Chapter 21
Agricultural and Water in Canada – Challenges and Reform for the 21 C

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Abstract Agriculture is the dominant water use in Canada and the main contributor to non-point source pollution in agricultural watersheds contributing to toxic algal blooms in some of Canada's and the world's largest freshwater lakes. Water governance in Canada is fragmented, with water resources managed separately from land uses that contribute to water challenges. The performance of agri-environmental policies encouraging the adoption of beneficial management practices is also mixed. Efficient and effective farm level water management strategies will increase in importance over the next century as climate change and increasing demands for food put pressure on water quality and quantity. This chapter examines farm level decisions that affect water quality and quantity, and the factors that contribute to adoptability of beneficial practices. Decentralized and fragmented governance contributes to weak institutions for integrating water and agricultural land management resulting in poor monitoring and governance gaps at scales required to manage nutrient loads into major freshwater lakes as well emerging threats from unregulated pollutants. The potential for water quality trading to address risks from non-point source pollution is examined, along with opportunities for reform in Canada.

21.1 Introduction

Agriculture is Canada's most significant land use and largest consumer of water. Agricultural water management affects most of the Canadian population. Historically, water on agricultural land was managed through drainage and irrigation to encourage Canadian settlement (Fowke 1957). Today agriculture anchors rural communities and is fundamental to the Canadian identity (CCA 2013; AAFC 2013). However, impacts of agriculture on water and the environment are a growing

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public concern. Agriculture relies on clean water for irrigation, stock watering, and industrial cooling and cleaning. At the same time, agriculture has an impact on aquatic ecosystems through water consumption and the release of nutrients and other pollutants to water bodies. Agricultural non-point source pollution from diffuse sources and runoff is one of the leading contributors to water quality problems (CCA 2013).

Water stresses from agriculture are a challenge in nearly every province in Canada. While Canada's overall agri-environmental performance is good, Environment Canada's Water Quality Agri-Environmental Performance Index has declined over the last decade, largely due to increased application of nutrients (Environment Canada 2013). Iconic watersheds, including the St. Lawrence, Lake Erie and Lake Winnipeg are experiencing eutrophication and increased frequency of extensive algal blooms causing risks to human health and economic losses from fishery and beach closures. In many locations, high nitrate and phosphorous concentrations exceed drinking water standards (CCA 2013; Conference Board of Canada 2015). In some places, like the South Saskatchewan River, water demand frequently exceeds availability causing both quantity and quality challenges. Climate change is expected to exacerbate these challenges with reduced snow packs and snow cover, and more frequent and severe drought causing water shortages and further deteriorating water quality (Pomeroy et al. 2010; Westbrook et al. 2011). In addition, there are human health risks due to pathogens and toxins entering drinking water supplies from livestock, and emerging threats related to endocrine disruptors found in hormones and pesticides.

In the twenty-first century, global population pressures coupled with rising incomes and stresses from climate change will result in even more intensive use of water by agriculture (CCA 2013). Managing agricultural impacts on water will be critical for both the sustainability of aquatic ecosystems, as well as the sector. So while over the last century agricultural water management in Canada focused on irrigation and drainage to bring marginal lands into production, the challenge in this century is to identify practices that will allow farmers to intensify production sustainably (Corkal et al. 2007).

In this chapter we review risks to water from agricultural practices, drawing attention to key uncertainties and examining new approaches to restore degraded watersheds. Because of the diffuse nature of agricultural pollution the focus of farm water management has been on incenting beneficial management practices (BMPs) that reduce water use and minimize pollution. However, to date programs and incentives have been ad-hoc, with continued issues in basins with high agricultural land use. The poor results are partly due to failed policy and governance approaches to water management. We begin the chapter with a review of the current state of knowledge of the impacts of farm management practices on water. We then review water governance and policy in Canada, highlighting gaps that create risks for the public as well as policies that interact with farm level decisions. We examine factors that influence BMP adoption and evaluate the potential for Canada to develop more innovative approaches to address agricultural non-point source pollution. We summarize governance challenges for ensuring sustainable agricultural water management, and conclude with opportunities for reform.

21.2 Risks to Water Quantity and Quality from Agriculture

Agriculture affects water quantity and quality through water use and consumption, land management, and the management of waste as well as nutrient, chemical, and pharmaceutical inputs. Hydrology is the primary process through which land use affects water, therefore it is useful to distinguish between practices, such as irrigation and drainage, that intervene directly in the hydrologic cycle, and practices that intervene indirectly through changes in vegetation cover, soil moisture, and compaction (Elliott et al. 2014; Arnold et al. 2012). Agricultural management practices and their effects vary widely across the country due to variations in climate, vegetation, underlying soils and geology, and farm enterprise type. BMPs protect water quality by managing tillage and nutrient inputs, and by reducing runoff and nutrient losses. However science based evidence of BMP effectiveness is sparse and mixed. Below we summarize the impacts of agricultural management practices on water, highlighting key scientific uncertainties.

21.2.1 Irrigation

In 2011, the Canadian agricultural sector consumed approximately 1.5 billion m^3 of water for crop and animal production (Statistics Canada 2014). Irrigation demand is driven by soil moisture conditions, climate and weather patterns, and choice of crop and crop rotation. Irrigation is used primarily in Alberta and central British Columbia (BC) where annual precipitation is insufficient to meet crop evapotranspiration demands (Harker et al. 2004). Irrigation affects hydrologic processes such as deep percolation and runoff, and subsequent discharges into aquifers and streamflow (Rahbeh et al. 2013). Return flows from irrigation (approximately 30 %) contain excess nutrients, sediments, and trace metals from soil salinization (Nakamoto and Hassler 1992; Westbrook et al. 2011). In the South Saskatchewan River Basin annual gross diversion requirements sometimes exceed licensed allocation limits, a factor that will exacerbate water quality challenges under climate change (Bennett et al. 2014; Weber and Cutlac 2014). The majority of irrigation in Alberta is through sprinkler systems which have less impact on surface hydrology than flood irrigation. In BC the use of micro-irrigation optimizes use of water and significantly reduces surface and subsurface losses (Harker et al. 2004). Irrigation scheduling may increase irrigation efficiency, reducing water use by 8–25 % on average and as much as 50 % in dry years (Wang et al. 2015). However, higher efficiency irrigation systems may also reduce return flows, negatively impacting instream flows with combined effects on water quality not well understood (Harker et al. 2004).

21.2.2 Drainage

In Central and Eastern Canada, where precipitation is higher and soils are less permeable, drainage is necessary for earlier and more efficient spring seeding. Drainage is accomplished through pumping and ditches, and through tile drainage. Tile drains, underground channels that remove water from the sub-surface, are used extensively in Ