteers because there will be a selective advantage for these weeds given the widespread use of glyphosate across the prairies (Brule-Babel et al., 2006). In turn, depending on the production system, minimum tillage farmers may have to pay between $5 to $52 per acre to control GM wheat volunteers (Van Acker et al., 2004), which is likely to undermine this important practice and its associated environmental benefits (Van Acker et al., 2003). Another risk that may be associated with GM crops, particularly those that are HT, is that they increase the potential for herbicide resistant weeds.

That both HT canola and HT wheat could be grown across the prairies has led some to believe that this could increase the risk of evolution of glyphosate resistant weeds (Van Acker et al., 2003). The use of GM crops, particularly those resistant to glyphosate, allows for repeated spraying and increases the chance that herbicide resistant weeds will develop (Nottingham, 2002). Moreover, glyphosate resistant crops allow for in-crop spraying, which was not previously possible with non-HT crops, which further increases the chance for resistance development in a broader spectrum of common weeds (Van Acker et al., 2003). Monsanto initially developed glyphosate in 1974 and has argued until recently that resistance to this chemical was unlikely (Bradshaw et al., 1997). However, with the widespread use of glyphosate in agriculture, compounded by the increased use of GM crops tolerant to the herbicide, there have now been a dozen documented examples of weeds developing resistance to the product (Service, 2007). The evolution of glyphosate-resistant weeds is a major threat to minimum tillage practices, which use this chemical for weed control instead of tillage (Van Acker et al, 2003). Some speculate that the success of glyphosate-tolerant crops will lead to their own demise, which in turn, will adversely affect farmer livelihoods and the environment (Service, 2007). The superior weed control efficacy of GM crops may also cause other environmental problems.

That HT crops offer superior weed control may also have unintended consequences for agricultural biodiversity. In 2003, UK scientists released the finding of the Farm-Scale Evaluations (FSE), which was the first large-scale study investigating HT crops - including canola, maize, and beet - and their overall impact on agricultural biodiversity (Andow, 2003). Both HT canola and beet offered superior weed control and this significantly reduced broadleaf weeds (Heard et al., 2003), which subsequently reduced weed dependent invertebrates (Brooks et al., 2003), butterflies and bees in-crop (Haughton et al., 2003) and butterflies at field margins (Roy et al., 2003). It is also likely that reduced weed biodiversity may also adversely affect farmland birds that are dependent on these plants (Andow, 2003). This FSE research was high in visibility and further alarmed the public regarding the potential risks associated with GM crops.

Worldwide, the introduction of GM crops has raised consumer concerns about the long-term safety of this technology for the environment and human health, which has adversely affected markets for farmers (Smyth et al., 2004). When GM canola was introduced in Canada in 1995, exports to Europe immediately dropped and ultimately ceased in 1998 (Smyth, 2006). European consumers were alarmed that these first imports would not be segregated and labelled, and this stigmatized GM crops and the agbiotechnology industry as a whole (Poortinga and Pidgeon, 2007). As a result of GM contamination, Canadian organic canola farmers and honey producers cannot guarantee their products are GM-free, and have lost millions of dollars in European sales (Smyth et al., 2002). The potential market harm associated with introducing GM wheat is likely to affect Canadian farmers' $4 and $6 billion in annual sales, given that over 80% of their wheat buyers have rejected the crop, largely citing consumer concern over eating GM foods (Huygen et al., 2003). Despite the market harm associated with GM crops, the CFIA's "science-based" approach does not allow for the consideration of socioeconomic risks, particularly for farmers (Smyth, 2006).

A review of the decade long Canadian experience with GM crops, particularly HT varieties, concludes that very little research has been carried out on the sociological impacts associated with this technology (Beckie et al., 2006). Only one study in the literature addresses some of these issues in a Canadian context. It suggests that GM crops benefits larger-scale farmers, as they have more capital to buffer risk, which inadvertently marginalizes smaller farms that are often a boon to community health (Mehta, 2005). Although larger scale farmers have benefited, GM crops may compromise their autonomy, as they must sign contracts to use this technology thereby restricting their ability to seed save, which in turn might erode and "deskill" important cultural knowledge regarding farming (Mehta, 2005). Furthermore, that industry has sued and monitored farmers suspected of using GM crops without a license may create a "culture of surveillance", create conflict between neighboring farmers, and overall reduce "social cohesion" in rural communities (Mehta, 2005). The study concludes that more research is needed on the social impacts of GM crops on farmers and rural communities (Mehta 2005).

To-date, no peer-reviewed literature exists regarding GM crops and the risk they might pose for farmers in the Canadian prairies. Given that previous waves of agricultural change, particularly industrial agriculture, have had sweeping socioeconomic, cultural, and political impacts for farmers and rural communities, this represents a major gap in the literature. Research in this area is particularly important given that current approaches to risk assessment, based on substantial equivalence, do not consider important these non-science based risks.

FARMER KNOWLEDGE, RISK ANALYSIS, AND GM CROPS

Post-normal science and GM crops

Some have argued that society has now entered a "post-normal age" that requires a new form of "post-normal science" to manage environmental risks, which are increasingly difficult to understand and have high stakes implications for a diversity of stakeholders (Funtowicz and Ravetz, 1993). This approach argues that traditional Kuhnian "normal science" (1962), which is rooted in 18th century Enlightenment principles that dominate governance in western societies, is no longer appropriate for managing the inherent uncertainties of the present epoch. It is believed that this "mainstream" approach to scientific inquiry faces a "crisis of confidence", as it is too reductionistic, value-laden, linked with industry, and ill equipped to manage uncertainty and support responsible decision-making (Ravetz, 2004).

Proponents of post-normal science advocate a more holistic methodology, which includes normal science and expert advice, and focuses on including "extended peer communities" in decision-making (Funtowicz and Ravetz, 1993). In effect, extended peer communities include broader societal and cultural institutions, particularly members of the public with local knowledge (**LK**) that are directly affected and keenly aware of environmental problems facing them (Funtowicz and Ravetz, 1993). By including LK, it is argued that post-normal science increases legitimacy in decision-making, but more importantly, it actually enriches scientific investigation by helping to identify important problems and phenomena (Funtowicz and Ravetz, 1993). By embracing rather than denying uncertainty, as is the case with science-based risk assessment (Jasanoff, 2003), post-normal science allows for the strengths of LK and science to complement one another (Healy, 1999). However, post-normal science also challenges "normal science", as it is based on a precautionary approach, which is critical of expert-driven knowledge that is increasingly privatized as intellectual property, and seeks to restore democracy, transparency, and the role of public knowledge in decision-making (Ravetz, 2004).

The use of post-normal science has been advocated for complex scientific and societal issues such as global warming (Funtowicz and Ravetz, 1993), environmental toxicants like agricultural chemicals (Ravetz, 2004), and BSE and GM crops (Marchi and Ravetz, 1999). As some point out, biotechnology actually exists between normal and post-normal science, and fluxes between linear and non-linear knowledge production (Mehta, 2006). This is demonstrated by the paradigm shift for normal science occurring in genetics, which has been concurrent to the public controversy over GM crops, expert knowledge, and risk assessment, and has forced the issue of agbiotechnology into a post-normal era. Scholars further indicate that post-normal science and more inclusive approaches to risk research have many parallels, as they are both concerned with the crisis of uncertainty in industrial society (Healy, 1999), and both may be useful in refining conventional risk assessment, management, and communication (Marchi and Ravetz, 1999)

Risk analysis, public input and GM crops

It is generally accepted that there are "two cultures" within the academic discipline of risk analysis, with some focused on science-based risk assessment, and others studying the psychological, sociological, legal, and economic nature of risk (Jasanoff, 1993). The former dominates regulatory decision-making regarding GM crops, and has been extensively criticized for its narrow focus. To summarize the conflict, science-based risk assessment largely focuses on "thin" hazards, such as probability of gene flow and mortality of species, and generally excludes potential "thick" harms like socioeconomic and cultural impacts (Wachbroit, 1991). Risk analysis, in contrast, incorporates both "thick" and "thin" harms within a broader social, cultural, economic, and political context, potentially mitigating the shortcomings of conventional risk assessment (Auberson-Huang, 2002). Engaging the public has been central in risk analysis, particularly regarding the use of controversial technologies like nuclear power and GM crops (Taylor-Gooby and Jens, 2006). This interdisciplinary definition of risk analysis, which combines both scientific and social issues and public input, is used throughout this thesis.

However, government and industry often use a different definition of risk analysis, and it is important to differentiate this approach from the one used in this thesis. Some claim that Canada uses a "Risk Analysis Framework", which utilizes a tiered system of risk assessment (i.e. science-based evaluation of probability of hazard), risk management (i.e. decision-making based on science), and risk communication (i.e. top-down communication to public about science-based decisions), in its decision-making regarding GM crop approvals (Isaac, 2006). This approach is science-based, expert-driven, predicated on a belief in technological progress, and excludes public input in decision-making (Isaac, 2006). Given the dominant role of science in all stages of assessment, management, and communication, I argue that it is really a form risk assessment with a few more bells and whistles. More holistic approaches to risk analysis – like the one used in this thesis – have been informed by a wider variety of disciplines and theories on technology and society.

Urlich Beck's "risk society" theory has been central in advocating a shift away from government and industry fixation with science-based approaches to risk assessment and advocating for greater citizen participation in decision-making (Beck, 1992). Beck (1992; 1995) documents how technological innovation is producing risks, particularly for the environment, which are increasingly difficult to predict, regulate, and manage. According to the theory, risk transformed across three epochs: "pre-industrial society" (traditional society), "industrial society" (first modernity), and now the "risk society" (second modernity) (Beck, 1992). In the risk society, anthropogenic "manufactured risks" dominate - these differentiated from "natural hazards" that were of principal concern in previous epochs – and are best exemplified by nuclear, chemical, and genetic technologies (Beck, 1992). These manufactured risks are believed to be increasingly catastrophic and outpace experts' ability to understand, predict and mitigate their potential impact. This, Beck argues, has turned society into a giant laboratory (Fischer, 2000). Due to this purported failure of science and industrial modernity, Beck (1992; 1995) argues that a new approach is required, which is rooted in "reflexive modernization" and "ecological democracy", and has citizens engaged in decision-making regarding issues that affect their lives.

To date, the majority of risk research that has engaged the public focuses on their "perceptions of risk". Social and cognitive psychologists have carried out much of this research using the so-called "psychometric paradigm", which uses empirical questionnaires coupled with factor analysis to understand people's underlying heuristics (e.g. dreadfulness of risk, controllability of risk, etc) regarding risk perceptions (Pidgeon et al., 2006). Psychometric studies have focused on a diversity of topics (e.g. chemicals, ecological hazards, nuclear power, biotechnology, etc) (Pidgeon et al., 2006) and offer decision-makers insights into public risk preferences that allow for the development of socially accepted policy (Zinn and Taylor-Gooby, 2006). Research in this area shows that lay public risk perception is rational and influenced by a diversity of factors including emotion, affect, worldviews, and trust (Slovic, 1999). Overall, psychometric research demonstrates that risk is more than just the magnitude and probability of a hazard, as defined by risk assessment, and has other social and subjective factors (Zinn and Taylor-Gooby, 2006).

A focus of risk research in the social sciences has been to dichotomize lay and expert risk perceptions, and many of the early studies assumed that scientific knowledge was superior to that of the public (Zinn and Taylor-Goodby, 2006). However, more recently studies have found that the public is highly capable of estimating hazard potential, which has led some to question the assumption that experts superior and more veridical risk judgment (Wright et al., 2002). Indeed, research has shown that the public has a broad and complex conception of risk (Slovic, 1987), whereas expert perception of risk is more often restricted to probability of harm (Cohen, 1985). Recognizing that the public and experts view risk differently is important, as those that define risk will control the "rational solution to the problem", giving that party considerable power (Slovic, 1999). Risk analysis has contributed to the GM crop debate by exploring how the public defines risks associated with this technology.

Consumers in Europe, Japan and North America are increasingly skeptical of GM crops, and believe they may cause adverse impacts on human health and the environment, while also lacking trust in regulators and risk assessment as a whole (Priest, 2000; Macer and Chen Ng, 2000; Taylor-Gooby, 2006; Gaskell et al., 2006). The absence of consumer benefit with GM crops, not a misunderstanding of risk, seems to be a driving force behind these high-risk perceptions (Gaskell et al., 2004). While still generally critical, the US public is more accepting of GM food than Europeans, in part due to its greater trust in industry and government over environmental and consumer groups (Priest, 2003). Other studies also suggest that trust in institutions affects risk and benefit perceptions regarding gene technology (Siegrist, 2000). Negative attitudes toward agbiotechnology may be explained by previous risk research, which suggests that when risks are unfamiliar, uncontrollable and potentially catastrophic they are less acceptable, as some of these factors may be associated with GM foods (Poortinga and Pidgeon, 2007). Policymakers have benefited from these studies on public risk perceptions toward agbiotechnology, however, some argue this may actually harm citizens.

Quantitative risk research surveys often deal with aggregate data, and have been criticized for focusing more on risk itself than the citizens involved (Marris et al., 1997), which may further marginalize the public in decision-making (Simmons, 2007). Some argue further that these large-scale surveys could be improved by incorporating individual experience (Barnett and Breakwell, 2001) as well as social and cultural factors into the analysis, as these variables better represent how citizens form risk perceptions and communities as a whole (Simmons, 2007). Indeed, some advocate that people's risk perceptions can only be understood by evaluating the sociocultural context from which they arise, and methods to achieve this include quantitative, qualitative, and descriptive approaches (Zinn and Taylor-Gooby, 2006).

Specific sociocultural studies demonstrate that individual analysis is indeed important to risk perception. One investigation shows that personal experience, culture and place were all important factors that discerned how different stakeholders viewed the risk of industrial development encroaching on farmland in Alberta (Masuda and Garvin, 2006). Another demonstrates how the psychological, emotional, and economic wellbeing of resource-based communities (e.g. farming) can be highly affected by stigmatized technologies (e.g. pesticides), which suggests that experience is critical to risk research (Gregory and Satterfield, 2002). Indeed, the issue of GM crops is highly stigmatized, and therefore studying the sociocultural and experiential impact of this technology on farmers is important.

Local Knowledge, Risk Analysis, & GM crops

Many argue that the life experience of people is another generally neglected form of expertise (Fischer, 2000). Some have characterized this local knowledge (**LK**) as the informal "popular, or folk knowledge that can be contrasted to formal or specialized knowledge that defines scientific, professional, and intellectual elites in both Western and non-Western societies" (Brush, 1996). Given the diversity of human experience, it is important that when speaking about LK one avoids essentialism (Semali and Kincheloe, 1999), although some underlying principles can be identified. Conceptually LK includes indigenous knowledge (**IK**) and traditional ecological knowledge (**TEK**) and is described as being experience-based, place and culture specific, and orally transmitted across generations (Berkes, 1999). Many argue that the LK of hunters, fishers, farmers allows them to sustainably manage natural resources, which can enrich scientific understanding regarding various environmental problems facing society (Berkes and Folke, 1998).

Although LK has existed for all of human history, scientists and decision-makers have largely been ignorant of its potential (Berkes, 1999). A systematic evaluation of the ecological literature demonstrates that less than 1% of published studies incorporate LK (Brook, 2007). Scientists and other experts often claim an authority position over knowledge production (Wynne, 1989), and believe that they are the only ones capable of anticipating and managing the social and technological complexity of modern societies (Fischer, 2000). However, increasingly this "dominant expertise" is viewed as paternalistic and many call for the "democratization of science" and encourage the importance of other "ways of knowing" (Leach et al., 2005). Arguably, the disciplines of anthropology, native studies, and international development have been at the forefront of engaging communities and learning about their LK.

Anthropology has a long tradition of advocating the importance of LK (Sillitoe, 2007) and some of the first research in this area was conducted by Boaz (1888) who investigated Inuit hunter knowledge regarding sea ice type and ringed seal abundance. Since Boaz's seminal fieldwork, research has further documented Inuit knowledge regarding the ecology and management of beluga (Kilabuck, 1998) and bowhead (Hay et al., 2000) whales, polar bear (Keith, 2004), and caribou (Thorpe et al., 2003). Some argue that this experience-based Inuit knowledge is as sophisticated as science (Wenzel, 1999), embedded in a complex cultural and spiritual fabric (Fienup-Riordan, 1990), based on principles of respect for natural resources and community cooperation (Wenzel, 1994), and useful for environmental impact assessment (Stevenson, 1996).

Modern civilization has precipitated an environmental crisis, which many feel requires LK to help solve, given its focus on relationships between humans and ecosystems (Semali and Kincheloe, 1999). For example, the global "climate crisis" will likely adversely affect human society (Gore, 2006), yet science-based approaches may be limited in their ability to predict and manage this "post-normal" uncertainty and risk (Funtowicz and Ravetz, 1993), and therefore Inuit are increasingly viewed as key knowledge holders regarding potential impacts like the melting of glaciers (Cruikshank, 2005) and strategies for resilience (Berkes and Jolly, 2001). Similarly, farmers are largely regarded as being important custodian of knowledge regarding agriculture in more southern climes.

As discussed at the beginning of this literature review, farmers and their LK were instrumental in the development of agricultural biodiversity through domestication and selective breeding of crops over millennia (Fowler and Mooney, 1990; Diamond, 1997; Manning, 2004). This farmer LK was critical for developing the North American germplasm base (Kloppenburg, 2002). In Canada, farmers were directly responsible for importing, breeding, and sharing wheat and rapeseed that arguably led to settlement of the prairies (Kuyek, 2007). Some believe that farmers pass LK and land down through generations, with each generation hoping for a better future for the next, which ensures a long-term commitment to sustainable use of resources (Francis, 1994). This LK is also shared amongst farmers of the same generation, which further increases sustainability (Pretty, 2002), and enhances resiliency, reciprocity, and social capital in rural communities (Flora and Flora, 2005). This deeply rooted and complex LK represents a rich resource for scientists and policy-makers hoping to develop environmentally responsible and culturally appropriate agricultural technology (Altieri, 1993)

Farmer LK is widely incorporated in development projects in the Global South and has contributed to understanding already released agricultural technologies and their impacts on natural resource management and socioeconomics in over 50 countries (Eyzaguirre, 1992). Because agricultural technology directly affects the well being of farmers, they are well positioned to evaluate and to consider economic, sociocultural, and ecological impacts that may be associated with its use (Cleveland and Soleri, 2007). Research demonstrates how farmers have used this holistic LK to informally experiment with and refine agricultural technology to best suit the needs of their communities and environments (Sumberg and Okali, 1997). In some parts of Africa, LK has been incorporated into environmental impact assessment to predict, mitigate, and monitor agricultural technology (Appriah-Opoku, 2005). It has been suggested that LK might even be useful in evaluating GM crops (Eyzaguirre, 1992)

However, studies on GM crops at the farm-level are mostly economic in nature and focus only on benefits associated with this technology. Increased yields, economic gains, and reduced pesticide use were found for GM cotton in the US (Klotz-Ingram et al., 1999; Marra et al., 2002), South Africa (Ismael et al., 2002), and India (Bennet et al., 2006). Similar findings were found for GM soybean in Romania (Brooks, 2005). One US study indicated that while pesticides may be reduced with GM cotton and soybean, the yields and economic benefits did not increase (McBride and Books, 2000). In Argentina, increased yield and reduced pesticides associated with GM cotton were curbed by the cost of the technology (Qaim and de Janvry, 2003). One Canadian study suggests that the economic benefits of GM canola accrue unevenly for farmers (Fulton and Keyowski, 1999). This economic research, while important in its own right, does not fully characterize the diverse nature of farmer attitudes and experiences regarding GM crops.

Worldwide, only a few studies that have explored farmer perceptions toward GM crops. One study evaluated farmers' perceptions toward "golden rice" and found that farmers were either unaware of this technology or believed it had little agronomic or economic benefit (Chong, 2003). Another explored farmer attitudes toward GM eggplant and found the benefits of this technology outweighed moral concerns regarding its potential use (Chong, 2005). Farmers in Mesoamerica and Cuba believed that GM corn might harm regional biodiversity due to gene flow with traditional varieties (Soleri et al., 2005). In Australia and New Zealand, farmer attitudes toward GM crops indicated high levels of awareness and interest in the technology (McDougall et al., 2001; Cook and Fairweather, 2003). In all this peer-reviewed literature, only one study from Illinois State explored farmer perceptions with GM crops that they had actually grown, and found general satisfaction with the technology (Chimmiri et al., 2006). Not surprisingly, none of these studies mentioned the important role that farmer local and experiential knowledge can play in the assessment of GM crops.

That farmer experience regarding the over decade long use of GM crops in agriculture has yet to be evaluated anywhere in the world represents a major gap in the literature. Farmers are arguably most affected by the introduction of GM crops, and given their holistic LK can play an important role in evaluating the social, economic, cultural, and ecological benefits and risks associated with this technology. Indeed, many believe that farmer LK can help assess all agricultural technology (Lynman and Herdt, 1992) and will be important for developing sustainable alternatives to the industrial food system (Cleveland and Soleri, 2007). However, science-based risk assessment does not allow for public input (Isaac, 2006), which suggests broader approaches like risk analysis offer an ideal vehicle for including farmer LK in the evaluation of GM crops. To-date, this has yet to occur, which makes this thesis study on farmer knowledge, risk analysis, and GM crops in the Canadian prairies unique and important.

NOTES

1. While both Canada and the US had extensive government supported seed sharing programs in place, they started at different times. Kuyek (2007) indicates that the Canadian system began in 1895, and was in high demand, with approximately 35,000 packets of seed being mailed to farmers annually. Kloppenburg (2002) documents the US system well underway by 1849, with 60,000 packets of seed being mailed to farmers annually. However, gradually these programs lost cache with governments, and were quickly abandoned in favor of scientific breeding program based on the new discipline of genetics
2. Rapeseed is a plant that has been used in China for over 2000 years and is an important oilseed crop for that country. Two varieties were imported into Canada, one by farmer Fred Solvoniuk that had rapeseed mailed to him from his Polish homeland in the 1930s, and the other was found on a wharf in Argentina and brought to Canada in the early 1940s. The former is *Brassica campestris,*

informally known as "polish canola", and the latter *B. napus* colloquially known as "argentine canola" (Kneen, 1990).

REFERENCES

Abell, H.C. (1970). The social consequences of the modernization of agriculture. In M. Tremblay & W.J. Anderson (Eds.), *Rural Canada in Transition.* Ottawa ON: Agricultural Economics Research Council of Canada.

Abergel, E., & Barret, K. (2002). Putting the cart before the horse: A review of biotechnology policy in Canada. *Journal of Canadian Studies, 37,* 135-161.

Altieri, M. (1993). Ethnoscience and biodiversity: Key elements in the design of sustainable pest management systems for small farmers in developing countries. *Agriculture, Ecosystems and Environment, 46,* 257-272.

Altieri, M. (2000). Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming. In F. Magdoff, J.B. Foster, & F.H. Buttel (Eds.), *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment.*

Anderson, L. (1999). *Genetic Engineering, Food, and Our Environment.* White River Junction, VT: Chelsea Green Publishing Company.

Andree, P. (2002). The biopolitics of genetically modified organisms in Canada. *Journal of Canadian Studies, 37,* 162-191.

Andree, P. (2007). *Genetically Modified Diplomacy: The Global Politics of Agricultural Biotechnology.* Vancouver: UBC Press.

Andow, D. (2003). UK farm-scale evaluations of transgenic herbicide-tolerant crops. *Nature Biotechnology, 21,* 1453-1454.

Appriah-Opoku, S. (2005). *The Need for Indigenous Knowledge in Environmental Impact Assessment: The Case of Ghana.* Queenston, ON: Edwin Mellen Press.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology, 20,* 1076-1078.

Baker, J., & Preston, C. (2003). Predicting the spread of herbicide resistance in Australia canola fields. *Transgene Research, 12,* 731-737.

Barnett, J., & Breakwell, G.M. (2001). Risk perception and experience: Hazard personality profiles and individual differences. *Risk Analysis, 21,* 171-177.

Beck, U. (1992). *Risk Society: Towards a New Modernity.* London: Sage.

Beck, U. (1995). *Ecological Politics in an Age of Risk.* Cambridge: Polity Press.

Beckie, H.J., Seguin-Swartz, G., Nair, H., Warwick, S.I., & Johson, E. (2004). Multiple herbicide-resistant canola can be controlled by alternative herbicides. *Weed Sciencie, 52*, 152-157.

Beckie, H.J., Harker, K.N., Hall, L., Warwick, S.I., Legere, A., Sikkema, P.H., Clayton, G.W., Thomas, A.G., Leeson, J.Y., Seguin-Swartz, G.G., & Simard, M.J. (2006). A decade of herbicide-resistant crops in Canada. *Canadian Journal of Plant Science, 86*, 1243-1264.

Benbrook, C. (2001). Do GM crops mean less pesticide use? *Pesticide Outlook.* Available at: http://www.mindfully.org/Pesticide/More-GMOs-Less-Pesticide.htm

Bennett, R., Kambhampati, U., Morse, S., & Ismael, Y. (2006). Performance of genetically modified cotton in Maharashtra, India. *Review of Agricultural Economics, 28*, 59-71.

Berkes, F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management.* New York: Taylor and Francis.

Berkes, F., Folke, C., & Colding, J. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience.* Cambridge, UK: Cambridge University Press.

Berkes, F., & Jolly, D. (2001). Adapting to climate change: Social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology.* Available at: www.consecolo.org/vol15/iss2/art18

Bernauer, T., & Aerni, P. (2007). Competition for public trust: Causes and consequences of extending the transatlantic biotech conflict to developing countries. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave MacMillan.

Blackshaw, R.E., & Harker, N. (2002). Selective weed control with glyphosate in glyphosate-resistant spring wheat. *Weed Technology, 16*, 885-892.

Blaine, K., & Powell, D. (2001). Communication of food-related risks. *AgBioForum, 4*, 179-185.

Boaz, F. (1888). *The Central Eskimo.* 6th Annual Report of the Bureau of American Ethnology for the Years 1884-1885. Washington, DC.

Bouchie, A. (2002). Organic farmers sue GMO producers. *Nature Biotechnology, 20*, 210.

Boyens, I. *Another Season's Promise: Hope and Despair in Canada's Farm Country.* Toronto. Penguin.

Bradshaw, LD. ,Padgette, S.R., Kimball, S.L., & Wells, B.H. (1997). Perspectives on glyphosate resistance. *Weed Technology*, *11*, 189-198.

Brooks et al. (2003). Invertebrate responses to the management of genetically modified herbicide-tolerant and conventional spring crops. I. Soil-surface-active invertebrates. *Transactions of the Royal Society of London B*, *358*, 1847-1862.

Brook, R. (2007). *Elk-Agriculture Conflicts in the Greater Riding Mountain Ecosystem: Building Bridges Between the Natural and Social Sciences to Promote Sustainability.* Environment and Geography Ph.D. thesis: University of Manitoba.

Brooks, G. (2005). The farm-level impact of herbicide-tolerant soybeans in Romania. *AgBioForum*, *8*, 235-241.

Brooks, G., & Barfoot, P. (2005). GM crops: The global economic and environmental impact – the first nine years 1996-2004. *AgBioForum*, *8*, 187-196.

Brush, S.B. (1996). Whose knowledge, whose genes, whose rights? In. S.B. Brush & D. Stabinsky (Eds.), *Valuing Local Knowledge: Indigenous People and Intellectual Property Rights*. Washington, DC: Island Press.

Brule-Babel, A.L., Willenborg, C.J., Friesen, L.F., & Van Acker. R.C. (2006). Modeling the influence of gene flow and selection pressure on the frequency of GE herbicide-tolerant trait in non-GE wheat and wheat volunteers. *Crop Science*, *46*, 1704-1710.

Buckland, J. (2004). *Ploughing Up the Farm: Neoliberalism, Modern Technology and the State of the World's Farmers.* Winnipeg, MB: Fernwood Publishing.

Bud, R. (1991). Biotechnology in the Twentieth Century. *Social Studies of Science*, *21*, 415-457.

Buth, J. (2006). Canola Council of Canada. Personal Communication.

CCC (Canola Council of Canada) (2001). *An Agronomic and Economic Assessment of Transgenic Canola.* Prepared by Serecon Consulting and Koch Paul Associates. Available at www.canola-council.org/report_gmo.html

CCC (Canola Council of Canada) (2005). *Herbicide Tolerant Volunteer Canola Management in Subsequent Crops.* Prepared by Serecon Consulting. Available at www.canola-council.org/report

CFIA (2007). *Regulation of Agricultural Biotechnology in Canada: A Post-Secondary Educators Resource.* Ottawa, ON: Canadian Food Inspection Agency.

CFIA (2008a). *The CFIA Assessment Process and What is Expected from Industry.* Available at: www.inspection.gc.ca/english/sci/biotech/reg/proce.shtml

CFIA (2008b). *Food Labelling.* Available at: www.inspection.gc.ca/english/sci/biotech/labeti/labetie.shtml

Chimmiri, N., Tudor, K.W., & Spaulding, A.D. (2006). An analysis of McLean county, Illinois farmers' perceptions of genetically modified crops. *AgBioForum, 9,* 152-165.

Chong, M. (2003). Acceptance of golden rice in the Philippine "rice bowl". *Nature Biotechnology, 21,* 971-972.

Chong, M. (2005). Perceptions of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research, 8,* 617-634.

Clark, A. (2004). GM crops are not containable. In B. Breckling, & R. Verhoeven (Eds.), *Risk Hazard Damage: Specification of Criteria to Assess Environmental Impact of Genetically Modified Organisms.* Bonn, Germany: Federal Agency for Nature Conservation.

Clark, A. (2006). Environmental risks of genetic engineering. *Euphytica, 148,* 47-60.

Clapp, J. (2007). Transnational corporate interests in international biosafety negotiations. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave MacMillan.

Cleveland, D.A., & Soleri, D. (2007). Farmer knowledge and scientist knowledge in sustainable development: Ontology, epistemology and praxis. In P. Sillitoe (Ed.), *Local Science vs Global Science: Approaches to Indigenous Knowledge in International Development.* New York: Berghahn Books.

Cohen, B.L. Criteria for technology acceptability. *Risk Analysis, 5,* 1-2.

Colyer, P.D., Kirkpatrick, T.L, Caldwell, W.D., & Vernon, P.R. (2000). Root-knot nematode reproduction and root galling severity on related conventional and transgenic cotton cultivars. *Journal of Cotton Science, 4,* 232-236.

Commoner, B. (2002) Unraveling the DNA Myth: The Spurious Foundations of Genetic Engineering. *Harpers Magazine.* February Issue.

Conner, A.J., Glare, T.R., & Nap, J.P. (2003). The release of genetically modified crops into the environment: Overview of ecological risk assessment. *Plant Journal, 33,* 19-46.

Conway, G. (1998). *The Doubly Green Revolution: Food For All in the 21st Century.* Ithaca, NY: Cornell University Press.

Cook, G. (2004). *Genetically Modified Language: The Discourse of Arguments for GM crops and Food.* New York: Routledge.

Cook, A.J., & Fairweather, J.R. (2003). New Zealand farmer and grower intentions to use gene technology: Results from a resurvey. *AgBioForum*, *6*, 120-127.

Cruikshank, J. (2005). *Do Glaciers Listen?: Local Knowledge, Colonial Encounters, & Social Imagination.* Vancouver: UBC Press.

Dale, P. (2005). Where science fits into the GM debate. In G.M. Poppy & M.J. Wilkinson (Eds.), *Gene Flow from GM Plants.* Oxford, UK: Blackwell Publishing.

Dasgupta, S. (1988). *Rural Canada: Structure and Change.* Queenston, ON: Edwin Mellen Press.

De Vore, B.A. (2002). Nature's backlash. In D.L. Jackson and L.L. Jackson (Eds.), *The Farm as Natural Habitat: Reconnecting Food Systems with Ecosystems.* Washington, DC: Island Press.

Devine, M.D. (2005). Why are there not more herbicide-tolerant crops? *Pest Management Science*, *61*, 312-317.

Devine, M.D., & Buth, J.L. (2001). Advantages of genetically modified canola: A Canadian perspective. In *Proc. Brighton Crop Protection Conferences – Weeds.* Farnham, UK: British Crop Protection Council Symposium.

Diamond, J. (1997). *Guns, Germs, and Steel: The Fates of Human Societies.* New York: W.W. Nortan and Company.

Downey, K., & Beckie, H.J. (2002). *Isolation effectiveness in canola pedigreed seed production.* Report to Canadian Seed Growers' Association. Saskatoon, SK: Agriculture and Agri-Food Canada.

Dyck, B., Fries, T., Glen, B., McMillan, D., & Zacharias, K. (2007). Wheat research must include GM – WP editorial. *Western Producer.* December 29.

Ervin, D.E., Welsh, R., Batie, S.S., & Carpentier, C.L. (2003). Towards an ecological systems approach in public research for environmental regulation of transgenic crops. *Agriculture, Ecosystems and Environment*, *99*, 1-14.

Evans, C.L. (2002). *The War on Weeds: In the Prairie West: An Environmental History.* Calgary, AB: University of Calgary Press.

Ewen, S.W.B., & Pusztai, A. (1999). Effect of diet containing genetically modified potatoes expressing *Galanthus nivalis* lectin on rat small intestine. *Lancet, 354*, 1352-1354.

Eyzaguirre, P. (1992). Farmer knowledge, world science, and the organization of agricultural research systems. In J.L. Moock and R.E. Rhoades (Eds.), *Diversity, Farmer Knowledge, and Sustainability*. Ithaca, NY: Cornell University Press.

Falkner, R. (2007a). Introduction: The international politics of genetically modified food. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law*. New York: Palgrave MacMillan.

Falkner, R. (2007b). International cooperation against the hegemon: The Cartagena Protocol on Biosafety. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law*. New York: Palgrave MacMillan.

Fienup-Riordan, A. (1990). *Eskimo Essays*. New Brunswick: Rutgers University Press.

Fischer, F. (2000). *Citizens, Experts, and the Environment: The Politics of Local Knowledge*. London: Duke University Press.

Fliert, E.V., & Braun, A.R. (2002). Conceptualizing integrative, farmer participatory research for sustainable agriculture: From opportunities to impact. *Agriculture and Human Values, 19*, 25-38.

Flora, C.B., & Flora, J.L. (2005). Creating social capital. In J. Pretty (Ed.), *Sustainable Agriculture*. London: Earthscan Publications Limited.

Fowler, C., & Mooney, P. (1990). *Shattering: Food, Politics, and the Loss of Genetic Diversity*. Tucson, AZ: University of Arizona Press.

Francis, D. (1994). *Family Agriculture: Tradition and Transformation*. London: Earthscan Publications Limited.

Friesen, L. F., Nelson, A. G., & Van Acker, R. C. (2003). Evidence of contamination of pedigreed canola (Brassica napus) seedlots in western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal, 95*, 1342-1347.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K.G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42*, 1181-1193.

Fujimura, J.H. (2005). Postgenomic futures: translations across the machine-nature border in systems biology. *New Genetics and Society*, 24, 195-225.

Fulton, M., & Keyowski. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum*, *2*, 85-93.

Funtowicz, S.O., & Ravetz, J.R. (1993). Science for the post-normal age. *Futures*, *7*, 739-755.

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Revuelta, G., Schreiner, C., Stares, S., Torgersen, H., & Wagner, W. (2006). *Europeans and Biotechnology in 2005: Patterns and Trends.* A report to the European Commission's Directorate-General for Research.

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., & Bardes, J. (2004). GM foods and the misperception of risk perception. *Risk Analysis*, *24*, 184-194.

Giangrande, C. (1985). *Down to Earth: The Crisis in Canadian Farming*. Toronto: Anansi Press Limited.

Gliessman, S.R. (2005). Agroecology and agroecosystems. In J. Pretty (Ed.), *Sustainable Agriculture*. London, UK: Earthscan.

Gore, A. (2006). *An Inconvenient Truth*. A Paramount Classics and Participant Productions Film. Directed by D. Guggenheim.

Gregory, R.S., & Satterfield, T.A. (2002). Beyond perception: The experience of risk and stigma in community contexts. *Risk Analysis*, *22*, 347-358.

Hails, R.S. (2002). Assessing the risks associated with new agricultural practices. *Nature*, *418*, 685-688.

Halford, N.G. (2006). From primitive selection to genetic modification, ten thousand years of plant breeding. In N. Halford (Ed.), *Plant Biotechnology: Current and Future Applications of Genetically Modified Crops*. Etobicoke, ON: John Wiley and Sons, Ltd.

Hall, L., Topinka, K., Huffman, J., & Good, L. (2000). Pollen flow between herbicide-resistant Brassica napus is the cause of multiple-resistant B. napus volunteers. *Weed Science, 48*, 688-694.

Hanin, M., Volrath, S., Bogucki, A., Briker, M., Ward, E., & Paszowski, J. (2001). Gene targeting in *Arabidopsis*. *The Plant Journal*, 28, 671-677.

Harker, K.N., Blackshaw, R.E., Kirkland, K.J., Derksen, D.A., & Wall, D. (2000). Herbicide-tolerant canola: Weed control and yield comparisons in western Canada. *Canadian Journal of Plant Science, 80*, 647-654.

Haughton et al. (2003). Invertebrate responses to the management of genetically modified herbicide-tolerant and conventional spring crops. II. Within-field epigeal and aerial arthropods. *Transactions of the Royal Society of London, 358*, 1863-1877.

Hay, K. (2000). *Inuit Bowhead Knowledge Study, Nunavut Canada.* Iqaluit, NU: Nunavut Wildlife Management Board.

Healy, S. (1999). Extended peer communities and the ascendance of post-normal politics. *Futures, 31*, 655-669.

Heard et al. (2003). Weeds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. I. Effects on abundance and diversity. *Transactions of the Royal Society of London B, 358*, 1819-1832.

Horne, J.E., & McDermott, M. (2001). *The Next Green Revolution: Essential Steps to Healthy, Sustainable Agriculture.* New York: Food Products Press.

Howatt, K.A., Endres, G.J., Hendrickson, P.E., Aberle, E.Z., Lukack, J.R., Jenks, B.M., Riverland, N.R., Valenti, S.A., & Rystedt, C.M. (2006). Evaluation of glyphosate-resistant hard red spring wheat (Triticum aestivum). *Weed Technology, 20*, 706-716.

Hucl, P., & Matus-Cadiz, M. (2001). Isolation distances for minimizing out-crossing in spring wheat. *Crop Science, 41*, 1348-1351.

Huygen, I., Veeman, M., & Lerohl, M. (2004). Cost implication of different GM tolerance levels: Non-genetically modified wheat in western Canada. *AgBioForum, 6*, 169-177.

Isaac, G. E. (2006). Biotechnology policy and the risk analysis framework. In P.W.B. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology.* New York: Nova Science Publishers, Inc.

Isaac, G.E., & Kerr, W.A. (2007). The biosafety protocol and the WTO: Concert or conflict? In R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave MacMillan.

Ismael, Y., Bennett, R., & Morse, S. (2002). Benefits of Bt cotton use by smallholder farmers in South Africa. *AgBioForum, 5*, 1-5.

Jackson, D. (2002). The farm as natural habitat. In D.L. Jackson & L.L. Jackson (Eds.), *The Farm as Natural Habitat: Reconnecting Food Systems with Ecosystems.* Washington, DC: Island Press.

James, C. (2007). Global status of commercialized biotech/GM crops: 2007. *ISAAA Brief No. 37.* Ithaca, NY: ISAAA. Available at: www.isaaa.org

Jasanoff, S. (1993). Bridging the two cultures of risk analysis. *Risk Analysis*, *13* 123-129.

Jasanoff, S. (2003). Technologies of humility: Citizen participation in governing science. *Minerva*, *41*, 223-244.

Jasanoff, S. (2006). Biotechnology and Empire: The Global Power of Seeds and Science. *Osiris*, *21*, 273-292.

Jensen, K.K., Gamborg, C., Madsen, K.H., Jorgensen, R.B., Krauss, M.K., Folker, A.P., & Sandoe, P. (2003). Making the EU 'risk window' transparent: The normative foundations of the environmental risk assessment of GMOs. *Environmental Biosafety Research*, *3*, 161-171.

Jones, H. (2007). Advances in transformation technologies. In N. Halford (Ed.), *Plant Biotechnology: Current and Future Applications of Genetically Modified Crops.* Etobicoke, ON: John Wiley and Sons, Ltd.

Keith, D. (2004). *Inuit Qaujimaningit Nanurnut: Inuit Knowledge of Polar Bears.* Edmonton, AB: University of Alberta Press.

Kilabuck, P. (1998). *A Study of Inuit Knowledge of the Southeast Baffin Beluga*. Iqaluit, NU: Nunavut Wildlife Management Board.

Klotz-Ingram, C., Jans, S., Fernandez-Cornejo, J., and McBride, W. (1999). Farm-level production effects related to the adoption of genetically modified cotton for pest management. *AgBioForum*, *2*, 73-84.

Kloppenburg, J. (2002). *First the Seed: The Political Economy of Plant Biotechnology.* Madison, WI: University of Wisconsin Press.

Kneen, B. (1992). *The Rape of Canola*. Toronto: NC Press.

Kneen, B. (1999). *Farmageddon: Food and the Culture of Biotechnology*. Gabriola Island, BC: New Society Publishers.

Krayer von Krauss, M.P., Casman, E.A., & Small, M.J. (2004). Elicitation of expert judgments of uncertainty in the risk assessment of herbicide-tolerant oilseed crops. *Risk Analysis*, *24*, 1515-1527.

Kuhn, T. (1962). *The Structure of Scientific Revolutions.* Chicago: The University of Chicago Press.

Kuyek, D. (2007). *Good Crop/Bad Crop: Seed Politics and the Future of Food in Canada*. Toronto: Between the Lines.

Larkin, P., & Harrigan, G.G. (2007). Opportunities and surprises in crops modified by transgenic technology: Metabolic engineering of benzylisoquinoline alkaloid, gossypol and lysine biosynthetic pathways. *Metabolomics, 3*, 371-382.

Latham, J.R., Wilson, A.K., & Steinbrecher, R.A. (2006). The mutational consequences of plant transformation. *Journal of Biomedicine and Biotechnology*, 25, 1-7

Lawton, M. (2003). Management of herbicide tolerant crops and future research. *Technical Workshop on the Management of Herbicide Tolerant Crops*. Ottawa, ON: Canadian Food Inspection Agency. Available at: www.inspection.gc.ca/english/plaveg/bio/consult/herbtolrepe.shtml

Leach, M., Scoones, I., & Wynne, B. (2005). Introduction: science, citizenship and globalization. In M. Leach, I. Scoones, & B. Wynne (Eds.), *Science and Citizens: Globalization and the Challenge of Engagement*. New York: Zed Books.

Legere, A. (2005). Risks and consequences of gene flow from herbicide-resistant crops: canola (Brassica napus L) as a case study. *Pest Management Science, 61*, 292-300.

Levidow, L. (1998). Democratizing technology – or technologizing democracy?: Regulating agricultural biotechnology in Europe. *Technology in Society, 20*, 211-226.

Levidow, L. (2007). The transatlantic agbiotech conflict as a problem and opportunity for EU regulatory policy. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law*. New York: Palgrave MacMillan.

Levidow, L., & Carr, S. (2000). Unsound science? Transatlantic regulatory disputes over GM crops. *International Journal of Biotechnology, 2*, 257-273.

Levidow, L., & Murphy, J. (2003). Reframing regulatory science: Trans-atlantic conflicts over GM crops. *Cahiers d'Economie et Sociologie Rurales, 68*, 48-74.

Lewontin, R.C. (1991). *Biology as Ideology: The Doctrine of DNA*. Toronto: House of Anansi Press Inc.

Lewontin, R.C. (2000). The maturing of capitalist agriculture: Farmer as proletarian. In F. Magdoff, J.B. Foster, & F.H. Buttel (Eds.), *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment.*

Lurquin, P.F. *The Green Phoenix: A History of Genetically Modified Plants*. New York: Columbia University Press.

Lynam, J.K., & Herdt, R.W. (1992). Sense and sustainability: Sustainability as an objective in international agricultural research. In J.L. Moock & R.E. Rhoades (Eds.), *Diversity, Farmer Knowledge, and Sustainability*. Ithaca, NY: Cornell University Press.

Macer, D., & Chen Ng, M.A. (2000). Changing attitudes to biotechnology in Japan. *Nature Biotechnology, 18*, 945-947.

Manning, R. (2004). *Against the Grain: How Agriculture Has Hijacked Civilization.* New York: North Point Press.

Marchi, B.D., & Ravetz, J.R. (1999). Risk management and governance: A post-normal science approach. *Futures, 31*, 743-757.

Marra, M.C., Pardey, P.G., & Alston, J.M. (2002). The payoffs to transgenic field crops: An assessment of the evidence. *AgBioForum, 5*, 43-50.

Marris, C., Langford, I., Saunderson, T., & O'Riordan, T. (1997). Exploring the psychometric paradigm: Comparisons between aggregate and individual analyses. *Risk Analysis, 17*, 303-312.

Marvier, M. (2002). Improving risk assessment for nontarget safety of transgenic crops. *Ecological Applications, 12*, 1119-1124.

Masuda, J.R., & Garvin, T. (2006). Place, culture, and the social amplification of risk. *Risk Analysis, 26*, 437-454.

Matus-Cadiz, M.A., Hucl, P., Horak, M.J., & Blomquist, L.K. (2004). Gene flow in wheat at the field scale. *Crop Science, 44*, 718-727.

Mayers, P.R., Kearns, P., McIntyre, K.E., & Eastwood, J.A. (2002). The concept of substantial equivalence. In K.T. Atherton (Ed.), *Genetically Modified Crops: Assessing Safety.* New York: Taylor and Francis.

McBride, W.D., & Books , N. (2000). Survey evidence on producer user and costs of genetically modified seed. *Agribusiness, 16*, 6-20.

McDougall, D.J., Longnecker, N.E., Marsch, S.P. & Smith, F.P. (2001). Attitudes of pulse farmers in western Australia towards genetically modified organisms in agriculture. *Australasian Biotechnology, 11*, 36-39.

Millstone, E., Brunner, E., & Mayer, S. (1999). Beyond 'substantial equivalence'. *Nature, 401*, 525-526.

Mehta, M.D. (2005). The impact of agricultural biotechnology on social cohesion. In M.D. Mehta (Ed.), *Biotechnology Unglued: Science, Society, & Social Cohesion.* Vancouver: UBC Press.

Mehta, M.D. (2006). Paradigm wars: A post-normal science approach to regulating biotechnology and nanotechnology. In P. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology*. New York: Nova Science Publishers, Inc.

Mellon, M., & Rissler, J. (2004). *Gone to Seed: Transgenic Contaminants in the Traditional Seed Supply*. Cambridge, MA: UCS Publications. Available at: www.ucsusa.org

Moch, K. (Ed.) (2006). *Proceedings of the Conference Epigenetics, Transgenic Plants & Risk Assessment*. Frankfurt: Institute for Applied Ecology.

Montgomery, D.R. (2007). *Dirt: The Erosion of Civilizations*. San Francisco, CA: University of California Press.

Moore, E. (2002). The new direction of federal agricultural research in Canada: From public good to private gain? *Journal of Canadian Studies, 37*, 112-134.

Murphy, J., & Levidow, L. (2006). *Governing the Transatlantic Conflict over Agricultural Biotechnology: Contending Coalitions, Trade Liberalisation and Standard Setting*. New York: Routledge.

Murray, D.R. (2003). *Seeds of Concern: Genetic Manipulation of Plants*. New York: CAB Publishing.

Nader, R. (1999). Foreword. In M. Teitel, & K.A. Wilson, *Genetically Engineered Food: Changing the Nature of Nature*. Rochester, VT: Park Street Press.

Nap, J.P., Metz, P.L., Escaler, M., & Conner, A.J. (2003). The release of genetically modified crops into the environment: Overview of current status of regulations. *Plant Journal, 33*, 1-18.

Newell, P. (2007). Corporate power and 'bounded autonomy' in the global politics of biotechnology. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law*. New York: Palgrave MacMillan.

NFU (National Farmers Union). (2003). *The Farm Crisis, Bigger Farms, and the Myths of 'Competition' and 'Efficiency'*. Saskatoon, SK: National Farmers Union. Available at: www.nfu.ca/briefs.html

NFU (National Farmers Union). (2005). *The Farm Crisis & Corporate Profits*. Saskatoon, SK: National Farmers Union. Available at: www.nfu.ca/briefs.html

NFU (National Farmers Union). (2007). "Free trade": is it working for farmers? Comparing 2007 to 1988. *Union Farmer*. Saskatoon, SK: National Farmers Union. Available at: www.nfu.ca/briefs.html

NRC (National Research Council). 2002. *Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation*. Washinton, DC: National Academy Press.

Nottingham, S. (2002). *Gene Escapes: The Ecology of Genetic Engineering*. New York: Zed Books.

Olmstead, A.L., & Rhoade, P.W. (2004). Biological innovation in American wheat production: Science, policy, and environmental adaptation. In S.R. Schrepfer & P. Scranton (Eds.), *Industrializing Organisms: Introducing Evolutionary Biology*. New York: Francis and Taylor Books, Inc.

Paarlberg, D, & Paarlberg, P. (2000). *The Agricultural Revolution of the 20th Century*. Ames, IA: Iowa State University Press.

Phillips, P. (2006). Assessing the risks of biotechnology: Challenges, issues and opportunities. In P. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology*. New York: Nova Science Publishers, Inc.

Phillips, P., & Corkindale, D. (2002). Marketing GM foods: The way forward. *Agbioforum*, *5*, 113-121.

Pidgeon, N., Simmons, P., & Henwood, K. (2006). Risk, Environment, & Technology. In P. Taylor-Gooby, & J.O. Zinn (Eds.), *Risk in Social Science*. Oxford: Oxford University Press.

Pimentel, D. (1996). Green revolution agriculture and chemical hazards. *The Science of the Total Environment*, *188*, S86-S98.

Poortinga, W., & Pidgeon, N. (2007). Public perceptions of agricultural biotechnology in the UK: The case of genetically modified food. In D. Brossard, J. Shanahan, & T.C. Nesbitt (Eds.), *The Public, The Media & Agricultural Biotechnology*. Cambridge, MA: CAB International.

Pretty, J.N. (1995). *Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance* . Washington, DC: Joseph Henry Press.

Pretty, J. (2002). *Agri-Culture: Reconnecting People, Land and Nature*. London: Earthscan Publications Limited.

Pretty, J. (2005). Reality cheques. In J. Pretty (Ed.), *Sustainable Agriculture*. London, UK: Earthscan.

Priest, S.H. (2000). US public opinion divided over biotechnology? *Nature Biotechnology*, *18*, 939-942.

Priest, S.H., Bonfadelli, H., & Rusanen, M. (2003). The "trust gap" hypothesis: Predicting support for biotechnology across national cultures as a function of trust in actors. *Risk Analysis*, *23*, 751-766.

Qaim, M., & de Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. *American Journal of Agricultural Economics*, *85*, 814-828.

Rampton, S., & Stauber, J. (2001). *Trust Us, We're Experts: How Industry Manipulates Science and Gambles with Your Future*. New York: Penguin Putnam Inc.

Ramsey, G. (2005). Pollen dispersal vectored by wind or insects. In G.M. Poppy & M.J. Wilkinson (Eds.), *Gene Flow from GM Plants*. Oxford, UK: Blackwell Publishing.

Ravetz, J. (2004). The post-normal science of precaution. *Futures*, *36*, 347-357.

Rieger, M. A., Lamond, M., Preston, C., Powles, S. B., & Roush, R. T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science*, *296*, 2386-2388.

Rifkin, J. (1998). *The Biotech Century: Harnessing the Gene and Remaking the World.* New York: Penguin Putnam Press.

Rissler, J., & Mellon, M. (1996). *The Ecological Risks of Engineered Crops*. Cambridge, MA: The MIT Press.

Roff, R.J. (2007). Shopping for change? Neoliberalizing activism and the limits to eating non-GMO. *Agriculture and Human Values*, *24*, 511-522.

Roy et al. (2003). Invertebrates and vegetation of field margins adjacent to crops subject to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. *Transactions of the Royal Society of London*, *358*, 1879-1898.

RSC (Royal Society of Canada). (2001). *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*. Ottawa, ON. Available at: www.rsc.ca/index.php?page_id=119

Sanogo, S., Yang, X.B., & Scherm, H. (2000). Effects of herbicide on *Fusarium solani f. sp.* Glycines and development of sudden death syndrome in glyphosate-tolerant soybean. *Phytopathology*, *90*, 57-66.

Semali, L.M., & Kincheloe, J.L. (1999). What is indigenous knowledge and why should we study it? In L.M. Semali and J.L. Kincheloe (Eds). *What is Indigenous Knowledge?: Voices from the Academy*. New York: Falmer Press.

Service, R.F. (2007). A growing threat down on the farm. *Science, 316*, 1114-1117.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*, 195-203.

Sillitoe, P. (2007). Local science vs. global science: An overview. In P. Sillitoe (Ed.), *Local Science vs Global Science: Approaches to Indigenous Knowledge in International Development.* New York: Berghahn Books.

Sim, R.A. (1988). *Land and Community: Crisis in Canada's Countryside.* Guelph, ON: University of Guelph Office for Educational Practice.

Simmons, W.M. (2007). *Participation and Power: Civic Discourse in Environmental Policy Decisions.* Albany, NY: State University of New York Press.

Skogstad, G. (2005). The uphill struggle to prevail: National farm organizations in Canada. In D. Halpin (Ed.), *Surviving Global Change? Agricultural Interest Groups in Comparative Perspective.* Burlington, VT: Ashgate Publishing Company.

Slovic, P. (1987). Perception of risk. *Science, 236*, 280-285.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis, 19*, 689-701.

Smyth, S.J. (2006). Managing risk: Different approaches to the regulation of genetically modified crops. In P. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology.* New York: Nova Science Publishers, Inc.

Smyth, S., Khacahatourians, G.G., & Phillips, P.W.B. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology, 20*, 537-541.

Smyth, S.J., & Phillips, P.W.B. (2006). Pervasiveness of risk in modern society. In P. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology.* New York: Nova Science Publishers, Inc.

Smyth, S., Phillips, P.W.B., & Khachatourians, G.G. (2004). *Regulating the Liabilities of Agricultural Biotechnology.* Cambridge, MA: CAB International.

Soleri, D., Cleveland, D.A. Aragon, C.F., Fuentes L. M. R., Rios L. H., & Sweeny, S.H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: Maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research, 4*, 141-166.

Soule, J.D., & Piper, J.K. (1992). *Farming in Nature's Image: An Ecological Approach to Agriculture.* Washington, DC: Island Press.

Stevenson, M. (1996). Indigenous knowledge in environmental assessment. *Arctic, 49*, 278-291.

Stokstad, E. (2004). Monsanto pulls the plug on genetically modified wheat. *Science, 304*, 1088-1089.

Sumberg, J., & Okali, C. (1997). *Farmers' Experiments: Creating Local Knowledge.* London: Lynne Rienner Publishers.

Tait, J., & Levidow, L. (1992). Proactive and reactive approaches to risk regulation. *Futures, 16*, 219-231.

Taylor-Gooby, P. (2006). Social divisions of trust: Skepticism and democracy in the GM nation? *Journal of Risk Research, 9*, 75-95.

Taylor-Gooby, P., & Zinn, J.O. (2006). The current significance of risk. In P. Taylor-Gooby, & J.O. Zinn (Eds.), *Risk in Social Science.* Oxford: Oxford University Press.

Tegtmeier, E.M., & Duffy, M. (2005). External costs of agricultural production in the United States. In J. Pretty (Ed.), *Sustainable Agriculture.* London: Earthscan.

Teitel, M., & Wilson, K.A. (1999). *Genetically Engineered Food: Changing the Nature of Nature.* Rochester, VT: Park Street Press.

Thorpe, N., Hakongak, N., Eeyegetok, S., and The Kitimeot Elders. (2003). *Thunder on the Tundra: Inuit Qaujimajatuqangit of the Bathurst Caribou.* Toronto: Douglas and McIntyre.

Tiberghien, Y. (2007). Europe: Turning against agricultural biotechnology in the late 1990s. In S. Fukuda-Parr (Ed.), *The Gene Revolution: GM crops and Unequal Development.* Sterling, VA: Earthscan.

Troughton, M. (2005). Fordism rampant: The model and reality, as applied to production, processing and distribution in the North American agro-food system. In S.J. Essex, A.W. Gilg, & R.B. Yarwood (Eds.), *Rural Change and Sustainability: Agriculture, the Environment and Communities.* Cambridge, MA: CAB International.

Van Acker, R.C., Brule-Babel, A., & Friesen, L. (2003). *An Environmental Safety Assessment of Roundup Ready Wheat: Risks for Direct Seeding Systems in Western Canada.* Winnipeg, MB: Canadian Wheat Board.

Van Acker, R.C., Brule-Babel, A., & Friesen, L. (2004). Intraspecifc gene movement can create environmental risk: The example of Roundup Ready wheat in Western Canada. In B. Breckling, & R. Verhoeven (Eds.), *Risk Hazard Damage: Specification of Criteria to Assess Environmental Impact of Genetically Modified Organisms.* Bonn, Germany: Federal Agency for Nature Conservation.

Vaucheret, H., Beclin, C., Elmayan, T., Feuerbach, F., Godon, C., Morel, J., Mourrain, P., Palauqui, J., & Vernhettes, S. (1998). Transgene-induced gene silencing in plants. *The Plant Journal*, *16*, 651-659.

Wachbroit, R. (1991). Describing risk. In M. Levin & H. Strauss (Eds.), *Risk Assessment in Genetic Engineering: Environmental Release of Organisms*. New York: McGraw-Hill.

Waines, J.G., & Hedge, S.G. (2005). Intraspecific gene flow in bread wheat as affected by reproductive biology and pollination ecology of wheat flowers. *Crop Science*, *43*, 451-463.

Weis, T. (2007). *The Global Food Economy: The Battle for the Future of Farming*. Winnipeg, MB: Fernwood Publishing.

Wenzel, G. (1999). Traditional ecological knowledge and Inuit: reflections on TEK research and ethics. *Arctic*, *52*, 113-124.

Wenzel, G. (2004). From TEK to IQ: Inuit qaujimajatuqangit and Inuit cultural ecology. *Arctic Anthropology*, *41*, 238-250.

Wright, G., Bolger, F., & Rowe, G. (2002). An empirical test of the relative validity of expert and lay judgments of risk. *Risk Analysis*, *22*, 1107-1122.

Wilson, A.K., Latham, J.R., & Steinbrecher, R.A. (2006). Transformation-induced mutations in transgenic plants: Analysis and biosafety implications. *Biotechnology and Genetic Engineering Reviews*, *23*, 209-237.

Wynne, B. (1989). Establishing the rules of laws: Constructing expert authority. In R. Smith & B. Wynne (Eds.), *Expert Evidence: Interpreting Science in the Law*. New York: Routledge.

Yarrow, S. (1999). Biosafety issues of genetically engineered herbicide-tolerant plants – Agriculture and Agri-Food Canada's perspective. In S. Shantharam & J.F. Montgomery (Eds.), *Biotechnology, Biosafety, and Biodiversity*. Enfield, NH: Science Publishers Inc.

Zinn, J.O., & Taylor-Gooby, P. (2006). Risk as an interdisciplinary research area. In P. Taylor-Gooby, & J.O. Zinn (Eds.), *Risk in Social Science*. Oxford: Oxford University Press.

Chapter 3:

The Double Helix of Risk – Towards a Holistic Evaluation of Agbiotechnology

"I regard the consilience of equal regard between science and the humanities as a combination of great power for our small world of scholars because such joining of truly independent entities, always in close and mutually reinforcing contact, and always pursuing a common goal of fostering the ways and means of human intellect, so deftly combines the different strengths of the fox and the hedgehog that we must win (or at least prevail), so long as we don't allow the detractors to break our common resolve and bond"

Stephen J. Gould

<u>The Hedgehog, the Fox, and the Magister's Pox</u>

CHAPTER SUMMARY

Worldwide, regulators use "science-based" risk assessment to evaluate and approve genetically modified (GM) crops, and this process explicitly excludes the public from decision-making regarding this important technology. This approach was first developed at the now famous Asilomar Conference and subsequently internationalized by the OECD. I argue that a more holistic approach is required, which seeks balance and connection between the scientific and social strands in risk assessment, and present the "double helix of risk" as a conceptual model to achieve this. I investigate the Cartagena Biosafety Protocol, the major and relatively new United Nation's agreement on living modified organisms (**LMOs**), and explore how the double helix of risk model is similar and may further benefit international governance of this technology. In contrast, North American governments fail to acknowledge the need for holism in risk evaluation of GM crops, which has led to significant problems as exemplified by the controversy over GM wheat and *Monsanto vs. Schmeiser* lawsuit. The barriers and possibilities for holism in risk evaluation are discussed.

INTRODUCTION

Safety assessments for agbiotechnology have largely been science-based, thereby excluding social determinants in risk assessment, despite the technology's demonstrable impact on human systems. A more holistic approach to genetically modified (**GM**) crop evaluation must be developed and I introduce the "double helix of risk" as a conceptual model (**Figure 1**), which explicitly recognizes the interconnectedness between scientific and social strands of risk evaluation. I argue that, in order to reduce polarity in the GM debate, balance must be found between these two strands and future risk research would benefit by including marginalized perspectives, particularly farmers, indigenous people, and rural communities.

TWO STRANDS TAKE FORM

The scientific and public conception that recombinant DNA (**rDNA**) and potential harm are intertwined was fertilized at the Asilomar Conference, in California, in 1975. This 3-day meeting has been called the 'Woodstock of molecular biology', convened in response to safety concerns over this emerging science, specifically crossing the species boundary with rDNA and creating genetically modified organisms (**GMOs**) (Barinaga, 2000). It was an exciting time for molecular researchers; however, it also required 'scientific soul searching' (Barinaga, 2000).

Elite scientists, physicians, and lawyers, largely from the US, dominated the meeting. Their decision was to overturn a previous moratorium on the use of rDNA, in favor of research protocols that ensured safe use of the technology (Fredrickson, 2001). Scientists hailed this approach as 'a landmark of social responsibility and self-governance' (Barinaga, 2000). Indeed, the guidelines that were drafted and promulgated by the US National Institute of Health were progressive, thoughtful, and emphasized the need for precaution and biological containment proportional to estimated risk. These guidelines, however, were strictly science-based and ethical considerations were left out, otherwise consensus would not have been reached (Barinaga, 2000). This document stated that it was the 'first assessment of potential bio-hazards' associated with rDNA, and in turn, is likely the world's premiere risk assessment for GMOs.

Journalists from 16 reputable scientific and popular publications such as *Nature, Science, New York Times, Washington Post,* and *Rolling Stone,* amongst others, were invited with the express purpose of bringing the science and debate regarding GMOs into the public eye (Fredrickson, 2001). However, some scientists were unhappy with this token public involvement and the removal of social and ethical determinants from the risk calculus. On the last day of the meeting, a group called 'Science for the People' distributed an open letter stating 'decisions at this crossroad of biological research must not be made without public participation' and requested continuation of the moratorium until the public was properly consulted, fearing that the scientific community was incapable of wisely regulating themselves (Fredrickson, 2001). Ironically, the Asilomar conference, as progressive as it was, recognizing the need for science-based risk assessment for GMOs, also set the precedent for externalizing public perspectives from decision-making regarding this important technology.

In this context, the double helix of risk was conceived, with science and public participation running antiparallel in each strand of the overall structure of risk evaluation. Science was clearly established as the 'dominant strand' for GMO risk assessment and these scientific methodologies were refined and replicated internationally, which ultimately lead to commercial release of agbiotechnology in the mid-1990s. In contrast, social considerations have largely been under represented or non-existent in GMO risk evaluation and, thus, form the 'lagging strand'. These two strands appear to be influenced by distinct ideological directionality, which has lead to the rapid uptake of one strand over the other. Arguably, this bias contributed to geopolitical conflict over agbiotechnology and exacerbated the divide between 'expert' and 'lay' perspectives regarding risk.

SCIENCE: THE DOMINANT STRAND

The Organization for Economic Co-operation and Development (**OECD**), building on the work at Asilomar, was the first organization to synthesize, standardize and internationalize science-based 'risk assessment' for GMOs. Their 1986 publication, *Recombinant DNA Safety Considerations*, also known as *The Blue Book*, set the intergovernmental standard for proactive approaches to evaluating environmental safety of these products (McCammon, 2006). It prescribed a tiered approach, which still largely exists today, assessing risk at each step. This approach moves from the laboratory to the greenhouse and then to limited field-testing and finally large-scale release. The goal of this type of risk assessment is to make a reasonable pre-release prediction of the behavior of a GM crop and to detect, and avert, potential problems (Sharples, 1991). It is generally conducted on a 'case-by-case' basis in order to gauge the 'possibility, probability and consequences of harm' (Nap et al., 2003). This largely expert-based approach has proved reliable, assisting in the introduction of 577 million hectares of GM crops worldwide (James, 2006), which have been deemed 'substantially equivalent' to, and therefore as safe as, their non-GM counterparts (Jasanoff, 2000). The directionality of this strand, I argue, is highly influenced by ideological world views associated with 'progress', 'technological optimism', 'economy' and 'globalism'. In turn, this strand of risk assessment is viewed as highly credible, generalizable, and objective.

SOCIAL: THE LAGGING STRAND

Social (e.g. socio-economic, ethical, political and cultural) considerations are important when evaluating the safety of GM crops. Yet, given the multidimensionality and often incommensurable nature of these issues, they are rarely incorporated in regulatory decision-making (Auberson-Huang, 2002). 'Risk analysis', in contrast to 'risk assessment', attempts to reconcile this absence of social determinants in decision-making, incorporating science within the larger context of public policy, with a specific emphasis on stakeholder involvement (Arvai, 2003). The importance of public participation in risk regulation is gaining recognition as it can contribute to a more rich and thorough understanding of potential hazards (Arvai, 2003). Yet, agreement on how to best include people remains a challenge (Anex and Focht, 2002). To date, consultation regarding GM crops has focused on lay people, specifically consumers, and is largely quantitative in nature and limited to large-scale surveys (Townsend and Campbell, 2004). Interestingly, in the GM crop debate, the important voice of farmers is often overlooked, despite their vast knowledge regarding its potential impact (Mauro and McLachlan, 2008). It has been argued that including stakeholder views in governance is essential, especially for controversial genetic technologies, as this will sustain trust and allow for continued research (Caulfield et al., 2006). The directionality of the lagging strand, I believe, is highly influenced by ideological world views associated with 'precaution', 'technological pessimism', 'environmentalism', and 'localism'. As a result, this strand of risk analysis is often viewed as lacking credibility, anecdotal, and subjective.

BARRIERS TO HOLISM

Risk decision-making over GM crops is often highly polarized. Scientific and social considerations are usually pitted against one another and viewed as opposites on a continuum of risk, which leads to acrimonious debates about their relative importance. Consequently, most studies are conducted on an either/or basis, with scholars choosing between scientific or social strands of risk evaluation, resulting in a notable gap in research that addresses the complex interplay between the two. Understandably, in this context, most governments have embraced 'objectivity' and adopted the dominant strand of risk assessment, which has allowed for comparison of risk across countries and subsequent release and globalization of agbiotechnology. However, it has been argued that this scientific exclusivity predefines what risks are considered, creating a value-laden 'risk window', which explicitly excludes social impacts and further exacerbates conflict associated with GM crops (Jensen et al., 2003). As a result, many social researchers suggest a more integrated approach, which includes public and broader policy perspectives, is required (Slovic, 1999). I believe that holistically re-visualizing the structure of risk regarding GM crops, recognizing the fundamental interconnectedness and need for balance between scientific and social issues (i.e. 'the double helix of risk'), is a critical step towards more effective risk evaluation, and may ease contention over agbiotechnology overall.

LIFE IN THE REAL WORLD

After having 'created' this novel 'double helix of risk', it is time to 'field test' it, to see if it is an adequate conceptual model to explain present risk controversies over GM crops. At the international level, the Cartagena Biosafety Protocol (**CBP**), the major

United Nation's (**UN**) negotiated agreement on living modified organisms (**LMOs**), seems to recognize the importance of both strands of risk evaluation. With further research and negotiation, the CBP may be a useful vehicle for holism in risk evaluation for abiotechnology. Whereas, in the US and Canada, North American-style regulations fail to recognize the importance of social considerations and are solely science-based. Despite this, real world case studies from these countries indicate the intrinsically linked nature of scientific and social issues, which underscores the gaps and inadequacies of North American-style regulation and further validates the conceptual model and need for holism.

THE BIOSAFETY PROTOCOL

Under the umbrella of its parent treaty, the Convention on Biological Diversity, the CBP came into force September 2003, and has at least 140 ratified members. Supporters of the CBP hail it as a critical component in emerging global governance for agbiotechnology and embrace its precautionary approach (Gupta and Falkner, 2006). Simultaneously, critics claim that it is doomed to fail because it may be viewed as a barrier to trade liberalization and therefore in contravention of World Trade Organization (**WTO**) rules (Isaac and Kerr, 2007). Despite this dispute, the CBP is the world's only multilateral environmental agreement (**MEA**) regarding biosafety and therefore understanding its ability to enable holistic risk evaluation for LMOs is important.

The CBP's overall objective is to protect biodiversity from potential risks associated with LMOs, through their safe transfer, handling and use, particularly regarding transboundary movement (Mackenzie et al., 2003). This international and legally binding framework is largely a starting point for governments, particularly countries importing LMOs, ensuring that they have adequate information and are able to make informed biosafety decisions (Mackenzie et al., 2003). The CBP's central provisions create an Advanced Informed Agreement (**AIA**) and Biosafety Clearing House (**BCH**), via an internet-based information exchange, which ensures countries are notified and aware of potential risks associated with LMOs prior to import (Mackenzie et al., 2003). Significantly, the CBP allows importers to block entry of LMOs if they are deemed a threat to biodiversity and the social systems that support it (Mackenzie et al., 2003).

The CBP empowers decision-making using conventional science-based risk assessment (Article 15) and management (Article 16), while simultaneously allowing for public awareness and participation (Article 23) and socio-economic considerations (Article 26) (**Figure 2**). This recognition of both strands of risk evaluation represents a responsible evolution in GMO regulation, as it respects the strength and predictive capacity of scientific approaches advocated at Asilomar and by the OECD, while allowing for transdisciplinary considerations regarding the potential social impacts associated with the introduction of novel organisms. Negotiating the integration of both these strands, however, was extremely difficult and contentious, and demonstrates the ideological directionality and antiparallel nature of the 'double helix of risk'.

Polarity existed amongst groups negotiating the CBP, particularly between countries importing and exporting LMOs. The 'Like-minded Group', comprised of Southern countries rich in biodiversity, were strong advocates for an internationally binding agreement that was broad and explicitly included social considerations in risk evaluation, largely because of the potential impact LMO imports might have on local biodiversity and livelihood of their small-scale and often poverty stricken farmers (Glover et al., 2003). However, the 'Miami Group', led by the US, Canada and other industrialized countries heavily invested in the production and export in LMOs, resisted a legally binding framework and blocked consensus, until finally compromising to an agreement that they believed allows international trade and science to dominate decision-making (Falkner, 2007). The EU took a diplomatic approach. They sided with the 'Like-minded Group' regarding the need for social and precautionary considerations, but with the 'Miami Group' in opposing binding liability and redress rules and inclusion of GM pharmaceuticals under the CBP (Falkner, 2007). Overall, that the CBP was successfully negotiated represents a major achievement in international cooperation (Falkner, 2007), and indicates that interconnecting the two strands of risk evaluation is inherently polarizing, but ultimately possible.

This integration represents an important first step towards achieving holism in risk evaluation; however, the challenge of finding balance between these two strands still remains. Under the CBP, science-based risk assessment is mandatory, whereas incorporation of public participation and socio-economic considerations is largely discretionar (Mackenzie et al., 2003). Compounding this further is that Article 26 does not indicate how participation or socio-economic considerations should be 'taken into account' (Mackenzie et al., 2003). In effect, this means national laws and regulations guide the 'scope, extent, and methodologies' for social assessment and, as a result of the CBP's wording, must be closely linked to impacts of LMOs on biodiversity (Mackenzie et al., 2003). Additionally, any obligation to consult the public and include socio-economics in risk evaluation must respect confidential business information and be consistent with other international agreements, principally the WTO (Mackenzie et al., 2003). Initial research suggests that substantial work, at the national level, is required to overcome challenges associated with increasing public participation.

Comparative research, commissioned by the UN's Environment Programme, documented 16 different countries, ranging from 'developed' to 'developing', making initial attempts to fulfill public participation obligations as outlined by the CBP (Glover et al., 2003). A key finding is that there is no standard 'tool-kit' for public involvement, and that debate over agbiotechnology will differ globally, depending on socio-economic, political, cultural, and environmental factors affecting the people in a particular region (Glover et al., 2003). Even within a region, there may be ethnically and linguistically diverse stakeholders, and it may be difficult and costly to effectively include all members of society, making it complicated to integrate consultation into official decision-making (Glover et al., 2003). Fearing that consultation might lead to loss of control over decision-making, the study indicated that many governments were inclined to pay 'lip service' to public participation, instead of actually engaging with and for the public (Glover et al., 2003). More recently, however, research from Mexico, China, and South Africa indicates that, now in practice, the CBP is used as a type of 'biosafety compass', which provides a sense of direction, and allows countries to adopt regulation that respects the protocol while suiting their domestic needs (Gupta and Falkner, 2006). As a result, these countries now have greater appreciation for both strands of risk evaluation. While science is at the center of their national regulations, they are attempting to make decision-making more democratic (Gupta and Falkner, 2006).

An important component of the CBP, which should further enable its success, is that it recognizes LMOs might pose unique risks for 'indigenous and local communities' (Mackenzie et al., 2003). In many countries of the world, indigenous and local communities, whether agriculturalists or hunter-gatherers, are often knowledgeable stewards of biodiversity, and their livelihoods are predicated on this tradition (Kloppenburg, 1991). Specific to agriculture, it has long been advocated that farmers' 'local knowledge' must be included at the onset of technological research, development, and assessment (Chambers et al., 1989). I believe that working with farmers is an important strategy, which will help bolster the social strand in agbiotechnology risk evaluation, and bring balance to 'the double helix of risk'. Indeed, much of my work in the North American context has been related to this.

NORTH AMERICA: REGULATION AND CONTEXT

North American-style regulation for agbiotechnology subscribes to the dominant strand of risk assessment. In the US, a combination of the United Department of Agriculture (**USDA**), Environmental Protection Agency (**EPA**) and the Food and Drug Administration (**FDA**) oversee environmental release of GM crops (Mandel, 2004), whereas in Canada the Canadian Food Inspection Agency (**CFIA**) performs this task (RSC, 2001). Using the 'double helix of risk' as a conceptual model, I now investigate its applicability to case studies regarding agbiotechnology risk controversies in these countries.

GM WHEAT

The GM wheat controversy, which spanned North America and ultimately the globe, demonstrates the complex scientific and social considerations required in regulation of agbiotechnology. Monsanto had Roundup Ready (**RR**) wheat – which is herbicide-tolerant (**HT**) - under review by regulatory agencies in both the US and Canada and was conducting field trials with a plan for commercialization (Wilson et al., 2003). Monsanto's plan was to simultaneously introduce RR wheat in both countries and deal with the North American market as a whole (Berwald et al., 2006). However, the continental wheat industry was concerned about the interconnected issues of gene spread, containment, segregation and market harm. These concerns were made worse especially given that 82% of international buyers stated they would not purchase RR wheat, due largely to consumer unrest over the technology (CWB, 2003).

In Canada, the grain industry felt that a strictly 'science-based' regulatory approach was inadequate, and recommended that RR wheat be subjected to a cost/benefit analysis to assess market harm, which would close the 'regulatory gap' (CWB, 2003). However, the CFIA explicitly stated that they had "neither the mandate nor the authority to consider market acceptance" in approving GM crops (CFIA, 2003). Yet, the CFIA continued to allow field trials – and Monsanto largely carried these tests out in undisclosed locations across the prairies – further exacerbating the controversy and fear that RR wheat would escape and harm markets. The government's blatant disregard for public concern led to the unprecedented coalition of farm, rural municipality, industry, and environmental and consumer groups banding together to ask the then Prime Minister Chrétien to "act immediately to prevent the introduction of GM wheat" unless their concerns were adequately addressed (MacRae et al., 2002).

Arguably, in the RR wheat debate, farmers in both countries had the most at stake, namely their livelihoods. However, given that public participation and socio-economics are not part of the North American-style regulatory system, there was no formal government process to include farmers in decision-making. This led one Canadian farm organization, the Saskatchewan Organic Directorate (**SOD**), to seek an injunction on the commercialization of RR wheat. They feared it would disrupt millions of dollars in organic wheat sales and their ability to farm organically altogether (Bouchie, 2002). At one point, all the major farm organizations in Canada launched an ad campaign entitled 'We're not ready for Roundup Ready Wheat', calling for Monsanto to withdraw its environmental release application given the potentially severe economic and agronomic impact that the crop might pose for farmers. Interestingly, the CFIA's inability to include stakeholder perspectives, particularly farmers, became a liability, as these highly affected groups rallied together and created a massive public outcry to which politicians had to respond.

To address these regulatory gaps, transdisciplinary research at the University of Manitoba was conducted, which explicitly combined farmer perspectives and science-based research to holistically evaluate the impact of RR wheat. As part of my doctoral research, a prairie-wide survey was conducted with farmers and rural residents regarding their attitudes toward RR wheat, which found that over 80% were opposed to its introduction (Chapter 7). While much of this concern was due to economic harm, farmers were also worried about corporate control of seed supply, and agronomic risks associated with RR wheat, which included volunteers, contamination and impacts on non-GM growers, and RR-resistant weeds (Mauro and McLachlan, 2008). Agronomic research supported these concerns, suggesting that RR wheat might outcross, be a persistent volunteer weed, complicate crop rotations, and ultimately undermine reduced tillage across the prairies (Van Acker et al., 2003).

Eventually, Monsanto capitulated to public pressure - backed by scientific and social research indicating potential harm associated with RR wheat - and in May 2004 they deferred its release (Fox, 2004). Arguably, consumers and farmers may have been more critical of GM wheat as a result of their previous experience with other GM crops, principally canola.

MONSANTO VS SCHMEISER

Worldwide, the most high profile example of the intertwined ways in which GM crops affect farmers is that of Percy and Louise Schmeiser, the Saskatchewan-based couple sued by Monsanto for patent infringement over GM canola. Monsanto's RR canola was introduced commercially in 1996, after having passed the necessary science-based risk assessments, and in 1997 the Schmeisers discovered it in one of their fields. Nearly retired and in their late 60s, the Schmeisers were 'seed savers', and as was their tradition, they kept seed from their fields, which inadvertently contained the RR gene (Fox, 2001). In 1998, after an investigation, Monsanto sued them for possession of patented genetic material. The case went all the way to the Supreme Court of Canada in 2004, where the Schmeisers lost in a 5-4 jury split. The decision maintained Monsanto's patent rights over RR canola, wherever it exists in nature, yet overturned the lower court financial awards against the farmers, as it was determined that they had not sprayed Roundup on their crops, and therefore did not directly benefit from the technology

(Mauro, 2005). This bizarre outcome left both parties claiming victory and commentators confused about the precedent and future implications (Kondro, 2004).

Although GM canola was introduced in the mid-1990s, very little scientific research existed on its gene flow, persistence, and larger environmental impact. *Monsanto vs. Schmeiser* was largely a testing ground to establish facts regarding these issues. The decision was predicated on Monsanto's sample results indicating that the Schmeisers' fields were 95-98% RR and believed to be planted from commercial seed; however, these data have always been rivaled and called into question by independent research at the University of Manitoba. Grow-out tests of the Schmeisers' 1998 crop – conducted on behalf of the defense and presented in the original trial - show that presence of the RR trait ranged from 3 to 67%. This suggests that the source of the RR trait may have been outcrossing and/or direct seed movement, which significantly diminished the 'standby utility' of the crop and rationale for a guilty verdict regarding patent infringement (Van Acker, 2004). Follow-up research demonstrates that HT traits can enter non-HT crops up to 3 km via pollen-mediated gene flow (Rieger et al., 2002). As a result, RR canola has become relatively ubiquitous in non-RR canola in the Canadian prairies (Van Acker, 2004), even when grown in highly regulated environments intended to produce certified pedigreed seed (Friesen et al., 2003). After the original trial, even Monsanto's expert witness regarding canola biology - who testified against the likelihood of cross-pollination as a source of RR canola in the Schmeisers' fields - published similar results, which demonstrated that 41 of 70 tested non-GM seed lots had been contaminated with GM traits, despite efforts to ensure genetic purity (Downie and Beckie, 2002). The *Monsanto vs Schmeiser* case demonstrates that scientific knowledge, particularly regarding new technology, is continually evolving, often highly contested, and perhaps not always reliable.

Reflecting on this controversy, the Schmeisers are quick to acknowledge the intimate connection between the environmental and social impacts of GM crops, particularly their affect on rural communities (Mauro et al., 2005). In the original trial, Monsanto described their protocol for monitoring and investigating farmers believed to be using RR canola without a license, which included solicitation of anonymous phone tips, hiring private investigators to sample crops in ditches alongside farmers fields, and ultimately the use of the courts (Mauro, 2005). The Schmeisers believe that the introduction of agbiotechnology, coupled with these investigations, pit farmers against farmers, destroying the 'rural social fabric', and the culture of rural people working together (Mauro et al., 2005). Some sociologists of biotechnology agree, suggesting that this 'culture of surveillance' damages social cohesion, and undermines rural community health and its ability to collectively buffer change (Mehta, 2005). In this way, biological effects of GM crops, may directly affect social systems and farm communities in particular.

Taking a step back, it's important to consider the broader societal implications of the *Monsanto vs Schmeiser* case, particularly as it relates to the issue of life patenting. In sum, this precedent "allows Monsanto to do indirectly what Canadian patent law has not allowed them to do directly: namely, to acquire patent protection over whole plants" (Gold and Adams, 2001). The four dissenting judges in *Monsanto vs Schmeiser* recognized this, and discussed the incommensurable nature of findings of guilt against the Schmeisers, when the ruling in *Harvard Mouse* explicitly states patents over higher life forms are invalid in Canada. Essentially, in Canada, important matters of public policy relating to the patenting of life forms, with associated ethical and societal consequences, have been left to the courts, due to the stark absence of Parliamentary guidance and regulation on this issue (Morrow and Ingram, 2005).

Interestingly, in 2005, after the Supreme Court ruling, the Schmeisers claimed that RR canola was once again in their fields (Pratt, 2005), and when tests were carried out by Monsanto scientists, this was verified and communicated in writing by their lawyers (Schmeiser, pers comm.). The Schemisers launched a small claims court case against Monsanto for cleanup costs associated with this contamination, and the company eventually settled (out of court in spring 2008) for the $660 expense. The Schmeisers' experience demonstrates that the dominant strand of risk assessment largely failed to anticipate a number of unforeseen consequences associated with GM canola, relating to both scientific and social impacts, leading to this controversial and seemingly contradictory legal precedent. One must question, if the Schmeisers had been sued today, given the current state of knowledge regarding the complex impacts associated with GM canola, would they still have been found guilty by the Supreme Court of Canada?

GENOME OF RISK

After critically evaluating (or 'sequencing') these North American case studies, an interconnected relationship between scientific and social issues has emerged, which is presented as complimentary 'base pairs' inside a simplified 'genome of risk' (**Figure 3**). This further validates the 'double helix of risk', demonstrating the wide array of impacts associated with some GM crops, and the need for balance and strength amongst both strands of risk evaluation.

It is important that the structure of these 'base pair' relationships is well understood. Thus, if one of the strands of risk evaluation is weak, the capacity to understand the diversity of potential impacts associated with GM crop introductions decreases. Like with DNA itself, the build up of missing information in the genome of risk may lead to damage within and beyond the system. If this 'damaged DNA' is not acknowledged and repaired, risk controversies may mutate, and become far more problematic and dangerous.

Thinking more broadly, this also suggests that specific 'base pairs' may likely repeat themselves in other risk controversies. Identifying those that might be common in multiple scenarios may help to mitigate problems in the future. Furthermore, it suggests that, like DNA, risk evaluation must be dynamic and continually evolving, taking into consideration the latest knowledge regarding the broad impacts associated with agbiotechnology.

TOWARDS HOLISM

Agbiotechnology is a very powerful tool that has the capacity to transform society – both positively and negatively. It is important that the technology is introduced responsibly, in a way that maximizes benefit and minimizes risk, not just for companies and governments, but also for farmers, indigenous people, and society as a whole. In order to do so, a broader approach to risk evaluation must be undertaken, which considers the interconnections between scientific and social impacts associated with GM crops. I have introduced, tested and now release the 'double helix of risk' as conceptual model that allows for a holistic evaluation of agbiotechnology.

While connecting the two strands of risk evaluation in decision-making may be controversial, it has proven both conceptually and technically possible, and would allow for a better understanding of the impacts associated with agbiotechnology. Science-based risk assessment is an important tool as its ability to assess the probability of a particular harm is very useful for decision-making (Raybould and Cooper, 2005). Despite the strengths of risk assessment, North American scientific experts now believe that it largely failed to anticipate specific problems associated with volunteers, gene flow and contamination, and market harm (Krayer von Krauss et al., 2004). Arguably, if North American regulations had been more robust, and more thoroughly considered the 'lagging strand' of risk assessment, problems associated with the release of GM crops may have been averted. Importantly, social research methodologies, particularly those practiced in risk analysis of agbiotechnology, are becoming more refined and widespread, and may help to balance 'the double helix of risk'.

The use of reliable and peer-reviewed social methodologies is critical in future risk research. North American countries, which might want to mitigate risks not currently evaluated by science, will find them very useful, as will countries seeking to fulfill and/or enhance public participation and socio-economic obligations under the CBP. Conveniently, a comprehensive review of strategies that integrate socio-economics and public participation into national and international biosafety regulation and governance exists. It advocates the use of 'economic modeling', 'cost/benefits analysis', 'social impact assessment', 'sustainable livelihoods framework', 'relevance assessment' and 'participatory research' (Fransen et al., 2005). Additional techniques include 'citizen juries' and 'consensus conferences' (Einsiedel, 2001) and video research (Mauro et al., 2003). Pros and cons exist for each of these methods, and domestic and demographic issues must be considered, which will ensure that appropriate methods, perhaps in combination, are employed for specific regions and peoples.

Increased funding for 'lagging strand' research is perhaps one of the most significant initiatives that will enable holism in risk evaluation. This is especially true in the North American context. Ideally, this would help to establish equivalency across disciplines, and an environment of mutual respect amongst scholars, which might lead to more sophisticated collaboration and research. However, equivalency in principle is not enough, and it is the adoption of national laws and regulation that mandates citizen participation and social considerations, and allocation of resources to enable and facilitate this, which is essential. Currently, research into the ethical, legal, and social impacts of genomics and biotechnology is poorly funded and generally lacking in Canada and the US, especially when compared to the EU (Beer and Jansen, 2004). This is largely a result of transatlantic differences in regulation.

The EU's approach to agbiotechnology evaluation is centered on the 'precautionary principle', which allows for decision-making, in the absence of scientific certainty, if a potential threat to the environment or human health might occur (Murphy and Levidow, 2006). While the EU considers important and uses science-based risk assessment, its citizens are very critical of GM foods, and governments have implemented an 'unofficial defacto moratorium' on the approval of new GM crops until new legislation can restore public confidence (Murphy and Levidow, 2006). These additional regulations include food labeling, traceability and consideration of ethical and social issues in decision-making (Murphy and Levidow, 2006). In this way, EU-style regulation has recognized the need to bolster the 'lagging strand' and bring it into balance with the 'dominant strand', thus successfully implementing 'the double helix of risk' in praxis.

Despite the demonstrated inadequacies of North American-style regulation, the US and Canada resist change, and in fact, have aggressively attacked the EU's regulatory position. In 2003, the US and Canada led a WTO challenge against the EU's slow approval process for agbiotechnology, complaining it was not 'science-based'. The WTO, in 2006, ruling on narrow legalistic and procedural issues, found that, indeed, the EU had 'illegally' imposed 'undue delays' (Murphy and Levidow, 2006) and their regulations were therefore 'incompliant with international trade rules' (Isaac and Kerr, 2007). While the EU was the explicit target of this trade action, scholars have pointed out that the implicit target was actually the CBP (Isaac and Kerr, 2007). Essentially, the CBP 'multilaterlizes' the EU's precautionary approach, and the WTO complaint attempts to undermine the CBP's legitimacy and discourage countries from using it to block imports of GM crops (Isaac and Kerr, 2007). Clearly 'biopolitics' is the critical issue that must be resolved in order for holism in risk regulation to be achieved internationally.

Is global regulatory convergence under a banner of holism possible? Many commentators believe that the WTO challenge will backfire, as EU citizens will resist international efforts to undermine their domestic food sovereignty (Falkner, 2007), which in turn will erode confidence in the WTO (Murphy and Levidow, 2006), and ultimately call its legitimacy as an arbitrator in global governance, particularly regarding environmental issues, into question (Isaac and Kerr, 2007). Interestingly, some scholars believe this may force North America into regulatory convergence with the EU, especially given intense pressure from US state legislatures for change, largely as a result of the GM wheat fiasco, and the increase in court challenges over inadequacies associated with regulation (Kollman and Prakash, 2007). Recently US courts, for the first time ever, revoked the approval of GM alfalfa and halted field trails of GM turfgrass, after they were deemed in violation of federal environmental laws (Fox, 2007). In Canada, the organic farmers of Saskatchewan were denied class-action status for their lawsuit against Monsanto and Bayer over GM canola contamination, which has caused significant financial damage to the industry (Smyth et al., 2002). While these cases may cause a shift towards holism in North American regulation, another scenario forecasted by experts is that the transatlantic regulatory divergence will continue. In this future, it has been argued that the CBP may be implemented as a countervailing, as opposed to complimentary, force used to contend WTO-style trade liberalization and, in turn, promote biosafety (Isaac and Kerr, 2007). Clearly, no matter what the outcome of these scenarios, the CBP will remain and important global agreement in the evaluation of agbiotechnology.

Strengthening and further developing the CBP is important. Areas to focus include use of credible scientific information (Greef, 2004), bridging the gap between the research and policy community and promoting information exchange (Galloway McLean, 2005), and most importantly, continuing to develop and implement strategies that facilitate socio-economic and public involvement in decision-making (Jaffe, 2005). Ideally, as risk controversies mature, particularly in regions with North American-style regulations, the CBP will be viewed as a useful policy tool, and additional countries may decide to ratify and use it. If not, it is important that these countries move away from conflict-laden WTO challenges, towards co-existence and appreciation of the diverse possibilities of regulation.

Critical to the success of future risk evaluation is the explicit inclusion of farmers and indigenous peoples, as these groups often have the most at stake, in combination with vast experience and knowledge about potential impacts associated with agbiotechnology. This unique position must be valued and respected. However, expert-based research should not necessarily be the driving force, or only modality for including these perspectives. Often the views of grassroot groups, which have not been officially 'consulted', may shed the most light on important, and perhaps systematically overlooked, impacts associated with agbiotechnology. Furthermore, these communities often want to speak for themselves - as was witnessed by the farm community uprising in the GM wheat debate and the Schmeisers' prolific battle to the Supreme Court - and governments and policymakers must have the capacity to adapt quickly and take these perspectives seriously.

An ability to adapt to the ever-changing scientific and social knowledge regarding the effects of agbiotechnology is a hallmark of 'the double helix of risk'. Like DNA, it is a 'blue print' for risk evaluation, which is reflexive, and allows for self-reading, self-repair, and most importantly, evolution. It is a dynamic way of thinking about risk, which attempts to better understand the diverse impacts associated with agbiotechnology, on both human and natural systems, via transdisciplinary research and the involvement of the public at large.

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REFERENCES

Anex, R.P. & Focht, W. (2002). Public Participation in Life Cycle Assessment and Risk Assessment: A Shared Need. *Risk Analysis*, 22, 861-877.

Arvai, J. (2003). Using Risk Communication to Disclose the Outcome of a Participatory Decision-Making Process: Effects on the Perceived Acceptability of Risk-Policy Decisions. *Risk Analysis*, *23*, 281-289.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology*, *20*, 1076-1078.

Barinaga, M. (2000). Asilomar Revisited: Lessons for Today? *Science*, *287*, 1584-1585.

Beer, W.M. & Jansen, A.J.A. (2004). *Ethical, Legal and Societial Aspects of Genomics Research in the EU, Canada and the US.* Netherlands Genomics Initiative, The Hague, Netherlands.

Berwald, D., Carter, C.A. & Gruere, G.P. (2006). Rejecting New Technology: The Case of Genetically Modified Wheat. *American Journal of Agricultural Economics*, *88*, 432-447.

Bouchie, A. (2002). Organic farmers sue GMO producers. *Nature Biotechnology, 20,* 210.

Caulfield, T., Einsiedel, E., Merz, J.F. & Nicol, D. (2006). Trust, patents and public perceptions: the governance of controversial biotechnology research. *Nature Biotechnology, 24,* 1352-1354.

CFIA (Canadian Fóod Inspection Agency). (2003). Submission to CFIA for approvals of Roundup Ready wheat: Questions and Answers. Ottawa, Ontario.

Chambers, R., Pacey, A. & Thrupp, L.A. (1989). *Farmer First: Farmer innovation and agricultural research.* London: Intermediate Technology Publications.

CWB (Canadian Wheat Board). (2003). Closing the Regulatory Gap: Industry-Supported Solutions for Genetically Modified Wheat. Presentation to the House of Commons Standing Committee on Agriculture and Agri-Food, Ottawa, Ontario; April 3.

Downie, R.K. & Beckie, H.J. (2002). *Isolation effectiveness in canola pedigreed seed production* Agriculture and Agri-Food Canada Report, Saskatoon, Saskatchewan.

Einsiedel, E. (2001). Publics at the technology table: the consensus conference in Denmark, Canada, and Australia. *Public Understanding of Science, 10,* 83-98.

Falkner, R. (2007). *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave Macmillan.

Fox, J. (2001). Canadian farmer found guilty of Monsanto canola patent infringement. *Nature Biotechnology, 19,* 396-397.

Fox, J. (2004). Monsanto Cuts GM wheat. *Nature Biotechnology, 22,* 645.

Fox, J. (2007). US courts thwart GM alfalfa and turf grass. *Nature Biotechnology, 25,* 367-368.

Fransen, L., La Vina, A., Dayrit, F., Gatlabayan, L., Santosa, D.A., & Adiwibowo, S. (2005). *Integrating socio-economic considerations into biosafety decisions: The role of public participation.* Washington, DC: World Resources Institute. Available at: www.wri.org/biodiv/pubs_description.cfm?pid=4033

Fredrickson, D.S. (2001) *The recombinant DNA controversy: A memoir.* Washington, D.C.: ASM Press.

Friesen, L.F., Nelson, A.G. & Acker, R.C. (2003). Evidence of contamination of pedigreed canola (Brassica napus) seedlots in western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal,* 95, 1342-1347.

Galloway McLean, K. (2005). Bridging the gap between researchers and policy-makers: International collaboration through the Biosafety Clearing-House. *Environmental Biosafety Research*, *4*, 123-126.

Glover, D., Keely, J., Newell, P. & McGee, R. (2003). *Public Participation and the Cartagena Protocol on Biosafety*. Institute of Development Studies (IDS). Available at: http://www.ids.ac.uk/ids/KNOTS/Projects/biotech/NBFs.html

Gold, E.R. & Adams, W.A. (2001). The Monsanto decision: The edge or the wedge. *Nature Biotechnology*, *19*, 587.

Greef, D. (2004). The Cartagena Protocol and the future of agbiotech. *Nature Biotechnology*, *22*, 811-812.

Gupta, A. & Falkner, R. (2006). The Influence of the Cartagena Protocol on Biosafety: Comparing Mexico, China and South Africa. *Global Environmental Politics*, *6*, 23-55.

Isaac, G.E., & Kerr, W.A. (2007). The biosafety protocol and the WTO: Concert or conflict? In R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law*. New York: Palgrave MacMillan.

Jaffe, G. (2005). Implementing the Cartagena Biosafety Protocol through national biosafety regulatory systems: an analysis of key unresolved issues. *Journal of Public Affairs*, *5*, 299-311.

James, C. (2006). *Global Status of Commercialized Biotech/GM Crops: 2006*. Available at: www.isaaa.org/resources/publications/briefs/35/executivesummary

Jasanoff, S. (2000). Between risk and precaution - reassessing the future of GM crops. *Risk Analysis, 3*, 277-282.

Jensen, K.K., Gamborg, C., Madsen, K.H., Jorgensen, R.B., Krauss, M.K., Folker, A.P., & Sandoe, P. (2003). Making the EU "risk window" transparent: the normative foundations of the environmental risk assessment of GMOs. *Environmental Biosafety Research, 2*, 161-171.

Kloppenburg, J. Social-Theory and the De Reconstruction of Agricultural Science - Local Knowledge for an Alternative Agriculture. (1991). *Rural Sociology*, *56*, 519-548.

Kollman, K.L. & Prakash, A. (2007). In Falkner, R. (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave Macmillan.

Kondro, W. (2004). Monsanto Wins Split Decision in Patent Fight Over GM Crop. *Science, 304*, 1229.

Krayer von Krauss, M.P., Casman, E. & Small, M.J. (2004). Elicitation of Expert Judgements of Uncertainty in the Risk Assessment of Herbicide-Tolerant Oilseed Crops. *Risk Analysis, 24*, 1515-1527.

Mackenzie, R., Burhenne-Guilmin, F., La Vina, A.G.M. & Werksman, J.D. (2003). *An Explanatory Guide to the Cartagena Protocol on Biosafety*. Cambridge, UK: Available at: www.iucn.org/themes/laws/pdfdocuments/ Biosafety%20Guide/ Biosafety-guide-prelims.pdf

MacRae, R., Penfound, H. & Margulis, C. (2002). *Against the Grain: The Threat of Genetically Engineered Wheat*. Greenpeace Report.

Mandel, G.N. (2004). Gaps, Inexperience, Inconsistencies, and Overlaps: Crisis in the regulation of genetically modified plants and animals. *William and Mary Law Review, 45*, 2167-2259.

Mauro, I.J. (2005). *Genetic Matrix: The Schmeiser Case and Fight for Life*. Dead Crow Production documentary film. Winnipeg, Canada.

Mauro, I.J. & McLachlan, S.M. (2008). Farmer knowledge and risk analysis: Postrelease evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis, 28*, 463-476.

Mauro, I.J., McLachlan, S.M. & Higgins, L. (2003). Exploring the use of video as a tool for research and community development. *Rural Sociology Annual Meeting*, Montreal, Quebec.

Mauro, I.J., McLachlan, S.M. & Sanders, J. (2005). *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture*. Dead Crow Productions and Dada World Data documentary film. Winnipeg, Manitoba. Available at: www.seedsofchangefilm.org

McCammon, S.L. (2006). Biosafety Research and Environmental Risk Assessment. *9th International Symposium on Biosafety of Genetically Modified Organisms*. Available at: www.isbr.info/isbgmo/

Mehta, M.D. (2005). The impact of agricultural biotechnology on social cohesion. In M.D. Mehta (Ed.), *Biotechnology Unglued: Science, Society, & Social Cohesion*. Vancouver: UBC Press.

Morrow, D.A. & Ingram, C.B. (2005). Of Transgenic Mice and Roundup Ready Canola: The Decision of the Supreme Court of Canada in *Harvard College v. Canada* and *Monsanto v. Schmeiser*. *UBC Law Review, 38*, 189-222.

Murphy, J. & Levidow, L. (2006). *Governing the Transatlantic Conflict over Agricultural Biotechnology*. New York: Routledge.

Nap, J.P., Metz, M., Escaler, M. & Conner, A.J. (2003). The release of genetically modified crops into the environment: overview of current status of regulations. *The Plant Journal*, *33*, 1-18.

Pratt, S. (2005) Roundup Ready Canola back in Schmeiser's field. *The Western Producer.* October 26.

Raybould, A. & Cooper, I. (2005). Tiered tests to assess the environmental risk of fitness changes in hybrids between transgenic crops and wild relatives: the example of virus resistant *Brassica napus*. *Environmental Biosafety Research*, *4*, 127-140.

Rieger, M.A., Lamond, M., Preston, C., Powles, S.B. & Roush, R.T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science*, 296, 2386-2388.

RSC (Royal Society of Canada). (2001). *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada.* Ottawa, Ontario. Available at: http://www.rsc.ca/index.php?page_id=119

Sharples, F.E. (1991). Ecological aspects of hazard identification for environmental uses of genetically engineered organisms. In M. Levin & H. Strauss (Eds.), *Risk Assessment in Genetic Engineering: Environmental Release of Organisms.* New York: McGraw-Hill

Slovic, P. (1999). Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield. *Risk Analysis*, *19*, 689-701.

Smyth, S., Khachatourians, G.G. & Phillips, P.W.B. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology*, *20*, 537-541.

Townsend, E. & Campbell, S. (2004). Psychological Determinants of Willingness to Taste and Purchase Genetically Modified Food. *Risk Analysis*, *24*, 1385-1393.

Van Acker, R.C. (2004). Letter to Chief Justice of Canada regarding the Supreme Court of Canada's ruling on the case of Schmeiser vs. Monsanto. Available at: http://www.grain.org/research/contamination.cfm?id=172

Van Acker, R.C., Brule-Babel, A.L. & Friesen, L.F. (2003). *An environmental safety assessment of Roundup Ready wheat: Risks for direct seeding systems in western Canada.* Canadian Wheat Board Report. Winnipeg, Manitoba

Wilson, W.W., Janzen, E.L. & Dahl, B.L. Issues in Development and Adoption of Genetically Modified (GM) Wheats. (2003). *AgBioForum*, *6*, 101-112.

FIGURES

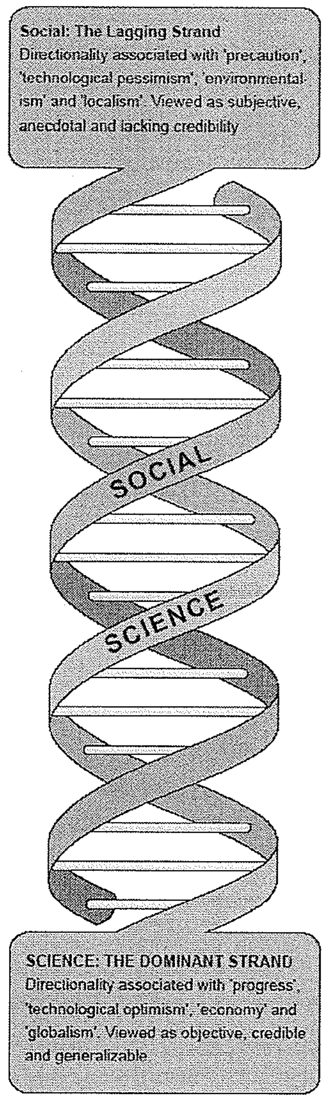


Figure 1: 'The double helix of risk' is a conceptual model introduced, for the first time, in this paper, and it recognizes the fundamentally interconnected, yet antiparallel structure of the two strands of risk evaluation for agbiotechnology. It suggests that for holism to be achieved, balance must be found between the 'dominant' and 'lagging' strands, which have distinct ideological directionality, and are characterized by science and social determinants, respectively.

Figure 2: Coexistence of scientific and social strands of risk evaluation

The Cartagena Biosafety Protocol (**CBP**) is the only multilateral environmental agreement (**MEA**) that oversees the transboundary movement of living modified organisms (**LMOs**) and their impact on biodiversity. It embraces 'the double helix of risk' by including both science and social determinants in the evaluation of risk associated with LMOs. Its negotiation was controversial and demonstrates that interconnecting these two strands is polarizing, but ultimately possible.

CBP clauses relating to the 'double helix of risk'

Risk Assessment and Management: Articles 15 and 16, and Annex III, describe the procedures for carrying out 'scientifically sound' risk assessment and management. Both human health and biodiversity are considered. Techniques are largely based on standards set by the OECD. Risk assessments may be iterative, taking into consideration the unique biodiversity of importing regions. Interestingly, provided it is collected in a scientific manner, indigenous and traditional knowledge may be included.

Public Participation and Socio-Economics: Articles 23 and 26 are a mix of mandatory and discretionary actions expected of the parties to the Protocol. Parties are required to 'promote and facilitate' public participation and awareness, and must consult the public when decisions are being made regarding LMOs and biosafety. Socio-economic risks, principally those affecting 'indigenous and local communities', may be used as a reason to not adopt LMOs. However, these risks must be related to biodiverstiy, and not conflict with other international agreements

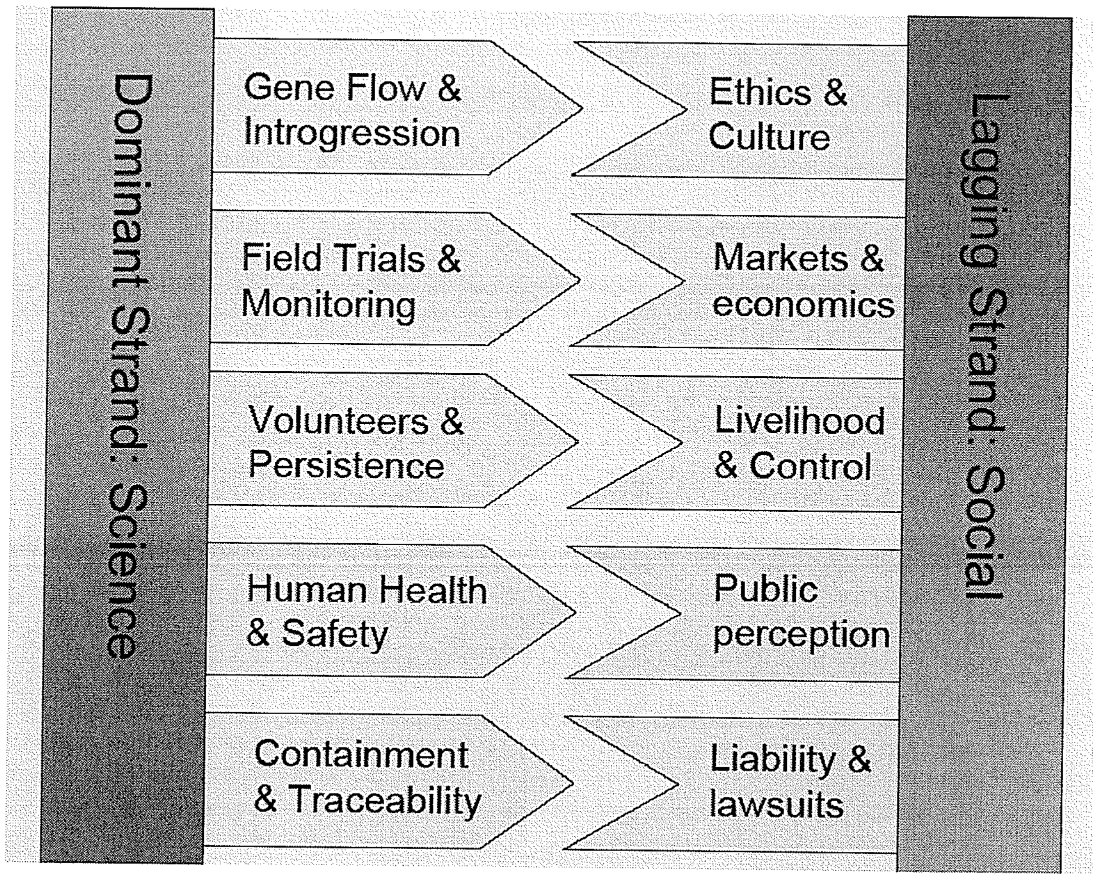
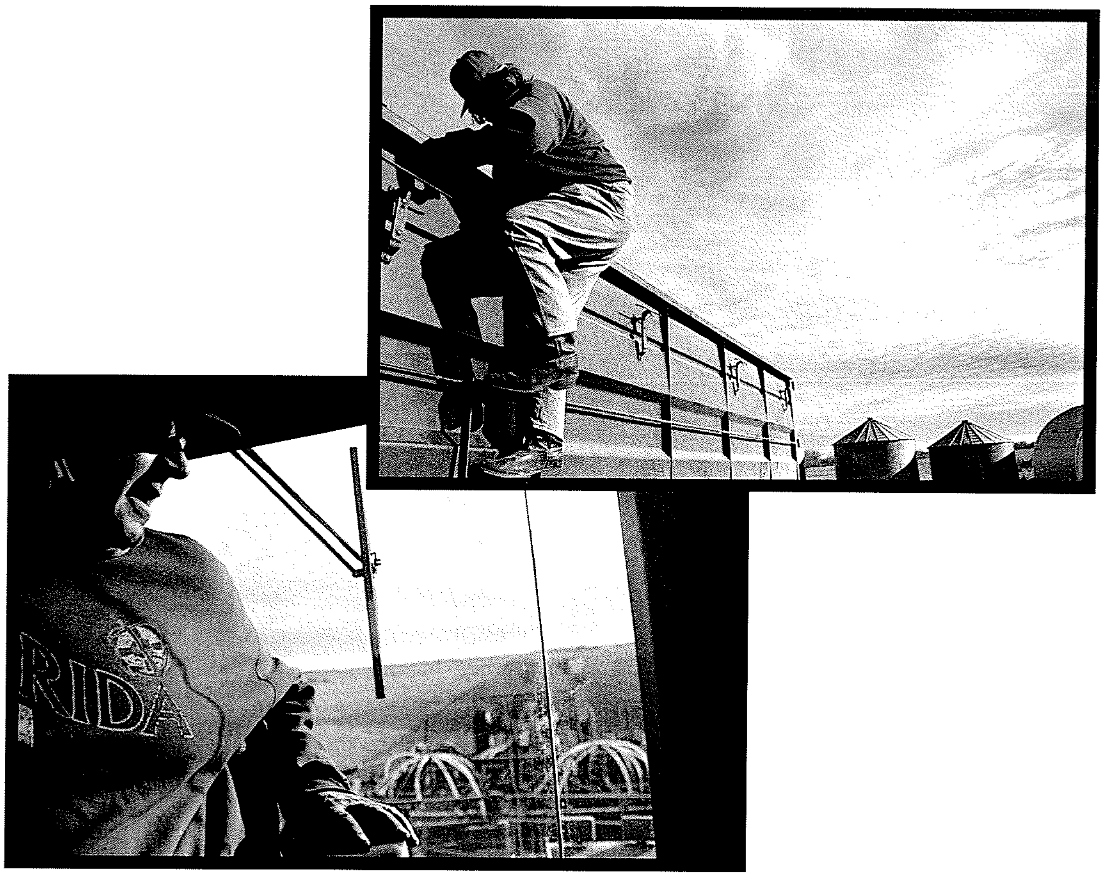


Figure 3: This simplified 'genome of risk' was derived by 'sequencing' North American risk controversies over GM wheat and canola. It demonstrates the interconnected 'base pairs' between scientific and social impacts associated with agbiotechnology. It suggests that balance between both strands of risk evaluation is imperative; otherwise, missing information can lead to mutations in risk controversies, making them far more problematic and dangerous.

Chapter 4:

Farmer Knowledge & Video Research – Planting "Seeds of Change" Regarding GM Crops in the Canadian Prairies



"The opening out and out, body yielding body: the breaking through which the new comes, perching above it shadow on the piling up darkened broken old husks of itself: bud opening to flower opening to fruit opening to the sweet marrow of the seed – taken from what was, from what could have been. What is left is what is"

Wendell Berry
<u>The Broken Ground</u>

CHAPTER SUMMARY

The global debate regarding the use of GM crops has been urban-based and dominated by industry and activists. The voice of farmers and rural communities remains notably absent from this exchange, despite their many years of experience with this technology. The purpose of this study was to characterize farmer experiences and perceptions regarding the risks of GM crops, in particular herbicide tolerant (HT[i]) canola and wheat, and to develop a participatory documentary video to communicate this information. In-depth video interviews were conducted with farmers (n=15) across Canada. Participants identified environmental, political, socio-economic and legal risks associated with HT crops. All farmers indicated that they were worried about contamination of HT traits and the presence of HT volunteers in their fields. Those most affected by HT crop contamination and associated volunteers included farmers practicing conservation tillage[ii], organic[iii] methods and seed saving. Farmers were also concerned about the long-term commitment by industry to manage these problems, and all were strongly opposed to the introduction of GM wheat. They were also concerned about the future of agriculture and rural communities and the loss of their autonomy as producers, particularly over seed supply. Farmer knowledge represents a rich, reliable and holistic source of information on impacts associated with HT crops and video was an ideal method to collect, analyze, and present this information. Unfortunately, policy makers generally continue to ignore the contribution that farmer knowledge can make to assessing and managing risk associated with this and other new technology.

1. INTRODUCTION

Industry and environmental groups dominate the global debate regarding genetically modified (GM) crops, often using rhetorical and acrimonious language, which attempts to persuade the public of either the benefits or risks associated with this technology (Cook, 2004). Consumers in Europe, Japan and North America are often suspicious of this technology, have concerns about its adverse environmental and health implications, and lack trust in food safety regulators (Macer and Chen Ng, 2000; Priest, 2000; Frewer et al., 2004; Taylor-Gooby, 2006). This is perhaps not surprising, as "first generation" GM crops had no explicit consumer benefits, and were developed specifically for agricultural production (Scholderer and Frewer, 2003). Agricultural research on GM crops is often expert-based and located in the natural sciences.

Scientific studies demonstrate that both benefits and risks may be associated with GM crops. On-farm benefits that have been identified with GM crops include ease of use, better weed and insect control, reductions in pesticides, higher yields and profitability, and environmental sustainability (Horsch, 1993; Falk et al., 2002; Phipps and Park, 2002; Devine, 2005; Dewar et al., 2003; Brookes and Barfoot, 2005). In contrast, risks associated with GM crops are less well understood. Some studies suggest that there may be problems associated with gene flow and contamination by GM traits (Quist and Chapela, 2001; Demeke et al., 2006), declines in on-farm biodiversity (Brooks et al., 2003; Haughton et al., 2003; Heard et al., 2003a; Heard et al., 2003b), out-crossing with weedy relatives (Rissler and Melon, 1996; Ellstrand et al., 1999; Warwick et al., 2003; Wilkinson et al., 2003), and damage to field margin environments (Roy et al., 2003).

These studies are characteristic of "science-based" risk assessment, which is used worldwide to approve GM crops, and is essential for predicting and averting potential hazards associated with this technology (Nap et al., 2003). That regulators rely solely on risk assessment to evaluate GM crops has been criticized, as some argue this creates a value-laden "risk window" whereby scientific issues are only considered (Jensen et al., 2004), while broader social, economic and cultural factors important to the public are ignored (Abergel and Barrett, 2002). This effectively excludes non-experts from having any meaningful input in the evaluation of GM crops (Leiss, 2001), despite research demonstrating that the public has a sophisticated capacity to assess food related risk (Hansen et al., 2003). Amongst the public, farmers are likely best suited to evaluate GM crop risk, given their experience using this technology,

However, most farmer-focused studies involving GM crops have been economic in nature, regarding adoption rates in Canada (Fulton and Keyowski, 1999), US (Bernard et al., 2004; Wu, 2004; McBride and Books, 2000), Argentina (Qaim and de Janvry, 2003), India (Bennet et al., 2006; Qaim and Zilberman, 2003), Romania (Brookes, 2005) and South Africa (Ismael et al., 2002). Worldwide, only a few studies have characterized farmer perspectives on attendant risks. These have examined farmer attitudes to the potential introduction of GM crops in Australia (McDougall et al., 2001) and New Zealand (Cook and Fairweather, 2003), and experiences with GM maize in Cuba, Guatemala and Mexico (Soleri et al. 2005), GM eggplant in India (Chong, 2005), GM corn and soybean in the US (Chimmiri et al., 2006), and links between farmer education, integrated pest management and GM cotton in China (Yang et al., 2005). Even fewer studies acknowledge that farmers represent a valuable source of knowledge on this issue, these generally originating from the Global South (e.g. Cleveland and Soleri, 2005; Soleri et al., 2005). Although Canada - along with the US and Argentina – was one of the first countries to commercialize GM crops (James, 1997) and has over a decade of experience with this technology no studies have documented the knowledge of farmers in this northern clime.

Farmer local knowledge (LK) is a rich and reliable source of information regarding agroecosystems (Chambers, 1983) and can make a valuable contribution to the GM crop debate. This LK is largely experience-based, orally transmitted, bioregional in nature, and difficult to access by "outsiders" (Sumberg et al., 2003). Although agriculturally based LK research is primarily conducted in the Global South its importance in shaping "local farming systems, culture and beliefs" in rural communities worldwide is recognized (Millar and Curtis, 1999). While LK is often framed as being "opposite" to scientific knowledge, scholars suggest it can be informed by scientific ways of knowing (including natural, social and economic disciplines), and is therefore dynamic and holistic (Millar and Curtis, 1999). Research further suggests that farmer LK may be used in *a priori* and post-release risk assessment to predict, mitigate, and monitor environmental impacts associated with agricultural technology (Appriah-Opoku, 2005; Bacic et al., 2006).

Dismissal of farmer knowledge is pervasive in countries where agriculture is heavily modernized (Morgan and Murdoch, 2000). Scientists and policy makers in these countries often discount farmer perspectives regarding agricultural technology on the grounds that it is non-scientific, subjective and unreliable (Chambers, 1983; Harrison et al, 1998; Tsouvalis, 2000). When acknowledged at all, farmers are generally viewed as passive research subjects or passive adopters of expert-developed technology (Fliert and

Braun, 2002). However, these assumptions are increasingly questioned and greater and more meaningful farmer involvement in agricultural research has been advocated (e.g. Kloppenburg, 1991; Middendorf and Busch, 1997; Dahlberg, 2002).

A novel approach to documenting farmer knowledge is with video (Chambers, 1989). Documentary video is both participatory and inherently a form of qualitative data assessment (Nicolas, 2002). Some argue that because video allows participants to express themselves orally – "in their own voice" - it elicits responses otherwise unattainable by conventional social science research (Letiche, 2002). Thus video is incredibly useful for documenting orally based farmer knowledge. Importantly, documentary video allows for "giving back" and creating a research product that is relevant for participants and other stakeholders, and may used for capacity building, education, and political change (Russell and Bohan, 1999). In the GM debate there is a need for resources that communicate farmer perspectives to urbanites, policymakers, and industry.

The purpose of this study was to characterize farmer experiences and perceptions regarding the risks of GM crops, in particular herbicide tolerant (HT[2]) canola *(Brassica napus)* and wheat (*Triticum aestivum*), and to develop a documentary video to communicate this information. This research documentary was made across Canada in the provinces of Ontario, Manitoba, Saskatchewan and Alberta and included 15 farmers.

2. MATERIALS AND METHODS

2.1 Study area

In 1995, the government agency charged with regulating GM crops in Canada, the Canadian Food Inspection Agency (**CFIA**), determined that herbicide-tolerant[i] (**HT**) canola was "substantially equivalent" to conventional canola varieties and permitted its large scale commercial release (Leiss, 2001; Stringam et al, 2003). Three varieties of novel-trait HT canola have been introduced: Roundup Ready (**RR**), Liberty Link (**LL**) and Clearfield (**CF**), these tolerant to glyphosate, glufosinate and imidazolinone herbicides, respectively (Lawton, 2003). Farmers rapidly adopted HT canola and at present they represent 96% of the 5.25 million ha of canola grown in Canada; approximately 50% of this being RR, 32% being LL and 14% being CF (Buth, 2006). The world's first GM wheat, tolerant to Roundup, had also been field-tested and is at the final stages of regulatory approval in Canada, although it has yet to be released (Stokstad, 2004).

Wheat and canola are two of the most widely grown crops in western Canada, and cover 11.8 and 9.9 million ha, respectively (Statistics Canada, 2006a). Although agriculture is still a dominant industry in the prairies, the number of farmers in this region is in long-term decline, with significant losses between 2001 and 2006 in Manitoba (-9.6%), Saskatchewan (-12.4%) and Alberta (-7.9%) (Statistics Canada, 2006b). As a result, prairie agriculture has shifted towards "fewer, bigger farms", with an average farm size increasing from 273 to 295 ha (Statistics Canada, 2006b). Conservation tillage[ii] continues to increase in prevalence and is currently practiced on 46% of the landbase nationally (Statistics Canada, 2006b). Organic[iii] farming has also increased in popularity in western Canada; however, only 1.2% of farmers in Manitoba, 2.5% in Saskatchewan, and 0.4% in Alberta are currently organic (Macey, 2005).

2.2 Farmer participation

In spring 2002, prior to conducting farmer interviews, we had discussions with representatives from farm organizations, commodity groups, agronomists, rural extension officers, as well as individual farmers in Manitoba. This helped us identify some of the important issues with respect to HT crops, shaped the questions we used in the subsequent interviews, and helped us identify knowledgeable farmers for the study. We employed a "snowball" strategy (Patton, 2002) to locate and recruit farmers across Ontario, Manitoba, Saskatchewan and Alberta that were particularly knowledgeable with respect to issues surrounding HT crops. We ensured that a diversity of farming approaches, genders, ages, farm sizes, and geographical locations were reflected. Upon contacting farmers, between May and August 2002, a participatory rural appraisal (**PRA**) approach facilitated a "role reversal" in that we recognized farmers as experts regarding experiences with GM crops (Chambers, 1989). Participants were excited and appreciated that we were interested in their insights and found this to be a fairly unique approach to otherwise production-oriented University agriculture research. With this mutual respect in place, the project moved forward, and we continued to keep in touch with participants via farm visits, telephone and written project updates. The development of the final video was iterative, and at various points, we traveled back to individual farms to screen drafts of the video for participants. We collected feedback and made changes to the final documentary to ensure it reflected participants' perspectives. This established strong, trust-based relationships with participants that continue until today, these creating a collaborative working relationship with farmers and these promoting feelings of co-ownership over the study and its outcomes.

2.3 Sample of Farmers

Participants in this study had diverse farming backgrounds: one practiced conventional tillage, five practiced minimum tillage[ii], two practiced zero tillage[ii], three were organic producers (including one couple), two were vegetable farmers, and one had a mixed cattle, corn, and vegetable farm. In total, eleven men and four women were interviewed; one over eighty, two over sixty, ten were at least forty, one under forty, and only one less than 30, years of age. Seven farmers had not intentionally grown any HT crops (three organic, two vegetable, one mixed, and one conventional tillage). The other eight participants had intentionally grown at least one HT crop variety. Farms ranged from 32 ha to 1214 ha in size. Principal crops grown by most were wheat, canola, barley and oats, although the three farmers also grew garden vegetables, herbs and heirloom seeds.

2.4 Interview Design

From the onset, we communicated the importance of farmer knowledge in our research. Participants all consented to having their interviews videotaped, analyzed and included in future research publications and videos. Their insights, interests and experiences largely shaped the direction of the interviews (Patton, 2002), and helped us discern how the outcomes were being shaped by our own assumptions and understanding of previous research from the interview process (Kennedy and Lingard, 2006)

We conducted fifteen in-depth, semi-directed video interviews (Maxwell, 2005). Farmers across the prairies were interviewed on their farms and associated farm tours and field walks were undertaken to better understand the specifics of their operations.

Interviews ranged from 90 to 180 minutes in length and additional notes were recorded in the field. The Ontario farmer was interviewed at a conference on biotechnology in Toronto. The University of Manitoba's Joint-Faculty Research Ethics Board (JFREB) approved our research protocol. For the purpose of this study, pseudonyms have replaced the identity of research participants, in accordance with our JFREB protocol.

2.5 Video data analysis & management

We made innovative use of Final Cut Pro HD video editing software (Apple, 2004) when analyzing and managing the qualitative interview data (Mauro et al., 2003). All interviews were "logged" from tapes into Final Cut Pro and placed into "bins", or electronic folders, within the program. Content analysis was used to identify primary patterns in the data (Patton, 2002). Both researchers listened to and watched the interviews, while taking notes, until we had a detailed impression of the emerging narratives. Memos were used to document important comments, assisting in the development of codes, and ultimately producing analytical categories that emerged from the farmer statements (Maxwell, 2005). The emerging categories were grounded in the data (Glaser and Strauss, 1967; Dey, 1999).

Video assisted in categorizing and contextualizing the coded data. We coded comments from the original interviews and sorted them into categories and sub-categories, as video clips on the video timeline. Since video clips were digitally linked to the larger interview it was easy to review the context in which comments were made, eliminating the potential for "context stripping" (Maxwell, 2005). Interview data were robust, and few discrepancies existed between each of our coding schemes and field notes also matched the emergent memos, codes and categories, which served as an "analytical triangulation" (Patton, 2002). Once the coded video clips were assembled into categories, a short, preliminary documentary was produced, this facilitating the meaningful and ongoing participation of farmers in the research. In the fall of 2002, we revisited farmers and screened the draft video or sent it to participants to get feedback, ensuring they were represented properly, that the data were interpreted correctly, and that the categories and themes were appropriate. The participants were overwhelmingly supportive of analysis, which further affirmed our results.

3. RESULTS

3.1 Benefits

Farmers that used herbicide tolerant (HT) crops felt that they provided agronomic benefits, specifically better weed control. Farmers were able to spray these crops with non-selective herbicides, which did not kill the plants, but controlled surrounding weeds. These farmers generally agreed that HT crops were more effective than conventional varieties, easier to use, and reduced dockage (i.e. weed seeds, chaff, and other foreign materials) in the final product.

> *"...you're going from 10 to 2 or 3% dockage. That means that every time a truckload of Canola goes down the road he is hauling 7% more canola as opposed to a waste product. So in the overall scheme of things, it does reduce your transportation costs"* (Johnny, minimum tillage farmer, HT user, Alberta)

Due to the ease of use, the technology also allowed farmers to cover a larger land base more efficiently, and in some cases helped reduce time spent in the field. Overall, these benefits increased profitability for many of the farmers interviewed.

"Why I grow it is because it is economically viable and I've yet to have anyone give me adequate research or reason to tell me I shouldn't grow it" (Shaun, minimum tillage farmer, HT user, Manitoba).

Given the tight financial margins in farming, these farmers felt that HT canola had helped their operations and were an important technology in agriculture.

"I still think of us as producers, for the most part have benefited fairly well from GM canola over the past number of years" (David, minimum tillage farmer, HT user, Manitoba)

While many farmers in the study used and benefited from HT canola, most participants expressed concerned that these crops could escape from planted fields and cause problems, which was a primary risk associated with this technology.

3.2 Contamination

Farmers indicated pollen flow and direct seed movement as important vectors for the escape of HT traits. That canola cross-pollinated frequently, farmers were uncertain about the purity of their crops, and felt that they could easily be contaminated by neighbouring fields.

"Canola…it just gets out of control, you don't know really what's going to happen out there in the following year" (Troy, minimum tillage farmer, Manitoba)

Two of the participants were commercial seed producers and they indicated that HT canola outcrossing had negatively affected their operations.

"I was a member of a seed company, we had few things happen and we had to destroy (seed) lots. One of the genes was in our canola that wasn't supposed to be in there. It cost the company a lot of money. It happens a lot more often than what you hear" (Troy, minimum tillage farmer, HT user, Manitoba)

The other seed producer also had suffered financial losses due to the spread of HT traits. In the past, he had received contracts from companies to grow commercial canola seed, but due high levels of unwanted HT traits, companies had stopped producing seed in his region.

> *"If I look back over the last five years, the seed canola was a big crop to me. I know now that I'm giving up about $30,000 a year in income because we aren't producing seed canola any more in this area. It's a major loss to this area"* (Colin, zero tillage farmer, HT user, Manitoba)

When this farmer was asked to confirm that his financial loss was directly due to the introduction of HT crops, he said "yes, yes - definitely".

3.3 Volunteers

All producers communicated that the occurrence and persistence of HT volunteer canola represented a substantial environmental risk. They recognized that volunteer plants grow from seeds that shattered from previous crops in a field rotation, from wind blowing swathed canola into nearby fields, from seeds that "shell out" or from seeds blowing into a field off passing and improperly covered trucks. They perceived higher risk from HT canola volunteers, as these weeds were now resistant to commonly used herbicides and thus often harder and more expensive to control. They were especially concerned that HT crops were escaping into areas where they would be undesirable.

> *"We are starting to see these volunteers showing up in fields that have never been planted to these crops. Farmers that have never seeded genetically modified crops are finding volunteers on their farm and that the volunteers picture is much broader than we had expected to see"* (Ryan, zero tillage farmer, HT user, Manitoba)

Many of the non-organic producers relied on the herbicide glyphosate for broad-spectrum weed control and were concerned that glyphosate-tolerant canola would negatively affect their operations. They indicated how important this herbicide was for their systems as a pre-seed treatment ("burn-off") when killing weeds. They further communicated that glyphosate helped reduce tillage and, in the case of those practicing zero-till, eliminated it completely. This, in turn, had helped reduce soil erosion and the cost of weed management. Those that had experienced unwanted glyphosate volunteer canola on their land indicated that they had to pay for and use additional herbicides, particularly 2, 4-D, in order to manage this new weed problem.

> *"If you have any Roundup Ready canola volunteers in your field and you are doing spring burn off, if you don't add 2, 4-D or some other chemical you can't kill this Roundup volunteer canola because Roundup won't kill it. The gene is in the canola that it won't die"* (Bradley, minimum tillage farmer, HT user, Manitoba)

One zero-till farmer had experienced multiple tolerant, or gene-stacked, volunteers that had adversely affected his operation. In 2001, glyphosate-tolerant volunteer plants invading his land survived a pre-seed treatment of glyphosate, which was his normal practice. He had his fields tested by a third party and learned that the plants were double-stacked, having traits from both the Roundup Ready or RR (i.e. glyphosate-resistant) and Liberty Link (i.e. glufosinate-resistant) systems.

> *"You know, looking back we should have known that it would spread quickly and it would cross pollinate this quickly, but it's come as quite a surprise. I would have never imagined five years ago that I would have plant populations of five Roundup Ready canola per square meter, with 60% of them double resistant to Liberty as well, having never grown the crop"* (Colin, zero tillage farmer, HT user, Manitoba)

<u>*3.4 Lawsuits over GM crops*</u>

Clint, the Saskatchewan-based farmer and longtime seed saver and plant breeder, had a similar contamination event within his conventional non-HT canola in 1997. He noticed Roundup Ready (RR) volunteers in the ditch alongside one of his fields and, not recognizing the extent of the contamination, he kept seed from the adjacent field and replanted it the following year. Although these volunteers had contaminated his land, the RR gene inside these plants is patented, and this precipitated a lawsuit.

> *"Monsanto without any prior warning to me launched a lawsuit against me and said that I was growing Monsanto Roundup Ready canola without a license"* (Clint, conventional tillage, non-HT user, Saskathchewan)

The judge in the case ruled that it did not matter how these volunteers entered a farmer's land, if they were present and contained the patented gene this constituted infringement. The farmer lamented this decision and warned others about its implications.

> *"Even if a farmer doesn't know he has it on his property or has some seed in his soil he violates Monsanto's patent"* (Clint, conventional tillage farmer, non-HT user, Saskatchewan)

3.5 Livelihoods and farm systems

Regardless of agronomic approach, both users and non-users of the technology had similar views regarding the possible effects of HT crops on rural livelihoods. Conservation till, organic producers, and seed savers all described how various aspects of the technology could compromise on-farm economics and the environment.

3.5.1 Conservation tillage systems

The conservation (i.e. minimum and zero) till producers found glyphosate-tolerant canola to be the most problematic of the HT varieties. They used glyphosate at the time of seeding to control weeds instead of tilling the soil. However, glyphosate-tolerant volunteer canola had contaminated their land and it could not be controlled with standard practices.

> *"Over the last few years we have started to see canola plants resistant to Roundup show up in our fields. We have never grown a crop of Roundup Ready canola - we have grown some of the other types of genetically modified canolas - but never the Roundup Ready canola because of the threat that it poses to zero-tillage... What we*

are finding now is that Roundup Ready canola plants have been introduced into the farm, in whatever manner, that we are unable to control" (Colin, zero tillage, HT user, Manitoba)

None of the zero till farmers interviewed had ever planted or would ever plant RR canola. The presence of unwanted glyphosate-tolerant volunteers in their production systems was clearly perceived to be a threat.

"the real threat with Roundup Ready crops is with zero-tillage"
(Ryan, zero tillage, HT user, Manitoba)

The producers indicated that they could normally control RR volunteers by adding other chemicals to their pre-seed glyphosate treatment. They recognized, however, that this additional cleanup cost had been externalized to farmers and ultimately might undermine the financial incentive to practice minimum and zero-tillage.

"It's really an economic decision, and if those economics were taken away from zero-till farmers, they would be forced back to more intensive tillage...I don't know if zero-till will survive the introduction of Roundup Ready canola. It will be tough" (Colin, zero tillage, HT user, Manitoba)

<u>3.5.2 Organic systems</u>

Organic producers interviewed in this study indicated that their farms were small, largely self-sustaining, explicitly based on ecological principles and did not use chemical sprays or HT seeds. They discussed the strategic use of crops and field rotations, instead of herbicides, to control weed and pest problems. They further stressed that HT crops put their organic production systems at risk, as important crops could become contaminated which might require remediation and might eventually require the removal of entire crops from their rotations. Thus, they referred to the elimination of canola as a crop due to the contamination from the introduction and outcrossing of HT varieties.

"Realistically, you can't have canola as part of your organic crop rotation right now"(Melissa, organic farmer, Manitoba)

These farmers stressed the importance of their autonomy as producers. They were concerned that HT crops could contaminate their land, cause damage, and compromise their ability to farm organically.

"It's taking something away from us. It is taking choice away from us. The reason we farm the way we farm is because we're self-sustaining, we're independent, there are really few outside forces that determine what happens on our farm because of the way we farm" (Melissa, organic farmer, Manitoba)

3.5.3 Seed savers

The farmer sued for patent infringement believed that the technology harmed rural livelihood for non-HT farmer, particularly seed savers. The lawsuit lasted several years, cost hundreds of thousands of dollars, was very stressful, and forced the farmer to abandon his traditional practice of seed saving canola. He believed that patented HT crops and associated lawsuits had global implications.

"What it means to farmers all around the world is the loss and right to use your own seed" (Clint, conventional tillage farmer, non-HT user, Saskatchewan)

He had been in contact with other farmers throughout North America that had been similarly threatened by corporations with patent infringement lawsuits. Many of these farmers were unable or scared to fight corporations in court and instead paid expensive settlement costs, which Clint felt undermined the livelihood of all farmers affected by these lawsuits.

3.6 Industry responses

There were varying attitudes toward the responsiveness and accountability of industry when dealing with problems associated with the introduction of HT crops. The farmer that had been negatively affected by multiple-resistant HT volunteers was cynical about this.

> *"Well unfortunately, under the present system industry doesn't have to take any responsibility for the problems they are causing"* (Colin, zero tillage farmer, HT user, Manitoba)

This criticism reflected his extensive interactions with the HT crop developer, which had apparently only exacerbated the problem. He personally paid for field-testing because the company would not accept any responsibility, and generally had found them unsympathetic toward his predicament.

> *"In my case, Monsanto has been very involved in every step in the problems I've had, but they're not prepared to accept responsibility. They will only argue on a field-by-field basis, and, even though we know we have Roundup Ready canola on every field, they are not prepared to admit that and compensate you for your additional costs. What we have to do is leave it until it is a problem and then they will argue with you as to whether it's a problem or not"* (Colin, zero tillage farmer, HT user, Manitoba)

Another farmer, while generally pleased by industry responses to these problems, raised an issue regarding the future control of HT volunteers.

> *"Now that we have these volunteers, they are going to be in the picture for a long time. I guess I really am uncertain about the level of commitment of the companies are to control these in the long-term"* (Ryan, zero tillage farmer, HT user, Manitoba)

His concern over HT volunteer control led to a discussion regarding 'Terminator Technology'. He was worried that Terminator Technology would undermine farmer rights to save, replant and exchange seed. However, he was quick to point out that this ability was already undermined by Technical Use Agreements (TUAs), which have to be signed by Canadian farmers who use RR canola and which only allow producers to use HT seed for a single season.

> *"This is the end of a farmer saving his own seed for producing for another year and then we saw the contract signed between the farmers and the seed companies saying that he could not produce those crops for seed anyways. So that's taken away that argument and now we seem to be at to the point where we are presented with the Terminator gene again and it seems like a good idea"* (Ryan, zero tillage farmer, HT user, Manitoba)

Although perhaps beneficial in the short term, it might end up undermining rural livelihoods in the future.

> *"It is an irony that we hated the idea when it first came out and now we are looking at it as our savior"* (Ryan, zero tillage farmer, HT user, Manitoba)

Some of the interviewed farmers were concerned that they may be sued, or prevented from saving their seed, if it were contaminated with HT traits.

> *"And what happens when we save our own wheat seed here, year after year, and it becomes contaminated. At what point does someone step in and say, you can't save this seed anymore because it has our genetic material in it?"* (Andrew, organic farmer, Manitoba)

In general, participants wanted to see a more equitable and farmer-centered system for assessing risks and assigning responsibility. They also felt that industry should contribute more to the costs of controlling their technology.

> *"Industry is responsible to their shareholders, they're not responsible to agriculture or farmers or the environment or anything like that, and their goal is to get their products commercialized as quickly as possible and with the maximum profits. I can accept that, that's the way it is, but I just don't believe they should*

> *have the right to introduce products that affect people like me as a zero tiller or an organic farmer negatively without being responsible for it"* (Colin, zero tillage farmer, HT user, Manitoba)

3.7 GM wheat

All those interviewed were opposed to the introduction of RR wheat, regardless of their farming system or whether they had previously grown HT crops.

> *"GM wheat. I do not want to grow! I won't grow it! On my farm I will not grow it! I don't want to see my neighbors grow it! But I'm not going to try and force my views on my neighbors. I really wish that they'd never ever done it"* (Bradley, minimum tillage farmer, HT user, Manitoba)

One of the main concerns regarding the introduction of RR wheat was that it might also escape and become a weed that was difficult to control. Given their experiences with HT canola volunteers, producers anticipated that the control of GM wheat would require the use of additional management techniques and herbicides, and thus additional time and costs.

> *"Well I am scared of it. I am scared it's going to turn into a bad weed. Like, we have a problem with Roundup Ready volunteer canola now; what kind of problem are we going to have with volunteer Roundup Ready wheat?"* (Bradley, minimum tillage farmer, HT user, Manitoba)

Many of those interviewed speculated that issues surrounding the control of RR wheat would be further exacerbated by RR canola. They indicated how RR wheat would be impossible to control with glyphosate in a field of RR canola, and indicated the same for RR canola in RR wheat. Those practicing conservation till were especially concerned about RR wheat volunteers adventitiously invading their production systems, given their dependence on glyphosate in pre-seed weed control. They indicated that it was especially problematic to control HT wheat volunteers.

> *"A Roundup Ready wheat will be much more difficult and more expensive to control, being a grassy weed, as compared to a broadleaf like the canola"* (Colin, zero tillage farmer, HT user, Manitoba)

While some believed that RR wheat volunteer control was feasible, they emphasized it would be cost-prohibitive.

> *"I have no idea how I would control my system affordably, technically it is possible, but from a practical point of view I just can't see handling it"* (Colin, zero tillage farmer, HT user, Manitoba)

Producers indicated that this additional cost might compromise, if not reverse, the already substantial achievements and promise of conservation tillage.

> *"If you take away some of the cost effective herbicides for controlling weeds prior to the crop emerging, you put pressure on the system, an economical pressure, and if that economical pressure becomes high enough, zero-tillage is no longer a viable operation"* (Ryan, zero tillage farmer, HT user, Manitoba)

Reverting back to tillage would amount to a major environmental and agronomic setback, undermining many of the advances regarding soil moisture and erosion associated with reduced tillage. Organic producers in the study similarly emphasized concerns over the threats that RR wheat posed to their farm operations and livelihoods. They anticipated that the release of RR wheat would contaminate their wheat fields and compromise their rotational practices. They further emphasized how important wheat was to organic producers across the prairies, and thus perceived the threat of HT wheat to be even greater than that of HT canola.

"On our farm we grow wheat almost every year. We use it for our own personal use. We use it with the animals and the chickens. So it would be a huge hole left in our whole operation, I don't know how we'd get along without it really" (Melissa, organic farmer, Manitoba)

The most common concern amongst all those interviewed was the threat that GM wheat represented for hard red spring wheat markets around the world. Should GM wheat escape, all producers feared that that the Canadian Wheat Board (**CWB**) would not be able to sell their wheat.

"I don't want Roundup Ready Wheat! The consumers don't want Roundup Ready Wheat! Europeans don't want it!" (Bradley, minimum tillage farmer, HT user, Manitoba)

Indeed, the huge controversy over GM wheat had all producers in this study reflecting on the future role of any HT technology in agriculture.

3.8 Future of herbicide-tolerant crops

When questioned about the future of HT crops, farmers expressed a unanimous desire for an agriculture that was environmentally, economically and socially sustainable. Farmers clearly viewed themselves as stewards of their agroecological systems. They expressed how they had developed intimate, long-term, nature-based relationships with the land on which they farmed and they wanted to ensure that it was effectively managed for their children and generations to come. Thus it was important to mitigate any long-term environmental risks associated with HT crops.

"My family has farmed here for over 100 years, and I would like to see this farm continue for another 100 years, which is to say I don't want to do what is wrong for the environment. I know most of my friends who farm around here are not trying to purposely go out and destroy the environment either. We live here, we live

closer to it than anybody does, because we are outside all the time, we are right in it. We hear some of these horror stories about what the long-term effects may be, we are very much concerned" (Shaun, minimum tillage farmer, HT user, Manitoba)

Although concerned about future risks associated with GM technology, users were still optimistic about the potential of these products. They generally felt that the benefits were significant and that continued use was justified. However, risks resulting from contamination events, volunteer persistence, liability issues and market uncertainties had producers concerned about long-term implications of their use.

"This is pretty exciting technology that we can do this, but we need to know what long-term effect we are going to have" (Ryan, zero tillage farmer, HT user, Manitoba)

While organic farmers interviewed in this study had similar perceptions regarding their role as stewards, they seemed to view the future differently, especially as it related to GM crops. They were less optimistic about the promise of the technology and largely rejected it as a viable tool for developing sustainable agricultural systems and for supporting rural communities.

"The GMO is just thinking of today. There is no thought of what it will do to future generations and how people will be able to farm in future generations. Will anybody have control of what they are going to sow 50 years from now?" (Melissa, organic farmer, Manitoba)

Despite these apparent differences in attitude, all producers communicated a desire for more information on the risks associated with the technology.

"Let's put the brakes on this a little bit and answer some of these questions. Because you can't move ahead with so many questions out in the general public as

with the consumers and with the farmers, we need some of these answered" (Ryan, zero tillage farmer, HT user, Manitoba)

Farmers were particularly interested in the future role of corporations that develop and deploy GM crops.

3.9 Corporations and the future of agriculture

Participants generally perceived a conflict between the goals of farmers, on the one hand, and those of GM crop developers and agri-business corporations on the other. They indicated that their vision for the future was multi-faceted, with on-farm profitability being an important priority, but one that existed within a larger context of more complex social and environmental values. Those interviewed believed that corporations did not have the same sort of commitment to their rural communities and environments, especially given that corporations were largely focused on short-term profits. One producer, referring to the situation with GM wheat, questioned how the government could allow companies to override the wishes of farmers, rural communities and consumers.

> *"They're not developing these GMOs because they think it's going to do us as consumers good and us as producers good, they're doing it because they can make a dollar out of it - or a lot of dollars! So you know, as small people in this whole process, we really have to question why our government is letting this happen"* (Melissa, organic farmer, Manitoba)

Another believed that the lack of government intervention regarding GM wheat on behalf of farmers, consumers, commodity and environmental groups, had to do with the nature of trade agreements between Canada and the US. He felt that these agreements would compromise the ability of the Canadian government to stop Monsanto from introducing RR wheat.

"No we have no control. Our federal government has no control and the reason I say our federal government has no control is because of the NAFTA and the Free Trade Agreement. Anybody who has looked at those two agreements will understand that if our federal government were to step in tomorrow and say Monsanto you cease and desist all development of your Roundup Ready wheat, Monsanto would just say 'well that's fine then, this is how much money you owe us'. And under the NAFTA and the Free Trade Agreement the federal government has to pay them that money" (Bradley, minimum tillage farmer, HT user, Manitoba)

Many of those interviewed more broadly discussed how little control farmers and rural communities had over the future of agriculture, and how that control continued to decline. They believed the disparity in market power - whereby companies have enormous wealth and influence and farmers have little if any influence – inevitably put farmers at a disadvantage. One expressed that this imbalance manifested itself in the battle for control and the eventual corporate takeover of seed supply.

"Like it just seems like we really don't have control on what we do anymore. I think pretty soon we are going to be told what to grow...that's probably going to be the next step" (Troy, minimum tillage farmer, HT user, Manitoba)

Those interviewed commented on these power dynamics that exist in agriculture. Much of this discussion focused on the role of technology and how it operated, simultaneously providing short-term benefit at the long-term expense of independence and self-determination. One of the organic farmers believed it was important to step outside these power relations and find methods to appropriate technology.

"We have to start making technology work for us, rather then us working for the technology. Any farmer out there or even consumers out there, if you sit down and if the bulk of what you are doing is going to pay for the gadgets and the toys and what not, then you're working for them, they're not working for you anymore. And that's the way it is with genetic modification and so on. Is this something we can

make work for us or are we going to end up working for it? And at 15 or 20 bucks an acre (the cost of a TUA) we're going to end up working for it" (Andrew, organic farmer, Manitoba)

Many talked about being in financial trouble due to disparity between the high costs of inputs (e.g. farm machinery, fuel, pesticides, and GM seed) and the low prices they continued to receive for their crops. Reflecting on corporate patents over GM crops and farmer livelihood, one participant stated:

> *"I don't think anyone should own nature, nature was created by God to give to the people on the earth and that's where it should stay...I think it's just the chemical companies...are getting fat and the farmers are getting skinnier all the time"* (Lynda, vegetable farmer, Alberta)

Users of HT canola indicated that they were trying to remedy the small returns per unit area by increasing the amount of land that they farmed. The use of this technology allowed them to cover a greater area, due to ease and efficacy of weed control. While this seemed to be working for some farmers, others indicated that this strategy was short-lived and that it ultimately exacerbated their already tight financial circumstances.

> *"Now I thought it was best, because you're making a small amount of money per acre profit, if you just keep going more acres more acres more acres. Like that's how you make more money - but it doesn't help"* (Troy, minimum tillage farmer, HT user, Manitoba)

Indeed, farmers felt that the resulting increases in farm size arguably contributed to further rural depopulation and rural decline. Linking this rural decline with GM crops, one farmer stated:

> *"If we continue to depopulate the country side and to promote these biotech agendas and yet we continue to loose farms who are we going to be producing*

this seed for?... were not going to have any [farmers] *left"* (Stuart, mixed grain, cattle, and vegetable farmer, Ontario)

Many referred to this ongoing rural decline in Canada and the associated stress and ensuing despair. Indeed, many spoke bleakly about the future.

"My boys, I don't really want them to farm anymore, and I don't think there will be opportunities going for them anyway. I suspect within ten or fifteen or twenty years, at the most, this farm will not be economically viable anymore. Because of all these factors...there's just really little sunshine in the picture, I guess, for the future of agriculture, for me and my family" (Shaun, minimum tillage farmer, HT user, Manitoba)

While expressing general optimism about the importance of their operations and their livelihoods, many repeatedly underscored the importance of the crisis that confronts agriculture and agriculturalists. They were highly critical of the increasing corporate control of agriculture, harsh economic realities for farmers, and the unsubstantiated claims that HT crops would solve these problems. Regardless of farming approach or worldview, they all recognized that something had to change if agriculture was to be economically and socially sustainable for rural residents. Some, especially organic farmers, indicated that society needed to deeply question what kind of agriculture it wanted. Indeed, one believed that this process of questioning must start with the re-definition of the concept of progress:

"That's something as a society that we have never ever done, we've never sat down and said – 'what is progress?' What is progress? If we are all out driving in a car and all of sudden the landscape starts to look familiar and we think we've been here before, and we want to go somewhere different, we think - is the answer to get into a bigger car and go faster? Is that going to get us somewhere different? No, we have to change directions. And as long as we leave the likes of Monsanto in the driver's seat, we are going to keep going around the same circle. And as long as they can keep making money off of us, we'll just keep on going around that

same circle. And it's about time that we stopped the car and said 'well, let's get out and walk around a little bit, and smell the grass, and hear the birds, and figure out where do we want to go here'. What is progress?" (Andrew, organic farmer, Manitoba)

4. DISCUSSION

The results of this study demonstrate the mix of benefits and risks that GM crops – specifically HT canola and HT wheat - pose for farmers across Canada. This research is amongst the first to document farmer local knowledge (LK) regarding GM crops, particularly in North America, and is likely the only study that has used video to accomplish this. The farmer statements presented here reflect a portion of the overall interviews conducted and included in the larger research documentary developed with participants. Given that "the medium is the message" (McLuhan, 1964), our written and video research stand as unique but related academic works, and the merits of each in relation to the issue of GM crops in agriculture will be discussed.

Farmers using herbicide-tolerant (HT) canola indicated that it provided significant benefit, particularly regarding ease-of-use, convenience, effective weed control, and, sometimes, increased yield and profitability. These findings consistent with an industry-funded report (CCC, 2001) and a subsequent large-scale survey we conducted in Manitoba (Mauro and McLachlan, 2008). These benefits are great enough that over 90% of canola growers across the prairies now use HT varieties (Buth, 2006). While these benefits are well understood and communicated widely, (Devine, 2005), less is known about the risks that GM crops pose for farmers and rural communities (Mehta, 2005). Our results indicate that HT crops represent substantial and often unappreciated challenges for individual farmers, rural communities, and the environment.

Interviewed farmers viewed HT trait contamination as the primary risk associated with the technology. Movement of HT canola traits was associated with cross-pollination, persistence and growth of HT volunteers, wind blowing swathed crops, tractors and other seed handling equipment, and, indeed, the outright contamination of seed supply. Although HT canola was commercially released in Canada in 1995, it was not until much later that three-way HT trait stacking (Hall et al., 2000) and large-scale pollen mediated gene flow (Rieger et al., 2002) were identified for canola. Extensive trait movement adversely affected many of the farmers in this study, including one who experienced double-resistant canola. Indeed, it is likely responsible for the contamination of pedigreed non-HT canola seed stocks across the Canadian prairies (Downie and Beckie, 2002; Friesen et al., 2003). This contamination has contributed to the loss of seed canola as a crop in parts of the region and has, in turn, created additional agronomic, corporate control, and economic hardships for producers.

Farmers practicing conservation tillage, organic methods, and seed saving were especially at risk from contamination, believing that HT crops might compromise, and in some cases had already compromised, their operations and livelihoods. The widespread and effective use of glyphosate (i.e. Roundup) for pre-seeding weed control by those practicing conservation tillage has been undermined by the spread of Roundup Ready (RR) volunteer canola. Most indicated that these problems would be exacerbated by the introduction of RR wheat. In turn, these problems might contribute to the decline in use of direct seeding systems and their widely recognized environmental benefits, these including reduced erosion, increased soil health, water conservation, carbon sequestration, and wildlife habitat (Van Acker et al., 2003).

Organic farmers in our study indicated that they could no longer grow canola due to the high probability of contamination by HT traits, a problem they also feared with RR wheat, as these crops are not permitted under their certification standards. Indeed, organic farmers in the US also find themselves to be at especially high risk from contamination by GM crops (Walz, 2004). This loss of livelihood formed the basis for a class action lawsuit against Monsanto and Bayer by organic farmers in Saskatchewan (Phillipson, 2005). They had hoped to establish corporate liability for the contamination, associated cleanup costs, and market loss caused by the introduction of GM canola, and had proposed an injunction against the introduction of RR wheat (Bouchie, 2002). However, these farmers were rejected class action certification in 2007 and the issue of corporate liability for damages caused by GM crops remains unresolved.

Farmers in our study were concerned that HT contamination might affect their ability to ensure seed purity, leading to the accidental planting of saved seed with HT traits, and potential financial and legal repercussions. This issue was recently addressed by the landmark Supreme Court of Canada decision on *Monsanto versus Schmeiser* (McLachlin and Fish, 2004). It essentially upheld industry's intellectual property claims over GM seeds and plants, making farmers liable for patent infringement, despite the fact that they may be planting their own seed that was inadvertently contaminated by HT traits (Gold and Adams, 2001; Cullet, 2005).

Many of those interviewed found that industry did not accept adequate responsibility for the problems and risks caused by HT crops, once they had been planted. Other studies have similarly observed that biotechnology firms seem to be driven by short-term profit, this taking precedence over and having adverse and long-term environmental and social consequences (e.g. Kneen, 1999; Tokar, 2001; Bailey and Lappe, 2002; Mendelson, 2002; Paul et al., 2003). One farmer, who had double-stacked glyphosate-tolerant canola contaminate his fields, was clearly upset by Monsanto's apparent lack of support, and the other that was sued believed that the company created new risks for farmers due to these aggressive legal tactics.

Another farmer was particularly concerned about the introduction of Terminator Technology – a type of Genetic Use Restriction Technology (**GURT**) - and its proposed use in preventing problems with contamination and volunteers (Van Acker et al., 2007). He believed it would prevent farmers from saving, reusing and sharing their seed, yet he recognized that farmers were already relinquishing these rights through contracts with seed companies such as the Technology Use Agreements (TUAs) that are regularly signed with Monsanto. While Terminator Technology has received considerable attention (Service, 1998; Masood, 1998; Conway and Toenniessen, 1999; Kaiser, 2000) and continues to do so because of a recent attempt to weaken the UN *defacto* moratorium on its use (ETC Group, 2006), few studies have documented farmer attitudes toward this technology. Indeed, this study helped inform a subsequent survey, where we found that 75% of Manitoba farmers disagreed that Terminator Technology would help to contain GM traits (Mauro and McLachlan, 2008).

Farmers in this study were unified in their vehement opposition to the commercial introduction of Monsanto's RR wheat, the world's first GM wheat. Rejection of the crop was subsequently expressed by a broad-based coalition of farm organizations that launched the "We're not ready for Roundup Ready wheat" campaign (CWB, 2003) and a related study indicates that 86% of farmers in Manitoba (Mauro and McLachlan 2003) and almost 90% of farmers across the Canadian prairies (Mauro, 2008; C7) opposed its introduction. Those interviewed believed that RR wheat would escape and become ubiquitous across the landscape causing problems similar to those associated with HT canola. Moreover, farmers felt that having both RR canola and wheat in rotation would exacerbate these problems, as volunteers from each crop would be difficult to control in the other. In addition, farmers also feared that international consumer opposition to GM wheat could compromise markets. Indeed, 82% of grain buyers around the world indicate they would not purchase GM wheat if it were grown and marketed in North America (Wells and Penfound, 2003; Wisner, 2003; 2005) The high profile battle waged by Canadian farmers against the RR wheat played an important role in the decision by Monsanto to delay the release of this crop (Stokstad, 2004)

All farmers expressed concern about the increases in control over government and agricultural policy by corporations, and the implications that this control has for their livelihoods and their communities. The complex and often adverse consequences of industrial control, and associated absentee-ownership, contract production and technology diffusion, for rural communities have been well documented for California in the early 1940s (Goldschmidt, 1978), the poultry industry (Heffernan, 1972), and more recently throughout the US (Lobao, 1990) and Canada (NFU, 2003). The need for a more democratic, farmer-oriented and sustainable approach to agriculture was voiced by most farmers in this study, and has been strongly advocated for by the international, farmer-led "food sovereignty" movement (Via Campesina, 2006).

Our use of participatory video helped democratize the research process, by getting the farmers to assist in the development and analysis of the project, while making the information relevant and accessible to other farmers, rural communities and, indeed, all that are interested in these issues. Our research video that was created as part of this project, *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture*[iv], has been screened in major cities and rural communities worldwide, and has been downloaded for free from our website by citizens, farm groups and policy makers. Since its release in 2005, our film has been watched online over 330,000 times and rural organizations in many countries continue to use it as an educational resource, organizing tool, and fundraiser. Despite the effectiveness of video as a communication tool, it has yet, in-of-itself, to be widely accepted as a valid form of research in many academic institutions.

In most empirical studies, interviews are generally transcribed into text for subsequent analysis (Patton, 2002). This written approach is important, especially given that it allows results to be compared with the literature, as was conducted in this study. However, advances in video technology are creating new and cost effective opportunities for qualitative research (Secrist et al., 2002). Video allowed farmers to speak for themselves and, arguably, it is more compelling and accessible than written transcripts in academic publications. Further, given that local knowledge (LK) is transmitted orally and embedded within a cultural context (Kloppenburg, 1991), we argue that video is a more appropriate methodology for collecting and presenting this qualitative information, especially when guided by a participatory and farmer-centered approach

While video research has many benefits, it is time consuming, requires smaller sample sizes due to the intensity of data analysis and management, may have unique legal implications (e.g. release forms, copyright issues, etc), and specialized equipment (e.g.

cameras, computers, editing software etc.), which can still be expensive and requires its own technological expertise (Mauro et al., 2003). However, video research is a rewarding method for participants and scholars alike, and facilitates the documentation and communication of oral history and experiential knowledge. Although our video methodology required smaller sample sizes, it allowed us to engage participants and document their rich knowledge, and in a subsequent study we found that these results were generalizable across large geographical scales in the Canadian prairies (Mauro and McLachlan, 2008).

In North America, GM crop regulation continues to rely on "science-based" risk assessment (Carr and Levidow, 2000), which generally fails to include any larger social, cultural and economic implications (Auberson-Huang, 2002). The seeming failure on the part of industry and regulators to anticipate the diversity of risks associated with GM canola and wheat, as presented in this study, demonstrates the limitations of this approach, and suggests that a new and more inclusive approach to risk assessment is required. We have clearly shown that farmer LK can make a valuable contribution to the GM crop debate, a contribution which might complement and add to scientific approaches to risk assessment, and which would help us better understand and manage both the benefits and risks associated with this technology. Adopting a more inclusive and farmer-focused approach to risk assessment might help grow a more democratic system for GM crop evaluation and deployment, and ultimately might plant the real seeds of change.

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[i] HT crops: All crops are naturally tolerant to some herbicides. Recently, however, herbicide-tolerant (HT) crops have been created using techniques such as conventional breeding, recombinant DNA technology and mutagenesis, which allow them to be sprayed with herbicides that would otherwise kill them. A number of HT crops have been commercialized including, corn, soybean, cotton, rice, wheat, sunflower and canola. In Canada, three HT canolas are available: Roundup Ready (RR), Liberty Link (LL) and Clearfield (CF), tolerant to glyphosate, glufosinate and imidazolinone herbicides, respectively. Both RR and LL were developed using recombinant DNA technology, whereas, CF is a mutagenic crop. For the purpose of this paper, all three of the HT canolas are considered to be GM, although not all are transgenic.

[ii] Conservation tillage: is an agricultural system that promotes crop production without disturbing the soil through tillage. It helps minimize soil compaction and erosion while retaining important soil moisture. Instead of tillage, farmers largely use herbicides to "chemically weed" their fields; largely with those that are non-selective like glyphosate. Variations of conservation tillage are practiced, from reduced tillage, which allows for some tilling, to zero tillage whereby farmers do not till at all, instead seeding directly into stubble from a previous harvest.

[iii] Organic farming: is an agricultural production system that relies on ecosystem management and which attempts to reduce or eliminate a reliance on off-farm inputs, especially synthetic ones, such as fertilizers, pesticides and genetically modified (GM) crops. It promotes and attempts to enhance biodiversity, biological cycles and soil biological activity, while recognizing the importance of locally adapted food systems.

[iv] Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture: is a documentary film co-directed by I.J. Mauro, S.M. McLachlan and J. Sanders. Developed as part of this research programme, it is a distinct research product that investigates farmer experiences in the Canadian prairies and includes expert testimony and a larger discussion about the benefits of GM crops. It is available free for download and streaming from our website: www.seedsofchangefilm.org.

REFERENCES

Apple. (2004). *Final Cut Pro HD Online Reference Manual.* US: Apple Software. Available at: www.apple.com/finalcutstudio/finalcutpro/

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology, 20,* 1076-1078.

Bailey, B., & Lappe, M. (Eds). (2002). *Engineering the Farm: Ethical and Social Aspects of Agricultural Biotechnology.* Washington: Island Press.

Bell, I. (2002). Compensation for Clearfield. *Western Producer,* August 8.

Bennett, R., Kambhampati, U., Morse, S., & Ismaelm Y. (2006). Farm-Level Economic Performance of Genetically Modified Cotton in Maharashtra, India. *Review of Agricultural Economics, 28,* 59-71.

Bernard, J. C., Pesek, J. D., & Fan, C. (2004). Delaware farmers' adoption of GE soybeans in a time of uncertain U.S. adoption. *Agribusiness, 20,* 81-94.

Beus, C. & Dunlap, R (1990). Conventional vs alternative agriculture: the paradigmatic roots of the debate. *Rural Sociology, 55,* 590-616.

Braimoh, A. K. (2002). Integrating indigenous knowledge and soil science to develop a national soil classification system for Nigeria. *Agriculture and Human Values, 19,* 75-80.

Bouchie, A. (2002). Organic farmers sue GMO producers. *Nature Biotechnology, 20,* 210

Brook, R.K., & McLachlan, S.M. (2005). On using expert-based science to 'test' local ecological knowledge a response to : Gilchrist et al. 2005. 'Can local ecological knowledge contribute to wildlife management? Case Studies of Migratory Birds'. *Ecology and Society.* Available at: www.ecologyandsociety.org/vol10/iss2/resp3/

Brook, R.K, & McLachlan, S.M. (2006). Factors influencing farmers' concerns regarding bovine tuberculosis in wildlife and livestock around Riding Mountain National Park. *Journal of Environmental Management, 80,* 156-166.

Brookes, G. (2005). The farm-level impact of herbicide-tolerant soybeans in Romania. *AgBioForum, 8,* 235-241.

Brookes, G., & Barfoot, P. (2005). GM crops: The global economic and environmental impact - the first nine years 1996-2004. *AgBioForum, 8,* 187-196.

Brooks, D. R., Bohan, D. A., Champion, G.T., Haughton, A.J., Hawes, C., Heard, M.S., Clark, S.J., Dewar, A.M., Firbank, L.G., Perry, J.N., Rothery, P., Scott, R.J., Woiwod, I.P., Birchall, C., Skellern, M.P., Walker, J.H., Baker, P., Bell, D., Browne, E.L., Dewar, A.J.G., Fairfax, C.M., Garner, B.H., Haylock, L.A., Horne, S.L., Hulmes, S.E., Mason, N.S., Norton, L.R., Nuttall, P., Randle, Z., Rossall, M.J., Sands, R.J.N., Singer, E.J., & Walker, M.J. (2003). Invertebrate responses to the management of genetically modified herbicide-tolerant and conventional spring crops. I. Soil-surface-active invertebrates. *Philosophical Transactions of the Royal Society (London), 358,* 1847-1862.

Buth, J. (2006). *Canadian herbicide-tolerant canola statistics.* Canola Council of Canada Internal Report. Winnipeg, MB, Canada.

CCC (Canola Council of Canada). (2001). *An Agronomic and Economic Assessment of Transgenic Canola.* Report Prepared by Serecon Consulting and Koch Paul

Associates. Winnipeg, MB. Available at www.canola-council.org/report_gmo.html

Carr, S. and L. Levidow (2000). Exploring the links between science, risk, uncertainty, and ethics in regulatory controversies about genetically modified crops. *Journal of Agricultural & Environmental Ethics, 12*, 29-39.

Chambers, R. (1983). *Rural Development: putting last first.* New York: Longman Group Limited.

Chambers, R., A. Pacey and L.A. Thrupp (1989). *Farmer First: Farmer innovation and agricultural research.* London, Intermediate Technology Publications.

Chimmiri, N., Tudor, K.W., and Spaulding, A.D. (2006). An Analysis of McLean County, Illinois Farmers' Perceptions of Genetically Modified Crops. *Agbioforum, 9*, 152-165.

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research, 8*, 617-634.

Clark, E.A. (2006). Environmental risks of genetic engineering. *Euphytica, 148*, 47-60.

Cleveland, D.A., & Soleri, D. (2005). Rethinking the risk management process for genetically engineered crop varieties in small-scale, traditionally based agriculture. *Ecology and Society, 10,* Available at: http://www.ecologyandsociety.org/vol10/iss1/art9/.

Conway, G., & Toenniessen, G. (1999). Feeding the world in the twenty-first century. *Nature, 402*, C55-C58.

Cook, G. (2004). *Genetically Modified Language: The Discourse of Arguments for GM crops and Food.* New York: Routledge.

Cook, A., & Fairweather, J. R. (2003). New Zealand farmer and grower intentions to use gene technology: results from a resurvey. *AgBioForum, 6,* 120-127.

Cullet, P. (2005). Monsanto v Schmeiser: A landmark decision concerning farmer liability and transgenic contamination. *Journal of Environmental Law, 17*, 83-108.

CWB. (2003). *We're Not Ready for Roundup Ready Wheat.* Canadian Wheat Board, Winnipeg, MB. Accessed on March 18 at www.cwb.ca/en/topics/biotechnology/roundup/index.jsp

Dahlberg, K. (2001). Democratizing society and food systems: Or how do we transform modern structures of power? *Agriculture and Human Values, 18,* 135-151.

Demeke, T., Perry, D. J., & Scowcroft, W. R. (2006). Adventitious presence of GMOs: Scientific overview for Canadian grains. *Canadian Journal of Plant Science, 85,* 1-23.

Devine, M. D. (2005). Why are there not more herbicide-tolerant crops? *Pest Management Science, 61*, 312-317.

Dewar, A. M., May, M. J., Woiwod, I. P., Haylock, L. A., Haylock, G. T., Champion, G. T., Garner, B. H., Sands, R. J. N., Qi, A., & Pidgeon, J. D. (2003). A novel approach to the use of genetically modified herbicide tolerant crops for environmental benefit. *Proceedings for the Royal Society (London), 270*, 335-340.

Dey, I. (1999). *Grounding Grounded Theory: Guidelines for Qualitative Inquiry.* New York: Academic Press.

Downie, R.K., & Beckie, H. (2002). *Isolation effectiveness in canola pedigree seed production*. Internal Research Report. Saskatoon, SK: Agriculture and Agri-Food Canada, Saskatoon Research Center.

Ellstrand, N., Prentice, H. C., & Hancock, J. F. (1999). Gene flow and introgression from domesticated plants into their wild relatives. *Annual Review of Ecology and Systematics*, *30*, 539-563.

ETC Group. (2006). UN upholds moratorium on terminator seed technology. *Ban Terminator Campaign News Release* (Ottawa). Available at: www.etcgroup.org/search.asp?slice=english&type=news

Falk, M. C., Chassy, B. M., Harlander, S. K., Hoban, T. J., McGloughlin, M. N., & Akhlaghi, A. R. (2002). Food biotechnology: benefits and concerns. *Journal of Nutrition*, *132*, 1384-1390.

Fliert, E., & Braun, A. R. (2002). Conceptualizing integrative, farmer participatory research for sustainable agriculture: From opportunities to impact. *Agriculture and Human Values*, *19*, 25-38.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology*, *42*, 1181-1193.

Friesen, L. F., Nelson, A. G., & Van Acker, R. C. (2003). Evidence of contamination of pedigreed canola (*Brassica napus*) seedlots in western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal*, *95*, 1342-1347.

Fulton, M. and Keyowski, L. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum*, *2*, 85-93.

Gepts, P. (2002). A comparison between crop domestication, classical breeding, and genetic engineering. *Crop Science*, *42*, 1780-1790.

Glaser, B., & Strauss, A. (1967). *The Discovery of Grounded Theory.* New York: Aldine, Hawthorne.

Gold, E.R., & Adams, W.A. (2001). The Monsanto decision: The edge or the wedge. *Nature Biotechnology*, *19*, 587.

Goldschmidt, W. (1978). *As You Sow: Three Studies in the Social Consequences of Agribusiness*. Montclair, NJ: Allanheld, Osmun, and Co.

Hall, L., Topinka, K., Huffman, J., & Good, L. (2000). Pollen flow between herbicide-resistant *Brassica napus* is the cause of multiple-resistant *B. napus* volunteers. *Weed Science*, *48*, 688-694.

Hansen, J., Holm, L. Frewer, L., Robinson, P., & Sandoe, P. (2003). Beyond the knowledge deficit: Recent research inot lay and expert attitudes toward food risk. *Appetite*, *41*, 111-121.

Harrison, C. M., Burgess, J., & Clark, J. (1998). Discounted knowledges: farmers' and residents' understandings of nature conservation goals and policies. *Journal of Environmental Management*, *54*, 305-320.

Haughton, A. J., Champion, G. T., Hawes, C., Heard, M.S., Brooks, D.R., Bohan, D.A., Clark, S.J., Dewar, A.M., Firbank, L.G., Osborne, J.L. , Perry, J.N., Rothery, P., Roy, D.B., Scott, R.J., Woiwood, I.P., Birchall, C., Skellern, M.P., Walker, J.H., Baker, P., Browen, E.L., Dewar, A.J.G., Garner, B.H., Haylock, L.A., Horne, S.L., Mason, N.S., Sands, R.J.N., & Walker, M.J. (2003). Invertebrate responses to the management of genetically modified herbicide-tolerant and conventional spring crops. II. Within-field epigeal and aerial arthropods. *Philosophical Transactions of the Royal Society (London), 358*, 1863-1877.

Heard, M. S., Hawes, C., Champion, G.T., Clark, S.J., Firbank, L.G., Haughton, A.J. Parish, A.M., Perry, J.N., Rothery, P., Scott, R.J., Skellern, M.P., Squire, G.R., & Hill, M.O. (2003a). Weeds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. I. Effects on abundance and diversity. *Philosophical Transactions of the Royal Society (London)*, 358, 1819-1832.

Heard, M. S., Hawes, C., Champion, G.T., Clark, S.J., Firbank, L.G., Haughton, A.J., Parish, A.M., Perry, J.N., Rothery, P., Roy, D.B., Scott, R.J., Skellern, M.P., Squire, G.R., & Hill, M.O. (2003b). Weeds in fields with contrasting conventional and genetically modified herbicide-tolerant crops. II. Effects on individual species. *Philosophical Transactions of the Royal Society (London), 358*, 1833-1846.

Heffernan, W.D. (1972). Sociological dimensions of agricultural structures in the United States. *Sociologia Ruralis, 12*, 481-499.

Horsch, R. B. (1993). Commercialization of genetically engineered crops. *Philosophical Transactions: Biological Sciences, 342*, 287-291.

Ismael, Y., Bennett, R., & Morse, S. (2002). Benefits from Bt cotton Use by Smallholder Farmers in South Africa. *Agbioforum, 5*, 1-5

James, C. (1997). Global status of transgenic crops in 1997. International Service for the Acquisition of Agri-Biotech Applications. Available at: www.isaaa.org/kc/bin/isaaa_briefs/index/htm.

Kaiser, J. (2000). USDA to commercialize 'Terminator' Technology. *Science, 289*, 709-710.

Kennedy, T.J., & Lingard, L.A. (2006). Making sense of grounded theory in medical education. *Medical Education, 40*, 101-108.

Kloppenburg, J. (1991). Social-Theory and the De Reconstruction of Agricultural Science - Local Knowledge for an Alternative Agriculture. *Rural Sociology, 56*, 519-548.

Kneen, B. (1999). *Farmageddon: Food and the Culture of Biotechnology.* Gabriola Island: New Society Publishers.

Lawton, M. (2003). Management of herbicide tolerant crops and future research. In Canadian Food Inspection Agency (CFIA) (eds.), *Technical workshop on the management of herbicide tolerant (HT) crops.* September 9-10. Ottawa, ON. Available at: www.inspection.gc.ca/english/bio/consult/herbtolrepe.shtml#13.

Leiss, W. (2001). *In the Chamber of Risks: Understanding Risk Controversies.* Montreal, Quebec, McGill-Queens University Press.

Lobao, L.M. (1990). *Locality and Inequality: Farm and Industry Structure and Socioeconomic Conditions.* Albany: State Unversity of New York Press.

Macer, D., & Chen Ng, M. A. (2000). Changing attitudes to biotechnology in Japan. *Nature Biotechnology, 18*, 945-947.

Macey, A. (2005). *Organic Statistics 2004: Manitoba.* Certified organic production in Canada Report. Canadian Organic Growers and Agriculture and Agri-Food, Ottawa, ON.

Marvier, M. (2002). Improving risk assessment for nontarget safety of transgenic crops. *Ecological Application*, *12*, 1119-1124.

Masood, E. (1998). Monsanto set to back down over 'terminator' gene? *Nature*, *396*, 503.

Mauro, I.J., & McLachlan, S.M. (2008). Farmer knowledge and risk analysis: Postrelease evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis*, *28*, 463-476.

Mauro, I. J., S. M. McLachlan, and L. Higgins (2003). *Exploring the use of video as a tool for research and community development.* Paper read at Rural Sociology Annual Meeting, at Montreal, QC. July 29.

Maxwell, J. A. (2005). *Qualitative Research Design: An Interactive Approach.* Thousand Oaks, California, Sage Publications.

McBride, W. D., & Books, N. (2000). Survey evidence on producer use and costs of genetically modified seed. *Agribusiness*, *16*, 6-20.

McDougall, D., Longnecker, N. E., Marsch, S. P., & Smith, F. P. (2001). Attitudes of pulse farmers in western Australia towards genetically modified organisms in agriculture. *Australasian Biotechnology*, *11*, 36-39.

McLachlin, C.J., & Fish, J.J. (2004). *Monsanto Canada Inc. versus Schmeiser.* S.C.R. 902. Supreme Court of Canada, Ottawa, ON. May 21. Available at: www.scc.lexum.umontreal.ca/en/2004/2004scc34/2004scc34.html

McLuhan, M. (1964). *Understanding Media: The Extensions of Man* (pp. 1-20). New York: McGraw Hill.

Mendelson, J. (2002). Untested, unlabeled, and you're eatting it: The heatlth and environmental hazards of genetically engineered food. In A. Kimbrell (Ed.), *The Fatal Harvest Reader: The Tragedy of Industrial Agriculture.* Washington, DC: Island Press.

Middendorf, G., Skladany, M., Ransom, E., & Busch, L. (2000). New agricultural biotechnologies: The struggle for democratic choice. In F. Magdoff, J. Bellamy Foster, & F.H. Buttel (Eds.), *Hungry For Profit: The Agribusiness Threat to Farmers, Food, and the Environment.* New York: Monthly Review Press.

Middendorf, G., & Busch, L. (1997). Inquiry for the public good: Democratic participation in agricultural research. *Agriculture and Human Values*, *14*, 45-57.

Millar, J., & Curtis, A. (1999). Challenging the boundaries of local and scientific knowledge in Australia: Opportunities for social learning in managing temperate upland pastures. *Agriculture and Human Values, 16*, 389-399.

Morgan, K., & Murdoch, J. (2000). Organic vs. conventional agriculture: knowledge, power and innovation in the food chain. *Geoforum*, *31*, 159-173.

Nap, J.P., Metz, P.L., Escaler, M., & Conner, A.J. The release of genetically modified organisms into the environment: Overview of current status and regulations. *The Plant Journal*, *33*, 1-18.

NFU (National Farmers Union). (2003). *The Farm Crisis, Bigger Farms, and the Myths of 'Competition' and 'Efficiency'.* Saskatoon, Saskatchewan. Available at: www.nfu.ca/publications

Patton, M. J. (2002). *Qualitative Research and Evaluation Methods: 3rd Edition.* London: Sage Publications.

Paul, H., Steinbrecher, R., Kuyek, D., & Michaels, L. (2003). *Hungry Corporations: Transnational Biotech Companies Colonise the Food Chain.* New York: Zed Books

Phillipson, M. (2005). Giving away the farm? The rights and obligations of biotechnology multinationals: Canadian developments. *King's College Law Journal, 16*, 362-372.

Phipps, R. H., & Park, J. R. (2002). Environmental benefits of genetically modified crops: Global and European perspectives on their ability to reduce pesticide use. *Journal of Animal and Feed Sciences, 11*, 1-18.

Priest, S. H. (2000). US public opinion divided over biotechnology? *Nature Biotechnology, 18*, 939-942.

Qaim, M., & de Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. *American Journal of Agricultural Economics, 85*, 814-828.

Qaim, M., & Zilberman, D. (2003). Yield effects of genetically modified crops in developing countries. *Science, 299*, 900-902.

Quist, D., & Chapela, I. H. (2001). Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. *Nature, 29*, 541-543.

Rieger, M. A., Lamond, M., Preston, C., Powles, S. B., & Roush, R. T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science, 296*, 2386-2388.

Rissler, J., & Melon, M. (1996). *The Ecological Risk of Engineered Crops.* Cambridge, MIT Press.

Roy, D. B., Bohan, D. A., Haughton, A. J., Hill, M. O., Osborne, J. L., Clark, S. J., Perry, J. N., Rothery, P., Scott, R. J., Brooks, D. R., Champion, G. T., Hawes, C., Heard, M. S., & Firbank, L. G. (2003). Invertebrates and vegetation of field margins adjacent to crops subject to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. *Philosophical Transactions of the Royal Society (London), 358*, 1879-1898.

Scholdlerer, J., & Frewer, L. (2003). The biotechnology communication paradox: Experimental evidence and the need for a new strategy. *Journal of Consumer Policy, 26*, 125-157.

Secrist, C., Koeyer, I., Bell, H., & Fogel, A. (2002). Combining digital video technology and narrative methods for understanding infant development. *Forum: Qualitative Social Research, 3*, Available at: www.qualitative-research.net/fqs-texte/2-02/2-02secristetal-e.htm

Service, R. F. (1998). Seed-sterilizing 'Terminator Technology' sows discord. *Science 282*, 850-851.

Soleri, D., Cleveland, D. A., Aragon C., F., Fuentes L., M. R., Rios L., H., & Sweeny, S. H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research, 4*,141-166

Statistics Canada (2006a). *Estimated Areas, Yield, Production, Average Farm Price and Total Farm Value of Principle Field Crops, In Imperial Units, Annual, 1908-2006*, CANSIM Agriculture Statistics Database.

Statistics Canada (2006b). *Snapshot of Canadian Agriculture*. Available at http://www.statcan.ca/english/agcensus2006/articles/snapshot.htm

Stokstad, E. (2004). Monsanto pulls the plug on genetically modified wheat. *Science, 304*, 1088-1889.

Stringam, G. R., Ripley, V. L., Love, H. K., & Mitchell, A. (2003). Transgenic herbicide tolerant canola - The Canadian experience. *Crop Science*, *43*, 1590-1593.

Sumberg, J., Okali, C., & Reece, D. 2003. Agricultural research in the face of diversity, local knowledge and the participation imperative: theoretical considerations. *Agricultural Systems*, *76*, 739-753.

Taylor-Gooby, P. (2006). Social divisions of trust: Skepticism and democracy in the GM nation? *Journal of Risk Research*, *9*, 75-95.

Tokar, B. (Ed). (2001). *Redesigning Life?: The Worldwide Challenge to Genetic Engineering.* Montreal: McGill-Queens University Press

Tsouvalis, J., Seymour, S., & Watkins, C. (2000). Exploring knowledge-cultures: precision farming, yield mapping, and the expert-farmer interface. *Environment and Planning A*, *32*, 908-924.

Van Acker, R. C., Brule-Babel, A. L., & Friesen, L. F. (2003). *An Environmental Safety Assessment of Roundup Ready Wheat: Risks for Direct Seeding Systems in Western Canada.* Canadian Wheat Board Report for Submission to The Canadian Food Inspection Agency, Winnipeg, MB. Available at: www.cwb.ca/en/topics/biotechnology/report/pdf/070803.pdf

Van Acker, R.C., Szumigalski, A.R., & Friesen, L.F. (2007). The potential benefits, risks and costs of genetic use restriction technologies. *Canadian Journal of Plant Science*, *87*, 753-762.

Via Campesina (2006). *What is Food Sovereignty?* Jakarta, Indonesia. Available at: www.viacampesina.org

Walz, E. (2004). *Fourth National Organic Farmers' Survey: Sustaining Organic Farms in a Changing Organic Marketplace.* Organic Farming Research Foundation, Santa Cruz, CA. Available at: www.ofrf.org/publications/index.html

Warwick, S. I., Simard, M. J., Legere, A., Beckie, H. J., Braun, L., Zhu, B., Mason, P., Seguin-Swartz, G. G., & Stewart, C. N. (2003). Hybridization between transgenic *Brassica napus L.* and its wild relatives: *Brassica rapa L., Raphanus raphanistrum L., Sinapis arvensis L.*, and *Erucastrum gallicum* (Willd.) O.E. Schulz. *Theortical Applied Genetics*, *107*, 528-539.

Wells, S., & Penfound, H. (2003). The risks of modified wheat *The Toronto Star* (Toronto), February 25.

Wilkinson, M. J., Elliott, L. J., Allainguillaume, J., Shaw, M.W., Norris, C., Welters, R., Alexander, M., Sweet, J., & Mason, D. C. (2003). Hybridization between *Brassica napus* and *B. rapa* on a national scale in the United Kingdom. *Science, 302*, 457-459.

Wisner, R. (2003). Market risks of genetically modified wheat. Iowa State University and Western Organization of Resource Councils (WORC). Available at: www.worc.org/issues/art_issues/gmwheat.html.

Wisner, R. (2005). Market impacts from commercializing Roundup Ready Wheat: Spring 2005 Update. Iowa State University and Western Organization of Resource Councils (WORC). Available at: www.worc.org/issues/art_issues/gmwheat.html

Wu, F. (2004). Explaining public resistance to genetically modified corn: An analysis of the distribution of benefits and risk. *Risk Analysis*, *24*, 715-726.

Yang, P., Iles, M., Yan, S., & Jolliffe, F. (2005). Farmers' knowledge, perceptions and practices in transgenic Bt cotton in small producer systems in Northern China. *Crop Protection*, *24*, 229-239.

Chapter 5:

Seeds of Change: Farmers, Biotechnology, and the New Face of Agriculture

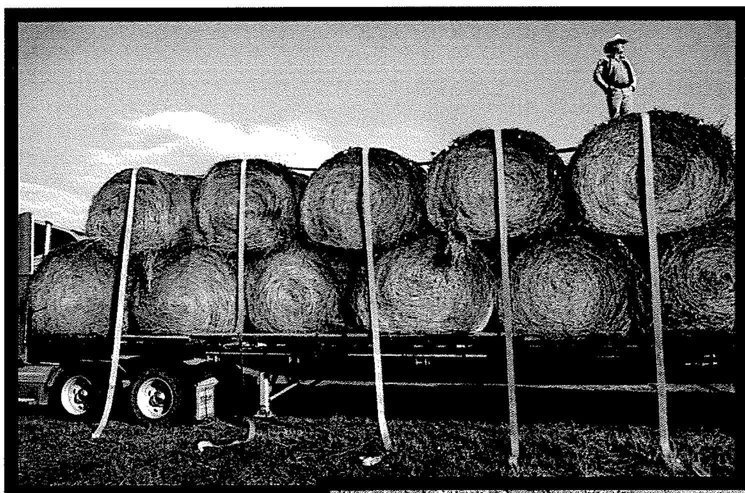
"From the first minute to the last scene, Seeds of Change is a powerful film that will change the way people think about farming and food production...it is must-see for farmers and non-farmers alike"

-Stewart Wells
President of the National Farmers Union

www.seedsofchangefilm.org

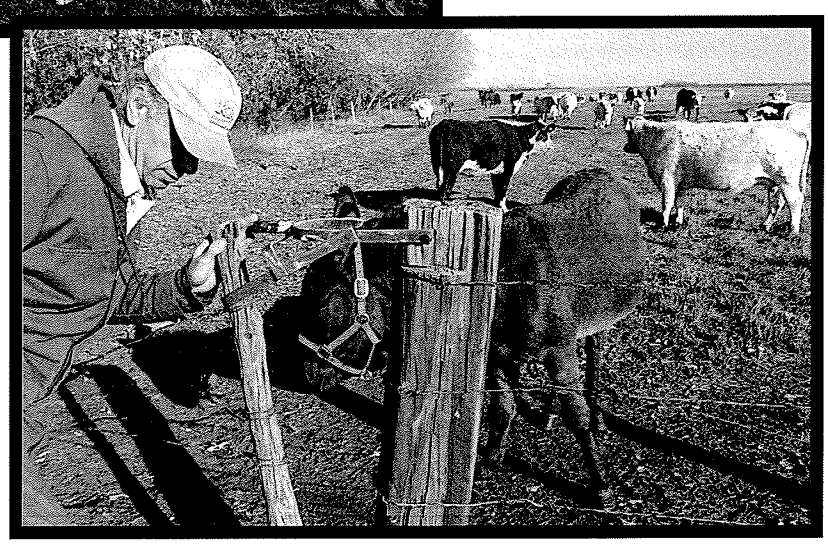
Chapter 6:

Farmer Knowledge & Risk Analysis – post release evaluation of herbicide-tolerant canola in western Canada



"The whole world is now one vast uncontrolled experiment – the way it always was, Crake would have said – and the doctrine of unintended consequences is in full spate"

Oryx & Crake by Margaret Atwood



CHAPTER SUMMARY

The global controversy regarding the use of genetically modified (GM) crops has proved to be a challenge for 'science-based' risk assessments. Although risk analysis incorporates societal perspectives in decision-making over these crops, it is largely predicated on contrasts between 'expert' and 'lay' perspectives. The overall objective of this study is to explore the role for farmers' knowledge, and their decade-long experience with herbicide tolerant (HT) canola, in the risk analysis of GM crops. From 2002 to 2003, data were collected using interviews (n=15) and mail surveys (n=370) with farmers from Manitoba and across Canada. The main benefits associated with HT canola were management oriented and included easier weed control, herbicide rotation and better weed control, whereas the main risks were more diverse and included market harm, Technology Use Agreements, and increased seed costs. Benefits and risks were inversely related, and the salient factor influencing risk was farmer experiences with HT canola volunteers, followed by small farm size and duration using HT canola. These HT volunteers were reported by 38% of farmers, from both internal (e.g. seedbank, farm machinery, etc) and external (e.g. wind, seed contamination, etc) sources, and were found to persist over time. Farmer knowledge is a reliable and rich source of information regarding the efficacy of HT crops, demonstrating that individual experiences are important to risk perception. The socio-economic nature of most risks combined with the continuing 'farm income crisis' in North America demonstrates the need for a more holistic and inclusive approach to risk assessment associated with HT crops, and, indeed, with all new agricultural technology.

1. INTRODUCTION

Society is entrenched in a global 'food fight' regarding the use of biotechnology in agriculture. Transgenic techniques, often referred to as genetic modification (**GM**) or genetic engineering (**GE**), are among the most contentious as they allow for the transfer of genes between species, resulting in genetically modified organisms (**GMOs**) that arguably have no biological antecedents (Gray, 2001). The controversy over GM crops continues unabated, is comparable to that surrounding nuclear power (Lomax, 2000), and has the potential to profoundly alter the practice of risk assessment (Bishop et al., 2001).

Since their release in the mid 1990s, the planting of GM crops around the world has increased 60-fold, this from 1.7 million ha to 102 million ha (James, 2006). The countries most committed to growing these crops are the US (54.6 million ha), Argentina (18 million ha), Brazil (11.5 million ha) and Canada (6.1 million ha) (James, 2006). The main crops that have been transformed include soybeans, cotton, maize and canola, and, as a whole, approximately 70% of the planted GM crops are herbicide-tolerant (**HT**) (James, 2006). Regulators have approved these crops for environmental release, using a 'science-based' risk assessment framework that deems them 'substantially equivalent' to their non-GM counterparts (Nap et al., 2003).

Risk assessment is regarded as an essential safety precaution prior to the release of GM crops. Its goal is to make a reasonable pre-release prediction of the behavior of a GM crop and to detect and avert potential problems (Sharples, 1991). While regulatory protocols vary somewhat around the world, GM risk assessment is generally conducted on a "case-by-case" basis that gauges the 'possibility, probability and consequences of harm' (Nap et al., 2003). This process is now becoming standardized, and scientific best practices and their ecological implications have been reviewed elsewhere (NRC, 2002; Conner et al., 2003). However, GM crop risk assessment is still criticized as lacking an overarching conceptual framework, common informational requirements, regulatory harmonization (Levin and Strauss, 1991), and statistical rigor (Marvier, 2002). Moreover, the ostensible reliance of assessment on 'substantial equivalence' has also been criticized for being 'pseudo-scientific' (Millstone et al., 1999), narrowing the scope of any considered risks (Carr and Levidow, 2000), and arguably favoring industry convenience at the expense of public safety (Abergel, 2007).

Some claim science-based risk assessments of these crops are expert-driven (Mauro and McLachlan, accepted) and generally focus on "thin" harms (e.g. physical harms including mortality, morbidity, probability of deleterious genes escaping, etc), whereas other potential "thick" harms (e.g. social disruption, economic losses, undermining of political and social institutions, etc) are normally excluded (Wachbroit, 1991). The highly restrictive and science-based regulatory structure for GM crops effectively excludes non-experts from any meaningful input (Leiss, 2001). That societal attitudes and concerns are deemed 'irrational', 'subjective' and 'foolish' (Slovic, 1999) and are therefore ignored perpetuates the controversy (Frewer et al., 2004).

Risk analysis, in contrast, incorporates both 'thick' and 'thin' harms (Jasanoff, 1993) within a broader social, cultural, economic and political context, potentially mitigating the shortcomings of conventional risk assessment (Auberson-Huang, 2002). It has made a major contribution to the debate surrounding GM crops by evaluating and promoting the importance of perceptions and participation of stakeholders. A more inclusive approach to risk assessment is gaining acceptance (Arvai, 2003), although agreement on how this might be achieved remains a challenge (Anex and Focht, 2002).

Importantly much of the risk analysis literature is predicated on contrasts between 'expert' and 'lay' conceptions of risk (Rowe and Wright, 2000), and other forms of experience, indeed, expertise, are rarely considered (Barnett and Breakwell, 2001). Outcomes of risk analysis indicate that public perceptions of biotechnology are more complex than that of conventional experts (Savadori et al., 2004). One interpretation suggests that the public identifies closely with broad (i.e. 'thick') views of risk, whereas experts are informed by data and statistics and, by comparison, have more conservative (i.e. 'thin') risk conceptions (Slovic, 1999). Public views, however, demonstrate sophisticated capabilities in assessing risk (Hansen et al., 2003), and the 'commonsense assumption' that experts have superior and more veridical risk judgment is increasingly questioned (Wright et al., 2002). Studies focusing on public views of GM crops have generally focused on consumers.

Consumers in Europe, Japan and North America often remain suspicious of GM technology, are concerned about negative environmental and health implications, and lack trust in food safety regulators and the risk assessment process as a whole (Slovic, 1999; Macer and Chen Ng, 2000; Priest, 2000; Taylor-Gooby, 2006). A recent study suggests that consumers in Europe are relatively supportive of medical and industrial biotechnology, although they still ardently oppose GM foods (Gaskell et al., 2006). In contrast, studies conducted in Mexico and the Philippines suggest consumers perceive greater agricultural and nutritional benefits from GM foods, but remain concerned about adverse effects on regional biodiversity (Aerni, 2002). These findings likely reflect the farmer-focus of the "first generation" of GM products, which, in turn, have few explicit benefits for consumers (Scholderer and Frewer, 2003).

Interestingly, these same farmers have yet to be meaningfully consulted regarding their attitudes towards and experiences with GM crops despite a decade of commercial use (Mauro and McLachlan, accepted). To date, most farmer-focused studies involving GM crops have primarily assessed economic benefits associated with canola in Canada (Fulton and Keyowski, 1999), soybeans and cotton in the US (McBride and Books, 2000), cotton in Argentina (Qaim and de Janvry, 2003) and soybeans in Romania (Brookes, 2005), as well as both the economic benefits and risks of corn for growers and society in the US (Wu, 2004). This economic research, while important in its own right, does not fully characterize the diverse nature of farmer attitudes and experiences with GM crops.

Worldwide, only a handful of studies have explored farmer perceptions on the benefits and risks of biotechnology. Farmer attitudes regarding the potential introduction of GM crops in Australia (McDougall et al., 2001) and New Zealand (Cook and Fairweather, 2003) indicated high levels of awareness and interest in the technology. Farmers in India indicated that economic benefits outweighed moral concern (Chong, 2005) while those from Central America were largely concerned about the contamination of traditional races of corn by transgenic maize (Soleri et al., 2005). Farmer experiences regarding this technology have yet to be fully studied for Canada, the US and Argentina as the first countries to commercialize GM crops, or are restricted to the benefits (CCC, 2001). The role and potential contribution of farmer knowledge also has yet to be systematically evaluated for any GM crops and, indeed, risk research as a whole.

The overall objective of this study is to explore the role for farmers' knowledge in the risk analysis of GM crops. More specifically, we will:

- Evaluate risks represented by herbicide tolerant (HT) canola relative to other risks facing rural communities;
- Characterize the benefits and risks associated with HT canola;
- Identify what factors contribute to the risks and benefits associated with this technology; and
- Explore the role that this farmer knowledge might play in the risk analysis of HT crops and, more generally, agricultural technology.

2. MATERIALS AND METHODS

2.1 HT crop use

Canadian farmers rapidly adopted herbicide-tolerant (HT) canola following its release in 1995. Three varieties of novel-trait HT canola[i] have been introduced: Roundup Ready (**RR**), Liberty Link (**LL**) and Clearfield (**CF**), these tolerant to glyphosate, glufosinate and imidazolinone herbicides, respectively (Lawton, 2003). At present, they represent 96% of the 5.25 million ha of canola grown in Canada; approximately 50% of this being RR, 32% being LL, and 14% being CF (Buth, 2006). The great majority of these crops are grown in the western Canadian provinces of Manitoba, Saskatchewan and Alberta.

2.2 Study area

Interviews were conducted in the Canadian Prairies Ecozone, which includes the provinces of Alberta, Saskatchewan, and Manitoba **(Figure 1)**, and is characterized by a continental climate having short warm summers and long, cold winters, with an annual mean temperature range from 1.5 °C to 3.5 °C (Smith et al., 1998). Manitoba's annual mean temperature ranges from a mean maximum of 26.1 °C in July to a mean minimum of –23.6 °C in January (Smith et al., 1998). Strong winds occur frequently in this province and summer precipitation occurs as heavy, localized storms. The mean annual precipitation is 504.4 mm; 404.4 mm falls as rain, which peaks in June, while 100 mm water equivalent of snow falls annually, peaking in January (Smith et al., 1998). Over the last century, natural habitat has been largely cleared and replaced by agriculture, including the production of canola, wheat, barley, oats, and cattle.

The survey portion of this study was situated in the two ecoregions, Lake Manitoba Plain (**LMP**) and Aspen Parkland (**AP**), which dominate southern Manitoba **(Figure 1).** The average growing season for both ecoregions ranges from 173 to 187 days and both are dominated by Black Chernozemic soils The LMP is generally recognized as having some of the most productive soils in Manitoba, largely due to fine-textured glaciolacustrine sediments that are especially suited to cereals, oilseeds, and pulses (Smith et al., 1998). On average, canola is seeded on 1.0 million ha in the province (Statistics Canada, 2006).

2.3 Data Collection

Our farmer-focused research on HT canola used a mixed methodology and was conducted in four iterative phases: 1) interviews with farmers across Canada; 2) development of a questionnaire that was mailed out and followed up with a non-response bias evaluation; 3) analysis and modeling of data using logistic regression and the information theoretic approach; and 4) incorporation of both qualitative responses and quantitative responses, thereby triangulating the results. The Joint-Faculty Human

Subject Research Ethics Board Protocol at the University of Manitoba approved the study design (#J2001:060).

Interviews with 15 farmers were conducted across western Canada between June and October of 2002. We purposefully sampled these farmers to participate in an in-depth interview process and to explore attitudes and experiences with HT canola (Mauro and McLachlan, accepted). The qualitative data collected during these interviews also assisted in the development of a questionnaire, helping ensure that its content and wording were appropriate.

The 12-page questionnaire queried farmers on their experiences and attitudes regarding HT canola. In particular, we assessed concern regarding HT canola relative to other stressors that confront rural communities, specific benefits and risks associated with this technology, and factors that contribute to risk perception amongst farmers, especially those that had experience growing HT canola. The questionnaire used a seven-point 'rank ordered' Likert scale, ranging from "strongly disagree" to "strongly agree", and open-ended questions. Researchers associated with universities and industry as well as farmers reviewed the survey for comprehensiveness, technical accuracy and impartiality.

Within each of the two ecoregions, rural municipalities (RMs) were equally divided into two classes (low or high abundance of volunteer[ii] canola), based on the 2001 Manitoba weed survey (Leeson et al., 2002). Farms were identified for each using mailing lists collected from Canada Post. In total, 5762 farms were identified and questionnaires were sent as unaddressed "ad mail". This less-than-ideal use of ad mail was necessary as there is no comprehensive mailing list available for farmers in Manitoba. A modified version of the "tailored design method" (Dillman, 2000) was used when mailing out the questionnaire. All recipients were mailed an introductory letter and questionnaire on March 17th, 2003. Two follow-up reminders (including a post card and subsequent letter) were sent, at two-week intervals, on March 31st 2003 and April 14th 2003 after the questionnaire was mailed in order to ensure the highest participation possible. Questionnaires were sent with self-addressed business reply envelopes allowing it to be returned at no cost to the recipient.

In total, 425 farmers responded to the survey, representing an adjusted response rate of 25%. This was calculated by dividing completed questionnaires from eligible farmers (n=370) by the total number of sent surveys verified as farms growing oilseed crops (n=1452). Response rates for natural resource management surveys have been declining over time (Connelly et al., 2003), and are particularly low for rural research, as few farmers generally fill out surveys (Pennings et al., 2002). The large number of received surveys allowed for meaningful analysis and statistical inference.

We conducted a non-response bias telephone survey, using twelve questions that were selected from the original questionnaire. The RMs were randomly selected from those used in the mailout and in these, residents were randomly selected using rural telephone directories. Of 455 rural residents that were telephoned, 259 agreed to participate, of which 74 were eligible farmers. The main reasons for not filling out the survey, in order of importance, included ineligibility, getting ready for seeding, and simple refusal to fill out surveys of any kind. However, no differences in attitudes were identified between respondents and non-respondents.

The great majority (97%) of respondents to our questionnaire were male, most (67%) were full-time farmers with an average of 28 years of farming experience. A large majority (85%) considered themselves knowledgeable about farming. The education background of respondents varied, although many (48%) had post-secondary training and this level was slightly higher than the Manitoba average (34%) (Statistics Canada, 2001a). Average farm size was 575 ha, again somewhat higher than the average for a Manitoba canola grower (409 ha) (Wilcox, 2007). Minimum tillage was practiced by 51% of respondents, this was similar to the provincial average (45.5%) (Statistics Canada, 2001b). The large majority (78%) of farmers grew HT canola, including Roundup Ready (47%), Liberty Link (22%), Clearfield (13%), and various combinations of these (15%), which are also reflected by national data (Buth, 2006).

2.4 Data Analyses

The perceptions of all farmers (n=370) toward overall risks facing rural communities were summarized using mean, standard error (**SE**) and Cronbach's alpha (Nunnally and Bernstein, 1994). HT farmers' attitudes toward ten benefit and ten risk items were assessed using the same approach and the internal consistency of both benefit and risk scales was assessed. Cronbach's alpha values were high, ranging from 0.88 to 0.91, and well above the 0.70 standard for multivariate variable reduction (Nunnally and Bernstein, 1994). Correspondence analysis (**CA**) (Greenacre and Blasius, 1994), a multivariate ordination technique for the modeling of complex data, was used to determine how HT canola growers (n=298) viewed these benefits and risks. This ordination technique uses a chi-squared distance measure to standardize the relationship between rows (i.e. farmers) and columns (i.e. responses) and summarizes the relationship in a biplot. This variable reduction allowed us to characterize the risk perception of individual farmers as a single CA score along a benefit/risk gradient.

Akaike's information criterion (**AIC**) (Burnham and Anderson, 2004) was used to model the independent variables that contributed to individual farmer perceptions regarding HT canola risks and benefits. The 298 HT canola surveys were sorted into high, medium and low risk perception based on CA scores. The CA scores for high (n=100) and low (n=100) categories were then used as a binary response variable in logistic regression (Allison, 2003) to determine the contributing factors that put farmers at risk.

A set of candidate models of risk was generated using explanatory (i.e. independent) variables arising from farm and demographic data from the survey, these generated using the literature and *a priori* hypotheses. Multicollinearity among the eight independent variables was evaluated using Spearman rank correlations and all variables were found to be independent. All possible combinations of explanatory variables were explored for a total of $2^8 = 256$ risk models. A global model was developed that included all eight variables and a set of alternate models that included subsets of these variables and their interaction terms. The use of the information theoretic approach allows for the modeling complex data on HT crops and, unlike null hypothesis testing, allows one to rigorously evaluate multiple predictors in combination (Johnson and Omland, 2004).

Models were evaluated and the most parsimonious were selected using Akaike's information criterion difference with small sample bias adjustment (ΔAIC_c) and Akaike weights (w) (Burnham and Anderson, 2002). Support exists for candidate models with $\Delta AIC_c < 4$, although the best model equals zero. We then calculated the cumulative AIC_c

weights for each explanatory variable by summing the AIC_c weights of every model containing that variable (Burnham and Anderson, 2004). Variables with the highest AIC_c weights contributed most to high-risk perception. This AIC-based approach allows models to be ranked, weighted, and compared using an empirical assessment of relative support for each competing hypothesis (Johnson and Omland, 2004). All statistical analyses were performed using SAS (SAS, 2007).

Emerging themes were identified from the qualitative interview and survey data using content analysis (Maxwell, 2005). Qualitative data were independently categorized and later reconciled by both researchers until we had a detailed impression of the emerging narratives. Memos were used to document important comments, assisting in the development of codes, and ultimately produced analytical benefit and risk categories that emerged from the farmer statements (Maxwell, 2005). These data were robust and emerging themes matched the quantitative findings. Reflecting our mixed methodological approach, the outcomes of the quantitative and qualitative analyses were combined to triangulate and further verify interpretation of these results.

3. RESULTS

3.1 Overall risks facing rural communities

Farmers (n=370) generally perceived the threat of HT crops to be low relative to other economic and environmental risks facing rural communities **(Table I)**. The main economic risks included input costs (e.g. fertilizer, herbicides, etc), machinery costs and commodity prices. The main environmental risks included excessive moisture, drought and natural disasters (**Table I**). Although respondents ranked HT crops 9th out of the 10 risks, they still 'moderately agreed' that HT crops were risky (mean = 5.1, SE = 0.09).

3.2 Benefits associated with HT crops

Benefit associated with HT crops were assessed for users of the technology (n=298). The main benefits were operational and, when ranked in descending order of importance according to mean included easier weed control, herbicide rotation, better weed control, and reduced dockage (i.e. chaff and other foreign material) (**Table II**).

One interviewee indicated the relative ease of using the technology:

> *"You get a much more even growth in the crops because of the effect of the herbicide plus it's also a better killer of weeds, it's a lower cost, it's much easier for farmers to handle, when you think about the dockage..."* (Alberta farmer, interview)

The majority (77%) of farmers were pleased with the overall performance of their HT canola and, when compared to a conventional non-HT equivalent, almost half (47%) believed that it was more profitable. Yet only some (21%) thought the HT canola yielded better.

One survey respondent commented on a number of other benefits:

> *"...there are many more positive aspects to GM crops... 1) ability to remove weeds earlier than with conventional herbicide programs; 2) far greater crop safety with GM crops vs. conventional herbicides; and 3) farm more acres with GM crops – less time per acre spent cultivating, incorporating herbicides, less time scouting and choosing tank mixes, more consistent yields with less risk of weed problems"* (Survey # 196)

Farmers disagreed with some other purported benefits. The majority (67%) disagreed that HT crops were protecting 'small farm heritage', and most (58%) disagreed that HT crops were 'the answer to feeding the world's hungry'. Many (39%) farmers also rejected the notion that HT crops made 'Canadian agriculture more competitive'.

3.3 Risks associated with HT crops

Risk associated with HT crops were also assessed for technology users (n=298) (**Table II**). The most pressing risks were economic and political in nature and, in descending order of importance according to mean, included loss of market, Technology Use Agreements[(iii)] restricting rights, increased seed cost, and lawsuits. All farmers expressed their concern regarding the loss of markets:

> *"The loss of [*European*] markets due to GM's had a huge financial impact. This was likely larger than cost of controlling volunteers or benefit of easy weed control"* (Manitoba farmer, interview)

Operational risks also ranked high and, in descending order of importance, included HT volunteers, gene spread, herbicide resistant weeds, and Roundup Ready crops causing problems in zero-tillage systems. One farmer indicated how he was sued over patented HT canola that contaminated his land, creating biological and legal risks that had implications for all farmers:

> *"What it means to farmers all around the world is the loss and right to use your own seed... My rights as a farmer have been taken away because now I can no longer grow canola under fear of a lawsuit"* (Saskatchewan farmer, interview)

Farmers generally believed that it was not possible to control HT traits from spreading in the environment. Thus, most felt that "Terminator Technology" (75%

of respondents) "segregation techniques" (67%), and "good farming practices" (51%) would not solve HT trait contamination problems.

3.4 Factors contributing to risk perception

Correspondence Analysis (**CA**) separated respondents along a primary risk/benefit gradient, with farmers experiencing high benefit and low risk on the right side of the ordination, and farmers experiencing high risk and low benefit on the left (**Figure 2**). The CA accounted for 45.52% of the contingency information in the data. These differing views were based on a farmer's specific experiences with HT technology, and suggested that HT-users were not a homogeneous group and that benefits and risks unevenly affected farmers.

We categorized farmer along this primary gradient of variation, those for which 1) benefits were greater than risks; 2) benefits were equivalent to risks; and 3) risks were greater than benefits. The perceptions of individual farmers were summarized in a composite CA score along this gradient and ranged from 3.55 (highest benefit) to -3.02 (highest risk).

Eight independent variables (**Table III**) were used to construct 256 possible models and the most parsimonious model had a Δ $AIC_C = 0$, and consisted of variables for farm size (Farmsize), years using HT canola (YrsHT) and volunteers (Vol) (**Table IV**).

The beta-coefficients for the variables in the most parsimonious model (**Table V**) suggested that farmers perceived greater risk if they operated a smaller farm (β= -1.81, SE = 0.60). Linking the demise of these small family farms with HT technology, one farmer stated:

> *"GM technology will most certainly hasten the demise of family farms if it is allowed to progress unchecked. When we started farming...seed could be saved from year to year... now, each year, a tremendous monetary outlay for seed must be made in order to grow canola because of the new GMO systems... more and more family farms will disappear – simply because they are unable to shoulder these costs which will happen annually without relief"* (Survey # 101).

Higher risk perception was expressed by those growing HT canola over multiple years (β= 1.37, SE = 0.38). A number of interviewed farmers similarly expressed concern that these risks increased over time:

> *"All of this is escalating and we really need a period of time to take a serious look at what the long-term effects are going to be"* (Manitoba farmer, interview).

Risks were also greatest for those that experienced volunteer canola on their land (β= 1.02, SE = 0.05). Indeed, many interviewees indicated having problems with HT volunteers:

> *"These volunteers are showing up in fields that have never been planted to these crops. Farmers that have never seeded genetically modified crops are finding volunteers on their farm and that the volunteer picture is much broader than we had expected to see"* (Manitoba farmer, interview).

The percent weight that independent variables contributed to each model was determined by summing their cumulative Akaike weights (**Table V**). The three variables that contributed most to risk were, in order of importance, HT volunteers (Vol: w = 0.99), years growing HT crops (YrsHT: w = 0.86), and farm size (Farmsize: w = 0.84). By comparison, the other five variables (minimum tillage, organic, finances, years farming and education) were of minimal importance.

3.5 Primary risk: HT volunteer canola

In total, 38% of HT farmers (n=298) had experienced HT volunteer canola on their land. Of these, 51% believed the source of HT volunteers came from 'within' their operations, 20% believed they came from 'outside', and 29% believed that it was from 'both' sources. Many respondents were concerned about the promiscuous and persistent nature of these volunteers, and that this would eventually compromise benefits currently associated with the technology:

> *"I had volunteer Roundup resistant canola in a sunflower field before I had ever used it, and, I could not remove it with Roundup [herbicide] or other means. We are finding resistant canola everywhere, even if it has never been seeded on that field. I like using Roundup as pre-emergent burn-off and its not working great anymore"* (Survey # 140).

Farmers that grew HT canola and had experienced HT volunteers believed that, on average, they were emerging in their fields 2.5 years after initially planting these crops. Moreover, HT volunteers were primarily Roundup Ready (72%) and emerged up to six years after having been planted (**Figure 3**). Multiple resistant volunteers were also prevalent (20%), followed by Clearfield (6%) and Liberty Link (2%) varieties. Many commented that HT volunteers continue to emerge in later years:

> *"I don't think enough attention has been paid to the fact that we have these crops growing volunteer, not just the year after we grow them. In fact, I've found with my own experience with a zero-till system that my volunteers are two years after I produce a crop"* (Manitoba farmer, interview).

Farmers affected by HT volunteer canola relied on a diversity of control methods, including, in ascending order of importance, hand pulling (1%), glyphosate (5%), others such as chemicals or letting the volunteers grow (7%), sweeps on the air seeder (9%), glyphosate and additional herbicide (17.5%), tilling (17.5%) and a combination of these techniques (43%). When examined in greater detail, many (9%) of the zero-till farmers in this study actually reverted to tillage to control Roundup Ready volunteers.

A large majority (76%) of survey respondents that used HT canola anticipated that HT volunteers would become 'more of a problem in the future'. And an even greater proportion (85%) believed that industry had shifted the burden of responsibility for HT volunteers onto farmers. Concerned about the issue of corporate responsibility, one respondent stated:

> *"Our biggest concern is Roundup Ready canola polluting our fields by being blown off neighbors fields and infesting our fields with voluntary plants. Is Monsanto going to compensate farmers in this situation?"* (Survey # 206).

4. DISCUSSION

Our study was designed to examine post-release benefits and risks associated with growing of herbicide-tolerant (**HT**) canola, and underlying factors that contribute to overall risk with the technology. Asking farmers to assess the 'real world' efficacy of and risks associated with HT canola arguably makes this publicly funded research the first of its kind in North America.

Overall, farmers in this study found that HT crops were less risky than other stressors confronting rural communities. Farm economics, these including inputs and machinery costs, as well as commodity prices, were of paramount concern. This reflects the decline of net income of Canadian farmers over the last twenty years (Boyens, 2001) and that farmers are now amidst the worst farm-income crisis in history (NFU, 2005). Environmental concerns that affected crop production, and in turn income, were also ranked high, these including excessive moisture, drought, and natural disasters. Although

HT crops were ostensibly of less concern and reflected many benefits, ranking 9th out of 10, they were still perceived as 'moderately risky'.

The main benefits of HT canola in our study were operational, supporting results of an unpublished study conducted by industry roughly at the same time (CCC, 2001). Respondents to our questionnaire identified that advantages included an improved ability to remove weeds earlier, increased safety associated with Roundup (the most popular herbicide used with HT crops), and an ability to farm more land. Unlike the industry sponsored study (CCC, 2001), however, those responding to our survey indicated little increase in yields associated with the technology. In general, the benefits identified in our and other studies are largely consistent with those promoted by technology developers themselves, and are thus already widely disseminated and well appreciated (Devine, 2005).

In contrast, market harm was the highest ranked risk for HT canola, as two of the three available HT varieties[(i)] are considered to be GM (i.e Roundup Ready and Liberty Link), a transformation technique entrenched with international trade-related problems. Until recently, the EU has had a moratorium against new GM crop approvals and was establishing stricter labeling and traceability requirements for products containing GM ingredients, this reflecting a 'precautionary approach' to risk that was ultimately challenged and recently overturned at the WTO by the US, Canada and Argentina (Falkner, 2007). Domestically, neither organic canola farmers nor conventional honey producers can guarantee their products as GM-free, due to potential outcrossing and contamination, and this has adversely affected sales to the EU (Smyth et al., 2002). The threat of market harm was also highlighted by the controversy surrounding Monsanto's

GM wheat at the time that our survey was distributed (Mauro et al., 2005), with over 80% of world grain buyers indicating that they would not purchase this technology if it were grown and marketed in North America (Huygen et al., 2003).

Corporate control of agriculture was also of concern to farmers, as reflected in the high ranking of risks associated with Technology Use Agreements(iii) (**TUAs**), increased seed costs, and lawsuits associated with HT crops. Although Monsanto is the only company that charges a $15/acre fee for HT canola, in large part because their technology is true reproducing and not a hybrid, there is now a wider trend towards contract production that may increase seed costs and erode farmer rights to save, re-use and exchange seeds (Lewontin, 2000; Boehm, 2006). Many of these contracts allow companies to investigate farmers, their land and community for evidence of appropriation of proprietary seed technologies, which may compromise 'social cohesion' (Mehta, 2005) and may undermine the 'rural social fabric' of rural communities (Mauro et al., 2005; Mauro and McLachlan, accepted) This issue was recently addressed by the landmark Supreme Court of Canada decision on *Monsanto versus Schmeiser*, which essentially upheld industry's intellectual property claims over GM seeds and plants, making farmers liable for patent infringement, despite the likelihood that the seed they plant may have been contaminated by GM traits (Gold and Adams; 2001; Cullet, 2005).

Risks of environmental contamination and cleanup costs, specifically relating to HT volunteers(ii) and gene spread, were also considered important. Although HT canola was commercially released in Canada in 1995, it was not until much later that three-way HT trait stacking in volunteers occurring in fields (Hall et al., 2000) and roadside ditches (Knispel et al., 2008), large-scale pollen mediated gene flow (Rieger et al., 2002) and contamination of pedigreed non-HT canola seed stocks across the Canadian prairies (Friesen et al., 2003) were identified. Our study shows that farmers were knowledgeable and understandably concerned about canola outcrossing and believed bioconfinement of HT traits would be nearly impossible. They rejected genetic use restriction technologies **(GURTs)** (Van Acker et al., 2007), specifically 'Terminator Technology', as a feasible containment strategy. These GURTs remain controversial and have been discussed widely (Service, 1998), especially in light of recent attempts to weaken the United Nations *defacto* moratorium on their use (ETC Group, 2006).

Farmers were further concerned about the impacts of HT volunteers on their operations and believed they would become more of a problem in the future. Indeed, Manitoba weed surveys indicate that volunteers have increased in relative abundance from 19th in 1997 to 10th in 2002 (Leeson et al., 2002). This increase is only partially due to increased plantings, and some experts (Gulden et al., 2003) and farmers alike are concerned that persistent HT volunteers may contaminate future canola crops. Our results indicate that volunteers emerged, 2.5 years, on average, and upwards of six years after initial planting of HT canola, this corroborated by ecological studies (Beckie et al., 2004). While HT volunteers can be controlled (Beckie et al., 2004) they may cause problems associated with crop competition and loss of quality, harvesting difficulties, and pest and disease spread (Orson, 1993). Importantly, 20% of farmers that reported volunteers indicated that these weeds were multiple resistant, suggesting that these trait stacked weeds may be more widespread than previously reported. These volunteers may lead to persistent metapopulations of feral HT canola (Knispel et al., 2008) and more research is needed to better understand the spatiotemporal dynamics of these volunteers and how they affect both natural and managed environments.

It was also recognized that Roundup Ready (RR) volunteers pose specific challenges for zero tillage farmers, a widespread cropping practice that has substantially reduced soil erosion and increased water conservation, carbon sequestration, and wildlife habitat across the North American mid-west. Zero till farmers have an additional challenge when controlling HT volunteers, in that they seed directly through stubble, instead of tilling, thus requiring glyphosate (i.e. Roundup) for pre-seeding weed control, which will not kill Roundup-tolerant volunteers. In Manitoba, these volunteers are in greater densities on land managed using zero till (Lawson et al., 2006), and additional, more expensive and persistent herbicides (e.g. 2, 4-D) are now required, costing another $1.50-2.00 Canadian dollars per acre (Smyth et al., 2002). This threat to zero till agriculture is one of the most substantial in a decade of HT crop use (Beckie et al., 2006) and, indeed, might contribute to a decline in the use of direct seeding systems and their widely recognized benefits (Van Acker et al., 2003).

Personal experience with HT volunteer canola was the salient factor that led farmers to identify with risks associated with this technology. Ironically, farmers generally have little control over "volunteers" or factors that give rise to them, whether these be gene flow, environmental conditions, seed contamination, or neighboring management decisions. This lack of control may, in part, underlie the heightened risk perception associated with these "involunteers", since it has long been recognized that risks are perceived as greater when viewed as involuntary and uncontrollable (Starr, 1969; Fischhoff et al., 1978; Slovic, 1987). Although volunteer experience was the most important risk variable, farm size and duration of HT crop use also influenced risk perception.

Farmers that operated smaller farms were more likely to perceive themselves at risk. Generally, small farms are considered risk-averse, as they have less capital for investment, and are therefore less likely to adopt new and potentially risky technologies (Feder, 1980). Larger farms, on the other hand, have been better able to buffer potential risks associated with HT canola, and to better capture benefits (Mehta, 2005), and arguably have been the focus of this technology development. Thus, HT crops may select for increased profits for and control by agribusiness (Mauro et al., 2005), this often occurring at the expense of small family farms, rural communities, and the environment (Altieri, 2000). These changes are further compounded by cumulative stressors – such as low commodity prices, high input costs, poor government policies focused on deregulation and free trade - that act to further marginalize small scale and family farms (Boyens, 2001).

Risks associated with HT canola also increased with the time that the technology was used. Diffusion models suggest that early adopters of a technology that works and that is initially superior and that has broad support, will benefit quickly (Geroski, 2000). These criteria were in place for the introduction of HT canola and presumably led to its rapid adoption and use. However, as the technology gains wider acceptance and use, benefits often plateau and the incentives for early adoption decline (Geroski, 2000) This phenomenon may help explain why farmers with the most experience using these crops devalued the benefits and favored the risks.

Our best candidate risk model comprised volunteers, small-scale farm and duration of HT canola use and clearly demonstrates that overall farmer experience contributed most to their attitudinal rankings of benefits and risks. That personal experience was central when evaluating HT crops, indicates that the geography of place and culture is important to risk perception (Masuda and Garvin, 2006), and that the local farmer knowledge derived from working their land and interacting with their communities plays an important role in risk conception (Kloppenburg, 1991). We suggest that experience-based knowledge might play a central role in risk analysis, and that it offers a meaningful perspective beyond the dichotomy of 'expert' versus 'lay' knowledge regarding GM crops and risk. Resource-dependent communities often have much insight into the risks associated with managing their environments (Gregory and Satterfield, 2002), and this is especially clear with respect to rural communities and HT crops.

A decade of intimate experience with this technology yields farmer insights that are rich and at once place-specific and generalizable to HT crops as a whole. Yet these experiences largely remain unheard by policy makers and managers, who continue to discount farmer perspectives regarding agricultural technology on the grounds that it is non-scientific, subjective and unreliable. When acknowledged at all, farmers are often viewed as passive research subjects or passive adopters of expert-developed technology. Although some question these assumptions and call for greater and more meaningful farmer involvement in agricultural research and policy making (Middendorf and Busch, 1997), regulation of biotechnology in North America continues to rely on 'science-based' and expert risk assessment (Abergel, 2007).

In Canada, the agency charged with assessing risks associated with HT crops (i.e. Canadian Food Inspection Agency) cannot explicitly incorporate social or economic data in their decision making, to say nothing of local farmer knowledge. Unsurprising, some leading experts on HT crops in Canada now recognize that risk assessment has failed to properly evaluate potential market harm, seed lot contamination, and impact of volunteers on agronomy and environment (Krayer von Krauss et al., 2004). Further, the Royal Society of Canada severely criticized the Canadian government and its role in regulating human health and environmental risks associated with biotechnology, particularly the use of 'substantial equivalence', and called for a more rigorous, independent, publicly accountable, and precautionary approach to risk assessment (RSC, 2001).

This seeming failure on the part of industry and regulators to anticipate the diversity of risks associated with HT canola, as presented in this study, demonstrates the limitations of conventional risk assessment and suggests that a new more inclusive, experience-based and farmer-centered approach to risk assessment would benefit farmers and society alike. Indeed, like any seed, risk analysis should grow from the ground up, and we believe that this means starting with farmers and their local knowledge in the GM debate.

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APPENDIX: TERMINOLOGY

i. Canola: Canola was developed in Canada in the early 1970s through conventional plant breeding of rapeseed and is now a popular edible oil. It is part of the mustard family, and herbicide tolerance has been predominately introduced into *Brassica napus,* although other species include *B. rapa, and B. juncea.* Two of the three available HT canola varieties, Roundup Ready and Liberty Link, are transformed using recombinant DNA, and are therefore considered GM products. The third, Clearfield, has a novel HT trait introduced using mutagenesis, and is therefore not considered a true GM product.

ii. Volunteer: A volunteer is essentially a crop growing in another crop, which competes for nutrients and other resources, making it a weed that some farmers choose to control. Volunteers may arise from harvest losses in a previous year or seed movement from wind, transportation, etc. Herbicide tolerant canola volunteers are resistant to specific chemicals and, depending on the agronomic context, may require additional management (e.g. herbicides, tilling, etc).

iii. Technology use agreements: Technology use agreements (TUAs) are contracts that farmers sign with certain seed companies to buy seed, particularly those that contain proprietary herbicide tolerant or other genetically modified traits. Companies that use these agreements, most notably Monsanto, often restrict farmers from saving seed annually and reserve the right to inspect a farmer's land for compliance. In the event of noncompliance, these TUAs are used to levy stiff penalties and may become the basis for lawsuits against farmers.

REFERENCES

Abergel, E.A. (2007). Trade, science, and Canada's regulatory framework for determining the environmental safety of GE crops. In I.E.P. Taylor. (Ed), *Genetically Engineered Crops: Interim Policies, Uncertain Legislation.* New York: Haworth Food & Agricultural Products Press.

Aerni, P. (2002). Stakeholder attitudes toward the risks and benefits of agricultural biotechnology in developing countries: A comparison between Mexico and the Philippines. *Risk Analysis, 22,* 1123-1137.

Allison, P.D. (2003). *Logistic Regression Using the SAS System: Theory and Application.* Cary, NC: SAS Institute and John Wiley and Sons, Inc.

Altieri, M. (2000). Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming. In F. Magdoff, J. Bellamy Foster & F.H. Buttel (Eds.), *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment.* New York: Monthly Review Press.

Anex, R. P., & Focht, W. (2002). Public participation in life cycle assessment and risk assessment: A shared need. *Risk Analysis, 22*, 861-877.

Arvai, J. L. (2003). Using risk communication to disclose the outcome of a participatory decision-making process: effects on the perceived acceptability of risk-policy decisions. *Risk Analysis, 23*, 281-289.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology*, *20*, 1076-1078.

Barnett, J., & Breakwell, G. M. (2001). Risk perception and experience: Hazard personality profiles and individual differences, *Risk Analysis, 21*, 171-177.

Beckie, H.J., Harker, K.N., Hall, L., Warwick, S.I., Legere, A., Sikkema, P.H., Clayton, G.W., Thomas, A.G. , Leeson, J.Y., Seguin-Swartz, G. G., & Simard, M.J. (2006). A decade of herbicide-resistant crops in Canada. *Canadian Journal of Plant Science, 86*, 1243-1264.

Beckie, H. J., Se´guin-Swartz, G., Warwick, S. I., & Johnson, E. (2004). Multiple herbicide-resistant canola can be controlled by alternative herbicides. *Weed Science, 52*, 152-137.

Bishop, W. E., Clarke, D. P., & Travis, C. C. (2001). The genomic revolution: what does it mean for risk assessment? *Risk Analysis, 21*, 983-987.

Boehm, T. (2006). Seed changes have wide impact. *Western Producer*, November 23, p7.

Boyens, I. (2001). *Another Season's Promise: Hope and Despair in Canada's Farm Country.* Toronto: Penguin.

Brookes, G. (2005). The farm-level impact of herbicide-tolerant soybeans in Romania. *AgBioForum, 8*, 235-241.

Burnham, K.P., & Anderson, D.R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach (2nd Edition).* New York: Springer.

Burnham, K. P., & Anderson, D. R. (2004). Multimodel inference: Understanding AIC and BIC in model selection. *Sociological Methods & Research, 33*, 261-304.

Buth, J. (2006). Canola Council of Canada. Personal Communication.

Carr, S., & Levidow, L. (2000). Exploring the links between science, risk, uncertainty, and ethics in regulatory controversies about genetically modified crops. *Journal of Agricultural & Environmental Ethics, 12*, 29-39.

CCC (Canola Council of Canada). (2001). *An Agronomic and Economic Assessment of Transgenic Canola.* Prepared by Serecon Consulting and Koch Paul Associates. Available at: http://www.canola-council.org/report_gmo.html

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research, 8*, 617-634.

Connelly, N. A., Brown, T. L., & Decker, D. J. (2003). Factors affecting response rates to natural resources-focused mail surveys: empirical evidence of declining rates over time. *Society and Natural Resources, 16*, 541-549.

Conner, A. J., Glare, T. R., & Nap, J. P. (2003). The release of genetically modified crops into the environment: Overview of ecological risk assessment. *The Plant Journal, 33*, 19-46.

Cook, A., & Fairweather, J. R. (2003). New Zealand farmer and grower intentions to use gene technology: results from a resurvey. *AgBioForum, 6*, 120-127.

Cullet, P. (2005). Monsanto vs. Schmeiser: A landmark decision concerning farmer liability and transgenic contamination. *Journal of Environmental Law, 17*, 83-108.

Devine, M. D. (2005). Why are there not more herbicide-tolerant crops? *Pest Management Science, 61*, 312-317.

Dillman, D. (2000). *Mail and Internet Surveys: The Tailored Design Method (2nd Edition).* Toronto: John Wiley and Sons, Inc.

ETC Group. (2006). *UN Upholds Moratorium on Terminator Seed Technology.* Available at www.etcgroup.org/en/materials/publications.html.

Falkner, R. (2007). *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave Macmillan.

Feder, G. (1980). Farm size, risk aversion and the adoption of new technology under uncertainty. *Oxford Economic Papers, 32*, 263-283.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S. S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Science, 9*, 127-152.

Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42*, 1181-1193.

Friesen, L. F., Nelson, A. G., & Van Acker, R. C. (2003). Evidence of contamination of pedigreed canola (Brassica napus) seedlots in western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal, 95*, 1342-1347.

Fulton, M., & Keyowski, L. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum, 2*, 85-93.

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Revuelta, G., Schreiner, C., Stares, S., & Torgersen, H. (2006). Europeans and Biotechnology in 2005: Patterns and Trends. Available at: www.gmo-compass.org/eng/news/stories/227.eurobarometer_europeans_biotechnology.html

Geroski, P. A. (2000). Models of technology diffusion. *Research Policy, 29*, 603-625.

Gold, E. R., & Adams, W. A. (2001). The Monsanto decision: The edge or the wedge. *Nature Biotechnology, 19*, 587.

Gray, R. (2001). Introduction. In M. Fulton, H. Furtan, D. Gosnell, R. Gray, J. Hobbs, J. Holzman, B. Kerr, J. McNaughten, J. Stevens & D. Stovin (Eds.), *Transforming Agriculture: The Benefits and Costs of Genetically Modified Crops.* Canadian Biotechnology Advisory Committee. Ottawa, ON.

Greenacre, M., & Blasius, J. (1994). *Correspondence Analysis in the Social Sciences*. San Diego: Academic Press, Inc.

Gregory, R. S., & Satterfield, T. A. (2002). Beyond perception: The experience of risk and stigma in community contexts. *Risk Analysis, 22*, 347-357.

Gulden, R. H., Shirtliffe, S. J., & Thomas, A. G. (2003). Secondary seed dormancy prolongs persistence of volunteer canola in western Canada. *Weed Science, 51*, 904-913.

Hall, L., Topinka, K., Huffman, J., & Good, L. (2000). Pollen flow between herbicide-resistant Brassica napus is the cause of multiple-resistant B. napus volunteers. *Weed Science, 48*, 688-694.

Hansen, J., Holm, L., Frewer, L., Robinson, P., & Sandoe, P. (2003). Beyond the knowledge deficit: recent research into lay and expert attitudes to food risks. *Appetite, 41*, 111-121.

Huygen, I., Veeman, M., & Lerohl, M. (2003). Cost implications of alternative GM tolerance levels: Non-genetically modified wheat in western Canada. *AgBioForum, 6*, 169-177.

James, C. (2006). *Global Status of Commercialized Biotech/GM crops: 2006.* Available at: www.isaaa.org/resources/publications/briefs/35/executivesummary/default.html.

Jasanoff, S. (1993). Bridging the two cultures of risk analysis. *Risk Analysis, 13*, 123-129.

Johnson, J. B., & Omland, K. S. (2004). Model selection in ecology and evolution. *Trends in Ecology and Evolution, 19*, 101-108.

Kloppenburg, J. (1991). Social-theory and the de reconstruction of agricultural science - Local knowledge for an alternative agriculture. *Rural Sociology, 56*, 519-548.

Knispel, A. L., McLachlan, S. M., Van Acker, R., & Friesen, L. (2008). Gene flow and multiple herbicide resistance in escaped canola populations. *Weed Science, 56*, 72-80.

Krayer von Krauss, M. P., Casman, E. A., & Small, M. J. (2004). Elicitation of expert judgments of uncertainty in the risk assessment of herbicide-tolerant oilseed crops. *Risk Analysis, 24*, 1515-1527.

Lawson, A. N., Van Acker, R. C., & Friesen, L. F. (2006). Emergence timing of volunteer canola in spring wheat fields in Manitoba. *Weed Science, 54*, 873-882.

Lawton, M. (2003). *Management of Herbicide Tolerant Crops and Future Research.* Canadian Food Inspection Agency. Available from http://www.inspection.gc.ca/english/plaveg/bio/consult/herbtolrepe.shtml

Leeson, J. Y., Thomas, A. G., Andrews, T., Brown, K. R., & Van Acker, R. C. (2002). Manitoba weed survey of cereal and oilseed crops in 2002. *Weed Survey Series Publication 02-2*. Agriculture and Agri-Food Canada, Saskatoon Research Centre, Saskatoon, SK.

Leiss, W. (2001). *In the Chamber of Risks: Understanding Risk Controversies*. Montreal: McGill-Queens University Press.

Levin, M. A., & Strauss, H, S. (Eds.) (1991). *Risk assessment in Genetic Engineering*. New York: McGraw-Hill.

Lewontin, R. C. (2000). The maturing of capitalist agriculture: Farmers as proletarian. In F. Magdoff, J. Bellamy Foster, & F.H. Buttel (Eds.), *Hungry For Profit: The Agribusiness Threat to Farmers, Food, and the Environment*. New York: Monthly Review Press.

Lomax, G. P. (2000). From breeder reactors to butterflies: risk, culture, and biotechnology. *Risk Analysis, 20*, 747-753.

Macer, D., & Chen Ng, M. A. (2000). Changing attitudes to biotechnology in Japan. *Nature Biotechnology, 18*, 945-947.

Marvier, M. (2002). Improving risk assessment for nontarget safety of transgenic crops. *Ecological Applications, 12*, 1119-1124.

Masuda, J. R., & Garvin, T. (2006). Place, culture, and the social amplification of risk. *Risk Analysis, 26*, 437-454.

Mauro, I. J., & McLachlan, S. M. (accepted). Farmer experiences and attitudes toward risks associated with genetically modified crops, in Manitoba, Canada. *Agriculture and Human Values*.

Mauro, I. J., McLachlan, S. M., & Sanders, J. (2005). *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture*. Winnipeg: Dead Crow Productions and Dada World Data. Documentary film. Available at: www.seedsofchangefilm.org

Maxwell, J.A. (2005). *Qualitative Research Design: An Interactive Approach*. Thousand Oaks, CA: Sage Publications.

McBride, W. D., & Books, N. (2000). Survey evidence on producer use and costs of genetically modified seed. *Agribusiness, 16*, 6-20.

McDougall, D. J., Longnecker, N. E., Marsch, S. P., & Smith, F. P. (2001). Attitudes of pulse farmers in western Australia towards genetically modified organisms in agriculture. *Australasian Biotechnology, 11*, 36-39.

Mehta, M.D. (2005). The impact of agricultural biotechnology on social cohesion. In Mehta, M.D. (Ed.), *Biotechnology Unglued: Science, Society, and Social Cohesion.* Vancouver: UBC Press.

Middendorf, G., & Busch, L. (1997). Inquiry for the public good: Democratic participation in agricultural research. *Agriculture and Human Values, 14*, 45-57.

Millstone, E., Brunner, E., & Mayer, S. (1999). Beyond 'substantial equivalence'. *Nature, 401*, 525-526.

Nap, J. P., Metz, P. L., Escaler, M., & Conner, A. J. (2003). The release of genetically modified crops into the environment: overview of current status and regulations. *The Plant Journal*, *33*, 1-18.

NFU (National Farmers Union). (2005). Corporate Profits: A Report by Canada's National Farmers Union. Saskatoon, SK. Available at: http://www.nfu.ca/briefs.html

NRC (National Research Council). (2002). *Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation.* Washington, DC: National Academies Press.

Nunnally, J.C., & Bernstein, I.H. (1994). *Psychometric Theory (3rd Edition).* New York: McGraw-Hill.

Orson, J. H. (1993). The penalties of volunteer crops as weeds. *Aspects of Applied Biology, 35*, 1-8.

Pennings, J. M. E., Irwin, S. H., & Good, D. L. (2002). Surveying farmers: A case study. *Review of Agricultural Economics, 24*, 266-277.

Priest, S. H. (2000). US public opinion divided over biotechnology? *Nature Biotechnology, 18*, 939-942.

Qaim, M., & de Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: The case of Bt cotton in Argentina. *American Journal of Agricultural Economics, 85*, 814-828.

Rieger, M. A., Lamond, M., Preston, C., Powles, S. B., & Roush, R. T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science, 296*, 2386-2388.

Rowe, G., & Wright, S. (2000). Differences in expert and lay judgments of risk: myth or reality? *Risk Analysis, 21*, 341-356.

RSC (Royal Society of Canada). (2001). *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada*, Ottawa, ON. Available at: http://www.rsc.ca/index.php?page_id=119

SAS. (2007). *SAS OnlineDoc 9.1.3.* Cary, NC: SAS Institute Inc. Available at: http://support.sas.com/onlinedoc/913/docMainpage.jsp

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis, 24*, 1289-1299.

Scholderer, J., & Frewer, L. (2003). The biotechnology communication paradox: Experimental evidence and the need for a new strategy. *Journal of Consumer Policy, 26*, 125-157.

Service, R. F. (1998). Seed-sterilizing 'Terminator Technology' sows discord. *Science, 282*, 850-851.

Sharples, F. E. (1991). Ecological aspects of hazard identification for environmental uses of genetically engineered organisms. In M. Levin & H. Strauss (Eds.), *Risk Assessment in Genetic Engineering: Environmental Release of Organisms*. New York: McGraw-Hill.

Slovic, P. (1987). Perception of risk. *Science, 236*, 280-285.

Slovic, P. (1999). Trust, emotion, sex, politics, and science: surveying the risk assessment battlefield. *Risk Analysis*, *4*, 689-701.

Smith, R. E., Veldhuis, H., Mills, G. F., Eilers, R. G., Fraser, W. R., and Lelyk, G. W. (1998). Terrestrial ecozones, ecoregions, and ecodistricts, an ecological stratification of Manitoba's natural landscapes. In *Technical Bulletin 98-9E*. Land Resources Unit, Brandon Research Centre: Research Branch, Agriculture and Agri-Food Canada.

Smyth, S., Khachatourians, G., & Phillips, P. W. B. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology*, *20*, 537-541.

Soleri, D., Cleveland, D. A., Aragon C, F., Fuentes L, M. R., Rios L, H., & Sweeny, S.H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research, 4*, 141-166.

Starr, C. (1969). Social benefit versus technological risk. *Science, 165*, 1232-1238.

Statistics Canada. (2001a). *Farm operators by highest level of schooling, 2001 (Manitoba).* Available at: http://www.statcan.ca/english/freepub/95F0303XIE/ tables/html/agpop0701.htm#P46

Statistics Canada. (2001b). *Land management: conservation and no-till seeding more common.* Available at www.statcan.ca/english/agcensus2001/first/farmop/05land.htm.

Statistics Canada. (2006). Estimated Areas, Yield, Production, Average Farm Price and Total Farm Value of Principle Field Crops, in Imperial Units, Annual, 1908-2006: CANSIM Agriculture Statistics Database. Ottawa, ON.

Taylor-Gooby, P. (2006). Social divisions of trust: Skepticism and democracy in the GM nation? *Journal of Risk Research, 9*, 75-95.

Van Acker, R.C., Brule-Babel, A.L., & Friesen, L.F. (2003). *An Environmental Safety Assessment of Roundup Ready Wheat: Risks for Direct Seeding Systems in Western Canada.* Winnipeg, MB: Canadian Wheat Board.

Van Acker, R.C., Szumigalski, A.R., & Friesen, L.F. (2007). The potential benefits, risks and costs of genetic use restriction technologies. Canadian Journal of Plant Science, *87*, 753-762.

Wachbroit, R. (1991). Describing risk. In M. Levin and H. Strauss (Eds.), *Risk Assessment in Genetic Engineering: Environmental Release of Organisms.* New York: McGraw-Hill.

Wilcox, D. (2007). What is a typical Manitoba crop producer? *Yield Manitoba.* Available at: www.masc.mb.ca/Downloads/YM07_006_TypicalCropMix.pdf

Wright, G., Bolger, F., & Rowe, G. (2002). An empirical test of the relative validity of expert and lay judgments of risk. *Risk Analysis, 22*, 1107-1122.

Wu, F. (2004). Explaining public resistance to genetically modified corn: An analysis of the distribution of benefits and risk. *Risk Analysis*, *24*, 715-726.

FIGURES AND TABLES

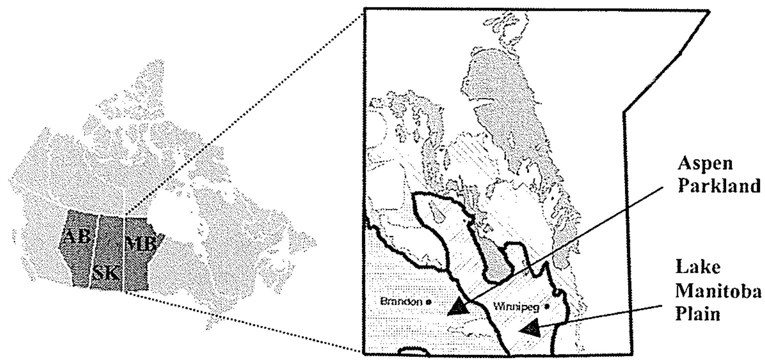


Figure 1. Interviews were conducted across the Canadian Prairies and questionnaires mailed to farms in Manitoba. Portrayed are the provinces of Alberta (AB), Saskatchewan (SK), and Manitoba (MB) (left) and the Aspen Parkland and Lake Manitoba Plain ecoregions in Manitoba (inset).

Table I. Farmer perceptions toward general risks facing rural communities in order of importance (n=370).

Rank	Item	Mean	Standard Error	Cronbach's Alpha
1	Input costs	6.72	0.04	0.65
2	Cost of machinery	6.67	0.04	0.65
3	Commodity prices	6.60	0.05	0.67
4	Lack of urban understanding	6.13	0.06	0.68
5	Excessive moisture	5.54	0.07	0.68
6	Drought	5.29	0.08	0.67
7	Natural disasters	5.29	0.07	0.65
8	Toxic chemicals	5.15	0.08	0.67
9	HT crops	5.08	0.09	0.70
10	Farm accidents	4.65	0.08	0.67

Table II. Herbicide-tolerant (HT) canola farmer perceptions and experiences regarding the benefits and risks of this technology, in order of importance (n=298).

	Rank	Item	Mean	SE[a]	Alpha[b]
Benefits					
	B1	Easier weed control	5.47	0.08	0.88
	B2	Herbicide rotation	5.37	0.08	0.88
	B3	Better weed control	5.28	0.08	0.88
	B4	Reduced dockage[c]	4.97	0.09	0.88
	B5	Reduced need for tillage	4.66	0.09	0.89
	B6	Higher yields	4.49	0.10	0.89
	B7	Simpler pest management	4.39	0.09	0.89
	B8	Less time required	4.36	0.10	0.88
	B9	Environment	4.23	0.10	0.88
	B10	Increased revenue	4.17	0.09	0.88
Risks					
	R1	Loss of markets	5.87	0.08	0.91
	R2	TUA[d] restricting rights	5.56	0.10	0.91
	R3	Increased seed cost	5.36	0.08	0.91
	R4	Lawsuits	5.20	0.10	0.91
	R5	HT[e] volunteers	5.08	0.09	0.91
	R6	Gene spread	5.07	0.09	0.91
	R7	Herbicide resistant weeds	5.02	0.09	0.91
	R8	RR[f] crops & tillage	4.98	0.10	0.91
	R9	Seed saving	4.88	0.10	0.91
	R10	Damage to non-target species	3.67	0.09	0.91

[a]SE = Standard Error; [b]Alpha = Cronbach's coefficient alpha; [c]Dockage = chaff and other foreign materials; [d]TUA = Technology Use Agreement[(iii)]; [e]HT = Herbicide tolerant; [f]RR = Roundup Ready.

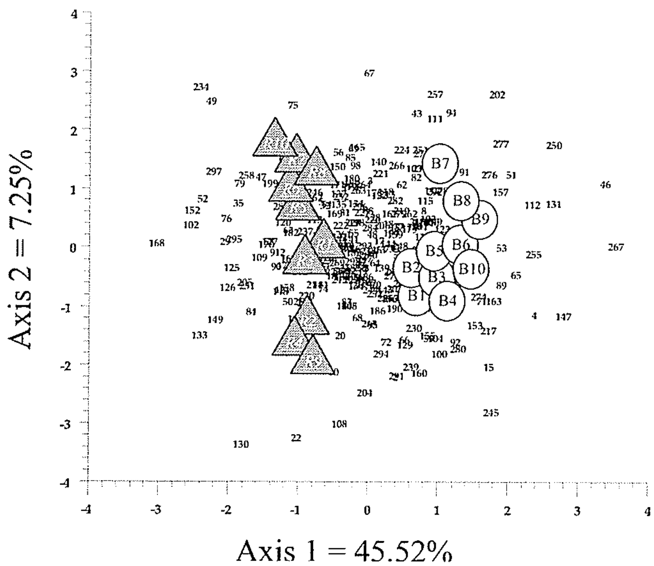


Figure 2. Two-dimensional ordination biplot arising form the Correspondence Analysis of farmer attitudes (n=298) regarding risks and benefits associated with herbicide-tolerant canola in Manitoba. Indicated are the risks (R1-R10) and the benefits (B1-B10) that correspond with rankings in Table II. The first two eigenvalues as percent λ_1=45.52% and λ_2 =7.25% together summarize 52.77% of the contingency information for the data.

Table III. Description of independent variables used to explain farmer perceptions and experiences regarding the benefits and risks of herbicide-tolerant canola

Abbreviation	Variable Description
Education	ranking of education of respondent (grade/high school, college/university)
FarmSize	total acres of farm, including owned and rented land
Finances	qualitative description of farm family's finances
MinTill	total acres of land in minimum and/or zero-tillage production
Organic	total acres of land in organic production (certified and non-certified)
Vol	experience of herbicide-tolerant volunteer canola on farmer's land (yes, no)
YrsFarm	total number of years that farmer had been actively farming
YrsHT	total number of years that farmer had used herbicide-tolerant canola

Table IV. Selected set of candidate models in order of importance (based on AICc[a] $\Delta < 4$, with best model = 0) with their associated AICc weights (w) and number of model parameters (k) for independent variables that best predict farmers being at risk from herbicide-tolerant canola.

Model[b]	*-2Log(L)*	k	$AIC_c\ \Delta$[c]	$AIC_c\ w$[d]
Vol+HTyrs+Farmsize	253.39	4	0.0	0.23
Vol+Farmsize+HTyrs+MinTill	252.28	5	0.9	0.14
Vol+Farmsize+HTyrs+organic	252.26	5	0.9	0.14
Vol+Farmsize+HTyrs+Fina	252.3	5	0.9	0.14
Vol+Farmsize+HTyrs+YrsFarm	252.7	5	1.3	0.11
Vol+HTyrs+MinTill	255.68	4	2.3	0.07
Vol+Farmsize	259.20	3	3.8	0.03

[a]AICc = Akaike's Information Criterion with small sample bias adjustment (Burnham and Anderson, 1998).
[b]Variables in models described in Table III.
[c]$AIC_c\ \Delta$ = A measure of each model relative to the best model
[d]$AIC_c\ w$ = Another measure of the strength of evidence for each model, and is the ratio of $AIC_c\ \Delta$ values for each model relative to the entire set of candidate models

Table V. Cumulative AICc[a] (*w*) weights, Beta-coefficients (β), and Standard Error (SE) for all eight independent variables hypothesized to influence farmer benefit and risk perception and experience with herbicide-tolerant canola

Variable[b]	Cumulative AICc weight[c]	Beta Coefficient	Standard Error
Vol	0.99	1.02	0.05
Yrs HT	0.86	1.37	0.38
Farm Size	0.84	-1.81	0.60
Min Till	0.43	-0.56	0.64
Organic	0.38	1.27	1.58
Finances	0.35	0.24	0.32
Yrs Farm	0.32	0.21	0.28
Education	0.26	-0.01	0.02

[a]AICc = Akaike's Information Criterion with small sample bias adjustment (Burnham and Anderson, 1998).
[b]Variables described in Table III.
[c] These 'model averaged' weights were computed by summing the AICc weights of every model containing that particular variable

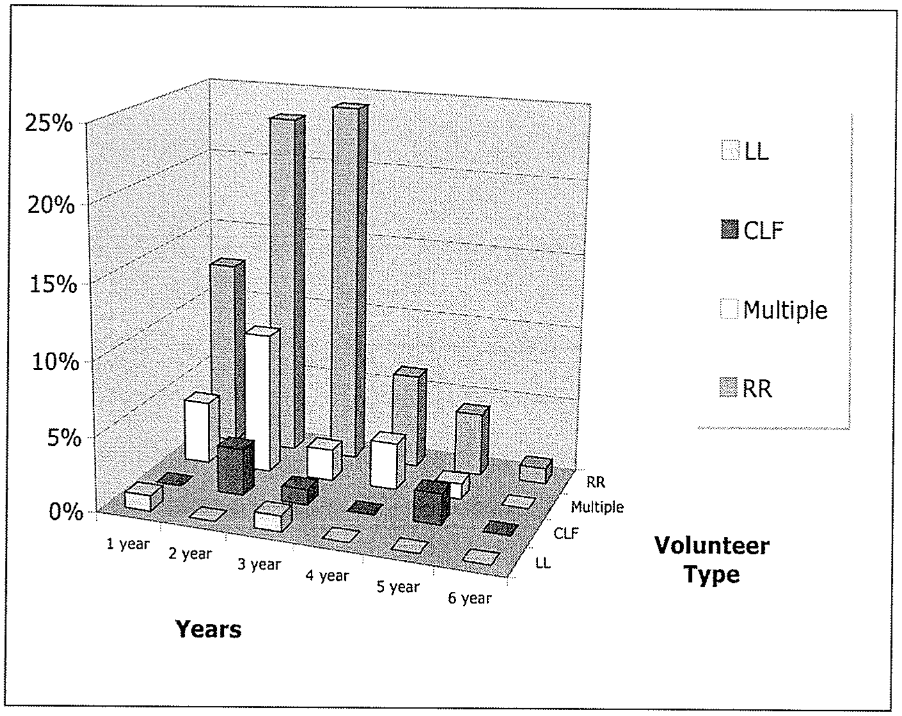


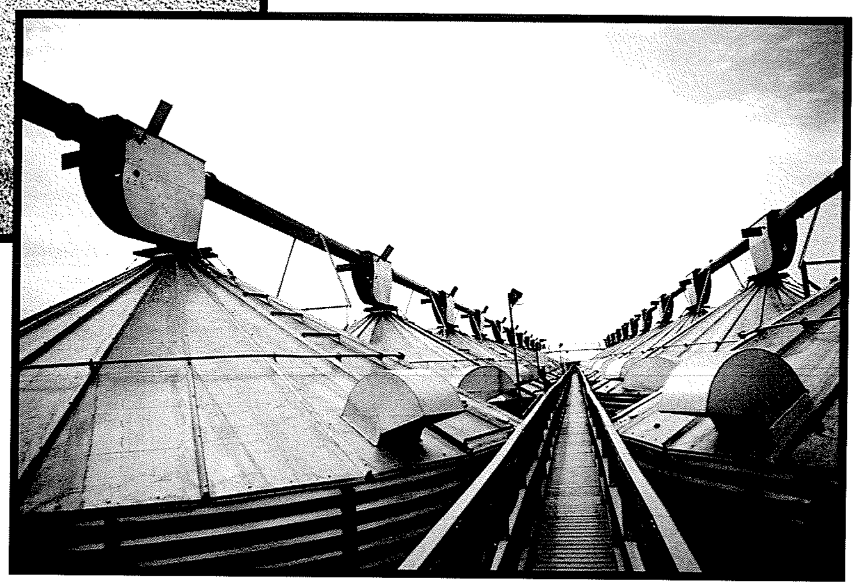
Figure 3. Farmer (n=95) experiences with herbicide tolerant (HT) canola volunteers, specifically the number of years till emergence represented as percentage. The different types of HT canola volunteers included Liberty Link (LL), Clearfield (CF), and Roundup Ready (RR), as well as a combination of these varieties (Multiple).

Chapter 7

Farmer knowledge and a priori risk analysis: A pre-release evaluation of genetically modified Roundup Ready wheat across the Canadian prairies

"We identify arrogant ignorance by its willingness to work on too big a scale, and thus to put too much at risk. It fails to foresee bad consequences not only because some of the consequences of all acts are inherently unforeseeable, but also because the arrogantly ignorant often are blinded by money invested; they cannot afford to foresee bad consequences"

Wendell Berry
The Way of Ignorance



CHAPTER SUMMARY

The controversy over the world's first genetically modified (**GM**) wheat, Roundup Ready wheat (**RRW**), challenged the efficacy of "science-based" risk assessment, largely because it excluded the public, particularly farmers. Risk analysis, in contrast, is more broad and considers science and public input in decision-making. The overall objective of this study was to include farmer local knowledge (**LK**) in the *a priori* risk analysis of RRW. In 2004, data were collected from farmers (n=1566) using mail surveys sent across the Canadian prairies. The main benefits associated with RRW were related to weed control, while the main risks included market impact, corporate control, agronomic problems, and the likelihood of contamination. Overall, risks were ranked much higher than benefits, and the farm community was strongly against RRW commercialization. These "high risk" attitudes were influenced by distrust in government and corporations, previous experience with GM canola, as well as a strong belief in the importance of community and environment. Farmers were critical of expert-based risk assessment, particularly RRW field trials, and believed that their LK was valuable for assessing agbiotechnology. Farmer LK is holistic in nature. Many of the farmer-identified risks revolved around socio-economic and legal concerns that are not recognized by risk regulators in Canada, demonstrating that LK can help inform decision-making regarding GM crops, making it more robust and legitimate.

1. INTRODUCTION

The development, field trials, and proposed introduction of the world's first genetically modified (**GM**) wheat crop in North America was controversial, and arguably challenged the legitimacy of "science-based" regulation for agbiotechnology. The disputed crop was Monsanto's transgenic Roundup Ready wheat (**RRW**), which is designed to be herbicide-tolerant (**HT**) to glyphosate. Although voluntarily withdrawn from commercialization in May 2004 (Stokstad, 2004), renewed interest in and advocacy for GM wheat, particularly RRW, is now being expressed as a way to increase innovation and grain supply (Dyck et al., 2007). This will likely lead to yet another attempt at reintroduction and polarized debate.

Each year, wheat is grown across the Canadian prairies, and sold to more than 70 countries, with export sales worth between $4 and $6 billion (US dollars) (Huygen et al., 2003). This wheat is marketed by the Canadian Wheat Board (**CWB**), a farmer-controlled organization that is the largest seller of wheat and barley in the world, this representing over 20% of the global market (CWB, 2008). Over 80% of Canada's wheat export markets have indicated they would not purchase GM wheat if it were grown in Canada (Huygen et al., 2003), thus its introduction would likely cause significant market harm. Despite this, the Canadian Food Inspection Agency (**CFIA**), the government agency responsible for approving environmental release of GM crops, denied the CWB's request to have socio-economics incorporated into risk assessment (Carter et al., 2005)

A priori risk assessment for GM crops is a strictly scientific process (NRC, 2002), which attempts to predict and avert potential problems (Sharples, 1991), and excludes socio-economic considerations such as market impact (Yarrow, 1999). Worldwide, field trials are central to risk assessment (Nap et al., 2002), as decision makers consider them the most appropriate and rigorous tool to determine the ecological and agronomic safety of GM crops prior to their release (Conner et al., 2003). However, it is recognized that field trials have weaknesses due to their small-scale and short-term nature, which reduces statistical power and predictions of ecosystem effects such as landscape level gene flow and potential invasiveness (NRC, 2002).

That "science-based" regulation of agbiotechnology in North America cannot incorporate non-scientific issues in risk assessment (Murphy and Levidow, 2006) has been criticized (RSC, 2001), particularly for acting as an institutional barrier to considering the important social, economic, and ethical implications of these products (Abergel and Barrett, 2002). Some argue that risk assessment creates a value-laden "risk window" that only makes visible scientific impacts, and thereby restricts the scope of information it can provide (Jensen et al., 2003).

A broader framework for assessing adverse impacts, risk analysis incorporates scientific data as well as socio-economic, ethical and legal concerns (Auberson-Huang, 2002), potentially mitigating the shortcomings of and increasing legitimacy in conventional "science-based" risk assessment (NRC, 2002). Public attitudes play an important role in risk analysis, particularly regarding controversial issues such as biotechnology (e.g. Aerni, 2002; Poortinga and Pidgeon, 2006), and the contribution that lay people can bring to bear on issues that affect society as a whole is increasingly recognized (Pidgeon et al., 2006).

To-date, however, most of the data on RRW has been gathered by experts from outdoor field trials sponsored by Monsanto since 1994 (MacRae et al., 2002) and conducted throughout Canada and the US (Zhou et al., 2003). Scientists studying the pre-release impacts of RRW have argued that benefits associated with it are substantial and include simplified weed control, suppression of perennial weeds (Van Acker et al., 2003), increased yields (Blackshaw and Harker, 2002), early seeding, reduced herbicide injury to wheat (Carter et al., 2005), and cleaner grain (Wilson et al., 2003). Yet its introduction might also have adverse implications for crop production and the environment as a whole, including difficulties in controlling volunteers, threats to conservation tillage systems, loss of seed saving, evolution of glyphosate resistant weeds (Van Acker et al., 2003), and gene flow between RRW and non-GM wheat (Brule-Babel et al., 2006).

Field trials for RRW were particularly contentious in Canada, grown across the prairies in "secret" locations, and managed by contracted farmers, Monsanto, and the federal government (Warick, 2003). Media reports indicated that some farmers were concerned that RRW might escape field trials and disrupt markets and their livelihoods (Bell, 2004). Despite the serious impacts RRW might have for farmers, their experiences and concerns have been excluded from decision-making, even though their knowledge is valuable in GM crop risk analysis (Mauro and McLachlan, 2008).

The local knowledge (**LK**) of farmers represents a rich and reliable source of information regarding the impacts associated with agricultural technology (Altieri, 1993, Mauro and McLachlan, 2008). This LK is experience-based, place-specific, holistic, and complements scientific agricultural research (Kloppenburg, 1991; Brook and McLachlan 2006). Research in this area has demonstrated that farmer LK is sometimes better than the "laboratory knowledge" of experts. One study found that sheep farmers affected by the Chernobyl disaster were skeptical of science-based pronouncements of safety, and ultimately had a more detailed understanding of radiation impacts than did experts

(Wynne, 1996). Another study documented farmer expertise regarding the health effects of agricultural chemicals, showing that scientists were naïve and incapable of adequately assessing how these products were actually used on farms (Wynne, 1992).

Farmer LK is widely incorporated in development projects in the Global South and has contributed to understanding already released agricultural technologies and their impacts on natural resource management and socioeconomics in over fifty countries (Eyzaguirre, 1992). Research further suggests that LK may be used in *a priori* risk assessment to predict, mitigate, and monitor environmental impacts associated with agricultural technology (Appriah-Opoku, 2005; Bacic et al., 2006). However, LK is rarely incorporated into research where agriculture is heavily modernized (Morgan and Murdoch, 2000) as scientists, policymakers, and industry often discount it as being anecdotal, subjective, and unreliable (Chambers, 1983; Tsouvalis, 2000).

Most of the farmer-focused research on GM crops conducted in North America has discounted LK, and focuses on economic benefits associated with canola in Canada (Fulton and Keyowski, 1999), soybeans and cotton in the US (McBride and Books, 2000), and the economic benefits and risks of GM corn in the US (Wu, 2004). In the Global South, studies are generally more inclusive, and importantly, have focused on farmer a priori risk perceptions associated with "golden rice" in the Philippines (Chong, 2003), GM eggplant in India (Chong, 2005), and GM corn in Mesoamerica and Cuba (Soleri et al., 2005). To-date, only two studies have explicitly explored the importance of farmer LK in the risk analysis of GM crops, these focusing on the post-release evaluation of GM canola (Mauro and McLachlan, 2008) and the combined impacts of GM canola and GM wheat (Mauro et al., 2005) in Canada.

Farmers will likely be most affected by the introduction of RRW and, arguably have important knowledgeable about its impacts, yet little research exists in this area. Given renewed calls for the release of RRW, this represents a gap in the literature, as well as an important opportunity to include farmer LK in the *a priori* risk analysis of this controversial crop. The overall goal of this study is to describe and understand farmer LK regarding RRW and empower its use in a priori risk analysis of future agricultural technology. More specifically, it will:

- Characterize farmer attitudes toward benefits and risks associated with RRW;
- Evaluate underlying variables contributing to benefit and risk perceptions, especially trust in government and corporations;
- Identify farmer perceptions regarding RRW field trials and future commercialization of the crop; and
- Explore the role that this farmer knowledge might play in a priori risk analysis of GM crops and more generally agricultural technology

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in the provinces of Alberta, Saskatchewan, and Manitoba. This region, the Canadian Prairies Ecozone (**Figure 1**), is characterized by a continental climate having short warm summers and long, cold winters, and strong winds (Smith et al., 1998). Mean annual temperatures range from 1.5 °C to 3.5 °C and mean winter and summer temperatures range from -12.5 °C to -8.0 °C and 14 °C to 16 °C, respectively (Smith et al., 1998). Mean annual precipitation varies, ranging from 250 mm in arid regions of Saskatchewan and Alberta to 550 mm in Manitoba's lake areas, and approximately 25% of this precipitation falls as snow (Smith et al., 1998). Chernozem soils dominate the ecozone and agricultural crops have largely replaced native vegetation, and it comprises over 60% of Canada's cropland (Smith et al., 1998). Wheat and canola are the main crops grown across the prairies, and over a ten-year average, are harvested on 10 million and 5 million ha, respectively (Statistics Canada, 2008).

2.2 Data Collection

This farmer-focused research on GM wheat used a mixed methodology (Creswell, 2002) and was conducted in six iterative phases: 1) interviews with farmers across western Canada (Mauro and McLachlan, accepted); 2) pre-testing of GM wheat questions in a previous study (Mauro and McLachlan, 2008); 3) development of a questionnaire that was mailed out across the prairies and followed up with a non-response bias evaluation; 4) analysis and modeling of the data using factor analysis and information theoretic approach; 5) systematic evaluation of responses to open ended questions in questionnaire; and 6) incorporation of both qualitative and quantitative responses, thereby triangulating the results. The Joint-Faculty Human Subject Research Ethics Board Protocol at the University of Manitoba approved the study design (#J2001:060).

Phase 1. Interviews were conducted with 15 farmers across western Canada between June and October of 2002. We purposefully sampled these farmers to participate in an in-depth interview process, in order to explore attitudes and experiences with HT canola and wheat (Mauro and McLachlan, accepted). Data collected during these interviews in part assisted in the development of questionnaires, ensuring that their content and wording were appropriate.

Phase 2. A 12-page survey was created that queried farmers and rural residents on their attitudes and experience with GM crops, with respect to this study specifically GM wheat, and about agriculture as a whole. The questionnaire included both quantitative seven-point Likert scale questions and open-ended questions. A shorter four-page survey, comprised of a subset of important and identically worded and formatted questions from the larger questionnaire, was also developed. This shorter survey was created for participants that had been unable to complete or misplaced the larger form. The use of this "mixed-mode" methodology (i.e. long and short surveys) has been demonstrated to increase response rates (Dillman, 2000).

Researchers associated with universities and industry as well as farmers reviewed the survey for comprehensiveness, technical accuracy and impartiality. Ordering of questions, in both versions of the survey, was randomized to ensure that self-administration was unbiased. The survey was further pre-tested with 10 farmers from Manitoba, which helped to further refine the research instrument.

A stratified random sampling approach was used. Within each province, four separate sampling regions were identified, and two of these were located near randomly selected Agriculture Canada research stations, which have excellent data on regional weather, agronomic, and environmental conditions. In each of these four regions, across the provinces, a central sampling location was identified, and an equal number of homes self-identifying as farms with Canada Post were identified surrounding this point. In total, 11,000 farms were randomly selected and questionnaires were sent as unaddressed "ad mail" in over 200 rural communities throughout Manitoba, Saskatchewan, and Alberta. The use of ad mail was necessary as no comprehensive mailing list for farms is available across the prairies.

We followed a version of the "tailored design method" (Dillman, 2000) when mailing out the survey. All recipients were sent a questionnaire on February 23, 2004. A post card and letter were sent on March 1 and March 15 2004, respectively, to encourage participation. The shorter survey was sent on April 12 2004 and further increased participant response. Questionnaires were sent with self-addressed business reply envelopes allowing them to be returned at no cost to the recipient. During this period, reminders were also printed in farm newspapers across the country (e.g. Western Producer, Farmers' Independent Weekly, etc) and various local, national, and international media reported on the study and its objectives (e.g. Rampton, 2004; White, 2004; Friesen, 2004).

In total, 1814 farmers and rural residents responded to our questionnaire. Responses from non-farmers were eliminated and the response rate was calculated by dividing the number of all eligible farmers (n=1566), this combined from the completed large (n= 903) and small (n=663) surveys, by the total number of sent surveys verified as farms growing wheat (n=4746) according to Statistics Canada's census of agriculture data. The adjusted response rate for the survey was 33%. Response rates for natural resource management surveys have been declining over time (Connelly et al., 2003), and are particularly low for rural research as few farmers fill out surveys (Pennings et al., 2002).

We conducted a telephone survey to test for non-response bias, using ten questions having to do with agbiotechnology that were contained in the original questionnaires. Communities across the prairies were randomly selected from those used in the mailout and within these, residents were randomly selected using rural telephone directories. Geographic information system (**GIS**) software (ESRI, 2008) was used to match post offices that had received surveys with the corresponding telephone exchanges in order to contact farmers who had received the surveys but who had not responded. In total, 20 farmers in each of the three provinces were contacted but only 6 had completed one of the surveys. The reasons cited for not filling out the survey, in order of importance, were ineligibility, being too busy, and simple refusal to fill out a survey of any kind. No statistical difference was found between responders and non-responders for nine of the ten questions. Only one question showed significant (P = 0.01**, SE = 0.2) difference between responders and non-responders, which referred to the importance of education, this likely an artifact of the telephone-based interaction with a university-associated researcher.

The majority (85%) of respondents to our questionnaire were male and averaged 52 years of age (SE = 0.33), farm size of 686.8 ha (SE = 21.83), of which 56% had some college/university education. Respondents were similar in age (52 years) (Statistics Canada, 2006a), although more educated (36%) (Statistics Canada, 2001) with slightly larger farms (473 ha) (Statistics Canada, 2006b) when compared with census data across the prairies. Farmers practiced minimum and zero tillage on 55% of reported acres, this lower than the national average of 72% (Statistics Canada, 2006c). The proportion of organic farmers (10% vs. 6.8%) was slightly higher than the national average (Statistics Canada, 2006c). Many farmers (61%) reported having previously grown herbicide-tolerant (**HT**) canola, including Roundup Ready (50%), Liberty Link (17%), Clearfield (11%), and combinations of these (21%), which are usage rates similar to national data (Buth, 2006).

2.3 Data Analyses

Respondents were classified into four mutually exclusive groups: as organic, HT, non-HT, and conservation tillage. Where farmers practiced multiple techniques, the individual farm data was evaluated, and the most suitable class was selected. A common combination included both HT and conservation tillage use and, in this scenario, farmers practicing both were classified as HT users, and therefore conservation till users in this study represent those that only used minimum tillage practices but not HT crops. The proportion of respondents indicating either positive or negative attitudes to agbiotechnology was calculated for each of the four groups. The mean of these various farmer attitudes were analyzed using ANOVA, and when the overall ANOVA model was significant, post-hoc Student-Newman-Keuls (**SNK**) tests were conducted to separate means (SPSS, 2006). Farmer attitudes toward RRW field trails and the future release of RRW were summarized with averages. Risk perceptions of farmers were summarized using mean, standard error (SE) and Cronbach's alpha (Cronbach, 1951). Cronbach's alpha was high, between 0.94 and 0.96 for all questions, substantially above the 0.70 standard required for multivariate variable reduction (Nunnally and Bernstein, 1994). Using SAS (2007), these two groups of thirteen benefit and nineteen risk questions, identified by the literature and our previous research, were each submitted to principal components factor analysis, using a promax rotation, in order to group items (loading set at 0.4) onto conceptually similar factors (Hatcher, 1994).

A set of independent variables from the survey was selected in order to explain the risk perceptions. These variables included farm and demographic data, as well as indices created from multiple questions in the survey, which measured trust in government and corporations, and the degree to which a respondent believed in the importance of community and environment. Each index included between six and eight variables, which were coded so that trust and/or importance was associated with higher ranking on the Likert scale, and the average of these was taken to create the composite variable. The government index measured trust in regulatory competency and impartiality related to agbiotechnology. The corporate index measured trust in industry's motives associated with the development of agricultural technology. The community index measured general attitudes towards the value of sustaining rural areas. The environmental index measured the degree to which respondents valued the natural world and considered themselves stewards of it. Multicollinearity among the eleven explanatory variables was evaluated using Spearman rank correlations and all variables were found to be independent.

Factor scores for benefit and for risk were sorted into thirds, representing high, medium, and low perceptions of benefit and risk. The medium scores were eliminated to create binary responses, which allowed for modeling of high and low benefit and risk, and any respondents with missing data were removed from further analysis. The remaining factor scores were subjected to logistic regression to model the probability that benefit and risk perception would be high. All 2047 possible binary logistic regression models were run individually, for both benefits and risks, and Akaike's information criterion with small sample adjustment (AICc) and Akaike weights (w) were calculated (Anderson and Burnham, 2002). Cumulative AICc weights for each explanatory variable were calculated by summing the AICc weights of every model containing that variable (Burnham and Anderson, 2004). Explanatory variables with the highest cumulative AICc weights best predicted why farmers perceived “high benefit” and “high risk” for RRW. All AIC-based calculations were performed with SAS (2007).

Qualitative data were coded and any emerging themes were identified (Maxwell, 2005). Emerging themes were matched with quantitative findings. This mixed methods approach was used to both triangulate responses and to further interpret the results.

3. RESULTS

3.1 Comparison of farmer attitudes toward Roundup Ready wheat

Farmers showed a remarkably uniform response to Roundup Ready Wheat (**RRW**). This held true even when respondents were examined according to very different approaches to farming, including organics, HT users, non-HT users, and conservation tillage (**Table 1**). These groups were unified in their opposition (P = 0.033, mean = 2.09+/-0.04, proportions between 0.80 and 0.89) to RRW being approved for unconfined release in the environment. They were highly unlikely to grow RRW if it was on the market (mean = 1.98+/-0.04, proportions between 0.83 and 0.94), and farmers practicing organics and conservation tillage were most against its use (P < 0.0001). A main reasons for not growing it was consumer antipathy (mean = 6.39+/-0.04, proportions between 0.88 and 0.98), this of least concern to HT users (P < 0.0001). As one HT user from Alberta indicated:

> *"Genetically altered wheat...should not be released until consumer acceptance and all issues related to it have been addressed"* (Alberta farmer, HT user, A48)

Most indicated that herbicide tolerance in wheat is not a major benefit (proportions between 0.74 and 0.86), although HT farmers felt less strongly in this regard (P <

0.0001). Comparing RRW with other GM crops, one HT user reflected the attitude of many:

> *"I don't condemn GM crops, especially for pest and disease control, but not for wheat where we have adequate chemicals and varieties"* (Saskatchewan farmer, HT user, S16)

Farmers were largely critical of the notion that companies need to patent GM wheat (proportions between 0.66 and 0.88), although organic, non-HT, and conservation till users felt more strongly about this than did those growing HT crops ($P < 0.0001$). Only half of HT farmers agreed (proportion = 0.49) that GM wheat would damage the social fabric of rural Canada, whereas most organic, non-HT, and conservation tillage users differed ($P < 0.0001$) and believed that it would. Linking patent control over GM crops, and the associated restrictions for farmers to save and reuse seed, with the demise of agriculture, one HT user from Saskatchewan indicated:

> *"The foundation of agriculture is reproduction. To not allow the farmer to seed what he has harvested is to kill agriculture"* (Saskatchewan farmer, HT user, S74)

3.2 Risks associated with RRW

Farmer perceptions regarding risks associated with RRW were ranked high and categorized into four major areas using factor analysis, which explained all variance (**Table 2**). The first factor, "market impact" (eigenvalue = 11.36) was dominant, capturing 88.2% of the variance, it included economic, logistical, and biological issues that might compromise consumer confidence and ultimately affect markets. Reflecting the holistic way that farmers viewed these issues, one HT user from Manitoba stated:

> *"I feel there is absolutely no way that RRW can be kept separate from regular wheat during growing, harvesting or at the elevator and shipping levels. If our*

importers do not want RRW, why is Monsanto pushing to develop it? The high standard of Canadian wheat will be contaminated and the market will disappear. It is difficult enough to survive in farming without having Monsanto take away any export markets Canadian farmers have. NO RRW" (Manitoba farmer, HT user, m162)

The second factor, "corporate impact" (eigenvalue = 0.76), held 5.9% of the variance, and focused on corporate control over seeds and farmer rights. Corporate domination over agriculture was of concern to many respondents in all user groups. As one HT user from Manitoba indicated:

"Farmers are treated like serfs or slaves to the large corporations and chemical companies. If allowed to do so our food supply is in danger. Our very existence as farmers is in danger" (Manitoba farmer, HT user, m64)

The third factor, "agronomic impact" (eigenvalue = 0.58), retained 4.5% of the variance and highlighted the affect of RRW on the agroecology of farm systems, particularly regarding weed management (i.e. HT volunteers and RR resistance). Many indicated that RRW volunteers would be much harder to control than RR canola:

"Controlling RR canola volunteers is easy, just a small amount of 2-4, D does the trick. Volunteer wheat is a whole different story, none of the chemicals to do that are cheap, so the cost of [conservation tillage] becomes a lot more expensive, and add that to the cost of paying a TUA on wheat and the cost would outweigh the benefits" (Alberta farmer, HT and Conservation till user, A82)

Further elaborating on the risk Roundup Ready wheat poses for conservation tillage, specifically the cumulative impacts associated with RR canola, two farmers stated:

"I am dead set against RR wheat. We do not need it. It could spell the end of [conservation till]. RR canola is already too much" (Saskatchewan farmer, HT and Conservation till user, S354)

> *"My biggest concern with RRW is that with crop rotation, as I use RR canola, and RRW volunteers would become a problem to control"* (Manitoba farmer, HT and conservation till user, m148)

Another commonly voiced concern related to RRW increasing the use of Roundup, an important herbicide in prairie agriculture, which in turn, might lead to weed resistance:

> *"Roundup is a very useful tool in our farming operation. RRW will greatly damage the effectiveness of this tool...RRW will only encourage more use of this product and as a result, increase the risk of developing resistant weed species"* (Alberta farmer, HT and Conservation till user, a123)

The fourth factor, "contamination impact" (eigenvalue = 0.53), contained 4.1% of the variance and demonstrated the contamination issues associated with RRW and the negative impact this might have on conventional and organic farmers.

> *"If GM wheat is ever approved by the government...it will totally destroy the organic and conventional farmers because wheat...will cross pollinate into wheat fields many miles away by wind and birds and water, etc. This will contaminate all farms"* (Alberta farmer, organic, A111).

3.3 Benefits associated with RRW

Respondents did identify benefits associated with RRW, although the mean rankings were associated with neutral, or lower, on the Likert scale, and they were seen as far less compelling than potential risks. Farmer perceptions regarding benefits associated with RRW were grouped into two major areas using factor analysis, which explained all variance (**Table 3**). The first factor, "weed control" (eigenvalue = 7.85), held 94.85% of the variance and included options for better and easier weed management. As one HT user from Manitoba indicated:

> *"I have on my fields wild oat and millet that is resistant to Group 1 and Group 4 herbicides. I need RRW"* (Manitoba farmer, HT user, m259)

The second factor, "agronomic" (eigenvalue = 0.51), contained 6.18% of the variance, and included various production benefits. Affirming this, another farmer indicated:

> *"I believe that the sooner we can sow RRW, the sooner I can benefit from...higher yield, with less input costs"* (Manitoba farmer, HT user, m142)

3.4 Independent variables that contributed to benefit and risk perception

Although most respondents were uniformly against RRW, individual farmers did have differing perspectives, and these were explored. The factor analyses produced factor scores for farmers that represented a composite variable of their individual risk and benefit perceptions. For the primary risks, relating to "market impact", these factor scores ranged from 0.74 (high risk) to -4.64 (low risk). For the primary benefits, relating to "weed control", these factor scores ranged from 1.82 (high benefit) to -2.00 (low benefit). Eleven independent variables (**Table 4**) were selected to analyze all 2047 possible models for both risk and benefit perceptions using logistic regression and Akaike's information criterion.

The most important variables that predicted "high risk" perception, determined by a high AICc cumulative model average weight, were low trust in government (β = -4.46) and corporations (β = -4.00), and a strong belief in the importance of community (β = 5.41) and environment (β = 4.00). One non-HT farmer holistically summarized this perspective:

> *"With a lifetime of experience in farming, I've found out that both government and agribusiness information can often be misleading; giving us only information that will benefit them, to the detriment of rural communities, the environment, and health"* (Saskatchewan farmer, non-HT, S292)

Farmer experience with already released HT canola (β = 0.81) was also an important predictor for "high risk" perceptions. Many farmers indicated that they had problems with HT canola due to contamination and volunteers. One farmer indicated the frustration of many regarding RR canola:

> *"I have never grown Roundup Ready canola on my farm. I use [another HT] canola myself. I have Roundup genetics spread on my entire farm. HOW DID IT GET THERE??? Who pays to control this new weed on my farm? ME!! Corporations want to extract their profit margins out of agriculture whether the farmer makes a living or goes broke"* (Saskatchewan farmer, HT user, S311)

One respondent indicated that the reason why he now uses Monsanto canola is because his farm was contaminated:

> *"The reason I grow Roundup Ready canola is that my neighbor grew it and the seed blew into my fields. My fields are now contaminated"* (Alberta farmer, HT and conservation till user, A160)

The most important variable that predicted "high benefit" perception, also based on model averaging, was high trust in government (β = 5.81). One farmer summed up this faith in government well:

> *"So long as [GM technologies] are sufficiently tested by independent, knowledgeable, responsible bodies (i.e. government or entities under the direct control of government) for both short-term and long-term effects, I think we should employ such technology"* (Alberta farmer, HT user, A143)

A low belief in the importance of community (β = -3.54) was also important in predicting "high benefit" perception. Although a minority, some farmers dismissed the impacts RRW might have on of rural communities, and believed that industry-led technology development should be a priority for agriculture, and in turn, might benefit communities. On this topic, one farmer stated:

"Roundup Ready will have little impact on...communities...we need to ensure that [regulations] are not so unnecessarily restrictive that they preclude adoption of new technology...can [agriculture] be sustainable without viable rural communities? It probably can. What is clear is that rural communities will not be sustainable without viable agricultural industry" (Saskatchewan farmer, HT user, S220)

Farmer experience with HT canola ($\beta = 0.70$) was also found to be an important predictor of farmer "high benefit" perceptions regarding RRW. One farmer indicated some of the reasons why farmers appreciate RR canola:

"Roundup ready canola has changed the amount of canola that can be grown. The [weed seeds and chaff] is as low as 1.5% compared to 10% plus for conventional canola. It has put a lot of money in the farmers' pockets in this area" (Alberta farmer, HT and conservation till user, A40)

3.5 A priori risk assessment: Roundup Ready wheat field trials and future commercialization

Throughout the RRW debate, the crop was being field tested in open-air research trials across the western Canada in little-known locations, and farmers (n=905) were asked to comment upon this. While most farmers (65%) believed that these trials were important to assess the safety of RRW, they felt (68%) that Monsanto should not be carrying out this research throughout the prairies. Many farmers (58%) believed that regulatory oversight of these test plots was inadequate, while some (29%) felt otherwise. Most farmers (82%) believed that they should have a say regarding the location of test plots, and many (66%) were frustrated that this research was taking place in secret locations. While only a few farmers (2%) thought RRW might have escaped trials and be in their fields, many (55%) suspected that this was possible. Believing that these test plots might cause harm, and concerned that farmers perspectives on RRW were being ignored, one farmer stated:

> *"I believe the biggest issue driving GM wheat research is the money there is to be made for the chemical companies, namely Monsanto. I believe they manipulate the research results in order to give the Government the information they want to hear...RRW test plots...might hurt our wheat markets and hurt zero till and minimum till farmers. How come those concerns have not been listened to?"* (Manitoba farmer, HT user, M257)

Amongst the RRW controversy, Monsanto promised the wheat industry and farmers that they would achieve certain "milestones" before introducing the world's first GM wheat. Farmers in both surveys were queried on the likelihood of Monsanto achieving these objectives and found that a minority believed market acceptance (17%), regulatory approvals (19%), a reliable segregation system (12%), and a solution for weed problems associated with RRW volunteers (20%) were possible. Few farmers (16%) indicated they would grow RRW if Monsanto achieved these abovementioned milestones. A majority of farmers expressed frustration over Monsanto's ongoing research into RRW and push to have it commercialized, and one farmer summarized this well by saying:

> *"Just because Monsanto is a large multinational company does not mean that they can bulldoze their way and products into our crop production practices and markets. We as producers are not allowed to engage in actions that endanger our environment. Why can Monsanto continue to promote and experiment with RRW that can potentially pollute all our bread wheat!?"* (Manitoba farmer, HT user, m188)

Importantly, the great majority of farmers (90%) believed that rural communities had knowledge that was important and useful for assessing the impacts of GM crops. In this regard, one farmer commented on the role of intellectuals and rural communities in risk analysis:

> *"Higher education is a wonderful thing as it can broaden the mind and prepare individuals to think for themselves, but in so many areas (e.g. agriculture and medicine) the education tends to be biased and corrupt; so, yes indeed, rural knowledge should be incorporated [into decision making]"* (Saskatchewan farmer, organic, S187)

Similarly, another respondent believed that fàrmers were the only stakeholders that should be responsible for whether RRW should be approved:

> *"The decision to have RRW should be made by all farmer stakeholders not Monsanto and not by the Government"* (Farmer, HT, m80)

4. DISCUSSION

The local knowledge (**LK**) of farmers, as presented in this study, was holistic in nature and well suited for assessing the *a priori* impacts associated with the unconfined release of Roundup Ready wheat (**RRW**) across the Canadian prairies. This knowledge, rooted in individual experience, was surprisingly uniform, regardless of farming approach, and the great majority of farmers were strongly opposed to the unconfined release of RRW. Overall, risks were ranked substantially higher than benefits, indicating that the farm community believes risk outweighs benefit for RRW.

These findings support those conducted for the Canadian Wheat Board that found "The cost-benefit analysis for Roundup Ready wheat was clearly negative, and that is why there was so much agreement among farmers that it was the wrong product at the wrong time" (CWB, 2004). Over 80% of wheat sales might be harmed by the introduction of RRW (Huygen et al., 2003) in both Canada and the US (Wisner, 2003; 2005), explaining why "market impact" was the major risk identified by farmers. Market harm, on balance, was the main reason why farmers rejected the crop. Few farmers expressed interest in growing RRW even if, as Monsanto promised, market acceptance, segregation, and solutions to biological problems became feasible.

Farmers had a deep understanding of how biological containment of GM traits was intrinsically tied to grain system segregation, and ultimately market accessibility. Moreover, most felt that gene flow in RRW would not be contained. These concerns have been reflected by others, who argue that RRW will likely outcross across the prairies (Van Acker et al., 2004) and, due to our inability to adequately or affordably segregate it from non-GM wheat, would create a situation whereby all North American wheat would be devalued (Furtan et al., 2005). In this way, biological effects associated with GM crops are inextricably linked to socio-economics, despite current risk assessment practices in Canada and the US that effectively ignores this important reality.

Organic farmers were particularly vulnerable to RRW gene flow and associated socio-economic impacts. Organic standards do not allow for the presence of GM-traits. The release GM canola contaminated seed supply and farm fields across the prairies (Friesen et al., 2003), and cost organic farmers upwards of $2 million (Canadian) in lost markets (Smyth et al., 2002). Organic farmers in this study were concerned that contamination would also happen in wheat, their most important crop, and "destroy" their ability to farm organically all together. In lieu of this, quality assurance standards have been developed to reduce GM contamination of organic crops (Van Acker and Martin, 2007), yet these do little to mitigate socioeconomic risks associated with this technology. Since socioeconomic risks are not considered in risk assessment, organic farmers in Saskatchewan, with support from their provincial association, were prepared to sue

Monsanto to halt the introduction of RRW, in order to protect their markets and livelihoods (Bouchie, 2002).

Farmers practicing conservation tillage were also at high risk from the introduction of RRW. These farmers use glyphosate herbicides (e.g. Roundup), instead of tillage, to control weeds prior to seeding, which increases soil health and carbon sequestration, and reduces fuel use, overall costs, loss of soil moisture and soil erosion (Van Acker et al., 2004). However, farmers were concerned that RRW volunteers resistant to glyphosate would increase in abundance due to selection pressure from herbicides, and would be difficult and costly to control. Other studies indicate frequent applications of glyphosate in conservation tillage systems will increase the RRW trait in volunteer populations, this despite relatively low rates of gene flow in wheat, (Brule-Babel et al., 2006). The need to use additional and more expensive herbicides could cost conservation till farmers between $5-52 (Canadian) per ha in additional herbicides used to control RR volunteers (Van Acker et al., 2004), thus undermining the viability of conservation tillage and its associated environmental benefits (Van Acker et al., 2003).

Many respondents recognized that RRW volunteers, in combination with RR canola volunteers, would cause cumulative adverse effects, increasing the potential for glyphosate resistant weeds and further undermining conservation tillage systems. Herbicide tolerant (**HT**) volunteers are already primary determinant of risks associated with GM canola (Mauro and McLachlan, 2008) and will be difficult to control in RRW (Mauro et al., 2005; Van Acker et al, 2004). Interestingly, a recent study co-authored by Monsanto even suggests that RRW is best suited for regions where other RR crops are grown infrequently, given the potential they pose for increasing weed resistance and problems associated with HT volunteers (Howatt et al., 2006). However, these cumulative effects are not presently recognized in risk assessment, as crops are evaluated on a 'case-by-case' basis (Nap et al., 2003), which suggests a new approach that investigates the combined impact of multiple GM crops, grown in rotation is necessary.

Another issue that is not recognized by "science-based" risk assessment is the increasing corporate control over agriculture, which farmers deemed to be a major risk associated with RRW. Farmers were against wheat seed patents, as they believed this would increase costs, while restricting their ability to save, exchange, and reuse seed, making them "serfs or slaves to the large corporations". Currently, 76% of wheat seed in Canada is saved annually, which represents an untapped market for large seed companies (Kuyek, 2007), 10 of which now own over 55% of commercial seed worldwide (USC & ETC, 2008). Some have similarly argued that patenting seeds is the nexus for corporate control over all of agriculture, in turn, forcing farmers onto a "genetic treadmill" that increases their reliance on external inputs (Kloppenburg, 2004). These changes would compromise generations of plant breeding by farmers, which helps prevent "genetic erosion" and the loss of agricultural biodiversity (Fowler and Mooney, 1990).

While risks ultimately outweighed benefits for RRW, some farmers recognized that this crop had advantages. The most important benefits were associated with "weed control", particularly for wild oat resistant to group 1 (grass herbicide) products. Between 1996 and 1997, group 1 resistant oat occurred in 50% of fields across the prairies, representing a significant threat to crop production and quality (Beckie et al., 2001). To this end, RRW provides over 95% efficacy in controlling wild oat (Blackshaw and

Harker, 2002), and, as recognized in this study, generally, increased the ease of weed management in wheat production (Harker et al., 2005)

Farmers generally did not view other "agronomic" benefits associated with RRW as important. They disagreed that RRW would increase yields, contrasting with field trial research that predicted a 9% (Blackshaw and Harker, 2002) and 10% (Howatt et al., 2006) increase in yield. Nor did respondents agree that RRW would provide cleaner grain (Wilson et al., 2003), facilitating conservation tillage, early seeding, greater product uniformity, and increased crop safety (Carter et al., 2005). In part, this reflects the cumulative nature of the agronomic risks associated with RRW, which in rotation with RR canola would cause significant weed competition and management problems that would likely decrease overall yield. Indeed, many were skeptical of expert-based research regarding RRW, which is consistent with literature showing increasing public distrust of risk assessment regarding complex technology, especially GM crops (Taylor-Gooby and Zinn, 2006).

Trust in expert-based institutions, particularly government and corporations, were important predictors of individual farmer benefit and risk perception. Farmers with "high risk" attitudes toward RRW had low trust in government and corporations, whereas farmers that perceived "high benefit" were more trusting in these institutions. These outcomes reflect those of other studies demonstrating that trust in government (Barnett et al., 2007; Grobe et al., 1999) and corporations (Siegrist, 2000) are good predictors of "lay" public attitudes towards genetic technologies.

However, it is important to recognize that farmers, given their decade-long experiences with GM crops, have a much more pragmatic and arguably deeper understanding of agbiotechnology than that of the "lay" public. In this study, farmers evaluated the combined risks and benefits, applying their lived knowledge of HT canola when anticipating the impacts of this yet unreleased technology. Although "lay" people often employ trust as a way to make decision, this becomes especially important when lacking direct information or experience regarding these technologies (Siegrist and Cvetkovich, 2000). In contrast, farmer attitudes toward risk, trust, and experts regarding agriculture is much more complex and is highly influenced by their LK of agroecosystems and socio-cultural factors embedded in rural communities (Neufeld and Cinnamon, 2004). This larger context was reflected in these results, which found that, high-risk perceptions were also associated with recognition of the importance of environment and community, and LK regarding HT canola. This further demonstrating the holistic knowledge farmers had about RRW, which recognized the intertwined impacts of environmental and socioeconomic risks associated with this technology.

While RRW was not commercially released in Canada, it was field tested across the prairies, and farmers distrusted and were frustrated by this research and its oversight by government and industry. "Afraid of contamination", the Saskatchewan Area of Rural Municipalities passed a 2003 resolution demanding test plot locations be made public, so farmers could know if they were at risk (Warick, 2003). Throughout this field-testing, ecological studies differed on the safe isolation distance needed to protect farmers and non-GM crops from RRW cross-pollination. Guidelines were altered so that buffer zones increased from 3 meters to 30 meters in 2000 (Raine, 2003) and ultimately to 300 meters in 2004 (Bell, 2004). A defining characteristic of environmental risk, like those posed by GM crop field trials, is that it is difficult to assess probabilistically, which leads to disagreement amongst experts, and an overall breakdown of formal risk assessment (Pidgeon et al., 2006; Beck, 1992).

These RRW field trials could be considered a "risk event" (Kasperson et al., 2003) whereby gene escape constituted a biophysical hazard, and the associated social and cultural implications of this technology, including the role of risk managers and industry, may have increased farmer distrust and risk perceptions. Media commentary on RRW and its associated benefits and risks was pervasive throughout North America, especially in the farm press, which can increase the social amplification or attenuation of risk perception in debates regarding GM crops (Frewer et al., 2002).

A major national news story in Canada that likely amplified farmer perceptions of risk, and their associated distrust of institutions, was that the the government and Monsanto had collaborated in the development of RRW. Through "access to information" documents, it was revealed that the federal government contributed nearly $2.5 million (Canadian) and in-kind support towards the RRW project, and was perceived as being in a "conflict of interest" as both regulator and co-developer of this technology (CBC, 2003). Indeed, the government was positioned to make millions of dollars in royalties from sales of the crop (Warick, 2003). The actions of organizations responsible for risk management (i.e. federal government), as opposed to the natural risk phenomena itself (i.e. RRW), are increasingly viewed as important in social amplification of risk (Pidgeon et al., 2006).

Concerned about RRW, secret field trials, and lack of farmer input in decision-making, Canadian farm organizations led actions across the country against the crop. These included an ad campaigns in newspapers stating, "We're not ready for Roundup

Ready wheat" (Warwick, 2003) and "The greatest threat to wheat farming isn't hail or drought, it's Roundup Ready wheat" (NFU et al., 2004), and a prairie-wide tour that engaged communities regarding risks associated with the technology (Magnan, 2007). Resistance to agbiotechnology, as witnessed in the RRW debate, has been attributed to the public being excluded from policy and decision-making (Abergel and Barrett, 2002) Alternative and more democratic approaches to evaluating impacts associated with agbiotechnology is needed and are exemplified in Europe's precautionary approach that includes widespread public consultation processes and mandates labeling regarding GM crops (Murphy and Levidow, 2006). Unfortunately, Canada resists this more transparent and publicly accountable regulatory system (Falkner, 2007), despite calls from the Royal Society of Canada (2001) to adopt a more inclusive and precautionary approach to evaluating the safety of GM crops.

This publicly funded research is the first in the world to include farmer knowledge in the *a priori* risk analysis of RRW and, arguably, given its prairie-wide scope, is the largest farmer-focused study on GM crops ever conducted. It has demonstrated that farmer LK is holistic in nature and experience-based, integrating socio-economic, cultural, political, and agroecological factors, which can contribute significantly to the pre-release evaluation of GM crops. That lived expertise contrasts strongly with expert science-based knowledge, suggests it can play a complementary role in decision-making regarding existing and new forms of agbiotechnology. This is especially important when the consequences of these technologies are little understood, especially when they may have potential to create great harm. The inclusion of farmers and other stakeholders will also enhance and even restore public confidence in "science-based" approaches to risk assessment. Farmers are indeed experts regarding RRW – and arguably any agricultural technology. So, should RRW be commercialized? The answer is blowing in the prairie wind; farmers indicated they must be the ones to decide, and right now, they have clearly indicated "No RRW".

REFERENCES

Abergel, E., & Barrett, K. (2002). Putting the cart before the horse: A review of biotechnology policy in Canada. *Journal of Canadian Studies, 37,* 135-161.

Aerni, P. (2002). Stakeholder attitudes toward the risks and benefits of agricultural biotechnology in developing countries: A comparison between Mexico and the Phillipines. *Risk Analysis, 22,* 1123-1137.

Altieri, M.A. (1993). Ethnoscience and biodiversity: key elements in the design of sustainable pest management systems for small farmers in developing countries. *Agriculture, Ecosystems and Environement, 46,* 257-272.

Appiah-Opoku, S. (2005). *The Need for Indigenous Knowledge in Environmental Impact Assessment: The Case of Ghana.* Queenston, ON: Edwin Mellen Press.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology, 20,* 1076-1078.

Bacic, I.L.Z., Bregt, A.K., & Rossiter, D.G. (2006). A participatory approach for integrating risk assessment into rural decision-making: A case study in Santa Catarina, Brazil. *Agricultural Systems, 87,* 229-244.

Barnett, J., Cooper, H., & Senior, V. (2007). Belief in public efficacy, trust, and attitudes toward modern genetic science. *Risk Analysis, 27,* 921-933.

Beck, U. (1992). *Risk Society: Towards a New Modernity.* London: Sage Publications.

Beckie, H.J., Thomas, A.G., & Stevenson, F.C. (2001). Survey of herbicide-resistant wild oat (Avena fatua) in two townships in Saskatchewan. *Canadian Journal of Plant Science, 2,* 463-471.

Bell, I. (2004). Buffer zone enlarged for GM wheat trials. *Western Producer.* March 4.

Blackshaw, R.E., & Harker, N. (2002). Selective weed control with glyphosate in glyphosate-resistant spring wheat. *Weed Technology, 16,* 885-892.

Bouchie, A. (2002). Organic farmers sue GMO producers. *Nature Biotechnology, 20,* 210-211.

Brule-Babel, A.L., Willenborg, C.J., Friesen, L.F., & Van Acker, R.C. (2006). Modeling the influence of gene flow and selection pressure on the frequency of a GE herbicide-tolerant trait in non-GE wheat and wheat volunteers. *Crop Science, 46,* 1704-1710.

Burnham, K.P., & Anderson, D.R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach (2nd Edition).* New York: Springer.

Burnham, K.P., & Anderson, D.R. (2004). Multimodel inference: Understanding AIC and BIC in model selection. *Sociological Methods & Research, 33*, 261-304.

Buth, J. (2006). Canola Council of Canada. Personal Communication.

Carter, C., Berwald, D., & Loyns, A. (2005). *The Economics of Genetically Modified Wheat.* Toronto: University of Toronto Press.

CBC (Canadian Broadcasting Corporation). (2003). Canadian government in conflict of interest over genetically modified wheat partnership with Monsanto. *The National (Television).* November 28. Available at: http://www.healthcoalition.ca/gmo-archives.html

Chambers, R. (1983). *Rural Development: putting last first.* New York: Longman Group Limited.

Chong, M. (2003). Acceptance of golden rice in the Philippine 'rice bowl'. *Nature Biotechnology, 21*, 971-972.

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant in Indian farmers. *Journal of Risk Research, 8,* 617-634.

Connelly, N.A., Brown, T.L., & Decker, D.J. (2003). Factors affecting response rates in natural resources-focused mail surveys: empirical evidence of declining rates over time. *Society and Natural Resources, 16*, 541-549.

Conner, A.J., Glare, T.R., & Nap, J.P. (2003). The release of genetically modified crops into the environment: Overview of ecological risk assessment. *The Plant Journal, 33*, 19-46.

Creswell, J.W. (2002). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (2nd Edition).* Thousand Oaks, CA: Sage Publication.

Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*, 297-334.

CWB (Canadian Wheat Board). (2004). *Grain Matters* (July/August). In C. Carter, D. Berwald, & A. Lyons (2005). *The Economics of Genetically Modified Wheat.*Toronto, ON: University of Toronto Press.

CWB (Canadian Wheat Board). (2008). Available at: http://www.cwb.ca

Dillman, D. (2000). *Mail and Internet Surveys: The Tailored Design Method (2nd Edition).* Toronto: John Wiley and Sons, Inc.

Dyck, B., Fries, T., Glen, B., McMillan, D., & Zacharias, K. (2007). Wheat research must include GM – WP editorial. *Western Producer.* December 29.

ESRI. (2008). Available at: http://www.esri.com/

Eyzaguirre, P. (1992). Farmer knowledge, world science, and the organization of agricultural research systems. In J.L. Moock, & R.E. Rhoades (Eds.), *Diversity, Farmer Knowledge, and Sustainability.* Ithaca, NY: Cornell University Press.

Falkner, R. (2007). International cooperation against the hegemon: The Cartagena Protocol on Biosafety. In. R. Falkner (Ed.), *The International Politics of Genetically Modified Food: Diplomacy, Trade and Law.* New York: Palgrave MacMillan.

Fowler, C., & Mooney, P. (1990). *Shattering: Food, Politics, and the Loss of Genetic Diversity.* Tucson, AZ: The University of Arizona Press.

Frewer, L.J., Miles, S., & Marsh, R. (2002). The media and genetically modified foods: Evidence in support of social amplification of risk. *Risk Analysis, 22,* 701-711.

Friesen, L.F., Nelson, A.G., & Van Acker, R.C. (2003). Evidence of contamination of pedigreed canola (Brassica napus) seedlots in western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal, 95,* 1342-1347.

Friesen, R. (2004). U of M survey measures attitudes toward GM wheat. *Manitoba Cooperator.* February 25. Available at: http://www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm_research

Fulton, M., & Keyowski, L. (1999). The producer benefits of herbicide-resistant canola. *AgBioForum, 2,* 85-93.

Furtan, W.H., Gray, R.S., & Holzman, J.J. (2005). Regulatory approval decisions in the presence of market externalities: The case of genetically modified wheat. *Journal of Agricultural and Resource Economics, 30,* 12-27.

Grobe, D., Douthitt, R., & Zepeda, L. (1999). A model of consumers' risk perceptions toward recombinant bovine growth hormone (rbGH): The impact of risk characteristics. *Risk Analysis, 19*, 661-673.

Harker, N. K., Clayton, G.W., Blackshaw, R.E., O'Donovan, J.T., Lupwayi, N.Z., Johnson, E.N., Gan, Y., Zentner, R.P., Lafond, G.P., & Irvine, R.B. (2005). Glyphosate-resistant spring wheat production system effects on weed communities. *Weed Science, 53*, 451-464.

Howatt, K.A., Endres, G.J., Hendrickson, P.E., Aberle, E.Z., Lukach, J.R., Jenks, B.M., Riverland, N.R., Valenti, S.A., & Rystedt, C.M. (2006). Evaluation of glyphosate-resistant hard red spring wheat (Triticum aestivum). *Weed Technology, 20*, 706-716.

Huygen, I., Veeman, M., & Lerohl, M. (2004). Cost implications of different GM tolerance levels: Non-genetically modified wheat in western Canada. *AgBioForum, 6*, 169-177.

Jensen, K.K., Gamborg, C., Madsen, K.H., Jorgensen, R.B., Krauss, M.K., Folker, A.P., & Sandoe, P. (2003). Making the EU 'risk window' transparent: The normative foundations of the environmental risk assessment of GMOs. *Environmental Biosafety Research, 3*, 161-171.

Kasperson, J.X., Kasperson, R.E., Pidgeon, N., & Slovic, P. (2003). The social amplification of risk: Assessing fifteen years of research and theory. In N. Pidgeon, R.E. Kasperson, & P. Slovic (Eds.), *The Social Amplification of Risk.* Cambridge, UK: Cambridge University Press.

Kloppenburg, J. (1991). Social-theory and the de reconstruction of agricultural science – Local knowledge for an alternative agriculture. *Rural Sociology, 56*, 519-548.

Kloppenburg, J. (2004). *First the Seed: The Political Economy of Plant Biotechnology (2nd Edition).* Madison, WI: The University of Wisconsin Press.

Kuyek, D. (2007). *Good Crop/Bad Crop: Seed Politics and the Future of Food in Canada.* Toronto, ON: Between the Lines.

Hatcher, L. (1994). *A Step by Step Approach to Using SAS for Factor Analysis and Structural Equation Modeling.* Cary, NC: SAS Institute Inc.

MacRae, M., Penfound, H., & Margulis, C. (2002). *Against the Grain: The Threat of Genetically Engineered Wheat.* Toronto, ON: Greenpeace.

McBride, W.D., & Books, N. (2000). Survey evidence on producer use and costs of genetically modified seed. *Agribusiness, 16*, 6-20.

Magnan, A. (2007). Strange bedfellows: Contentious coalitions and the politics of GM wheat. *Journal of Canadian Sociology and Anthropology, 44*, 289-317.

Mauro, I.J., & McLachlan, S.M. (accepted). Farmer knowledge & video research: Planting "Seeds of Change" regarding genetically modified crops in the Canadian prairies. *Agriculture & Human Values.*

Mauro, I.J., & McLachlan, S.M. (2008). Farmer knowledge and risk analysis: postrelease evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis, 28*, 463-476.

Mauro, I.J., McLachlan, S.M., & Sanders, J. (2005). *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture.* Winnipeg: Dead Crow Productions and Dada World Data. Documentary film. Available at: www.seedsofchangefilm.org

Maxwell, J.A. (2005). *Qualitative Research Design: An Interactive Approach.* Thousand Oaks, CA: Sage Publication.

Morgan, K. and J. Murdoch (2000). Organic vs. conventional agriculture: knowledge, power and innovation in the food chain. *Geoforum*, 31, 159-173.

Murphy, J., & Levidow, L. (2006). *Governing the Transatlantic Conflict over Agricultural Biotechnology.* New York: Routledge.

Mythen, G. (2004). *Urlich Beck: A critical introduction to the risk society.* London: Pluto Press.

Nap, J.P., Metz, P.L., Escaler, M., & Conner, A.J. (2003). The release of genetically modified crops into the environment: Overview of current status and regulations. *The Plant Journal, 33*, 1-18.

Neufeld, S.J., & Cinnamon, J.L. (2004). Farm parents' attitudes toward farm safety experts. *Rural Sociology, 69*, 532-551.

NFU (National Farmers Union), SOD (Saskatchewan Organic Directorate), COG (Canadian Organic Growers), and Greenpeace. (2004). The greatest threat to wheat farming isn't hail or drought, it's Roundup Ready wheat (ad). In *The Farmers Independent Weekly.* March 25.

NRC (National Research Council). (2002). *Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation.* Washington, DC: National Academy Press.

Nunnally, J.C., & Bernstein, I.H. (1994). *Psychometric Theory (3rd Edition).* New York: McGraw-Hill.

Penning, J.M.E., Irwin, S.H., & Good, D.L. (2002). Surveying farmers: A case study. *Review of Agricultural Economics, 24,* 266-277.

Pidgeon, N., Simmons, P., & Henwood, K. (2006). Risk, environment, and technology. In P. Taylor-Gooby, & J. Zinn (Eds.), *Risk in Social Science.* New York: Oxford University Press.

Poortinga, W., & Pidgeon, N. (2006). Exploring the structure of attitudes toward genetically modified food. *Risk Analysis, 26,* 1707-1719.

Raine, M. (2003). GM wheat buffer zone wider, moved from breeder seed area. *Western Producer.* March 27.

Rampton, R. (2004). Study probes Canadian farmers' views on GM wheat. *Forbes.com.* February 20. Available at: http://www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm _research

RSC (Royal Society of Canada) (2001). *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada,* Ottawa, ON. Available at: http://www.rsc.ca/index.php?page_id=119

SAS. (2007). *SAS OnlineDoc 9.1.3.* Cary, NC: SAS Institute Inc. Available at: http://support.sas.com/onlinedoc/913/docMainpage.jsp

Sharples, F.E. (1991). Ecological aspects of hazard identification for environmental uses of genetically engineered organisms. In M. Levin, & H. Strauss (Eds.), *Risk Assessment in Genetic Engineering: Environmental Release of Organisms.* New York: McGraw Hill.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20,* 195-203.

Siegrist, M., & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk Analysis, 20,* 713-719.

Smith, R. E., Veldhuis, H., Mills, G. F., Eilers, R. G., Fraser, W. R., and Lelyk, G. W. (1998). Terrestrial ecozones, ecoregions, and ecodistricts, an ecological stratification of Manitoba's natural landscapes. In *Technical Bulletin 98-9E.* Land Resources Unit, Brandon Research Centre: Research Branch, Agriculture and Agri-Food Canada.

Smyth, S., Khachatourians, G., & Phillips, P.W.B. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology, 20,* 537-541.

Soleri, D., Cleveland, D.A., Aragon, C.F., Fuentes L, M.R., Rios L, H., & Sweeny, S.H. (2005). Understanding the potential impact of transgenic crops in traditional agriculture: maize farmers' perspectives in Cuba, Guatemala and Mexico. *Environmental Biosafety Research*, *4*, 141-166.

SPSS. (2006). Version 15.0 Command Syntax Reference. Chicago, Ill: SPSS Inc.

Statistics Canada. (2001). Farm operators by education, by province (Manitoba, Saskatchewan, and Alberta). *Census of Agriculture.* Available at: http://www40.statcan.ca/l01/cst01/agrc40a.htm

Statistics Canada (2006a). Farm data and farm operator data. *Census of Agriculture.* Available at: www.statcan.ca/english/freepub/95-629-XIE/95-629-XIE2007000.htm

Statistics Canada. (2006b). Total farm area, land tenure and land in crops, by province (Manitoba, Saskatchewan, and Alberta). *Census of Agriculture.* Available at: http://www40.statcan.ca/l01/cst01/agrc25a.htm

Statistics Canada. (2006c). Snapshot of Canadian agriculture. *Census of Agriculture.* Available at: http://www.statcan.ca/english/agcensus2006/articles/snapshot.htm

Statistics Canada. (2008). Estimated Areas, Yield, Production, Average Farm Price and Total Farm Value of Principle Field Crops, in Metric Units, Annual, 1908-2007: CANSIM Agriculture Statistics Database. Ottawa, ON.

Statistics Canada. (2006a). Farm data and farm operator data. *Census of Agriculture.* Available at: http://www.statcan.ca/english/freepub/95-629-XIE/95-629-XIE2007000.htm

Stokstad, E. (2004). Monsanto pulls the plug on genetically modified wheat. *Science*, *304*, 1088-1089.

Taylor-Gooby, P., & Zinn, J. (2006). *Risk in Social Science.* Oxford: Oxford University Press.

Tsouvalis, J., S. Seymour and C. Watkins (2000). "Exploring knowledge-cultures: precision farming, yield mapping, and the expert-farmer interface." *Environment and Planning A*, *32*, 908-924.

USC & ETC (2008). *The Seed Map: Food, Farmers, and Climate Change.* Available at: http://usc-canada.org/resources/seed-map/

Van Acker, R.C., Brule-Babel, A.L., & Friesen, L.F. (2003). *An Environmental Safety Assessment of Roundup Ready Wheat: Risks for Direct Seeding Systems in Western Canada.* Winnipeg, MB: Canadian Wheat Board.

Van Acker, R.C., Brule-Babel, A., & Friesen, L. (2004). Intraspecifc gene movement can create environmental risk: The example of Roundup Ready wheat in Western

Canada. In B. Breckling, & R. Verhoeven (Eds.), *Risk Hazard Damage: Specification of Criteria to Assess Environmental Impact of Genetically Modified Organisms.* Bonn, Germany: Federal Agency for Nature Conservation.

Van Acker, R.C., McLean, N., & Martin, R.C. (2007). Development of quality assurance protocols to prevent GM-contamination of organic crops. In J. Cooper, U. Niggli, & C. Leifert (Eds.), *Handbook of Organic Food Safety and Quality.* Boca Raton, FLA: CRC Press.

Warick, J. (2003). Lining up against GM wheat: Farmers, Canadian Wheat Board largely united in opposing Monsanto's application to market 'Roundup Ready' genetically-modified wheat. *Saskatoon Star Phoenix.* Available at: www.healthcoalition.ca/sp-wheat.pdf

White, E. (2004). Survey seeks farmers' views on GM wheat. *Western Producer.* February 26. Available at: http://www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm _research

Wilson, W.W., Janzen, E.L., & Dahl, B.L. (2003). Issues in development and adoption of genetically modified (GM) wheats. *AgBioForum, 6,* 101-112.

Wisner, R. (2003). *Market Risks of Genetically Modified Wheat: The Potential Short-Term Impacts of GMO Spring Wheat Introduction on U.S. Wheat Export Markets and Prices.* Billings, MT: WORC. Available at: http://www.worc.org/issues/marketrisk-reports.html

Wisner, R. (2005). *Market Impacts from Commercialization of Round-Up Ready Wheat: Spring 2005 Update.* Billings, MT: WORC. Available at: http://www.worc.org/issues/marketrisk-reports.html

Wu, F. (2004). Explaining public resistance to genetically modified corn: An analysis of the distribution of benefits and risks. Risk Analysis, *24*, 715-726.

Wynne, B. (1996). May the sheep safely graze? A reflexive view of the expert-lay knowledge divide. In L. Scott, B. Szerszynski, & B. Wynne (Eds.), *Risk, Environment, and Modernity.* London: Sage.

Wynne, B. (1992). Risk and social learning: Reification to Engagement. In S. Krimsky & D. Golding (Eds.), *Social Theories of Risk.* New York: Praeger.

Yarrow, S. (1999). Biosafety issues of genetically engineered herbicide-tolerant plants – Agriculture and Agri-Food Canada''s perspective. In S. Shantharam & J.F. Montgomery (Eds.), *Biotechnology, Biosafety, and Biodiversity: Scientific and Ethical Issues for Sustainable Development.* Enfield, NH: Science Publishers, Inc.

Zhou, H., Berg, J.D., Blank, S.E., Chay, C.A., Chen, G., Eskelsen, S.R., Fry, J.E., Hoi, S., Hu, T., Isakson, P.J., Lawton, M.B., Metz, S.G., Rempel, C.B., Ryerson, D.K., Sansone, A.P., Shook, A.L., Starke, R.J., Tichota, J.M., & Valenti, S.A. (2003). Field efficacy assessment of transgenic Roundup Ready wheat. *Crop Science*, *43*, 1072-1075.

FIGURES AND TABLES

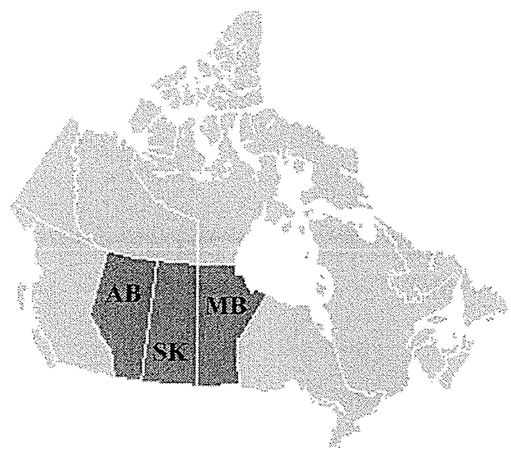


Figure I. Questionnaires mailed to farms in over 200 communities across the Canadian Prairies Ecozone. Portrayed are the provinces of Alberta (AB), Saskatchewan (SK), and Manitoba (MB) (left).

Table I: Comparison of farmers (n=1393) perspectives on agbiotechnology, particularly Roundup Ready Wheat (RRW), across different production classes, including organics, herbicide-tolerant (HT) crop users, non-HT users, and conservation till users.

	Proportion[a] of respondents for each class								Mean[b] and One-way ANOVAs[c] on Likert scale					
	Organics (n=141)		HT Users (n=847)		Non-HT users (n=255)		Cons till Users (n=150)		Mean				ANOVA (df=3)	
	-	+	-	+	-	+	-	+	Organics (n=141)	HT Users (n=847)	Non-HT users (n=255)	Cons till Users (n=150)	F value	P value
RRW should be approved for unconfined release into the environment	0.89	0.08	0.80	0.11	0.89	0.07	0.86	0.10	1.86	2.32	2.13	2.03	2.93	0.033
If RRW were on the market this year - how likely would you be to grow it?	0.94	0.02	0.83	0.11	0.88	0.03	0.94	0.06	1.51[a]	2.19[b]	2.38[b]	1.84[a,b]	7.10	<0.0001
I won't grow GM wheat if consumers don't want it	0.08	0.88	0.05	0.88	0.02	0.93	0.01	0.98	6.30[a,b]	6.17[a]	6.47[a,b]	6.61[b]	7.17	<0.0001
Herbicide tolerance in wheat is not an improvement, as farmers currently have adequate weed control options	0.10	0.86	0.21	0.74	0.11	0.85	0.11	0.84	6.02[a]	5.32[b]	5.81[a]	5.86[a]	11.29	<0.0001
Companies need the ability to patent GM wheat in order to encourage future innovations	0.88	0.05	0.67	0.22	0.84	0.07	0.80	0.14	1.96[a]	2.86[b]	2.37[a]	2.25[a]	12.45	<0.0001
GM wheat will damage the social fabric of rural Canada	0.23	0.72	0.37	0.49	0.17	0.71	0.23	0.66	5.48[a]	4.52[b]	5.56[a]	5.22[a]	21.92	<0.0001

[a]Proportions represent positive (+) and negative (-) sides of Likert scale for associated questions. [b]Means have been compared with a SNK post-hoc test, which compares all cell means pairwise. Statistical significance amongst classes is denoted by differing superscript letters, while classes with similar means have the same superscript letters. [c] One-way ANOVAs were conducted with an alpha set at 0.006 to minimize errors associated with multiple tests.

Table II. Factor Analysis[a] of farmers (n=771) risk perceptions regarding Roundup Ready Wheat. Four underlying factors were identified for market, corporate, agronomic, and contamination impacts and their variance is reported. Cronbach's alpha, mean, standard error (SE), and rank[b] of items contributing to each factor are also presented.

	Variance	Alpha	Load	Mean	SE	Rank
Factor 1: Market Impact (eigenvalue = 11.36)						
Markets	88.15%	0.96	0.70	6.41	0.04	1
Consumer confidence		0.96	0.85	6.33	0.05	2
Inability to segregate		0.96	0.72	6.31	0.05	3
Grain system containment		0.96	0.79	6.29	0.04	5
Cost of segregation		0.96	0.61	6.24	0.05	7
Seedlot purity		0.96	0.47	6.16	0.05	9
Factor 2: Corporate Impact (eigenvalue = 0.76)						
Increased Seed cost	5.92%	0.96	0.70	6.31	0.04	4
Corporate Control		0.96	0.60	6.27	0.05	6
Contracts restricting rights		0.96	0.66	6.15	0.05	11
Increased bureaucracy		0.96	0.59	6.07	0.05	14
Seed Saving		0.96	0.65	5.92	0.06	15
Factor 3: Agronomic impact (eigenvalue = 0.58)						
Selection pressure	4.48%	0.96	0.55	6.18	0.04	8
RRW volunteers		0.96	0.66	6.16	0.05	10
Weed resistance		0.96	0.62	6.12	0.05	12
Wheat and canola rotations		0.96	0.61	6.12	0.05	13
Minimum & no till		0.96	0.63	5.64	0.06	16
Factor 4: Contamination impact (eigenvalue = 0.53)						
Cross-pollination contamination	4.08%	0.96	0.80	5.61	0.06	17
Organic Livelihood		0.96	0.45	5.35	0.07	18
Animal vectors for RRW		0.96	0.74	5.24	0.07	19

[a]Promax rotation
[b]Rank is for the means reported

Table III. Factor Analysis[a] of farmers (n=722) benefit perceptions regarding Roundup Ready Wheat. Two underlying factors were identified including weed control and agronomic benefits and their variance is reported. Cronbach's alpha, mean, standard error (SE), and rank[b] of items contributing to each factor are also presented.

	Variance	Alpha	Load	Mean	SE	Rank
Factor 1: Weed control (eigenvalue = 7.85)						
Group 1 resistant wild oat control		0.95	1.00	4.56	0.07	1
Different in-crop mode of action		0.95	0.86	4.38	0.07	2
Broad spectrum weed control		0.94	0.73	4.36	0.07	3
Simplified weed management	94.85%	0.95	0.74	4.23	0.07	4
Single pass weed control		0.95	0.72	4.14	0.07	5
Volunteer cereal control		0.95	0.81	3.93	0.07	7
No herbicide carry over		0.95	0.92	3.85	0.07	8
Factor 2: Agronomic (eigenvalue = 0.51)						
Cleaner grain		0.94	0.73	3.96	0.07	6
Facilitating conservation tillage		0.95	0.78	3.81	0.07	9
Early seeding	6.18%	0.95	0.93	3.63	0.07	10
Higher yields		0.95	0.99	3.48	0.07	11
More uniform final product		0.95	1.00	3.29	0.07	12
Increased crop safety		0.95	0.65	3.19	0.07	13

[a]Promax rotation
[b]Rank is for the means reported

Table IV. Description of independent variables used to explain farmer attitudes regarding benefits and risks of Roundup Ready wheat

Abbreviation	
Age	age of respondent in years
Com	index of questions related to importance of community
Corp	index of questions related to trust in corporations
Ctill	minimum or zero-tillage production (yes, no)
Edu	ranking of education of respondent (grade/high school, college/university)
Env	index of questions related to importance of environment
Fin	ranking of farm family's financial situation
FS	total hectares of farm, including owned and rented land
Gov	index of questions related to trust in government
HT	previous use of HT canola (yes, no)
Org	organic production (certified and non-certified) (yes, no)

Table V. Cumulative AICc[a] weights[b] ($w+$), beta-coefficients (B), and standard error (SE) for all eleven independent variables[c] hypothesized to influence farmers risk and benefit perceptions associated with Roundup Ready wheat.

	Risks			Benefits		
Variable	*w+*	*B*	*SE*	*w+*	*B*	*SE*
Gov	**1.00**	-4.46	0.08	**1.00**	5.81	0.17
Com	**1.00**	5.41	0.06	**0.96**	-3.54	0.29
Corp	**1.00**	-4.00	0.11	0.30	0.20	0.28
Env	**0.98**	4.00	0.20	0.27	-0.08	0.12
HT	**0.96**	0.81	0.09	**0.95**	0.70	0.07
Fin	0.60	-0.54	0.43	0.27	-0.03	0.06
Age	0.55	-0.57	0.51	0.66	-0.82	0.57
Ctill	0.51	0.20	0.19	0.27	0.01	0.02
Org	0.32	-0.09	0.13	0.56	-0.32	0.29
FS	0.30	0.23	0.33	0.34	-0.40	0.52
Edu	0.29	0.10	0.15	0.39	0.29	0.36

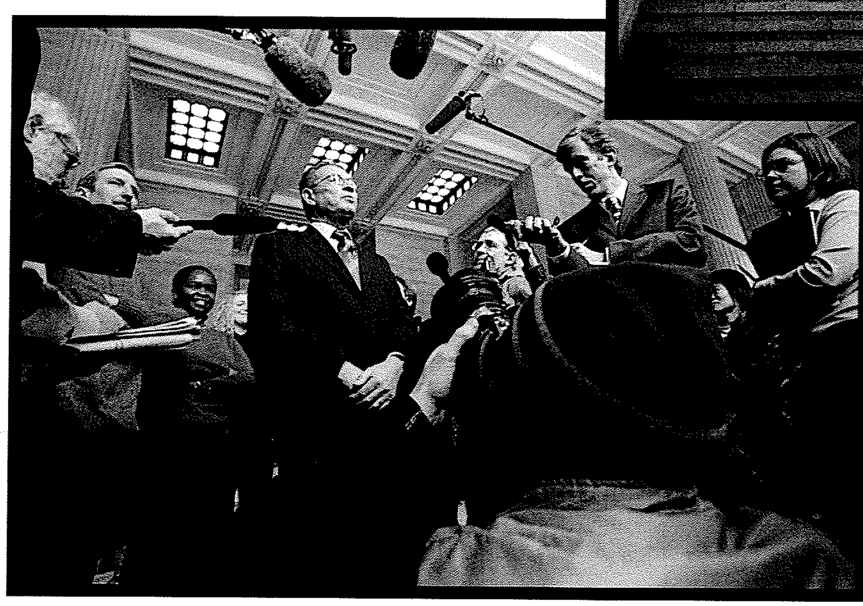
[a]AICc = Akaike's Information Criterion with small sample bias adjustment (Burnham and Anderson, 2002)
[b]These 'model averaged' weights were computed by summing the AICc weights of every model containing that particular variable
[c]Variables described in Table IV

Chapter 8

Genetically modified livelihoods and resistance: The Schmeiser and the Saskatchewan Organic Directorate cases

"I want the cultures of all lands to be blown around freely, but I refuse to be blown off my feet by any"

-Mahatma Gandhi



CHAPTER SUMMARY

The introduction of agbiotechnology in the Canadian prairies has "genetically modified" (GM) the livelihoods and culture of farmers, particularly those of seed savers and organic growers that choose not to use GM crops, as demonstrated by this research on the well known legal cases *Monsanto v Schmeiser* and *Hoffman v Monsanto.* Using interviews and ethnographic methods, the knowledge and experience of farmers involved in these legal disputes with industry over agbiotechnology were documented, and showed that GM crop contamination had caused deleterious agronomic, economic, and socio-cultural risks for farmers as well as their communities and environments. In a larger survey, prairie farmers as a whole expressed solidarity with the specific farmers engaged in these lawsuits, and had similar concerns regarding the adverse effects associated with GM crops and the need to hold corporations that developed this technology liable. The results of this study suggest that GM crops are indeed "manufactured risks" according to Beck's "risk society" theory. While corporations have considerable "biopower" over seeds, plants and life itself, the farmers in these precedent-setting lawsuits have shown that "reverse discourses" of resistance to agbiotechnology are possible. Arguably, the efforts of farmers in these lawsuits have catalyzed a global debate regarding the importance of sustainable agriculture and the need for "ecological democracy" and "responsible modernity".

INTRODUCTION

Rural communities have been confronted by substantial change around the world. Agricultural biotechnology has played an important role in this intensifying of agriculture. Although adopted by most farmers in North America, this technology represents substantial risks (Mauro and McLachlan, 2008). Worldwide, the two highest profile cases demonstrating risks associated with genetically modified (**GM**) crops are located in Canada and involve Percy and Louise Schmeiser and the Saskatchewan Organic Directorate (**SOD**). Monsanto sued the Schmeisers for patent infringement for using their farm saved seed that was contaminated by GM canola (Mauro, 2005), and the ensuing court case - *Monsanto v Schmeiser* - was the first in the world to argue that a patent over a life form had been violated (Mauro, 2005). The organic farmers of Saskatchewan, with support from their provincial association SOD, were the first in the world trying to establish liability for GM canola contamination, and their case – *Hoffman v Monsanto* – sought a collective (i.e. class-action) lawsuit against Monsanto and Bayer (Mauro et al, 2005a).

Monsanto and Bayer commercially released their proprietary, patent-controlled, GM canola varieties (Roundup Ready and Liberty Link brands, respectively) in the mid-1990s, which were altered to be herbicide-tolerant (**HT**), allowing for weed control without killing the canola plants themselves (Mehta, 2005). In 1998, the Schmeisers were sued by Monsanto for patent infringement, well before post-release studies indicated problems associated with GM canola, particularly large-scale pollen-mediated gene flow (Reiger et al., 2002) and non-GM seedlot (Friesen et al., 2003) and on-farm (Mauro and McLachlan, 2008) contamination across the Canadian prairies. Due to contamination, organic farmers could not guarantee their canola was GM free, and the European market was closed, costs that now exceed $2 million (Canadian) in lost sales (Smyth et al., 2002). In response, the SOD launched their class-action lawsuit in 2002 (Mauro et al, 2005a). The Schmeiser and SOD cases demonstrate how the theories of "risk society" and "biopower" operate in praxis.

Urlich Beck's theory of "risk society" documents how technological innovation is producing risks, particularly for the environment, which are increasingly difficult to predict, regulate, and manage (Beck, 1992; 1995). In the risk society, anthropogenic "manufactured risks" dominate and are best exemplified by nuclear, chemical, and genetic technologies (Beck, 1992). "Manufactured risks" are differentiated from "natural hazards" in the risk society (Beck, 1992). Increasingly catastrophic in nature, some of these manufactured risks remap the geography of risk on various temporal and spatial scales. Further, Beck argues that systems once of use in mitigating risk, particularly expert-based science and forms of insurance, are being outpaced by technological development and therefore manufactured risks are making it difficult, if not impossible, to ensure and insure safety (Beck, 1992; 1995).

Victims of manufactured risks are increasingly responsible for proving that harm exists with technology and must turn to the courts to establish liability (Mythen, 2004). However, the legal requirement to establish liability rests on causality, which is increasingly difficult to prove for manufactured risks, particularly forms of pollution that are often produced far away from contaminated areas (Beck, 1992; 1995). In the risk society, polluters are privileged in law, and accountability for risk production is evaded by industry (Beck, 1995). Ultimately, Beck (1995) believes that "advanced industrialism" is "toying with life" and may harm future generations of all living beings, a critique similar to Michel Foucault's concept of "biopower".

Foucault's idea of "biopower" is rooted in a historical analysis of governance, or "governmentality", of people, populations and other living beings in industrialized countries (Rabinow and Rose, 2003). Foucault was principally concerned with liberal and neoliberal control over humans via policies regarding health, reproduction, and race and the ensuing "biopolitical" struggle for life. The concepts of biopower and biopolitics are relevant today given advances in human genomic and pharmaceutical research (Rabinow and Rose, 2003), and particularly the release of GM crops and their effects on society (Andree, 2007).

The biopower of government and industry is particularly evident when reviewing the history of life patenting. In 1980, the US Supreme Court ruled on *Diamond v Chakrabarty,* and granted patent protection to a General Electric scientist for an oil-eating bacterium he had "invented" (Chakrabarty, 2002). This case represented a seismic shift in law, which previously only allowed ownership of non-living inventions (Wilson, 2002), and in its wake "thousands of patents on micro-organisms, plants, animals, genes, and cells have been granted in the US, Europe and Japan" (Swenarchuk, 2003). The "Harvard Mouse", a GM research mouse susceptible to cancer, was the first mammal to be patented in many of these countries (Swenarchuk, 2003). However, in 2002, the Supreme Court of Canada (**SCC**) decided in *Harvard Mouse* that only "lower life forms" (e.g. genes, cells, and micro-organisms) could be patentable in Canada, whereas "higher life forms" (e.g. seeds, plants, and animals) would be excluded from ownership (Morrow and Ingram, 2005). This ruling enabled the Schmeisers to subsequently make their appeal to the SCC in 2004, seeking to overturn lower court rulings that had found them guilty of infringing a patent on genes and cells that were contained in non-patentable seeds and plants that they harvested (Morrow and Ingram, 2005).

Monsanto argued successfully at the SCC that their patent over genes and cells in GM canola entitled them full control and ownership over any seed and/or plant containing these proprietary "inventions" wherever they existed in nature, despite Canadian law indicating that seeds and plants are not patentable (De Beer, 2007). Analysts point out that the "decision allows Monsanto to do indirectly what Canadian patent law has not allowed them to do directly: namely, to acquire patent protection over whole plants" (Gold and Adams, 2001). The SCC ruled that regardless of how the genes and cells entered the Schmeiser's fields and, ultimately their seeds and plants, the mere presence of this proprietary material constituted infringement (Morrow and Ingram, 2005). In effect, the Schmeiser's property rights were trumped by Monsanto's patent rights (De Beer, 2007), representing a dramatic shift in law and the power companies have over life forms (Phillipson, 2005), which caused great concern amongst farmers and citizens worldwide regarding GM crops and their affect on seed saving practices, food security, and corporate control over agriculture (Kuyek, 2007).

The SOD wanted to use the ruling in *Schmeiser* against Monsanto and Bayer and sought to make the de-facto owners of GM canola responsible, and more importantly liable, for harm caused by their technology to farmers (De Beer, 2007). However, SOD was ultimately denied class-action certification in the courts, and was not allowed to sue as a group, in part because causality is difficult to establish for GM contamination, as both companies and other farmers using GM canola are responsible for the release of this technology (Phillipson, 2005). The combined effect of *Schmeiser* and *Hoffman* allows companies to have unprecedented control over life forms, yet are not held accountable for the spread and any deleterious impact that these same life forms might have on farmers and the environment (Phillipson, 2005; De Beer, 2007).

Although the *Schmeiser* and *Hoffman* cases have been thoroughly evaluated (e.g. Phillipson, 2005; Morrow and Ingram, 2005; De Beer, 2007) the impacts of these legal struggles, each of which lasted six years, on the actual farmers involved has yet to be examined. Likewise, there is little if any insight into the attitudes of farmers toward these cases and the implications that these findings have for farmers and their livelihoods. The overall goal of this study is to describe farmer attitudes towards the *Schmeiser* and *Hoffman* court cases. More specifically, it will:

- Characterize the attitudes and experiences of both the Schmeisers and the SOD farmers toward GM crops, particularly GM canola
- Evaluate the impact of these legal struggles on farmers that participate in them, especially their livelihoods
- Explore the attitudes of the Canadian farm community toward issues raised in these precedent-setting court cases
- Determine the extent to which Canadian farmers support the Schmeisers and SOD farmers in their respective struggles against the agbiotechnology industry

MATERIALS AND METHODS

Study Area

In 1995, the Canadian Food Inspection Agency (CFIA), the government agency charged with regulating GM crops in Canada, determined that GM canola was "substantially equivalent" to conventional canola varieties and permitted its large-scale commercial release (Leiss, 2001). Two varieties of GM canola have been introduced: Roundup Ready (**RR**) and Liberty Link (**LL**), these tolerant to glyphosate and glufosinate herbicides, respectively (Lawton, 2003). Farmers rapidly adopted GM canola and at present it represent 83% of the canola grown in Canada; approximately 50% of this being RR and 32% being LL, while the remainder is largely planted to another non-GM HT canola variety (Buth, 2006). The world's first GM wheat, this also a RR crop, had also been field-tested in Canada but amongst controversy was voluntarily withdrawn from regulatory approval (Stokstad, 2004). Canola and wheat are primarily grown in the provinces of Alberta, Saskatchewan, and Manitoba (**Figure 1**), and over a ten-year average, they have covered 5 million and 10 million ha, respectively (Statistics Canada, 2008a). On average, one in four fields is seeded with canola, and very few regions across the Canadian prairies are isolated from GM canola (Beckie et al., 2006). The proportion of organic farmers across Canada is 6.8% (Statistics Canada, 2006) and in Saskatchewan specifically, there are 2197 organic farmers, of which 53.8% are certified (Statistics Canada, 2008b). The Joint-Faculty Human Subjects Research Ethics Board Protocol at the University of Manitoba approved this interview (#J2008:001) and survey (#J2001:060) research.

Phase 1: Qualitative Research

Community-based Action Research

In 2002, the Schmeisers and SOD farmers were first contacted and interviewed about their experiences with GM crops. This part of another study that merged qualitative data analysis with video research (Mauro and McLachlan, accepted) to produce a documentary film about the impact of GM crops on farmers across the prairies (Mauro et al., 2005b). This initial interaction with the Schmeisers and SOD led to a six-year interaction. We employed an approach located in action research, a collaborative approach that engages participants as knowledgeable and full contributors in research, and seeks to resolve a problem affecting a particular group (Stringer, 2007). The goal of this approach is to create democratic, equitable, liberating, and "action-oriented" opportunities for participants to create positive social change in their lives. Researchers thus become facilitators, and help empower research participants to resolve their problems (Brown and Strega, 2005).

Farmer Participation & Video

Percy and Louise Schmeiser were interviewed extensively between 2002 and 2008. These in-depth interviews were used to explore personal information, lived experience, and cultural knowledge about the impact of GM crops on their lives, and more generally agriculture and society as a whole. The Schmeisers' insights, interests, and experiences largely shaped the direction of these semi-directed interviews. These interviews began shortly after the Schmeisers were first found guilty of patent infringement in 2001 and throughout their Federal Court (2003) and SCC (2004) appeals. Most of the interviews were conducted on the Schmeiser's farm, in Bruno Saskatchewan (**Figure 1**). Additionally, Percy Schmeiser was interviewed while at his SCC trial in Ottawa, Canada, and on the day of the SCC decision, in Saskatoon, Canada. Similar in-depth and semi-directed interviews were used to explore SOD experiences and attitudes towards GM crops, particularly their effects on organic production and the livelihoods of organic farmers. These interviews were carried out between 2002-2008 while SOD attempted to achieve class action status, these spanning their first court case (2004), their

Federal Court appeal (2006), and their failed attempt to reach the SCC (2007). Interviews were conducted with eight organic farmers that are part of SOD; four of these were on a SOD committee overseeing the lawsuit (i.e. Marc Loiselle, Arnold Taylor, Larry Hoffman, and Dale Beaudoin) and four others were SOD members at large (i.e. Elmer Laird, David Orchard, Pat Neville, and Alwen Hoffman). In addition, one non-farmer (i.e. Cathy Holtslander) who is a spokesperson for SOD, and is also on the lawsuit committee, was also interviewed. Most interviews took place on farms in Saskatchewan, as well as in Regina, Canada, at the Federal Court appeal (**Figure 1**). Additionally, in spring 2003, SOD farmers were interviewed while on the "Planting Seeds of Doubt Tour", which made presentation in 11 communities across the prairies in order to discuss the risks associated with GM wheat (Magnan, 2007).

Video represents a particularly useful medium for collaborating with farmers. It allowed for interviews to be analyzed, interpreted, and used by both farmers and researcher at each stage in the process. Initially, I analyzed interviews using a qualitative video methodology (Mauro and McLachlan, accepted), which used content analysis to identify primary patterns in the data (Patton, 2002), and ultimately produced analytical categories that emerged from farmer statements (Maxwell, 2005). These "video transcripts" were shared with farmers, who then evaluated them and provided feedback, which allowed for a meaningful and representative narrative to form across interviews. This technique enabled farmers to watch interviews, instead of reading them, and led to final video research products that were "action-oriented" and could be used to communicate their respective struggles to a wider audience.

Phase 2: Quantitative Research

Survey Development

A 12-page survey was used to query farmers, across the prairies (**Figure 1**), regarding their attitudes towards GM crops and, with respect to this study specifically, issues raised by the Schmeiser and SOD court cases. The questionnaire had quantitative seven-point Likert scale questions. Researchers associated with universities and industry as well as farmers reviewed the survey for comprehensiveness, technical accuracy and impartiality. Ordering of questions was randomized to ensure that self-administration was unbiased. The survey was further pre-tested with 10 farmers from Manitoba, which helped to further refine the research instrument.

Sampling

In total, 11,000 farms were randomly selected and questionnaires were sent as unaddressed "ad mail" in over 200 rural communities throughout Manitoba, Saskatchewan, and Alberta. The use of ad mail was necessary as no comprehensive mailing list for farms is available across the prairies. A version of the "tailored design method" (Dillman, 2000) was used when mailing out the survey. All recipients were sent a questionnaire on February 23, 2004. A post card and letter were sent on March 1 and March 15 2004, respectively, to encourage participation. A shorter 4-page survey, with identically worded and formatted questions, was sent on April 12 2004 and further increased participant response. Questionnaires were sent with self-addressed business reply envelopes allowing them to be returned at no cost to the recipient. During this period, reminders were also printed in farm newspapers across the country (e.g. Western

Producer, Farmers' Independent Weekly, etc) and various local, national, and international media reported on the study and its objectives (e.g. Rampton, 2004; White, 2004; Friesen, 2004). The full methodology for this study is reported in greater detail elsewhere (Mauro, 2008).

Response, Demographics and Analysis

In total, 1566 farmers responded to this survey, which represented an adjusted response rate of 33%. The majority (85%) of respondents to our questionnaire were male and averaged 52 years of age (SE = 0.33), had an average farm size of 686.8 ha (SE = 21.83), and most (56%) had at least some college/university education. Compared to census data from the prairies, respondents were similar in age (52 years) (Statistics Canada, 2006a), although they more educated (36%) (Statistics Canada, 2001) and had slightly larger farms (473 ha) (Statistics Canada, 2006b). Responders practiced minimum and zero tillage on 55% of the reported acres, this lower than the national average of 72% (Statistics Canada, 2006c). The proportion of organic farmers was slightly higher than the national average (Statistics Canada, 2006c). Most (61%) respondents reported having previously grown herbicide-tolerant **(HT)** canola, including Roundup Ready (50%), Liberty Link (17%), Clearfield (11%), and combinations of these (21%), which are usage rates similar to national data (Buth, 2006).

A subset of the farmers we contacted responded to the larger survey (n=903), which contained questions regarding the Schmeiser and SOD lawsuits. Respondents were classified into GM and non-GM groups and the proportion of respondents indicating either positive or negative attitudes towards issues related to patenting, contamination, and liability were calculated. For GM (n=490) and non-GM (n=246) groups the means of these farmer attitudes were compared with t-tests. All data analysis was conducted with SPSS (SPSS, 2006).

The ethical treatment of participants in this study was a priority. The use of community-based action research, with the Schmeisers and SOD, ensured that they were meaningfully included in all stages of this research, and were central in guiding its outcomes. The larger survey included a detailed description of the objectives of the research and all farmers consented to participating in the study.

RESULTS

1. Monsanto v Schmeiser: Percy and Louise Schmeiser were the first farmers sued for patent infringement over GM crops. Their case demonstrates how corporate control over GM crops can adversely affect farmers, particularly seed savers, and rural culture as a whole.

Seed saving

The Schmeisers, now in their mid seventies, had a family and community history of being "seed savers". Their grandparents, parents and neighbors did and continued to engage, in this practice.

> *"A seed saver is a term that's been around for a long time...you develop and use your seed from year to year...and that was, and still is, the traditional practice"* (Percy Schmeiser)

The Schmeisers practiced seed saving over many decades and found that their canola seeds and plants were generally superior to those developed by and acquired from researchers and companies.

> *"[Seed saving is] one of the most important things...What I have found in my 50 years...the best varieties of seeds and plants didn't come from universities or research stations, they came from farmers...If you can use seed developed or grown on your own land, you do better than when you buy seed...seeds and plants have a way of adapting to your soil and climatic conditions..."* (Percy Schmeiser)

For the Schmeisers, seed saving and developing canola varieties that were best suited for their farm was a time-consuming process that they invested in emotionally.

> *"Anyone that is a seed developer will tell you that you're developing a form of life. It becomes just like part of your family, it's almost like a child, because you've developed something that you've spent so much time with"* (Percy Schmeiser)

Upon being sued, the Schmeisers realized that their right to seed save was being threatened and decided to fight, on behalf of their own rights and those of all farmers.

> *"We just stood up for what we believed in...that farmers' rights should not be taken away. Farmers should always be able to use their own seed"* (Percy Schmeiser)

Farmers across western Canada affirmed the Schmeisers' belief that seed saving is important. The "right to save seed" was ranked very high by both GM and non-GM farmers (Table I). However, GM users felt less strongly about this than non-GM farmers ($P=<0.0001$) each with 90% and 96% support, respectively.

Seed saving and genetically modified organisms (GMOs)

In 1996, Monsanto's patent-controlled GM canola was commercially released; found in the Schmeiser's fields in 1997, they were sued the following year. At that time, the Schmeisers knew very little about GM crops and their patentability.

> *"In 1998 and 1997…I didn't even know there was a patent on seeds and plants by Monsanto, and I was just doing what I've done since 1947, using my seeds from year to year"* (Percy Schmeiser)

By saving this seed, the Schmeisers had inadvertently infringed Monsanto's patent, despite the likelihood that their fields were contaminated by GM canola. The Schmeisers were forced by the courts to hand over all their seeds and plants to Monsanto, compromising years of their own breeding efforts.

> *"As a canola seed developer, I have lost all my research and development – I shouldn't say I, my wife and I - because our pure seed was contaminated by GMOs"* (Percy Schmeiser)

Most prairie farmers believed that "if a GM plant blows into a farmers field, that farmer should have the right to keep it" (Table I), thus supporting the Schmeisers saving their seed, despite it having been contaminated with GM traits beyond their control. Although both GM and non-GM farmers agreed with this, those not using GM crops felt more strongly (78%) than non-users (65%) in this regard ($P<0.0001$). The Schmeisers infringed Monsanto's patent even though they never used Roundup Ready canola for its intended purpose.

> *"[The Supreme Court of Canada] said…by possessing it, you could use it, so you violate the patent…I never used the patent, I never sprayed Roundup on my…canola crop…that was immaterial, the fact that [Monsanto's technology] was there…you violate the patent by possession of it"* (Percy Schmeiser)

Prairie farmers strongly disagreed that a farmer should be found guilty of patent infringement in these circumstances (Table I). Both GM (93%) and non-GM (97%) farmers disagreed that "If GM crops blew onto a farmer's land, that farmer is guilty of patent infringement".

Culture of fear

The Schmeisers believed that Monsanto had targeted them for a lawsuit as a way to generally undermine farmer independence and social cohesion in rural communities, by focusing on community leaders. It was their belief that Monsanto had created a "culture of fear" in rural Canada by suing farmers over GM crops.

> *"At my trial, Monsanto even admitted it was a test case…[Monsanto] did pick out people who had a higher profile in the community, like in my case, I was mayor in my community for a quarter century or more, I was a member of the provincial legislator, I was a seed developer in canola for half a century…they tried to make an example of me…How can an average farmer, or anybody, stand up to a multibillion-dollar corporation in court? And that's why farmers have such a fear of a multinational"* (Percy Schmeiser)

Percy Schemiser suspected – this later substantiated in court - that someone in their community had informed Monsanto that GM canola might be on their land. The introduction of GM crops was causing a breakdown of trust and resilience in these communities.

> *"The new culture of fear Monsanto was able to establish on the prairies – pitting one farmer against another farmer…They would advertise in their brochures that if you think your neighbor is growing Monsanto's GMO canola…without a license, you should inform on your neighbor. If a neighbor did that, immediately when Monsanto got that information they would send out their investigation officers, what we call 'gene police'…to a farmers home"* (Percy Schmeiser)

Prior to the actual lawsuit, private investigators hired by Monsanto (i.e. gene police) came to the Schmeiser farm and collected seed samples from their fields without permission. In the wake of their lawsuit, many farmers had contacted the Schmeisers to tell them about similar experiences.

> *"What really happened after that, when these 'gene police' would leave a farmers home, what do you think went through a farmers mind...was it this neighbor here, or that neighbor...that caused us all that trouble?...so all of a sudden you have that suspicion of not trusting one another...I think that's one of the worst things that could happen with the introduction of GMOs – that breakdown of our rural social fabric"* (Percy Schmeiser)

Others were sent threatening letters by Monsanto about "illegal" GM canola use, which they felt perpetuated a culture of fear.

> *"If [the gene police] couldn't find a farmer at home, they'd send a farmer 'extortion letters'. These are the things that people don't know what these multi-billion-dollar corporations like Monsanto are doing to farmers. Sending letters to a farmer and say 'we have reason to believe that you might be growing Monsanto's GMO canola...and in lieu of not taking you to court, send us $100,000'. I have one letter up to $170,000...so can you imagine the fear in a farm family when they get a letter from a multibillion-dollar corporation...these are the fear tactics that are being used to suppress farmers"* (Percy Schmeiser)

This fear and breakdown in trust would make it less likely that farmers would discuss their cropping choices, much less threats by the companies, and in turn increase hostility and distrust and the likelihood of legal action among farmers.

> *"I have never ever seen such fear as I now see amongst farmers where they're even scared to talk to their neighbor...If they grew GMO canola, there's a fear that their neighbor might sue em now, because they contaminated their neighbor, especially if they had an organic neighbor...I often say 'what neighbor wants to really sue his neighbor?'... But that is the position that...farmers are being put in because of Monsanto"* (Percy Schmeiser)

Farmers in the larger survey affirmed the Schmeiser's observation that lawsuits over GM crops are causing fear (Table I). Most non-GM (85%) and GM (65%) farmers agreed that corporate lawsuits regarding GM crops "are promoting a culture of fear in Canada's rural communities". Non-GM farmers, like the Schmeisers, felt significantly ($P<0.0001$) more threatened by this.

Stress of fighting Monsanto

The lengthy fight against Monsanto created much worry for the Schmeisers and their family and community. The Schmeisers were particularly troubled that Monsanto attempted to publicly discredit and tarnish their family name.

> *"It's been a long time to be in and out of court. A long period of time of stress on my wife and my family, and also my neighbors, and everybody in the community...I think that Monsanto went out of their way to discredit me in my own community.* (Percy Schmeiser)

In part this was achieved by accusing them of stealing the technology

> *And even though they had to admit...that I had never obtained their seed illegally...originally they had said that I had stolen it"* (Percy Schmeiser)

Prior to the original court case, Monsanto's director of legal affairs came to Saskatchewan and contacted and interviewed many of the Schmeiser's neighbors. Louise Schmeiser reflected on the impacts resulting from these activities.

> *"Monsanto was in this town for a whole month going from farmer to farmer to find something on Percy. You hear this. One neighbor came back to us and said 'I have to live in this community - I'm not saying anything'"* (Louise Schmeiser)

As part of these investigations, the investigators conducted surveillance and monitored their daily routines and farm practices.

> *"When we were watched...They would watch us day-by-day when we worked in our fields. They would drive into our driveway and sit there, or across the road from our home, and watch us all day long for two, three days a time. So it was very stressful"* (Percy Schmeiser)

The financial costs of court battle with Monsanto also represented a great burden for the Schmeisers. They spent their savings defending themselves and were appalled by Monsanto's tactics to undermine them.

> *"I believe it (the personal cost of the court case) is well in excess of $300,000. Initially, we spent our life savings, our retirement money, because we're both in retirement age. Then we borrowed money on our land. So, when we got to the appeal stages, then we no longer could afford it...we really needed financial help...because...Monsanto laid another lawsuit against me for $1 million for their court costs... And, after another year of legal battles, the judge awarded them $153,000... But worse, after that, they then put a lien or a caveat on all our farmland, even our house, that we couldn't borrow any more money to fight them".* (Percy Schmeiser)

This stress affected the Schmeiser family, particularly Louise.

> *"...there's sacrifices you pay when you take a stand...The stress and emotional strain...when you're in legal battles...you don't know if you'll have a home left, if you'll have a farm left...That was the only regret that I had...The stress that I put on...my family. [Family] were really concerned about our health. It has taken its toll. My wife developed high blood pressure"* (Percy Schmeiser)

Both GM (63%) and non-GM (84%) farmers across the prairies agreed that these lawsuits "are hurting rural communities", although non-GM farmers felt more strongly in this regard ($P<0.0001$).

Patenting and Biopower

The day before the Supreme Court hearing, Percy reflected on the significance and implications of the lawsuit:

> *"I think it's a very important moment in history...we're at a crossroads...there's so many issues: the food, environment, property rights, intellectual property rights. But most of all, the most important thing to me is – who owns life?"* (Percy Schmeiser)

The day after the hearing, he elaborated on his concern over life patenting and the appropriation of life by multinational companies:

> *"A seed or plant that might have been there for thousands of years or hundreds of years, developed by farmers and gardeners through a long period of time. And then by insertion of one gene, a company claims complete control over that seed or plant, which is totally wrong. What gives [Monsanto] that right to claim total ownership when they never developed that seed, they never ever developed that plant. They never owned it. So it's biopiracy"* (Percy Schmeiser)

Later on the farm, Louise reflected on the enormity of these issues, and the implications of their case for all life forms, including humans.

> *"Everything is born of a seed. Like people, plants, animals, it's a seed. If they control that, look what they all could control. It's to the point of scary"* (Louise Schmeiser)

They were particularly concerned about the outcome of their case for farmers in the Global South. Should GM crops be introduced in these countries and if farmers consequently lost their ability to seed save, the biopolitical consequences would be dire.

> *"In a third world country...they could control the food and seed supply...what better way can you control people than by the control of food"* (Percy Schmeiser)

Overall, prairie farmers believed (mean = 5.31, SE = 0.08) that "Percy Schmeiser is innocent of patent infringement" (Table I). However, significant ($P<0.0001$) differences in attitudes between GM and non-GM farmers existed with only 27% and 56% support for this statement, respectively. Many farmers ranked this question neutral, on the Likert scale, and were undecided about the specifics of the case.

Implications: Resistance and Liability

On May 20th 2004, the day before the Supreme Court decision, Percy reflected in the implications of the case while on his farm hauling saved seed and getting ready for spring planting:

> *"It's no longer a Percy Schmeiser case. It's a case now that affects all of society, whether you're a farmer, or any walk of life, because the patenting of genes, and inserting them into higher life forms, and then claiming control, has become a big concern for everyone"* (Percy Schmeiser)

The following day, the Supreme Court made public it narrow 5-4 decision upholding Monsanto's patent control over seeds and plants, while striking down previous judgments that the Schmeisers owed the company over $200,000 in legal fees and damages. The court found that the Schmeisers had not benefited from Roundup Ready canola, because they had not sprayed it with the glyphosate herbicide, and therefore did not owe Monsanto any profits from the crop. A victory for the Schmeisers, this allowed them to save their home and farm:

> *"I really believe, as of this morning, my battle is over. I brought it as far as I could, all the way to the Supreme Court. As I said before, it was a personal victory for me in regards to the awarding of costs, but I believe that in my heart, I'll always be fighting for the rights of farmers, for them to use their seed from year to year. So, as I said, the battle ends for me today, but not the battle in my heart"* (Percy Schmeiser)

Days after the decision, on the farm, the Schmeisers reflected on their motivation for fighting Monsanto, and Mrs. Schmeiser stated:

> *"I've been asked: why did you do it? Many times I was asked that. And I said, 'if you believe in something, and you think you can make a change, you work at it'"* (Louise Schmeiser)

Schmeiser had traveled around the world, in part to raise awareness of the risks associated with GM crops and in part to raise funds for the lawsuit.

> *"...if I wouldn't have had help then from the world community, I could not have stood up to Monsanto. [Monsanto] never felt that I could get help from the world community to fight them. That's one thing they never expected"* (Percy Schmeiser)

The court decision also had implications for establishing liability and compensation for other farmers in the future

> *"I was happy that I did not have to pay Monsanto any compensation or any amounts of money to them...on the other hand...we did not win on the issue of patenting life forms...to me that was very disturbing...I think that there are a lot of implications... If* [Monsanto] *own and control* [GM canola genes, seeds, and plants] *then along with the flow of the gene goes the flow of liability...Yet it might be a very hollow victory...in the long-term Monsanto could be faced with massive liability issues"* (Percy Schmeiser)

Schmeiser was relieved that their struggle was over, and while he was distraught about the continued corporate control over life and agriculture, he believed that the fight for justice was far from over.

> *"I might have lost this battle, but the war continues. The war will continue against these corporations"* (Percy Schmeiser)

<u>2. Hoffman v Monsanto:</u> The organic farmers of Saskatchewan were the first to sue GM crop developers for the agronomic and economic damages associated with the release of this technology. Their case demonstrates how the both the regulatory and legal system failed organic farmers adversely affected by GM crops.

Organic farming and relationships with the land

Organic farmers in Saskatchewan had an intimate relationship with the natural world and sought to mitigate the adverse impacts of their agricultural activities. As Elmer Laird, an organic farmer in his mid 80s who is regarded as one of the founding fathers of organic farming in Canada, stated:

> *"The big thing about being an organic farmers is I start working with Nature. And Mother Nature is a powerful old girl and I want Mother Nature on my side. My big challenge is try to understand what Mother Nature is all about and what she is going to do...The more I understand about that the better an organic farmer I am going to be. If you're a chemical farmer you're dealing with one chemical and one plant. The difference between chemical farming and organic farming is, with chemical farming it's like painting by number, but when you move over to organic farming, you're then getting into real art"* (Elmer Laird)

These farmers viewed organic farming as beneficial to the environment and human health. As David Orchard, a long-time organic farmer and politician, indicated:

> *"This whole idea of spraying....with a toxic lethal chemical just to get at one weed problem or one insect problem is affecting our entire environment. We've had astronomical rates of cancer...I lost my father to prostate cancer...These kinds of problems really changed my thinking...Organic farming puts the pleasure back into farming...in the fact that you're not applying these pesticides and they're not damaging wildlife and they're not damaging farm families as well. And we're producing food that doesn't have poisons on it"* (David Orchard).

While many viewed the organic industry as successful and were optimistic about its future, they discussed many challenges affecting agriculture as a whole, particularly the "farm income crisis", the impact of "mad cow disease" (bovine spongiform encephalopathy or BSE), and above all GMOs. As Marc Loiselle, an organic farmer specializing in Red Fife wheat indicated:

> *"One of the biggest challenges, regrettably, is the whole GMO issue. It's the single biggest factor, of the all the factors...that threaten the survivability of organic farming"* (Marc Loiselle)

Although organic farmers represent a minority group in agriculture, both non-GM (90%) and GM (76%) farmers, across the prairies, believed that non-GM farmers should "influence policy regarding GM crops" (Table II). Non-GM farmers felt more strongly in this regard ($P<0.0001$) (Table II).

Organic farming, GMOs, and legal action

The livelihoods and farm systems of these farmers had been adversely affected by the introduction of GM canola. They launched their lawsuit in 2002 wanting compensation and wanting to halt and introductions of future GM crops, particularly GM wheat.

> *"The purpose of the lawsuit is to get compensation for the loss of organic canola as a crop. Because it is now virtually impossible, practically impossible to grow canola on the prairie without getting genetic contamination from Liberty Link and Roundup Ready canolas. That market has been totally destroyed for organic farmers. The other thing that this lawsuit is about is to stop the introduction of genetically engineered wheat. Having genetically engineered wheat contaminating organic wheat basically spells the end of organic grain farming on the prairies, so this is something we have to stop"* (Cathy Holtslander)

Many of these farmers felt that the introduction of GM crops compromised their ability to take advantage of consumer interest in this fast expanding market. Ultimately, all organic farmers believed that GM crops would destroy the organic industry in western Canada.

> *We're protecting our position in the marketplace. If anybody's got any philosophical reasons, I'm sure they're there, but really, that's the fundamental position we're in. This is bread and butter, life and death for us. If we get GMO wheat and GMO other crops that we can't use, then they contaminate our other crops, and we're going to be out of business"* (Arnold Taylor)

The farmers believe that the companies that released GM canola should be responsible for the harm their technology inflicted on the organic industry. The farmers also recognized the scope of their lawsuit and contribution would make to farmers everywhere.

> *"The implications of the lawsuit, if we win this, if Monsanto and Bayer are held to be responsible...that's going to have a ripple effect around the world. So it's really a groundbreaking effort on the part of a small group of farmers. But that's always how the world has changed: it's not the majority, it's a small group that are committed to making change, and that's what we're struggling to do"* (David Orchard)

Prairie farmers as a whole generally felt that companies "should be held liable" if their GM technology harmed non-GM farmers and their land (Table II), although non-GM farmers (91%) believed this more strongly ($P<0.0001$) than did GM farmers (73%).

GM canola contamination

GM canola was released in the mid 1990s and the organic farmers observed that it quickly contaminated the environment, forcing them to change their farm systems. Both Marc Loiselle and Pat Neville had GM canola invade their organic farms and were case studies for the lawsuit (**Figure 2**).

> *"In 2001, we already had 5 or 6 years of GM canola introduction, and in that short span of time the contamination was obviously all over the place. And we were forced to remove canola from our rotations and that's a very significant thing that we need to have the courts acknowledge...Although we do not grow organic canola anymore - we've been forced out of that market - we still are experiencing contamination by GM canola"* (Marc Loiselle)

While the farmers were in the process of seeking class-action status, Loiselle had GM canola blow onto his organic farm, exemplifying how contamination occurs.

> *"Very strong wind…70-80 km per hour…picked up the swathed GM canola on my neighbors land and blew a significant portion of it across the road into my field. It just shows the nature of the kind of events that can occur that create gene transfer. In this case, whole plants moved over the road…shattered and there's seed on the ground…and every subsequent wind that we had, which there were probably four or five, blew more plants over the road…there's nothing I could do to prevent it and now I have to live with the consequences"* (Marc Loiselle)

Neville also had GM canola contaminate his farm, which undermined his organic pedigreed seed production business:

> *"We knew our neighbor had grown canola, but unbeknownst to us the canola had drifted…we had probably 57 acres that was affected by GM canola…We're concerned about that crop contaminating the whole farm"* (Pat Neville)

As a seed producer, Neville had regular inspections of his farm, and was thus able to detail how the Roundup Ready canola had contaminated his farm. Monsanto verified this contamination with laboratory tests. Although the company had the plants removed, problems would likely continue.

> *"Monsanto got a crew out here and they rouged the canola out of the crop…they had pulled it all out. That's going to be required, my estimate is, for the next…5 to 6 years and probably as many as 11 to 12 [years] and maybe even farther…it's going to be a long-term ongoing problem for us"* (Pat Neville)

The majority of prairie farmers felt that co-existence between GM and non-GM crops was impossible (Table II). Non-GM (94%) and, to a significantly ($p<0.0001$) lesser degree GM (75%) farmers disagreed that both types of crops could be grown across the prairies "without them mixing". Yet respondents felt that non-GM farmers "should have the right to zero tolerance for GM traits in their crops", although, this again was more prevalent among GM users (92% vs. 72%, P=0.0001).

Broader implications of GM contamination

All the SOD farmers recognized that GM contamination might put their organic status at risk. Although Neville ultimately did not lose his status, the contamination compromised his management options and required ongoing monitoring by his certification body.

> *"We did not lose our organic status because of it, but we had to make a long-term proposal not to grow small seeded crops on any of this land...If we had planted canola, trying to grow it organically, and had GMO canola in that canola, we would have lost our organic status for five years"* (Pat Neville)

The farmers were also fearful that GM contamination might adversely affect their ability to save and reuse their organic seed. Dale Beaudoin, organic farmer and plaintiff in the lawsuit, linked this contamination with the precedent set at the Schmeiser case, and spoke about the implications of corporate control over seed:

> *"This contamination is so severe now. We've got it in our seed, it's blown in from our conventional neighbors fields, it's impossible for us to grow* [organic canola]*....Also the seed supply is crucial...farmers should be in control of the seed supply, if we can't, big companies are going to take over"* (Dale Beaudoin)

Some participants indicated that GM contamination was causing tension within their communities. Pitting GM users against organic farmers, it compromised solidarity amongst farmers.

> *"What's happening is that it's also tearing apart the social fabric of the farming community. It's talking about the difference between the chemical farming with GMOs versus organics. But it's creating an artificial division between us farmers"* (Marc Loiselle)

GM wheat Resistance

As part of their lawsuit, the organic farmers were prepared to file an injunction against Monsanto's release of the first GM wheat, Roundup Ready wheat (**RRW**). In May 2004, Monsanto voluntarily withdrew RRW from commercialization, and these farmers believed their case played an instrumental role in this decision.

> *"It's a pivotal case...If this lawsuit did not exist, I think Monsanto probably would have...Roundup Ready wheat out for field scale production ...If we weren't doing anything I think we'd be run over"* (Larry Hoffman)

Prior to this decision, SOD farmers had campaigned extensively against the crop by lobbying government and raising awareness regarding the impact that this crop would have on the organic industry and agriculture as a whole. In particular, SOD co-sponsored and presented on the 2003 "Planting Seeds of Doubt Tour" that travelled to 11 communities across three western provinces to inform farmers and the public about risks associated with RRW. In Saskatoon, Loiselle spoke to 350 people about SOD's efforts:

> *"Customers of our wheat do not want wheat contaminated by GM varieties, period...It is critical that GM wheat be stopped now. This 'Planting Seeds of Doubt Tour' aims to help achieve that goal. For organic farmers, losing organic canola was bad enough, losing wheat or any other crop, that could be devastating"* (Marc Loiselle)

Some of these farmers also questioned Monsanto's open-air field trails of RRW that were being conducted in undisclosed locations across the prairies. SOD opposed this research, anticipating that these tests might contaminate seed supply and ultimately shut down wheat markets. Loiselle actually discovered one of these test plots in his community, which did not adhere to government protocol requiring isolation from other wheat fields (**Figure 3**), and was grown on land leased from a neighbour without their knowledge.

"Right away I could identify it...I took some photos and started asking questions...the farm land owners were not even aware that RRW was being grown on their land...there was something wrong with this picture...thirty meter isolation zones was probably inadequate...The farmer and his renter had grown wheat on three sides of this test plot...a perfect opportunity for contamination to happen" (Marc Loiselle)

On behalf of SOD, Loiselle publicly criticized the management of this field trial and notified the government, which precipitated a change in government protocol, ultimately changing the way that these trials are designed.

"To put a test plot essentially in the middle of another wheat field was not seen as being very kosher...the [government body responsible for establishing field trial protocols]*...ended up turning down the protocol for 30-meter buffer zones and introduced a 300-meter isolation zone, which I claim is a partial victory"* (Marc Loiselle)

Risk society and failure of regulation

The SOD farmers felt that the government had failed to regulate GM crops properly and forced those that were adversely affected by the technology to protect themselves.

"It's wrong that we have to do it. The regulations...and registration system is flawed...[The companies] put this stuff out there without regard to the organic producers or the other conventional farmers that don't want this technology...and they did it anyway with the blessing of the government...The way it's set up now, the onus is for organic farmers to deal with it and to protect ourselves" (Arnold Taylor)

They were further frustrated that government refused to take action to protect the organic industry from these problems, ultimately resulting in the lawsuit.

"...we've come to the point where we've said 'if there's going to be no movement politically, we're going to do it through the courts'. Which is something that shouldn't happen. We should have a government that's proactive" (Marc Loiselle)

The farmers recognized that regulations must be changed to protect farmers while requiring companies to prove the safety of GM crops prior to their release.

> *"The burden of proof shouldn't be on the people that are suffering...the farmers that are fighting to protect their farms from the drift of these products. The burden should be on these companies to prove that [GMOs] won't contaminate the rest of agriculture"* (David Orchard)

Those overseeing the lawsuit believed that it was unjust that they were forced to defend themselves by taking legal action. Many organic farmers discussed the financial and emotional burden of fighting these multinational companies.

> *"It's a huge undertaking. How do you raise hundreds of thousands of dollars to take on an adversarial role, in a sense, as a plaintiff...trying to defend ourselves?"* (Marc Loiselle)

Those directly involved in the lawsuit discussed how it had affected their lives and their families, although, they all believed it was worthwhile.

> "[Organic farmers]*...are giving their time and their energy because they want to protect their livelihoods. They want to protect the environment that we live in"* (David Orchard)

Prairies farmers believed that non-GM farmers had been "negatively affected" by GM canola (Table II), although this was much more prevalent among non-GM farmers (84% vs. 52%, P=0.0001).

Class action approach

The organic farmers attempted to sue Monsanto and Bayer using a class-action lawsuit and SOD facilitated this legal action on behalf of their representative plaintiffs

Larry Hoffman and Dale Beaudoin. The class action facilitated cooperation and enabled them to pool their resources in this struggle.

> "*I know I can't myself deal with Monsanto and Bayer…but, I'm only one person, if I can get a class of certified organic farmers with me, than we can do something*" (Larry Hoffman)

The lawsuit was designed so that all certified organic farmers in Saskatchewan were to be part of the class, unless they opted out. However, the organic farmers first had to establish in court that they were indeed a common group with a common claim (i.e. a class) before they could proceed. The farmers were committed to this long and arduous process.

> "*I want to see it through to the end. I want my day in court. I want to see us get certified as a class…I want to see us win and attach some liability to the chemical companies for both market loss and for cleanup costs…Whether it takes it to the Supreme Court or not*" (Arnold Taylor)

The SOD farmers had worldwide support for their legal action. They were invited to many countries to talk about their court case and felt it represented an opportunity for consumers to assist farmer resistance to corporate control over agriculture and the damages that GM crops were having on sustainable food systems.

> "*It has been amazing the number of people that have supported financially or just saying 'go for it'…It's not just a few farmers out here that are concerned about it. It's definitely not just a Saskatchewan or Canadian issue, it's a worldwide issue*" (Alwen Hoffman)

However, after six years of legal battle and over $400,000 in costs, courts ultimately rejected the claim that these organic farmers represented an identifiable class, and were denied the ability to sue collectively. The farmers were devastated by this and believed that the Schmeiser and SOD rulings ultimately favoured the corporations.

"Monsanto wants to have things both ways...The Roundup Ready gene and canola is out there all over the place...and they're not responsible for it, yet, in the Schmeiser case...no matter where that gene shows up it's Monsanto's property...You can't have it both ways" (Cathy Holtslander)

Prairie farmers supported non-GM farmers suing GM crop developers for damage caused by their technology (Table 2), although non-GM (92%) farmers were more inclined toward these legal actions (P<0.0001) than were GM (70%) farmers.

DISCUSSION

This study is the first to explore the impacts of the *Monsanto v Schmeiser* and *Hoffman v Monsanto* lawsuits on those involved farmers. It demonstrates the serious risks GM crops pose for seed savers and organic farmers, which have been unable to establish liability for the agronomic, social, and economic damages that GM crops have caused them. Overall, both GM and non-GM farmers across the prairies supported the Schmeisers and SOD farmers, and felt these legal battles to protect farmers' right to save seed and to establish liability for GM crops were important.

That GM crops contaminated non-GM farmer's land and caused harm was of critical importance to both the Schmeisers and SOD farmers. These farmers viewed GM technology as a new threat to agriculture that spread across and polluted agricultural landscapes. Having unpredicted and catastrophic consequences for seed savers and organic farmers alike, they are indeed "manufactured risks" (sensu Beck, 1992).

Although prairie farmers supported non-GM farmers growing GM free products, they did not believe that coexistence between GM and non-GM crops was possible, a finding substantiated by research demonstrating extensive GM contamination of farmland (Mauro and McLachlan, 2008) and non-GM canola seedlots (Friesen et al., 2003) across the Canadian prairies. Despite this widespread contamination, which the Schmeisers believed was the source of Monsanto's genetics on their farmland, they were still found guilty of patent infringement, and had to turn over all their seeds and plants to the corporation.

Prairie farmers were overwhelmingly critical of any farmer being found guilty of patent infringement in these circumstances, yet many were unsure about the Schmeisers' innocence, indicating that Monsanto's public smear campaign – which incorrectly and unfairly alleged that the Schmeisers had stolen Monsanto's genetics - was effective. Despite this confusion regarding the case, most still believed that the Schmeisers were innocent. Furthermore, prairie farmers were largely unified in their support for the Schemisers and SOD and the issues represented by their cases, which suggests that rural communities maintain their social cohesion despite ongoing threats to it posed by GM crops. Pervasive GM contamination has forced non-GM farmers like the Schmeisers and SOD organic growers into a biopolitical struggle with corporations over seeds, rural culture, and life itself.

Both the Schmeisers and SOD farmers believed that their cases reflected a larger trend toward corporations usurping agriculture from farmers, particularly their seed. Kloppenburg (2002) has argued that corporations have long sought to commodify seed, as it is the "nexus of control" over agriculture, and have used biotechnology to rupture its regenerative properties, which has allowed farmers to use seed as both the unit of production (i.e. seed for replanting) and product itself (i.e. seed for grain sales). We found that GM contamination could prevent farmers from saving and reusing their seed, given that GM crops are patented and unusable in organic systems. Thus substantiating claims that biotechnology may force farmers, who once relied on their own and sharing seed to become new customers for agribusiness. That corporations have developed GM crops, in part, to profit from control over seed supply demonstrates how they harness biopower (Andree, 2007) and use "biology as ideology" to promote capitalism (Lewontin, 1991). Although respondents strongly believed that seed saving was important, this practice is clearly under threat, especially given that Monsanto now controls 90% of GM seeds that are marketed worldwide (USC and ETC, 2007).

All the farmers we interacted with during this research were concerned about the impact GM crops were having on rural culture. They believed that GM contamination and associated lawsuits had pitted farmers against one another, which ultimately, as other studies recognize, caused a break down in the "social fabric" of rural communities (Metha, 2005). The Schmeisers further believed that Monsanto had created a "culture of fear" by investigating and suing farmers for patent infringement, a sentiment shared by prairie farmers as a whole. Monsanto's investigations and lawsuits are widespread. In the US, Monsanto has monitored hundreds of farmers, based on thousands of tips from fellow community members (Umeno and Kesan, 2007), and prosecuted at least 90 cases that resulted, on average, in $400,000 being paid to the company (CFS, 2005). Monsanto has an annual budget of $10 million and a staff of 75 specifically allocated to investigate and prosecute US farmers regarding GM crop patent infringement (CFS, 2005). Indeed, as the Schmeisers observed in Canada, Monsanto has sent many US farmers "extortion letters" (CFS, 2005). Some argue that Monsanto's investigations create a "culture of surveillance" that undermines "social cohesion" in rural communities (Mehta, 2005), which further substantiates the concerns of farmers in this study. The Schmeiser experience, particularly the personal, family, and community stress associated with their fight against Monsanto, is likely occurring to many farmers engaged in patent infringement lawsuits across North America, although most sign non-disclosure agreements making this difficult to assess.

That GM crops are causing harm to the "social fabric" of farming communities may have long-term implications for rural culture and knowledge. It is widely recognized that farmers possess important local knowledge (LK) about agriculture, which is experience-based, place specific, and intergenerational (Kloppeburg, 1991). This use of LK is highlighted in seed saving and conservation of heirloom varieties (Veteto, 2008), organic argoecological systems (Kaltoft, 1999), evaluating risks associated with introduced (Mauro and McLachlan, 2008) and future (Mauro 2008; C7) GM crops. Studies have shown that if culturally embedded LK is not valued or communicated to younger farmers, these important practices can be lost (Shennan, 2003). The introduction of GM crops, and associated restrictions on seed saving, has already lead to "farmer deskilling" (Mehta, 2005), and arguably may lead to the loss of this important practice entirely.

Five decades of breeding and crop development conducted by the Schemisers were confiscated. They felt that through patent law, Monsanto had stolen canola from the public, particularly farmers that had developed the crop over millennia. Indeed, canola was originally bred from rapeseed using public research money and support, and was ultimately privatized by corporations using biotechnology methods and patent law (Kneen, 1992). In effect, farmers who now purchase GM canola have to pay for it twice, first through taxes for the development of canola and second in royalties to corporations that have patented it and are reselling this once public crop. Furthermore, the combined implication of *Monsanto v Schmeiser*, which equated possession with infringement, disregarding how GM seeds and plants enter a farmer's field and how extensive contamination is by GM canola across the prairies (Mauro and McLachlan, 2008; Friesen et al., 2003), arguably makes all Canadian canola farmers patent infringers. In this way, Monsanto's patents are on the wind and effectively make farmers "trespassers in their own cultures" (Drahos and Braithwaite, 2003) and may eventually turn farmers into "bioserfs" that work the land to the benefit of corporations (Mehta, 2005).

The Schmeisers were particularly worried that the outcomes of their case might set an international precedent that would restrict farmers from seed saving around the world. Globally, it is estimated that 1.4 billion farmers rely on farmer saved seed for their daily food security (Conway and Toenniessen, 1999). Thus, a number of farm and civil society organizations made submissions to the Supreme Court, arguing that if the Schmeisers lost their case, farmers would be adversely effected world over (Council of Canadians et al., 2004). Patents laws are harmonized globally through the Trade Related Aspects of Intellectual Property Rights (TRIPs) treaty of the WTO, and countries could use the precedent in *Monsanto v Schmeiser* to influence their domestic jurisprudence (Shiva, 2000). The TRIPs agreement was designed to allow access to the biodiversity in any member state to being patented by corporations (Shiva, 2000). As of 1999, approximately 147 known cases of biopiracy from the Global South had occurred (Powledge, 2001), exemplified by patents on the neem tree and basmati rice in India (Shiva, 2000) and maca, ayahuasca (Hansen and VanFleet, 2003) and quinoa (LaDuke, 2005) in South America. This biopiracy has deep colonial roots, mirroring the first enclosure of the commons, and amounts to the theft of cultural knowledge, resources, and the essence of life from farmers and other stewards of biodiversity across the globe (Shiva, 1997).

The farmers interviewed in this study, particularly those in SOD, believed that regulation and law failed to protect them from the harm caused by GM crops. Governmental discourse around the regulation of these crops is framed around "manageable risk" and overzealous "truth claims" about the safety of this technology (Andree, 2002). While the Canadian regulatory system claims to be "science-based", it does not conduct independent testing of GM crops prior to or after their release (Andree, 2002), and instead allows corporations to evaluate and submit safety data on their own products (Yarrow, 1999). This approach is largely based on an assumption that GM crops are "substantially equivalent" to their non-GM counterparts therefore safe in the environment and for human health (Andree, 2002). Yet paradoxically corporations at once claim GM crops are the same as non-GM crops when justifying safety, yet when it comes to patents they argue that GM crops are "novel" and have never existed previously (Shiva, 2000). The assertion of ownership over plants and limiting of what is considered risky, allows for the quick and arguably irresponsible patenting and approval of this technology (Andree, 2002). The Canadian government has been a long-time supporter of the biotechnology industry, as both a promoter and financier (Andree, 2002), and the regulatory system was largely developed in closed-door dialogue and partnership among these parties (Leiss, 2001). That the regulatory system fails to protect seed savers and organic farmers from the dangers posed by GM crops, despite calls from the Royal Society of Canada to overhaul the regulatory system (RSC, 2001), is unsurprising.

These problems associated with the Canadian regulatory system are further compounded by the unpredictable and uninsurable nature of biological "manufactured risks" like GM crops. Indeed, "science-based" risk assessment failed to anticipate market harm, seedlot contamination, and the environmental impact of GM crops (Krayer von Krauss et al., 2004). Prior to the release of GM crops, the insurance industry was unconvinced that impacts could be predicted using risk assessment, and therefore would not insure the technology (Rifkin, 1998). GM crops were released into the environment without first establishing how farmers affected by genetic pollution might be compensated, leaving the question of liability unresolved (Rifkin, 1998). This obviously put farmers at risk, particularly those practicing organic methods, which ultimately led SOD to launch their class action lawsuit against Monsanto and Bayer.

Members of SOD, and prairie farmers as a whole, believed that liability should be established for GM contamination, which destroyed the ability to grow and market organic canola. Two SOD farmers in this study – Marc Loiselle and Pat Neville – had extensive GM contamination on their farms, which exemplified the deleterious effects GM crops pose for all organic farmers. These contamination events required extensive cleanup and monitoring, and in certain circumstances, it was found that farmers could lose their organic certification. Like SOD farmers, US organic farmers also believe their farms are at risk from GM crops (Walz, 2003), and want their organic standards to remain GM free, as they view organics as an alternative to industrial agriculture (Glenna and Jussaume, 2007). Indeed, prairie farmers as a whole believed that the views of organic farmers, despite being a minority in agriculture, were important and should help shape policy on GM crops. Like the SOD farmers, Beck (1992) believes that if industry were made liable for pollution they have caused, this would make their overall production practices more responsible, helping to mitigate risk and increase safety.

The organic farmers were convinced that a class action approach was the best way to protect their industry and establish liability for GM crops, as it allowed them to work collectively, and pool their resources against two powerful and well resourced corporations. After six years in the courts and nearly half a million dollars in court costs, they were devastated that the legal system would not allow them to sue as a class. Despite this loss, SOD's efforts public campaigning – like the Planting Seeds of Doubt Tour and their criticisms of the GM field trails - and lawsuit were critical in halting the introduction of Monsanto's GM wheat (Magnan, 2007), which could have destroyed their most important crop valued at $28 million Canadian (Bouchie, 2002). While SOD was ultimately unsuccessful in the courts, as was the Schmeiser's attempt to overturn Monsanto's patent rights, these farmers have made significant contributions to the global debate regarding the role of corporations, technology, and farmers' rights in agriculture.

The Schmeisers and SOD farmers have been lauded worldwide for their struggle against corporations and GM crops in agriculture. The Schmeisers have received the *Mahatma Gandhi Award* for their non-violent service to humanity and Alternative Nobel Prize called the *Right Livelihood* Award and, despite now being in their mid seventies, continue to speak internationally about their experiences. Interestingly, in the spring of 2008 Monsanto paid the Schmeisers $660 in an out of court settlement for yet another GM canola contamination event, which affirms, justifies, and ironically brings closure to the farmers' struggle against this multinational. Similarly, SOD farmers have been invited to talk about their lawsuit in many countries, and are regarded as the vanguard of an international new social movement that promotes the importance of sustainable agriculture (Bronson, 2005). Despite the biopower of corporations developing GM crops, the efforts of both demonstrates how resistance to domination over seeds, agri-"culture", and life is possible.

That the Schmeisers and SOD farmers were able to galvanize global grassroots support – financially, morally, and otherwise - for their causes, while raising public awareness regarding the impacts of GM crops, shows how the subversion of corporate biopower is possible. This community-based action research project also assisted in this resistance, as interviews with the Schmeisers and SOD farmers were edited into documentary videos that have screened around the world. The film about the Schmeisers, *Genetic Matrix* (Mauro, 2005), has been translated into Spanish and Japanese. The film about SOD, *Battling the Biotech Gene Giants* (Mauro et al., 2005a), was coupled with a video of David Suzuki - a well-known geneticist and environmentalist – speaking about the risks of biotechnology, and has raised tens of thousands of dollars for the farmer lawsuit. Finally, a research video *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture* and its website (www.seedsofchangefilm.org) has been viewed by hundreds of thousands of people around the world and helped raise funds for SOD. Their stories are compelling and of great interest to farmers and consumers alike, as they offers a "reverse discourse" (Foucault, 1978) about GM crops, which facilitates resistance to biopower .

As stewards of agricultural biodiversity, the Schmeisers and SOD farmers are in tune with life, and were able to articulate credible reverse discourses about the dangers of GM crops, while promoting the importance of farmers' rights and sustainable agriculture.

These and similar actions by others around the world allow for the rise of a "subpolitical" movement, which is a self-coordinated, action-oriented, and grassroots response to the risk society and that advocates for an alternative "responsible modernity" and "ecological democracy" (Mythen, 2004). Their efforts have prompted and supported discussions about alternatives to industrial agriculture, particularly GM crops, and the importance of a farmer-centered food system based on principles of justice, ecology, and democracy. Regardless of what the courts have said, this indeed is a victory.

REFERENCES

Amsalu, A., & Graaf, J.D. (2006). Farmers' views of soil erosion problems and their conservation knowledge at Beressa watershed, central highlands of Ethiopia. *Agriculture and Human Values*, *23*, 99-108.

Altieri, M. (2004). *Genetic Engineering in Agriculture: The Myths, Environmental Risks, and Alternatives*, 2nd Edition. Oakland: Food First Books.

Andree, P. (2002). The biopolitics of genetically modified organisms in Canada. *Journal of Canadian Studies*, *37*, 162-191.

Andree, P. (2007). *Genetically Modified Diplomacy: The Global Politics of Agricultural Biotechnology and the Environment.* Vancouver: UBC Press.

Beck, U. (1992). *Risk Society: Towards a New Modernity.* London: Sage.

Beck, U. (1995). *Ecological Politics in an Age of Risk.* Cambridge: Polity Press.

Beckie, H.J., Harker, K.N., Hall, L., Warwick, S.I., Legere, A., Sikkema, P.H., Clayton, G.W., Thomas, A.G., Leeson, J.Y., Seguin-Swartz, G.G., & Simard, M.J. (2006). A decade of herbicide-resistant crops in Canada. *Canadian Journal of Plant Science*, *86*, 1243-1264,

Bouchie, A. (2002). Organic farmers sue GMO producers. *Nature Biotechnology*, *20*, 210.

Bronson, K. (2005). *Of Global Cause and Consequence: The Organic Farmers of Saskatchewan versus Monsanto and Bayer.* Masters of Arts Thesis (Department of Sociology): University of Saskatchewan.

Brook, S. (2005). Biotechnology and the politics of truth: from the green revolution to an evergreen revolution. *Sociologia Ruralis, 45*, 360-379.

Brown, L., & Strega, S. (2005). *Research As Resistance: Critical Indigenous, and Anti-oppressive Approaches*. Toronto: Canadian Scholars Press.

Buth, J. (2006). Canola Council of Canada. *Personal Communication.*

Caulfield, T., Cook-Deegan, R.M., Kieff, F.S., & Walsh, J.P. (2006). *Nature Biotechnology, 24*, 1091-1094.

CFS (Center for Food Safety) (2005). *Monsanto vs U.S. Farmers*. Washington, DC: Centre for Food Safety.

Chakrabarty, A.M. (2002). Patenting of life-forms: from concept to reality. In D. Magnus, A. Caplan, G. McGee (Eds.), *Who Owns Life?* New York: Prometheus Books.

Connelly, N.A., Brown, T.L. & Decker, D.J. (2003). Factors affecting response rates in natural resources-focused mail surveys: empirical evidence of declining rates over time. *Society and Natural Resources, 16*, 541-549.

Conway, G., & Toenniessen, G. (1999). Feeding the world in the twenty-first century. *Nature, 402*, C55-C58.

Council of Canadians, ETC Group, Sierra Club of Canada, National Farmers Union, Research Foundation for Science, Technology and Ecology, and International Centre for Technology Assessment (2004). *Factum of the Interveners for Monsanto v Schmeiser*. Ottawa: Supreme Court of Canada.

Debeer, J. (2007). The rights and responsibilities of biotech patent owners. *UBC Law Review, 40*, 343-373.

Delamont, S. (2004). Ethnography and participant observation. In C. Scale, G. Gobo, J.F. Gubrium, & D. Silverman (Eds.), *Qualitative Research Practice*. Thousand Oaks, CA: Sage Publications.

Dillman, D. (2000). *Mail and Internet Surveys: The Tailored Design Method, Second Edition.* Toronto: John Wiley and Sons.

Dougall, D. (2004). Affidavit of Dianne Dougall on behalf of Ontario Provincial Government. Submitted to the Supreme Court of Canada for intervener status in *Monsanto v Schmeiser.*

Drahos, P., & Braithwaite, J. (2003). *Information Feudalism: Who Owns the Knowledge Economy?* New York: Oxford University Press.

Friesen, R. (2004). U of M survey measures attitudes toward GM wheat. *Manitoba Cooperator*. February 25. Available at: www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm_research

Friesen, L.F., Nelson, A.G., & Van Acker, R.C. (2003). Evidence of contamination of pedigreed canola (*Brassica napus*) seedlots in Western Canada with genetically engineered herbicide resistance traits. *Agronomy Journal*, *95*, 1342-1347.

Foucault, M. (1978). *The History of Sexuality: An Introduction*. New York: Random House.

Fowler, C., & Mooney, P.R. (1990). *Shattering: Food, Politics, and the Loss of Genetic Diversity*. Tucson: The University of Arizona Press.

Furedi, F. (2002). *Culture of Fear: Revised Edition*. New York: Continuum.

Glenna, L.L., & Jussaume, R.A. (2007). Organic and conventional Washington State farmers' opinions on GM crops and marketing strategies. *Renewable Agriculture and Food Systems*, *22*, 118-124.

Gold, E.R., & Adams, W.A. (2001). The Monsanto decision: The edge or the wedge. *Nature Biotechnology*, *19*, 587.

Hansen, S.A., & VanFleet, J.W. (2003). *Traditional Knowledge and Intellectual Property*. New York: American Association for the Advancement of Science.

Jensen, K., & Murray, F. (2005). Intellectual Property Landscape of the Human Genome. *Science*, *310*, 239-240.

Johnson, J.M. (2002). In-depth interviewing. In J.F. Gubrium, & J.A. Holstein (Eds.), *Handbook of Interview Research: Context and Method*. Thousand Oaks, CA: Sage Publications.

Kaltoft, P. (1999). Values about nature in organic farming practice and knowledge. *Sociologia Ruralis, 39,* 39-53.

Kloppenburg, J. (1991). Social-theory and the de reconstruction of agricultural science-local knowledge for an alternative agriculture. *Rural Sociology*, *56*, 519-548.

Kloppenburg, J. (2002). *First the Seed: The Political Economy of Plant Biotechnology*. Madison: The University of Wisconsin Press.

Kneen, B. (1992). *The Rape of Canola*. Toronto: NC Press.

Krayer von Krauss, M.P., Caseman, E.A., & Small, M.J. (2004). Elicitation of expert judgments of uncertainty in the risk assessment of herbicide-tolerant oilseed crops. *Risk Analysis, 24,* 1515-1527.

Kuyek, D. (2007). *Good Crop/Bad Crop: Seed Politics and the Future of Food in Canada.* Toronto: Between the Lines.

Lawton, M. (2003). *Management of Herbicide Tolerant Crops and Future Research.* Canadian Food Inspection Agency. Available at: www.inspection.gc.ca/english/plaveg/bio/consult/herbtolrepe/shtml

Leiss, W. *In the Chamber of Risk: Understanding Risk Controversies.* Montreal: McGill-Queens University Press.

Lewontin, R.C. (1991). *Biology as Ideology: The Doctrine of DNA.* Toronto: House of Anansi Press.

Magnan, A. (2007). Strange bedfellows: contentious coalitions and the politics of GM wheat. *Journal of Canadian Sociology and Anthropology, 44,* 289-317.

Mauro, I.J. (2008). Farmer knowledge and a priori risk analysis: A pre-release evaluation of genetically modified Roundup Ready wheat across the Canadian prairies. *Riding the Risk Wave: Farmer Knowledge and Experience With GM Crops in the Canadian Prairies.* Doctoral Thesis (Department of Environment & Geography): University of Manitoba.

Mauro, I.J. (2005). *Genetic Matrix: The Schmeiser Case and the Fight for the Future of Life.* Winnipeg, MB: Dead Crow Productions and the Council of Canadians. Documentary film. Available at: www.umanitoba.ca/environment/esc_est/ec_lab/genetic_matrix/index.php

Mauro, I.J., Stozek, T., & Douklias, G. (2005a). *Genetic Revolution and Battling the Biotech Gene Giants (Featuring Dr. David Suzuki).* Winnipeg, MB: Dead Crow Productions and The Saskatchewan Organic Directorate. Documentary film. Available at: www.saskorganic.com/oapf/order_dvd.html

Mauro, I.J., McLachlan, S.M., & Sanders, J. (2005b). *Seeds of Change: Farmers, Biotechnology and the New Face of Agriculture.* Winnipeg, MB: Dead Crow Productions and Dada World Data. Documentary film. Available at: www.seedsofchangefilm.org

Mauro, I.J., & McLachlan, S.M. (2008). Farmer knowledge and risk analysis: Post-release evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis, 28,* 463-476.

Mauro, I.J. & McLachlan, S.M. (accepted). Farmer knowledge and video research: Planting "Seeds of Change" regarding genetically modified crops in the Canadian prairies. *Agriculture and Human Values.*

Maxwell, J.A. (2005). *Qualitative Research Design: An Interactive Approach.* Thousand Oaks, CA: Sage Publications.

Mehta, M.D. (2005). The impact of agricultural biotechnology on social cohesion. In M.D. Mehta (Ed.), *Biotechnology Unglued: Science, Society, and Social Cohesion.* Vancouver: UBC Press.

Morrow, A.D., & Ingram, C.B. (2005). Of transgenic mice and roundup ready canola: the decision of the Supreme Court of Canada in Harvard college v. Canada and Monsanto v. Schmeiser. *UBC Law Review, 38*, 189-222.

Mythen, G. (2004). *Urlich Beck: A Critical Introduction to the Risk Society.* London: Pluto Press.

Patton, M.J. (2002). *Qualitative Research and Evaluation Methods: Third Edition.* London: Sage Publications.

Phillipson, M. (2005). Giving away the farm? The rights and obligations of biotechnology multinational: Canadian developments. *The King's College Law Journal, 16*, 362-372.

Powledge, F. (2001). Patenting, piracy, and the global commons. *Bioscience, 51*, 273-277.

Pretty, J. (2002). *Agri-Culture: Reconnecting People, Land and Nature.* London: Earthscan Publications Ltd.

Rabinow, P., & Rose, N. (2003). *The Essential Foucault: Selections from Essential Works of Foucault, 1954-1984.* New York: The New Press.

Rampton, R. (2004). Study probes Canadian farmers' views on GM wheat. *Forbes.com.* February 20. Available at: www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm_research

Rieger, M.A., Lamond, M., Preston, C., Powles, S.B., & Roush, R.T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science, 296*, 2386-2388.

Rifkin, J. (1998). *The Biotech Century: Harnessing the Gene and Remaking the World.* New York: Penguin Putnam Inc.

RSC (Royal Society of Canada) (2001). *Elements of Precaution: Recommendations for the Regulation of Food Biotechnology in Canada,* Ottawa, ON. Available at www.rsc.ca/index.php?page_id=119

Shennan, S. (2003). *Genes, Memes and Human History: Darwinian Archaeology and Cultural Evolution*. London: Thames Hudson Ltd.

Shiva, V. (2000). *Tomorrow's Biodiversity*. New York: Thames and Hudson.

Shiva, V. (1997). *Biopiracy: The Plunder of Nature and Knowledge*. Cambridge, MA: South End Press.

Smyth, S., Khachatourians, G., Phillips, P.W.B. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology*, *20*, 537-541.

Soule, J.D., & Piper, J.K. (1992). *Farming in Nature's Image: An Ecological Approach to Agriculture*. Washington, DC: Island Press.

SPSS. (2006). Version 15.0 Command Syntax Reference. Chicao, Ill: SPSS Inc.

Statistics Canada. (2006). Snapshot of Canadian agriculture. *Census of Agriculture.* Available at: www.statcan.ca/english/agcensus2006/articles/snapshot.htm

Statistics Canada. (2008a). Estimated Areas, Yield, Production, Average Farm Price and Total Farm Value of Principle Field Crops, Annual, 1908-2007: CANSIM Agriculture Statistics Database. Ottawa, ON.

Statistics Canada (2008b). *Census of Agriculture Counts 44,329 farms in Saskatchewan.* Available at: www.statcan.ca/english/agcensus2006/media_release/SK.htm#r3

Stokstad, E. (2004). Monsanto pulls the plug on genetically modified wheat. *Science*, *304*, 1088-1089.

Stringer, E.T. (2007). *Action Research, Third Edition.* London: Sage Publications.

Swenarchuk, M. (2003). *The Harvard Mouse and All That: Life Patents in Canada.* Toronto: Canadian Environmental Law Association. Available at: www.cela.ca

Tilman, D. (1998). The greening of the green revolution. *Nature*, *396*, 211-212.

Umeno, S., & Kesan, J.P. (2007). Dynamic pricing mechanism to achieve pareto optimality in a seed production contract. In J.P. Kesan (Ed), *Agricultural Biotechnology and Intellectual Property: Seeds of Change.* Cambridge, MA: CAB International.

USC & ETC. (2008). *The Seed Map: Food, Farmers, and Climate Change.* Available at: www.usc-canada.org/resources/seed-map/

Veteto, J.R. (2008). The history and survival of traditional heirloom vegetable varieties in the southern Appalachian Mountains of western North Carolina. *Agriculture and Human Values, 25*, 121-134.

Walz, E. (2003). *4th National Organic Farmers' Survey: Sustaining Organic Farms in a Changing Organic Marketplace.* Santa Cruz, CA: Organic Farming Research Foundation. Available at: www.ofrf.org

White, E. (2004). Survey seeks farmers' views on GM wheat. *Western Producer.* February 26. Available at: www.umanitoba.ca/environment/esc_est/ec_lab/?p=gm_research

Wilson, J. (2002). Patenting organisms: intellectual property law meets biology. In D. Magnus, A. Caplan, G. McGee (Eds.), *Who Owns Life?* New York: Prometheus Books.

Yarrow, S. (1999). Biosafety issues of genetically engineered herbicide-tolerant plants – Agriculture and Agri-Food Canada's perspective. In S. Shantharam & J.F. Montgomery (Eds), *Biotechnology, Biosafety, and Biodiversity: Scientific and Ethical Issues for Sustainable Development.* Enfield, NH: Science Publishers, Inc.

FIGURES AND TABLES

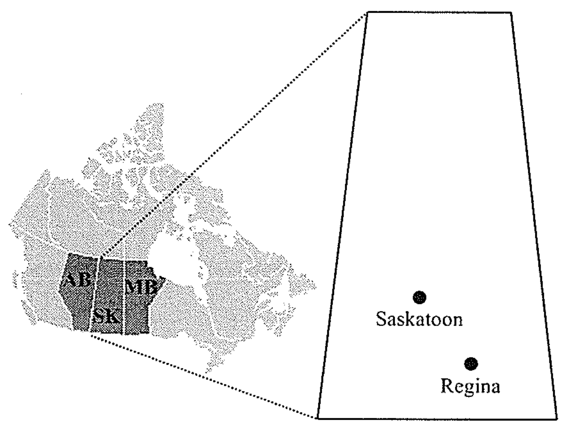


Figure 1. Interviews were conducted with the Schmeisers and SOD farmers on their farms across Saskatchewan and in the cities of Saskatoon and Regina (insert). Questionnaires were mailed to prairie farmers in Alberta (AB), Saskatchewan (SK), and Manitoba (MB).

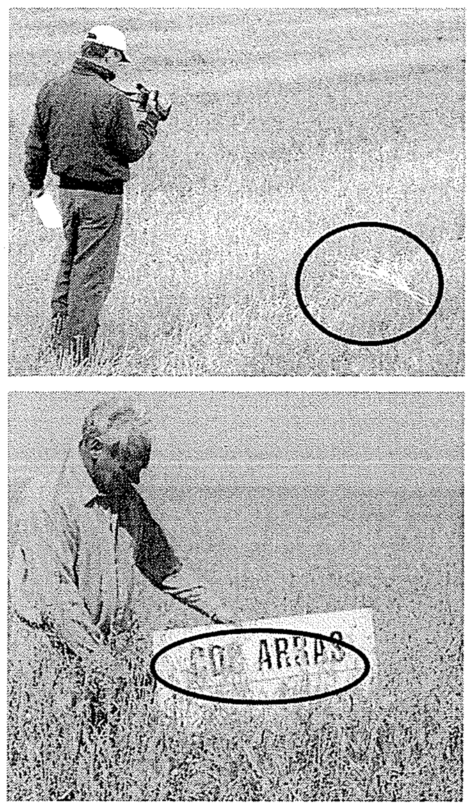


Figure 2. Organic farmers Marc Loiselle (top) and Pat Neville (bottom) documenting Monsanto's genetically modified (GM) canola that had contaminated their land.

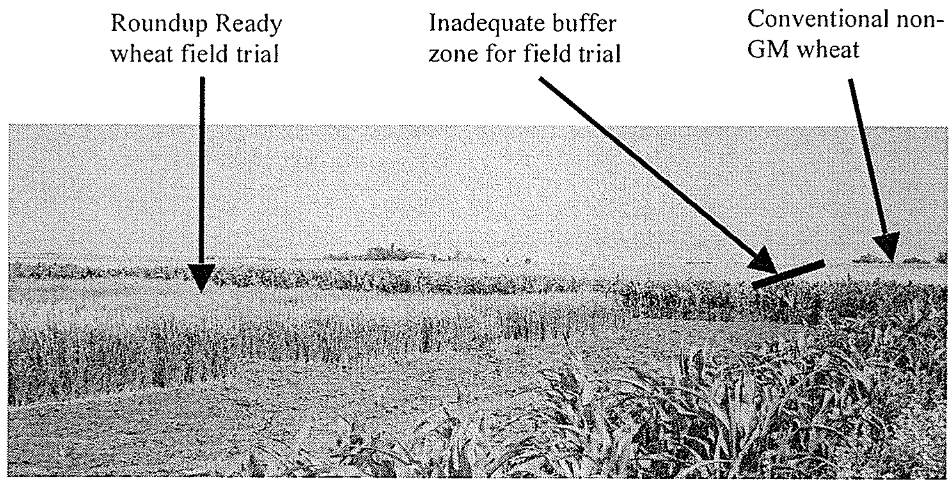


Figure 3: Roundup Ready wheat field trial discovered by Marc Loiselle. The field trial had an inadequate buffer zone between GM and non-GM wheat, which risked the unapproved GM wheat entering the food supply. That Mr. Loiselle made this information public changed the way that GM wheat field trials were regulated in Canada, changing protocols from a 30-meter to 300-meter buffer zone.

Table 1: Farmer attitudes (n=736) toward the contamination and patenting issues related to genetically modified (GM) crops on non-GM farmers, comparing GM (n=490) and non-GM (n=246) users.

	Proportion[1] of respondents				Mean[2] and Independent T-test[3] on Likert scale			
	GM (n=490)		Non-GM (n=246)		Mean		T-test	
	-	+	-	+	GM (n=490)	Non-GM (n=246)	P value	SE
By suing farmers, developers of GM crops are hurting rural communities	0.22	0.63	0.09	0.84	5.00	5.92	<0.0001	0.129
Corporations that sue farmers for illegal use of GM crops are promoting a culture of fear in Canada's rural communities	0.26	0.65	0.08	0.85	4.94	5.96	<0.0001	0.127
Farmers right to save seed is important	0.05	0.90	0.02	0.96	6.06	6.52	<0.0001	0.082
If a GM plant blows into a farmer's field, that farmer should have the right to keep it	0.14	0.65	0.08	0.78	5.18	5.79	<0.0001	0.130
If GM crops blew onto a farmer's land, that farmer is guilty of patent infringement for possessing genes they did not pay for	0.93	0.03	0.97	0.02	1.65	1.40	0.003	0.083
Percy Schmieser is innocent of patent infringement	0.34	0.27	0.11	0.56	4.81	5.86	<0.0001	0.169

[1]Proportions represent positive (+) and negative (-) sides of Likert scale for associated questions. [2]Means for Likert scale responses of GM and non-GM users reported. [3] Independent t-tests were conducted with a 95% confidence interval.

Table 2: Farmer attitudes (n=736) toward the impact of genetically modified (GM) crops on non-GM farmers, comparing GM (n=490) and non-GM (n=246) users.

	Proportion[1] of respondents				Mean[2] and Independent T-test[3] on Likert scale			
	GM (n=490)		Non-GM (n=246)		Mean		T-test	
	-	+	-	+	GM (n=490)	Non-GM (n=246)	P value	SE
GM canola has negatively affected non-GM farmers and their land	0.37	0.52	0.11	0.84	4.45	5.96	<0.0001	0.142
GM & non-GM crops can grow together on the prairies wihtout them mixing	0.75	0.18	0.94	0.05	2.78	1.75	<0.0001	0.128
If GM crops cause damage to a non-GM farmer's land the company that developed the crop should be held liable	0.14	0.73	0.05	0.91	5.40	6.25	<0.0001	0.113
If non-GM farmers can prove GM crops have harmed them, I support them suing the companies that developed the crop	0.15	0.70	0.03	0.92	5.28	6.35	<0.0001	0.108
Non-GM farmers a minority group in agriculture, their concerns should not influence policy regarding GM crops	0.76	0.12	0.90	0.08	2.58	1.90	<0.0001	0.129
Non-GM farmers should have the right to a zero tolerance for GM traits in their crops	0.13	0.72	0.02	0.92	5.42	1.90	<0.0001	0.109

[1]Proportions represent positive (+) and negative (-) sides of Likert scale for associated questions. [2]Means for Likert scale responses of GM and non-GM users reported. [3] Independent t-tests were conducted with a 95% confidence interval.

Chapter 9:

Riding the Risk Wave: A Discussion and Conclusion

"A perfection of means, and confusion of aims, seems to be our main problem"

-Albert Einstein

INTRODUCTION

This thesis has documented farmer local knowledge (**LK**) regarding the benefits and risks of genetically modified (**GM**) crops, particularly herbicide-tolerant (**HT**) canola and wheat varieties, across the Canadian prairies. As stewards of the land, farmers have rich and experiential insight into the impacts associated with agricultural technology, particularly on rural communities, agroecosystems, and the larger environment (Fujisaka, 1992; Neufeld and Cinnamon, 2004). However, until this study, farmer LK had either been ignored or systematically excluded in the evaluation of GM crops.

Despite GM crops being grown in Canada for over a decade, there have been no peer-reviewed studies conducted on farmer experience and attitudes regarding this technology. In part, this reflects how risks associated with GM crops are regulated by governments. Conventional risk assessment is "science-based" (Nap et al., 2003) and does not allow for *a priori* public input regarding their potential socioeconomic, cultural, and legal impacts (Abergel and Barrett, 2002; Isaac, 2006). Furthermore, GM crops are considered as "substantially equivalent" to their non-GM counterparts, thus *post-release* monitoring is not required to ensure the safety of this technology (Andree, 2002). However, it is increasingly recognized that agbiotechnology may affect both ecological and social systems and have long-term and substantial effects (Steinbrecher, 2001; Mehta, 2005), suggesting that "science-based" risk assessment is inadequate.

Risk analysis, in contrast, is a broader approach for evaluating GM crops, and considers both scientific and social issues (Auberson-Huang, 2002). It has made significant contribution to the GM debate by including consumer attitudes in the assessment of this technology. However, to-date, only a few studies have used a risk analysis framework to study farmer attitudes toward GM crops (e.g. Chong, 2005), and arguably none have explicitly evaluated farmer LK and experience regarding this technology. Indeed, in all the peer-reviewed literature examined, only one study from Illinois State explored farmer perceptions with GM crops that they had actually used (Chimmiri et al., 2006).

This chapter begins by discussing the contribution this thesis has made to theory and then summarizes the major findings from this farmer-focused study. It also provides recommendations for how risk research on GM crops might be reformed to better ensure safe deployment of this technology, while engaging in a broader discussion regarding the future of agriculture.

CONTRIBUTION TO THEORY

To my knowledge, this thesis is the first in the world to combine farmer LK and risk analysis in the evaluation of GM crops, and in doing so, has made a significant contribution to risk research theory. To-date, much of the risk perception literature has compared "lay" versus "expert" perspectives (Rowe and Wright, 2000), and this study suggests that experienced-based farmer LK might offer a meaningful alternative to this dichotomy. The effective use of farmer LK in both *a priori* and *post-release* risk analysis demonstrates that rural stakeholders should be included in all phases of evaluating agricultural technology, particularly GM crops.

Two important theoretical models have been developed in this thesis. First, the "double helix of risk" is an innovative conceptual model that demonstrates the need for holism in risk research regarding GM crops. It argues that balance between social and natural science must be established in regulation regarding GM crops, which will open space for public participation in the evaluation of this technology. Secondly, this final chapter presents a "risk wave" model as a summary of the risk-related findings of this thesis. It is a novel way to understand the diverse, cumulative, and intensified risks that may be associated with GM crops, particularly HT canola and wheat.

While farmer LK is widely recognized as holistic (e.g. Kloppenburg, 1991), this research documents how this works in praxis, and has found that farmer experience is central to risk perception, but it is also informed by distrust in industry and government and a belief in the importance of community and environment. The use of video to document and broadly communicate farmer LK is highly innovative and has been recognized as an emerging methodology in the social sciences (SSHRC, 2005a). That the *Seeds of Change* research video (Chapter 5) was made in a participatory and action-oriented manner demonstrates how research can extend beyond the "ivory tower" and engage with and assist farmers and rural communities. Furthermore, this video research has also been lauded for being highly accessible and of broad interest to society (SSHRC, 2005b), and at last check, the *Seeds of Change* website had over 315,000 people watch the film.

That this study is amongst the first to document farmer LK and experience with GM crops anywhere in the world has generated new insights into the impacts associated with this technology. In particular, risks associated with GM crops were found to be complex, and spanned across socioeconomic, cultural, legal, and agroecological issues. Importantly, the methodology and analysis used in this study allowed GM crops to be assessed at the individual farm-level, which elucidated the previously unreported pattern that the benefits and risks associated with this technology accrue unevenly to farmers.

That this study evaluated GM wheat immediately before it was deferred from commercialization, makes this the first and only research that will be available on farmers' *a priori* attitudes regarding this crop at the height of controversy surrounding its proposed introduction. While some farmer-focused risks have been discussed in the literature, this study is arguably the first to systematically document them across a broad geographic area, and represents an important contribution to the theory on GM crop hazards. Specifically, it documents how the widespread contamination of GM canola affects farmer attitudes toward the technology, its associated impact on rural culture and socioeconomics, and how this may be exacerbated by the introduction of GM wheat.

THE AGRONOMIC BENEFITS OF GM CROPS

Both GM canola and GM wheat, which are HT crops, were evaluated in this study. Using surveys and interviews, farmers evaluated the benefits of GM canola (*post-release*) and GM wheat (*a priori*). Farmer experience with GM canola was central to how they evaluated this crop, but it was also critical in shaping how they perceived the potential impacts associated with GM wheat. Farmers indicated that GM canola and GM wheat primarily offered agronomic benefits, particularly better weed control (Figure 1).

Overall, farmers using GM canola were pleased with its performance, and believed it to be superior to conventional varieties (Chapters 4, 5 & 6). Prior to the release of GM canola, farmers grew conventional canola by incorporating herbicides into the soil, which was time consuming, required harsher and less effective chemicals, and generally restricted the crop to less weedy fields (Beckie et al., 2006). The weed control benefits associated with GM canola allowed farmers to increase the use of reduced tillage, farm larger areas, rotate herbicides, and improve the quality of their product by reducing dockage (i.e. weed seeds, chaff and other foreign materials) (Chapters 4, 5 & 6). Farmers benefited most in the early phase of adopting this technology, which has acted as an incentive for the widespread use of GM canola across the Canadian prairies. Farmers that perceived the greatest benefit with GM canola were less likely to have experienced these plants growing adventitiously on their farms as "volunteers" (Chapter 6). However, these benefits did not accrue evenly to all farmers, and those experiencing volunteers, with smaller operations, and a longer history using GM crops felt that the risks outweighed the benefits for this technology (Chapter 6).

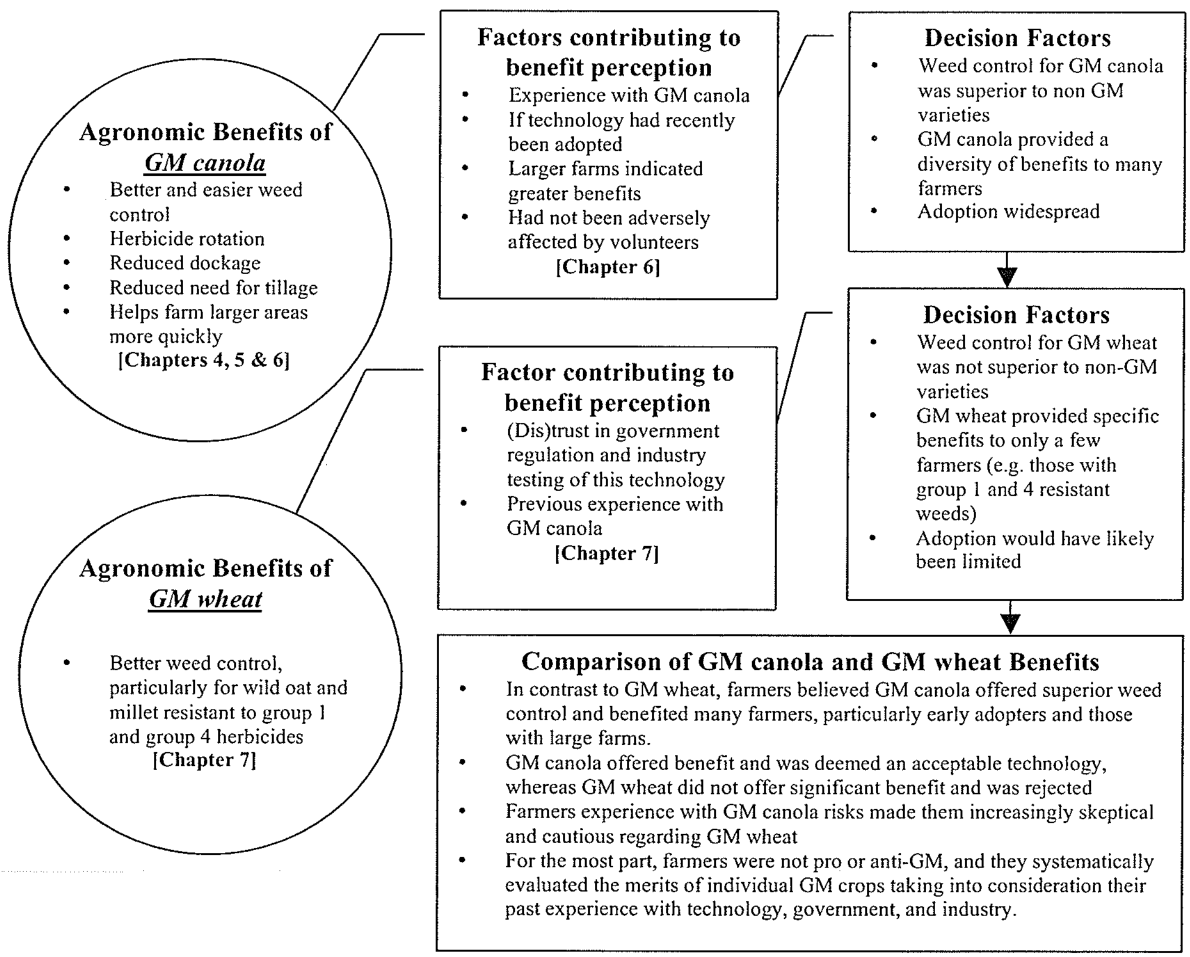


Figure 1. Comparative analysis of farmer-identified benefits and decision-making regarding herbicide-tolerant GM canola and GM wheat using data from Chapters 4, 5, and 6 of the thesis.

Some farmers believed that GM wheat also offered weed control benefits, although this was in very specific agronomic situations, particularly where wild oat and millet resistant to group 1 and group 4 herbicides were problematic (chapter 7). Overall, they ranked the weed control benefits associated with GM wheat quite low, and generally indicated that GM wheat would provide little or no value for adopters of the technology (Chapters 4, 5 & 7). They have many effective herbicide options for managing weeds in conventional wheat, and given that the main benefit associated with Roundup Ready wheat (**RRW**) is weed control, it was not viewed as superior to already available non-HT varieties (Chapter 7). Furthermore, after their experiences with GM canola, many farmers recognized that agbiotechnology might also pose new risks, and this increased their skepticism toward GM wheat (Chapters 4, 5 & 7). Many were distrustful of government regulation and industry testing of GM wheat, which further influenced their belief that this product was ultimately of little benefit (Chapter 7).

Overall, study participants using agbiotechnology believed that the benefits of GM canola were superior to those of GM wheat (Figure 1), indicating farmers have a pragmatic, rational, and balanced approach to evaluating this technology, and this allowed them to differentiate between the benefits and risks of different GM crops. For the most part, farmers in this study were not pro or anti GM, and instead they evaluated the merits of each GM crop and/or variety, while also considering any cumulative impacts associated with the adoption of multiple GM crops. Farmers demonstrated a holistic approach to evaluating GM crops, particularly regarding risks, which they recognized spanned across ecological and human systems.

THE RISK WAVE ASSOCIATED WITH GM CANOLA AND GM WHEAT

In each phase of this study, farmers holistically evaluated GM canola and GM wheat, and did this by considering the full spectrum of agroecological, cultural, legal, and socioeconomic impacts that might be associated with these crops. They consistently indicated that GM canola and GM wheat present common risk issues, including gene flow, agronomic, corporate, and market impacts. Indeed, it was remarkable how the ranking for these risks were quantitatively and qualitatively similar in pattern. Essentially, farmers indicated that risks intensified moving from scientific issues related to gene flow and agronomy to social issues like corporate control and market harm. Moreover, the cumulative effects of having both GM canola and GM wheat introduced commercially in Canada was viewed as an unacceptable and overwhelming situation for most farmers. In mulling over how to synthesize this information, I have come up with a conceptual model called the "risk wave", which demonstrates how these common risk issues, their intensity, and the cumulative impact of GM canola and GM wheat fit together (Figure 2). This "risk wave" summarizes the major findings of this study regarding risks associated with GM canola and GM wheat and is an innovative way to present these results. It enriches this discussion by pulling together multiple chapters of this thesis, while offering a new conceptual way to better understand the impacts of GM crops on farmers, rural communities, and the environment across the Canadian prairies.

GENE FLOW AND CONTAMINATION

The first pulse in the risk wave is related to gene flow and contamination (Figure 2). Farmers in this study were greatly concerned about the risks associated with gene flow from GM canola. Most of those surveyed that were using GM canola (n=298) believed "gene spread" was a significant risk and 38% reported unwanted GM canola plants (i.e. volunteers) on their land (Chapter 6). I interviewed four farmers that had had their farms contaminated by GM canola, these including two organic farmers, one practicing zero tillage, and one growing conventional non-GM canola (Chapters 4, 5 & 8). For the organic farmers, the presence of GM volunteers on their land was devastating, and required extensive, expensive, and enduring cleanup efforts (Chapter 8). Organic standards prohibit farmers from having GM materials in their crops and, as the organic farmers indicated, this contamination threatened their ability to certify their crops as GM-free. The zero till farmer interviewed (Chapter 4 & 5), indicated that the Roundup Ready canola (**RRC**) contamination of his farm was so extensive that it could have been harvested as a crop. After having his non-GM canola contaminated by RRC, the conventional farmer was sued by Monsanto for patent infringement and was forced to abandon his seed saving practices (Chapter 4, 5 & 8). These farmers believed that GM canola contamination on their farms was due largely to wind blowing GM pollen or seed onto their land.

Although wheat is considered a self-pollinating crop, farmers in this study were still concerned about gene flow and contamination issues related to GM wheat. Based on their previous experience with GM canola, many farmers believed that Roundup Ready wheat (**RRW**) would also contaminate their non-GM varieties and lead to problems (Chapters 4, 5 & 7). Although RRW had not been grown commercially in Canada, it was planted in field trials across the prairies, and many believed that regulatory oversight of this research was inadequate and might lead to gene escape (Chapter 7). Indeed, one farmer in this study actually found and photographed a RRW test plot that was poorly managed and had conventional wheat growing directly beside it, which prompted concern over contamination and an overhaul of regulatory protocols (Chapter 8). As we will see, this first section of the risk wave involving GM canola and GM wheat gene flow and contamination can translate into and aggravate subsequent risk issues.

This first part of the risk wave is an area ostensibly studied by "science-based" risk assessment, given that gene flow is a scientific issue that is considered important to regulators. Despite this, the Canadian government approved the release of GM canola in 1995 prior to a full evaluation of the extent to which gene flow occurs with this crop, and the associated impact that this might have for farmers and the environment. It was not until much later that studies identified how gene flow in HT canola could contaminate non-HT varieties up to 3 km away (Reiger et al., 2002). In wheat, depending on the variety, gene flow has been reported between 27 (Hucl and Matus-Cadiz, 2001) and 300 km Matus-Cadiz et al., 2004) from the pollen source. It is now recognized that risk assessment has largely failed to anticipate many adverse impacts associated with GM crops, particularly gene flow (Krayer von Krauss et al., 2004). Gene flow in turn has adverse agronomic implications, especially with respect to volunteers.

AGRONOMIC IMPACT

The second pulse in the risk wave is related to agronomic impact (Figure 2). Agronomic hazards caused by GM crops are primarily related to the proliferation of volunteers. On average, these GM canola volunteers were found to persist for 2.5 years, although they were reported to last as long as six years (Chapter 6). Twenty percent of GM canola volunteers reported by farmers were resistant to more than one herbicide (Chapter 6), which suggests that these "trait-stacked" plants are more widespread than previously reported. A large majority (76%) of farmers who used GM canola believed

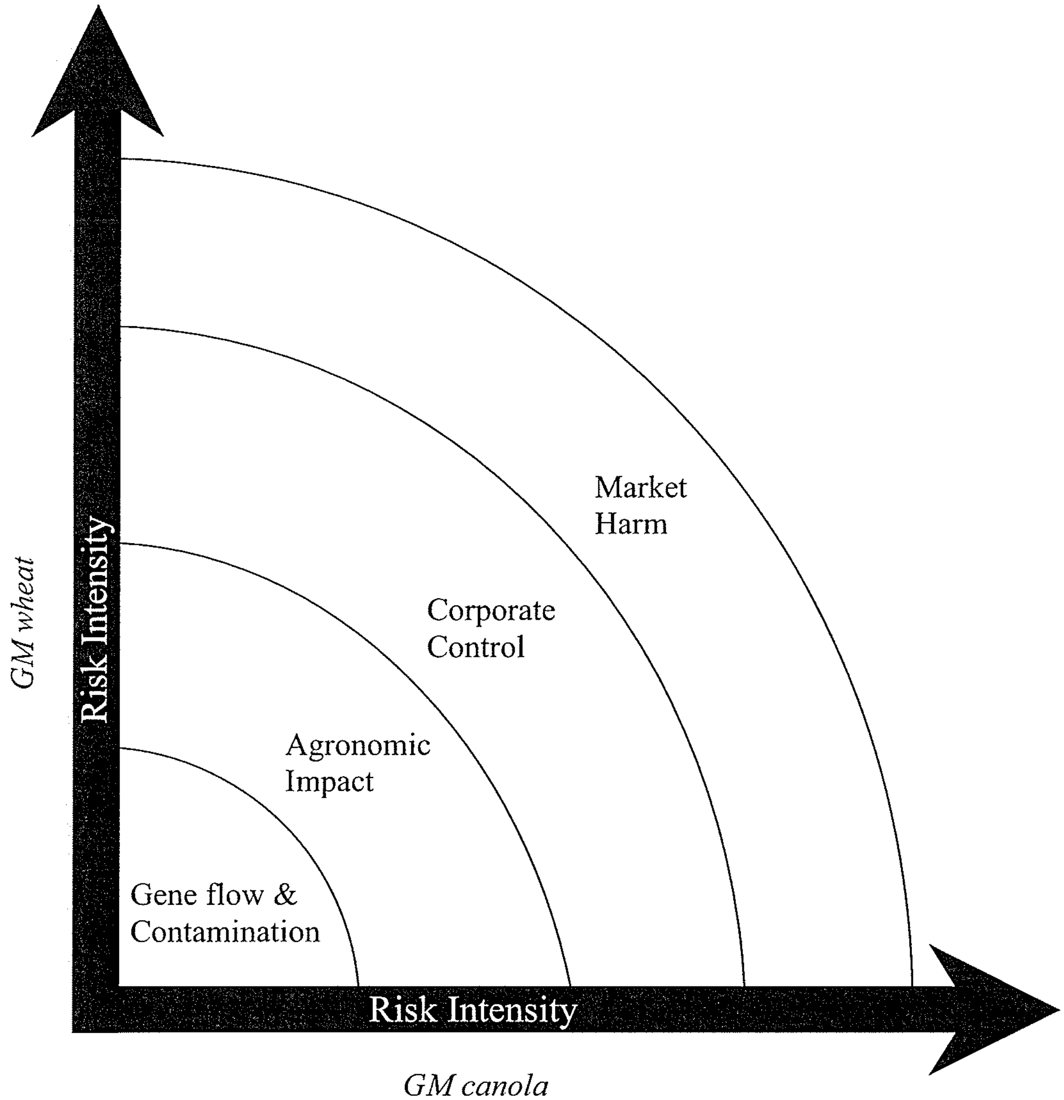


Figure 2. The "risk wave" is a conceptual model that summarizes the major risk-related findings of this thesis. Genetically modified (GM) canola and wheat were found to have common risk issues including gene flow and contamination, agronomic impact, corporate control, and market harm, which farmers believed increased in intensity. If both GM canola and wheat are introduced simultaneously this creates cumulative impacts that intensify into a "risk wave". While the inner two sections of the risk wave are included in "science-based" risk assessment, the outer two are not, which further exacerbates risk intensity.

that they would be more of a problem in the future, while an even greater proportion (85%) believed industry had shifted the burden of responsibility onto farmers (Chapter 6). One of the most important findings of this study is that when farmers experienced volunteer contamination their risk perception increased substantially, which left them believing that the risks outweigh the benefits for the technology (chapter 6).

These volunteers were particularly problematic for minimum and zero till farmers. Those having reduced tillage systems use glyphosate herbicide (e.g. Roundup) for pre-seeding weed control instead of tillage; however, the unwanted proliferation of Roundup-tolerant canola volunteers requires additional and more costly chemicals to control these unwanted plants (Chapters 4, 5 & 6). Some believed that these additional costs might shift the tipping point regarding the economics of minimum and zero tillage, resulting in the decline of these techniques that have many important environmental benefits (Chapters 4 & 5). Indeed, I found that many (9%) zero till farmers had reverted to tillage to control Roundup Ready volunteers (Chapter 6).

With the pending approval of RRW, many farmers were concerned about the combined impacts of RRW and RRC volunteers and how these might affect their rotations (Chapters 4, 5 & 7). Many across the prairies grow wheat and canola in rotation, and after harvest these seeds remain in the soil, such that canola volunteers are often found in wheat and wheat in the canola. That many also use glyphosate to control weeds, particularly those practicing conservation tillage, makes controlling RR volunteers difficult and more costly. This would further be exacerbated if both RRW and RRC were commercially available. In effect, glyphosate would no longer be effective in controlling RR resistant volunteers in either RRC or RRW, which would compromise the benefit of this technology. The cost of controlling RRW volunteers is more expensive than for

RRC, and many indicated that this extra expense combined with the cumulative agronomic impacts of RRW and RRC volunteers might destroy minimum and zero tillage all together (chapters 4, 5 & 7).

Organic farmers were greatly concerned about the agronomic impacts that the release of RRW might have on their operations. With the introduction of GM canola, organic farmers across the prairies had to stop growing canola because of the likelihood that it would be contaminated (Chapters 4, 5, 7 & 8). Instead of using chemicals, organic farmers use sophisticated crop rotations to control weeds, and the loss of canola was like losing a tool from their agricultural toolbox. However, wheat is by far the most important crop in organic rotations, and many organic farmers suggested that the introduction of GM wheat and associated contamination might destroy their industry all together (Chapters 4, 5 & 8).

Farmers also communicated their concern about how the increased use of Roundup, facilitated by the use of RR crops, might lead to weeds evolving resistance to the herbicide. (Chapters 4, 5, 6 & 7). The use of RR crops results in the repeated spraying of glyphosate and increases the likelihood that herbicide resistant weeds will develop (Nottingham, 2002). Moreover, glyphosate-resistant crops allow for in-crop spraying, which was not previously possible with non-HT crops, and further increases the probability for resistance to develop in a broader spectrum of common weeds (Van Acker et al., 2003). Worldwide, since the introduction of RR crops in agriculture, a dozen weed species have already evolved resistance to glyphosate (Service, 2007), and further undermine conservation tillage and the important environmental benefits associated with these practices (Chapters 4, 5, 6 & 7).

As we have seen, gene flow from GM crops has adverse agronomic implications, particularly the proliferation of volunteers, which can cause hazards for farmers especially those practicing organics and conservation tillage. These first two pulses of the risk wave can be studied scientifically and regulators consider them important and include them in risk assessment. However, given that risk assessment is carried out on a case-by-case basis, it does not consider the cumulative impact of multiple GM crops in rotation, which this study has shown may increase the chances of glyphosate-tolerant weeds and volunteers that may harm minimum, zero till, and organic farmers. Indeed, many experts believe the omission of cumulative impacts is a major failing of GM crop risk assessment (Krayer von Krauss et al., 2004). Another omission of risk assessment is its inability to address social issues.

CORPORATE CONTROL

Throughout this study, farmers indicated that increasing corporate control amounted to a major threat to agriculture, which was exacerbated by the introduction of GM crops. Seeking return on their investment, corporations have increased the cost of GM seeds relative to non-GM seeds. Indeed, increased seed cost was a consistently ranked as a high risk for both GM canola and GM wheat (Chapters 6 & 7). With Monsanto's GM crops, they actually charge an additional $15 per acre to use the technology, purportedly to recoup their expenses on research and development. That GM canola favors larger farms, smaller ones often have to adopt GM seed and expand their farms to stay competitive. This often places farmers in a "Catch 22", as they often need GM seed to survive, but it further increases their reliance on corporations and increases their debt. (Chapter 6). This study has documented the "genetic treadmill" in action, which is symptomatic of a larger pattern in industrial agriculture that has undermined the cohesion and population of rural communities since the 1950s (Chapters 2 & 6).

One of the most controversial forms of corporate control is the use of contracts, often called technology use agreements (TUAs), which must be signed if a farmer wants access to certain GM crops. Farmers consistently viewed these contracts as being a significant risk (Chapters 6, 7 & 8), which threatened their autonomy and further increased corporate control over agriculture, particularly that of seeds. In effect, companies now lease GM seeds to farmers and place severe restrictions on how this technology can be used. Monsanto's TUA demands that glyphosate only be purchased from them, which gives the company a monopoly over many of the inputs required by farmers to grow GM canola. Furthermore, Monsanto's TUA prohibits farmers from using GM canola without further contracts in subsequent years, sharing it with neighbors, or harvesting associated volunteers (Chapter 6). It also grants Monsanto the right to inspect a farmer's land for compliance over a three-year period, and if he or she is found in violation of the terms, the contract can be used to levy stiff penalties and may indeed become the basis for a lawsuit (Chapter 6). Some participants noted that they were increasingly being treated like serfs or slaves to the large corporations and chemical companies, in turn endangering their livelihoods (Chapter 7). Given that farmers often need this technology to stay competitive, many have abandoned traditional seed saving practices, which has in turn increased the control of corporations over seed supply. To prevent farmers from using GM seeds without a license, companies have patented this technology as another way to ensure their control over seed supply and agriculture as a whole.

Using patent law, agbiotechnology companies have literally claimed ownership over GM crops, and have sued non-GM farmers for illegal use of their proprietary genetic material. Worldwide, the most high profile case is that of Percy and Louise Schmeiser (Chapters 5 & 8), who were sued by Monsanto after their fields were contaminated by GM canola in 1997. This case was the first in the world to claim that a patent over a life form had been violated and drew international attention to the control that companies have over seeds, plants, and life in general. The Schmeiser case demonstrates how Monsanto ruthlessly investigates, defames, and attacks farmers suspected of patent infringement even if they have not fraudulently obtained GM seeds. These tactics, the Schmeisers and other prairie farmers believed, undermined the "rural social fabric" and created a "culture of fear" in rural communities (Chapter 8). In 2004, the Supreme Court of Canada ruled in *Monsanto v Schmeiser* that farmers effectively can no longer seed save even if the presence of the technology in their fields results from contamination, which many have argued is a precedent that will adversely affect farmers world over (Chapter 8). Many have recognized that accountability accompanies the corporate ownership of these plants.

The organic farmers of Saskatchewan sought to resist this increasing corporate control and to affirm corporate accountability over agriculture and seeds by launching a class-action lawsuit against Monsanto and Bayer for damages associated with GM crop contamination (Chapter 5 & 8). They believed that GM crops were undermining their autonomy and control over organic agriculture. They also believed that GM crops were adversely affecting rural communities, as they pitted GM against non-GM farmers, especially regarding contamination events (Chapter 8). Although organic farmers want nothing to do with GM crops, the gene flow and agronomic issues posed by this technology forced Saskatchewan organic farmers to defend themselves in a six-year long legal battle with agbiotechnology corporations. This battle with corporations over the future of organic agriculture created much stress for those farmers involved, this exacerbated when *the courts dismissed Hoffman v Monsanto*. Liability for GM crop damages remain elusive (chapter 8).

Overall, farmers consistently believed that increasing corporate control over agriculture was a major risk caused by GM crops. This study has clearly demonstrated how corporate pricing and legal control over GM crops can harm the socio-economic, cultural and psychological framework of rural communities. Moreover, these adverse effects are cumulative, and with each GM crop introduction the intensity of these risks increase for farmers (Figure 2). If GM wheat were introduced it would have been yet another crop controlled by companies through contract and patent law, and may have further exposed farmers to increased pricing, contamination, and lawsuits. Importantly, these corporate risks are often intimately connected with previous sections of the risk wave, as exemplified by seed saver and organic farmer lawsuits with industry over GM contamination and agronomic impact. Although corporate control over GM crops may cause adverse effects, "science-based" regulation does not recognize these, which further increases the intensity of these risks for farmers and rural communities (Figure 2). The final section of the risk wave relates to market harm.

MARKET HARM

Farmers believed the primary risk associated with both GM canola and GM wheat was market harm, and it was the highest ranked risk for both crops (Chapters 6 & 7). The threats associated with this harm was likely even greater than the costs of controlling volunteers or benefits of easy weed control (Chapters 4 & 5). Farmers have been caught in the GM crop crossfire, given that the technology has been approved yet consumers largely disapprove of its use in food.

Agbiotechnology is entrenched with international trade-related problems, as consumers around the world remain suspicious of GM crops and believe they are unsafe for human health and the environment, which has stigmatized the technology (Chapter 2). That public concern over GM crops has been excluded from "science-based" risk assessment perpetuates the controversy and has precipitated "transatlantic conflict" between North America and Europe over this technology (Chapter 2). Shortly after the release of GM canola in 1995, Europe halted all Canadian imports of the crop this adversely affecting both users and non-users of the technology (Chapter 2).

That GM canola contaminated the prairies had adverse effects on non-GM farmers, particularly those using organic methods (chapters 4, 5 & 8). This contamination effectively destroyed the ability of organic farmers to grow canola, as they could not guarantee it GM-free, which resulted in millions of dollars in lost market opportunities (Chapter 8). Seeking damages for this market harm, the organic farmers of Saskatchewan attempted to sue Monsanto and Bayer for damages, and had to engage in a protracted legal battle with these companies that cost hundreds of thousands of dollars only to be later rejected as a class (Chapter 8). These same farmers were also prepared to file a legal injunction against Monsanto regarding the introduction of GM wheat, as they believed it would also contaminate their crops, and further destroy high value organic markets and perhaps their industry all together (Chapter 8).

The farm community as a whole was united in their concern regarding the market harm that might be associated with the introduction of GM wheat (Chapters 4, 5, 7 & 8).

The proposed introduction sparked an international controversy and over 80% of foreign wheat buyers said they would not purchase the crop (Chapter 8). Canadian farmers' wheat markets - worth between $4 and $6 billion – were placed at risk, precipitating widespread concern that the already fragile socioeconomics of rural communities would be further undermined (Chapter 8). Many believed that GM wheat would be the proverbial final straw for rural communities (Chapter 8) that were already in the worst "farm income crisis" in history, with net incomes near or below those of the Great Depression and soaring farm debt in the billions (Chapter 2). Indeed, in this context, it is easy to see why farmers were concerned about market harm caused by GM crops, particularly Roundup Ready wheat.

It's important to point out, farmers viewed market harm as a complex issue, which was fundamentally connected with ecology. For the organic farmers, gene flow and contamination of their crops was the principle reason why their markets had been affected (Chapter 8). In the prairie-wide survey, respondents viewed market harm as being connected to the efficacy and cost of segregation efforts, which ultimately was based on whether or not GM and non-GM crops could ecologically co-exist (Chapter 7). This further exemplifies their' holistic perspective regarding the evaluation of GM crops in direct contrast to the perspective of regulators, whom have highly reductionistic views regarding GM crops.

Despite the tremendous market harm associated with GM crops, the Canadian Food Inspection Agency (**CFIA**), the government agency responsible for approving environmental release of GM crops, still does not consider socioeconomics important in risk assessment (Chapter 2). Although the CFIA is responsible for assessing gene flow, they fail to acknowledge how it can profoundly affect markets, and the devastating impact that this can have for rural communities. When this lack of regulation is combined with the cumulative impacts of market harm from both GM canola and GM wheat, it further intensifies risk for farmers, as depicted in the risk wave model (Figure 2). Although farmers view market harm and associated threats to livelihoods as the most substantial of all GM crop risks, Canadian regulators continue to ignore it as a hazard when evaluating and approving this technology.

RIDING THE RISK WAVE

The risk wave model shows the diverse, interconnected and cumulative nature of GM crop risks. Like a rock being thrown in a pond, the impacts of gene flow and contamination create risk waves, which increase in intensity as they move outward, and are associated with the combined agronomic, legal, cultural and socioeconomic risks for farmers. To summarize, the risk wave increases in intensity for three main reasons. Firstly, farmers viewed the human dimensions of GM crop risk, such as corporate control and market harm, as being the most significant and potentially harmful of all impacts considered. Secondly, risk assessment is "science-based", which means that the human dimensions of GM crop risk are not evaluated or mitigated when this technology is released. Thirdly, the cumulative impact of both GM canola and GM wheat would have intensified all risks associated with this technology. As demonstrated, regulators have failed to gauge "science-based" risks properly while completely ignoring associated impacts on human systems, which has effectively left Canadian farmers riding the risk wave.

The risk wave model shows how the introduction of GM crops infuses risk throughout ecological and human systems related to agriculture; however, it is important to point out that some farmers are more adversely affected by it than others. The risk wave has specifically crashed down on farmers practicing conservation tillage, seed saving, and organic methods (Figure 3). Conservation till farmers have been especially vulnerable to GM canola contamination, particularly from RR crops, and associated agronomic problems. Similarly, seed savers have been affected by contamination and agronomic impacts, but for them these issues have transcended into larger risks associated with corporate control. Arguably, organic farmers have been most seriously affected by the risk wave, as contamination, agronomic problems, corporate control, and extensive market harm caused by GM crops may threaten their ability to farm all together. However, adopters of GM crops, particularly larger farmers and recent users, have been able to ride atop the risk wave and garner benefit from the technology (Figure 3). The risk intensity for these farmers is low, provided that they have not experienced GM volunteers, which leads to subsequent and more hazardous phases in the risk wave.

FARMER KNOWLEDGE, HOLISM AND RISK REGULATION

In this thesis, I presented the "double helix of risk" as a conceptual model to increase holism in GM crop regulation, which seeks balance and reconnection between the scientific and social strands of risk evaluation (Chapter 3). Recognizing that science dominates North American risk regulation, the model calls for a bolstering of social research on GM crops, which will help to elucidate the full range of impacts associated with this technology. Once social impacts are better known and a balance between the two strands of risk evaluation affirmed, the integrated and holistic knowledge regarding GM crops and their effects on rural communities and agriculture as a whole will be

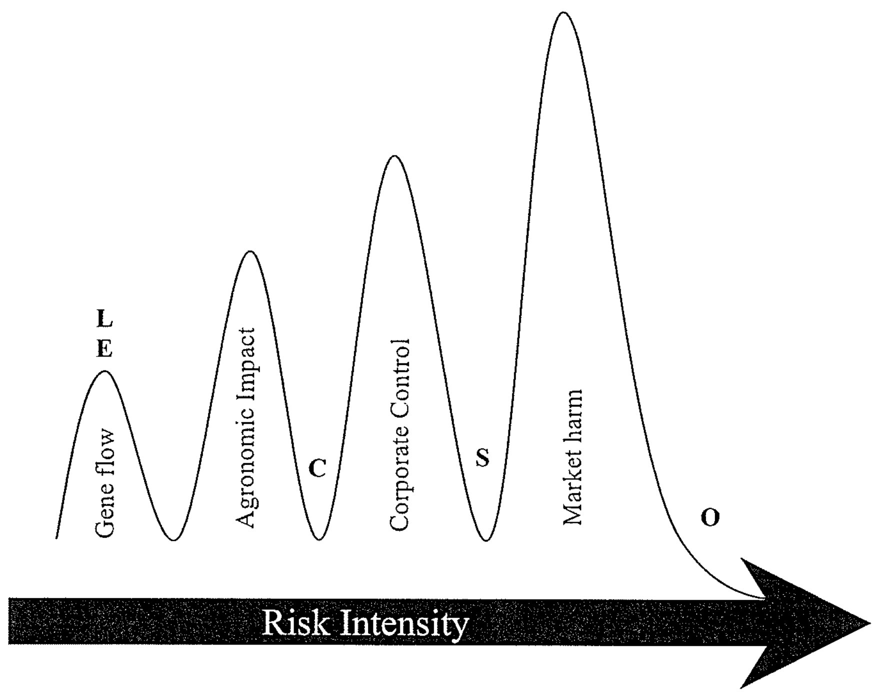


Figure 3. Contours of how farmers ride the risk wave, which demonstrates that it crashes down of specific farm types. Conservation tillage (C) farmers are primarily affected by gene flow and agronomic impact. Seed savers (S) are primarily affected by gene flow, agronomic impact, and corporate control. Organic farmers (O) are primarily affected by gene flow, agronomic impact, corporate control, and market harm. Larger farmers (L) and early adopters (E) have largely been able to ride atop the risk wave, provided that GM volunteers have not adversely affected their land.

recognized (Chapter 3). I have attempted to use this "double helix of risk" framework throughout this thesis.

By taking a farmer-focused approach, this research has documented and increased understanding regarding the social impacts associated with GM crops, particularly corporate control and market harm. As suggested by the "double helix of risk", these social impacts are fundamentally interconnected with scientific issues, as recognized immediately by farmers. They were able to identify the ecological effects associated with GM crops, particularly those related to gene flow and agronomy. In this way, farmers and their holistic knowledge systems straddle the "double helix of risk", and have much insight into both strands. This, in turn, suggests that farmers are in a unique position to provide holistic knowledge about GM crop risks and how they should be regulated.

However, it is my experience that Canadian farmers are rarely included in policy development and decision-making regarding GM crops, as experts largely dominate this process. In September 2003, I presented findings from this study to the CFIA in Ottawa at their *Technical Workshop on the Management of Herbicide-Tolerant Crops*. The CFIA convened some 40 experts from industry, government and academia to present and share information regarding HT crops. At this time, the CFIA was heavily embroiled in the controversy over GM wheat, and much of the meeting focused on this crop. Despite the serious nature of these negotiations, especially given that the future of GM wheat in Canada was being discussed, not a single farmer was in attendance at this meeting! My results were highly controversial within the meeting, and many experts were openly hostile towards this farmer-focused research. Many openly attacked me and viewed my findings as subjective, non-scientific, and outside the scope of the meeting because they dealt with both strands of the helix.

Although it may seem obvious that farmers should be involved in risk regulation of GM crops, this has yet to happen in Canada, and is a major barrier to holistic, responsible, and democratic evaluation of this technology. Making space for farmer knowledge in risk regulation will help to ensure that the full range of impacts associated with GM crops are anticipated and evaluated, which is an important step for moving past the narrow "science-based" approach currently used by the CFIA and the USDA in the US. This shift towards a more farmer-centred evaluation of this technology will require that scientists, government bureaucrats, and industry have humility. Farmer knowledge must be recognized as a legitimate and important form of expertise, which can complement technical approaches to risk assessment, and may help risk regulation become more robust. Indeed, this study has shown that farmer knowledge and science are compatible, and exemplifies how rural stakeholders can be included in risk research regarding GM crops.

FROM "SUBSTANTIAL EQUIVALENCE" TO "SUBSTANTIAL DIFFERENCE"

Significant policy changes will be required if farmer knowledge is to be included in risk evaluation regarding GM crops. Currently, the CFIA assumes GM crops are "substantially equivalent" to non-GM crops, and therefore this technology is generally considered safe, which means that broader public consultation and post-release monitoring is not required (Chapter 2). However, farmers in this study identified that "substantial difference" exists between GM and non-GM crops, including:

- Gene flow and direct seed movement from GM crops can contaminate non-GM fields, which creates new and often costly agronomic hazards for farmers, particularly the growth of HT volunteers
- These HT volunteers are different from previous non-HT volunteers, as they are resistant to certain herbicide, and pose specific challenges to conservation tillage farmers when they contain the RR gene
- The cumulative impacts of multiple HT crops can adversely affect agronomic rotations, especially if these cultivars are resistant to Roundup
- When GM crops contaminate organic farms, this can adversely affect crop rotations and certification standards
- HT crops allow for in-crop spraying of herbicides and may increase selection pressure for herbicide resistant weeds, especially where glyphosate is applied to RR crops
- The patenting of GM crops makes them fundamentally different than previous non-GM cultivars, given that these new crops change social relations between farmers and their seed, may lead to lawsuits, and generally increases corporate control over agriculture.
- GM crops create market harm, whereas non-GM crops do not.

Adopting a regulatory framework based on "substantial difference" instead of "substantial equivalence", will allow for a broader consideration of impacts associated with GM crops. Firstly, it will recognize that post-release monitoring is required, which will help to ensure safer deployment of this technology, and would likely necessitate greater farmer participation in research and decision-making. Secondly, it will force regulators to acknowledge socioeconomic, legal and cultural impacts associated with GM crops, which would facilitate increased *a priori* farmer involvement in risk evaluation. Overall, a regulatory system based on "substantial difference" would require that a broader and more interdisciplinary risk analysis approach be used to assess GM crops, which as this study has shown can and should include farmer knowledge in both *a priori* and post-release circumstances.

BREAKING BREAD

Indeed, the controversy over GM wheat serves as a stark reminder of the dangers of not including farmers in the evaluation of this agbiotechnology. Farmers feared that the introduction of GM wheat would not only "break bread" wheat, but also the rural communities that grow and harvest it. That the Canadian government and Monsanto were co-developers of RRW arguably impeded meaningful consultation with the farmers regarding the adverse effects of this technology for rural communities and society as a whole. The Canadian government must move away from supporting corporate neoliberal goals related to technology development, especially if this agenda might harm farmers, rural communities, and the environment.

Canadian farmers along with urban activists rallied across the country, "breaking bread" together in a fellowship of resistance to GM wheat, and challenged the federal government's "conflict of interest" as co-developer and regulator of this crop (Chapter 8). Overall, farmers demonstrated their capacity to galvanize widespread support from environmental, consumer, and civil society groups, which helped pressure Monsanto to defer this crop from commercialization.

I was heavily involved with farmers in this struggle, having been invited to present this research in the farmer initiated *Planting Seeds of Doubt* tour across the Canadian prairies (Chapter 8), and communicating our farmer-focused results to media. Indeed, farmer perspectives toward GM wheat were so important that this research became a focal point for the US government. In the spring of 2003, the US embassy requested a meeting with Dr. McLachlan and I to discuss our research, and when we subsequently met at the University of Manitoba they indicated that it had the ability to affect bilateral trade between Canada and the US. Monsanto sought to introduce GM wheat across North America, and if farmers rejected it in Canada, the embassy officials felt that this would affect trade. In particular, the US embassy was concerned that farmer rejection of GM wheat might adversely affect the business interests of Monsanto, which is a multinational corporation operating worldwide, but originates and operates largely from its headquarters in St. Louis Missouri.

Had the Canadian government been more proactive and democratic, and taken into consideration farmer concerns regarding GM wheat, the outcomes of this struggle would have been less controversial, confrontational, and costly. A more proactive approach would have benefited farmers as well as regulators and industry. Importantly, publicly funded University research like this farmer-focused study can assist in developing new approaches to risk research, which may assist government, industry and indeed all stakeholders in the GM debate. However, significant barriers exist to conducting publicly funded risk research on GM crops, especially when Universities themselves have become increasingly reliant on and beholden to the private sector.

INTELLECTUAL PROPERTY AND SEEDS OF CHANGE

This research, particularly the documentary *Seeds of Change: Farmer, Biotechnology, and the New Face of Agriculture* (Chapter 5), is an example of how University/Corporate partnerships can adversely affect academic freedom and the public interest as a whole. The University of Manitoba (**U of M**) blocked the release of our research film for over three years by claiming that they owned part of the copyright in the video. The U of M cited an outdated portion of the collective agreement, which stated that teaching videos were 50% their intellectual property (**IP**), and they would not allow the release of the film without insurance. They felt our research might offend the agbiotechnology industry, particularly Monsanto, and result in a lawsuit. Working in good faith with the U of M, we spent two years meticulously preparing a successful insurance application, and procured copyright permissions for the entire film and a second round of informed consent from all participants. Despite calling for insurance, the U of M rejected the affordable policy we had been quoted, and further delayed the timely release of our important findings. We became increasingly suspicious of the U of M's motive, which was affirmed when we learned that while negotiating the non-release of our research, they had been simultaneously negotiating with Monsanto to have the corporation relocate its Canadian corporate headquarters to the campus research park.

The Canadian Association of University Teachers (**CAUT**) indicates that our clash with the U of M is one of the major academic freedom cases in the country and has likened it to Nancy Oliveri's struggle with the University of Toronto and Apotex over a drug she believed was harmful. The CAUT states on their website, "The experience of McLachlan and Mauro is an object lesson in how a university's claim to intellectual property ownership can interfere with academic freedom" (CAUT, 2008). Our case has also been compared with other academic freedom cases, particularly those of Arpad Pusztai in Europe and Ignacio Chapela in the US, both whom were critical of GM crops and were subsequently reprimanded by their respective universities (Ho, 2005). That critical research on GM crops is often embroiled in controversy and sometimes suppressed makes it difficult to ascertain reliable knowledge regarding the impact of this technology on the human health, the environment, and society as a whole. This limits society's ability to make informed decisions about the benefit and risk associated with this technology and is cause for concern.

Ironically, our case has many parallels to that of Percy and Louise Schmeiser, and demonstrates how IP control can adversely affect knowledge production and seed saving practices alike. In both cases, external parties unfairly claimed IP over the knowledge and work of its rightful owners, and were able to prevent free exchange of information, whether this a research video or the genetics contained in a seed. This enclosure of the intellectual commons is now rampant in society, as evidenced by the widespread patenting of ideas, genes, and entire living organisms, and must be questioned. Knowledge is to be shared, not privatized, and universities must play a leading role in this effort. It is imperative that public university research be well funded, not beholden to an industry agenda, and like seed should be exchanged freely. Indeed, this is particularly important in agricultural research, where the industrial model promoted by corporations has largely failed rural communities and the environment. Agricultural research in the public interest, which is more proactive and critical of technology, will be increasingly important, given the future risks and uncertainty facing farming.

RISK WAVE IN A SEA OF UNCERTAINTY

Importantly, the risk wave caused by GM crops is compounded by the legacy of previous waves of agricultural technology. Industrial agriculture is predicated on the widespread use of mechanization and chemicals, which can be beneficial but can also have devastating implications for farming communities and the environment (Chapter 2). These technologies increase levels of production, making farmers redundant while depressing commodity prices, which has left rural communities in financial crisis and suffering from extensive depopulation (Chapter 2). Moreover, industrial agriculture has undermined soil content and fertility, largely destroyed biodiversity in areas where it is practiced, and is built on a precarious base of genetic uniformity and monocultures that is vulnerable to disease and global climate change (Chapter 2). Not surprisingly, farmers in this study viewed GM crops as being less risky than other financial and environmental pressures facing rural communities (Chapter 6). In short, the GM crop risk wave is but a current being thrashed around in a stormy sea of uncertainty and risk in modern agriculture.

Arguably, a tsunami is about to rise out of this sea of uncertainty given the complete reliance of industrial agriculture on fossil fuels. Liquid fossil fuel is running out and industrial scale farming - facilitated by tractor power, petrochemical fertilizers, chemicals and agbiotechnology - will no longer be possible. Estimates vary, but over the time span of carrying out this research (2002-2008), the maximum amount of fossil fuel pumped from the earth has hit its peak. Once peak oil has been hit, extracting the world's remaining oil reserves requires more energy and cost for less return. Studies suggest that at current levels of consumption, not including global population increases and further industrialization in places like China, the world has only about forty years of oil left (Kunstler, 2005). This is compounded by global climate change, which some anticipate will help create a "water crisis" due to widespread drought (Schindler and Donahue, 2006). Indeed, without fuel in the tank, industrial agriculture will undoubtedly collapse and will likely ruin any remaining farmers, especially those with large-scale and high input operations.

Given all these changes in agriculture, many farmers in this study did not believe that their farms would be financially viable in the future (Chapters 4 & 5). Many indicated that they were not encouraging their children to farm. As rural communities continue to decline, there is a danger that farmer knowledge will not be passed on to the next generation. Arguably, this might be the first generation where more farm knowledge is lost than is accumulated in rural Canada, which if true, presents serious challenges for the future of agriculture.

FARMER KNOWLEDGE, GM CROPS AND SUSTAINABLE AGRICULTURE

Given the crisis facing industrial agriculture, food production systems based on renewable, low-input, and locally based resources will be required in the future. These systems must promote ecological, social, and economic health within agriculture, which requires holistic farm management based on conservation of natural resources, social justice and self-reliance, and profitable and efficient production. Any agricultural system that subscribes to and implements these goals is generally considered sustainable.

Farmer knowledge will play a critical role in developing and transitioning to sustainable agricultural systems. In industrial agricultural systems, the movement away from external inputs could initially reduce per hectare yields by 10-20%, which requires farmers to substitute their knowledge, labour and management skills to make up the difference over the long-term (Pretty, 1995). Arguably, the most successful demonstration of this transition to low-input, self-reliant and knowledge-based agriculture has taken place in Cuba, which is now considered a world leader in sustainable agriculture.

After the fall of the USSR and subsequent US trade embargo, Cuba was largely unable to import food, chemicals, fertilizers, fossil fuel and machines required for their agricultural sector, which at that time was technologically comparable to California (Rosset and Bourque, 2002). Although the crisis initially caused drastic yield reductions in the country, small-scale farmers quickly increased domestic production, largely by relying on their knowledge of "old techniques" – such as intercropping, plant breeding, animal traction, manure spreading and composting - practiced by their parents and grandparents prior to the introduction of industrial inputs (Rosset, 1997). This success led the government to downsize industrial-scale state owned farms, which they gave to farmer cooperatives to manage using their knowledge of low-input and ecology-based agriculture (Funes, 2002). Technology was developed that supported this transition, as scientists developed new ecologically friendly biopesticides and biofertilizers to support the efforts of small-scale farmers (Rosset and Bourque, 2002). Cuba stands as an example of how farmer knowledge, science, and technology can be combined to create sustainable agriculture amidst crisis.

Indeed, Canadian agriculture will soon be confronted by a restriction of fossil fuels and fertilizers that is equivalent to that which confronted Cuba, and we will need our small-scale farmers and their knowledge to navigate this sea of uncertainty. However, the decline of Canadian rural communities and associated knowledge hinders our society's ability to transition to sustainable agriculture, and drastic changes are required to rectify this problem. Canadian agricultural policy must protect and support low-input, self-reliant, small-scale and knowledge-based farms, while encouraging and providing incentives for larger-scale producers to begin the long process of diversifying, downsizing, and decreasing the use of external and non-renewable inputs in their operations. Given that peak oil and global warming are converging, the sooner these initiatives are implemented, the easier the change to more sustainable food production systems will be.

In addition to farmer knowledge, the transition to sustainable agriculture will require scientific knowledge and associated technologies, as demonstrated by the Cuban experience. However, agricultural technology will only be appropriate in the future if it can facilitate sustainability, making farms more self-reliant, low-input, and smaller in scale. Given these criteria, it is unlikely that GMHT crops will make farming more sustainable, as this study shows that they facilitate larger-scale production, which is dependent on external inputs such as fossil fuel, petrochemical fertilizer, and herbicides. Furthermore, this study has also shown that these crops actually undermine small-scale, low-input and knowledge intensive forms of farming, particularly organics. This suggests that GMHT crops may actually be undermining the future sustainability of Canadian agriculture, and their short-term production benefits must be weighed against the long-term risk of destroying organic and small scale systems and their associated farm knowledge.

While GMHT crops are unlikely to increase sustainability in agriculture, other agbiotechnology products may indeed be important in the future. Scientists are now working on drought-tolerant crops that may become increasingly useful in areas seriously affected by global warming. Given the environmental uncertainty posed by global warming, this technology must be considered as a possible strategy for the future. Similarly, scientists continue research on GM crops that fix nitrogen, and if successful, this technology would help reduce fertilizer inputs and would certainly play an important role in sustainability. In short, GM crops should not be dismissed on ideology, as they may be useful in the future provided they are developed in a way that promotes ecological, socioeconomic and cultural sustainability.

CONCLUSION

The debate regarding how society evaluates the benefits and risks of GM crops is an important one. At its core, this debate is really about the future of agriculture, and by extension, the future of humanity and its place in the world. Since the Neolithic Revolution some 10,000 years ago, most of humanity has been dependent on agriculture for their "daily bread", and how it is carried out is really a reflection of whom we are as a species. Using this interpretation, it's easy to see why GM crops are so controversial, and why various stakeholders have engaged in an acrimonious battle over the use of this technology in agriculture. Given that Canadian farmers were amongst the first to use GM crops, their experience and knowledge can assist in a pragmatic and balanced evaluation of this technology, yet regulators, scientists, and society as a whole have largely overlooked this important perspective.

As these results have shown, Canadian farmers can provide important information in the post-release and *a priori* evaluation of GM crops, largely because they have holistic, place-specific, and experiential knowledge regarding agriculture. Farmers using GM canola indicated that it provided significant weed control benefits compared to conventional varieties, which was the main reason why it was adopted on such a widescale. However, these benefits accrued unevenly to farmers, and largely favoured large-scale operations and early adopters. In contrast, farmers believed that GM wheat would provide limited weed control benefit over conventional varieties and it was largely rejected. Risks associated with GM canola and wheat were substantially more complex than the benefits, affecting both ecological and human dimensions related to prairie agriculture. Gene flow and contamination from these crops created subsequent risk issues that related to agronomy, corporate control, and market harm. That regulators failed to evaluate "science-based" risks properly and completely ignored the associated impacts on human systems has left farmers riding a risk wave. This risk wave has crashed down hard on farmers practicing conservation tillage, seed saving, and organic methods.

A more holistic approach to GM crop risk evaluation is required, which includes and takes seriously the important knowledge of farmers, and considers the diverse impacts of this technology on both ecological and human systems. To achieve this, regulators must recognize that "substantial difference" exists between GM and non-GM crops, and that their safety cannot and should not be assumed. If farmers are not officially involved in *a priori* and post-release evaluation of GM crops, risks are created, not just for farmers and rural communities but also for government and industry as demonstrated by the controversy over and deferment of GM wheat. Indeed, more proactive approaches to evaluating all agricultural technology are needed, especially given the enormous challenges facing food production in the future.

Civilization is now entering an era of peak oil and global warming and producing food will be the paramount challenge of our time. As this study has shown, GMHT crops assist large-scale, high-input, and industrial-style farms, many of which have caused tremendous damage to the environment and rural communities. These farms will be unviable in the future given their scale and dependence on fossil fuel and petrochemical fertilizers. Although the minority in Canada, low-input, small-scale, self-sufficient and local knowledge-based farms will be required for sustainable agriculture, and policy must support these operations. That GM crops adversely affected small farms, particularly organics, indicates that this technology may actually be undermining the future of sustainable agriculture in Canada. Therefore, the short-term production benefits associated with GM crops must be weighed against the long-term risks of further damaging the environment, rural communities, and alternative agricultural systems that are essential for sustainable food production.

REFERENCES

Abergel, E., & Barret, K. (2002). Putting the cart before the horse: A review of biotechnology policy in Canada. *Journal of Canadian Studies*, *37*, 135-161.

Andree, P. (2002). The biopolitics of genetically modified organisms in Canada. *Journal of Canadian Studies*, *37*, 162-191.

Auberson-Huang, L. (2002). The dialogue between precaution and risk. *Nature Biotechnology*, *20*, 1076-1078.

Beckie, H.J., Harker, K.N., Hall, L., Warwick, S.I., Legere, A., Sikkema, P.H., Clayton, G.W., Thomas, A.G., Leeson, J.Y., Seguin-Swartz, G.G., & Simard, M.J. (2006). A decade of herbicide-resistant crops in Canada. *Canadian Journal of Plant Science, 86*, 1243-1264.

CAUT (Canadian Association of University Teachers). (2008). *Issues and Campaigns: Stephane McLachlan and Ian Mauro*. Available at: www.caut.ca/pages.asp?page=483&lang=1

Chimmiri, N., Tudor, K.W., & Spaulding, A.D. (2006). An analysis of McLean county, Illinois farmers' perceptions of genetically modified crops. *AgBioForum, 9*, 152-165.

Chong, M. (2005). Perceptions of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research, 8*, 617-634.

Fujisaka, S. (1992). Farmer knowledge and sustainability in rice-farming systems: Blending science and indigenous innovation. In J.L. Moock, & R.E. Rhoades (Eds.), *Diversity, Farmer Knowledge, and Sustainability*. Ithaca, NY: Cornell University Press.

Funes, F. (2002). The organic farming movement in Cuba. In F. Funes, L. Garcia, M. Bourque, N. Perez, & P. Rosset (Eds.), *Sustainable Agriculture and Resistance: Transforming Food Production in Cuba*. Oakland, CA: Food First Books.

Hucl, P., & Matus-Cadiz, M. (2001). Isolation distances for minimizing out-crossing in spring wheat. *Crop Science, 41*, 1348-1351.

Ho, M. (2005). *Liberating Knowledge*. London: Institute of Science in Society. Available at: www.i-sis.org.uk/LiberatingKnowledge.php

Isaac, G. E. (2006). Biotechnology policy and the risk analysis framework. In P.W.B. Phillips, S.J. Smyth, & W.A. Kerr (Eds.), *Governing Risk in the 21st Century: Lessons from the World of Biotechnology*. New York: Nova Science Publishers, Inc.

Kloppenburg, J. (1991). Social-theory and the de reconstruction of agricultural science-local knowledge for an alternative agriculture. *Rural Sociology, 56*, 519-548.

Krayer von Krauss, M.P., Casman, E.A., & Small, M.J. (2004). Elicitation of expert judgments of uncertainty in the risk assessment of herbicide-tolerant oilseed crops. *Risk Analysis, 24*, 1515-1527.

Kuntsler, J.H. (2005). *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*. New York: Atlantic Monthly Press.

Matus-Cadiz, M.A., Hucl, P., Horak, M.J., & Blomquist, L.K. (2004). Gene flow in wheat at the field scale. *Crop Science, 44*, 718-727.

Mehta, M.D. (2005). The impact of agricultural biotechnology on social cohesion. In M.D. Mehta (Ed.), *Biotechnology Unglued: Science, Society, & Social Cohesion.* Vancouver: UBC Press.

Nap, J.P., Metz, P.L., Escaler, M., & Conner, A.J. (2003). The release of genetically modified crops into the environment: Overview of current status of regulations. *Plant Journal*, *33*, 1-18.

Neufeld, S.J., & Cinnamon, J.L. (2004). Farm parents' attitudes toward farm safety experts. *Rural Sociology*, *69*, 532-551.

Nottingham, S. (2002). *Gene Escapes: The Ecology of Genetic Engineering.* New York: Zed Books.

Pretty, J.N. (1995). *Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance.* Washington, DC: Joseph Henry Press.

Rieger, M. A., Lamond, M., Preston, C., Powles, S. B., & Roush, R. T. (2002). Pollen-mediated movement of herbicide resistance between commercial canola fields. *Science*, *296*, 2386-2388.

Rosset, P.M. (1997). Alternative agriculture and crisis in Cuba. *Technology and Society*, *16*, 19-25.

Rosset, P., & Bourque, M. (2002). Lessons of Cuban Resistance. In F. Funes, L. Garcia, M. Bourque, N. Perez, & P. Rosset (Eds.), *Sustainable Agriculture and Resistance: Transforming Food Production in Cuba.* Oakland, CA: Food First Books.

Rowe, G., & Wright, S. (2000). Differences in expert and lay judgments of risk: Myth or reality? *Risk Analysis*, *21*, 341-356.

Schindler, D.W., & Donahue, W.F. (2006). An impending water crisis in Canada's western prairie provinces. *Proceedings of the National Academy of Sciences*, *103*, 7210-7216.

Service, R.F. (2007). A growing threat down on the farm. *Science*, *316*, 1114-1117.

SSHRC (Social Sciences and Humanities Research Council). 2005a. *Harvesting Knowledge: Manitoba researchers give farmers a voice in GM crop debate.* Winning Research Feature Story. [Online] www.sshrc-crsh.ga.ca/web/winning/winning_e.asp

SSHRC (Social Sciences and Humanities Research Council). (2005b). *Social Sciences and Humanities Research Council Annual Report (2005-2006).* Available at: http://www.sshrc-crsh.gc.ca/web/media/media_e.asp

Steinbrecher, R.A. (2001). Ecological consequences of genetic engineering. In B. Tokar (Ed.), *Redesigning Life? The Worldwide Challenge to Genetic Engineering*. Montreal: McGill-Queens University Press.

Van Acker, R.C., Brule-Babel, A., & Friesen, L. (2003). *An Environmental Safety Assessment of Roundup Ready Wheat: Risks for Direct Seeding Systems in Western Canada*. Winnipeg, MB: Canadian Wheat Board.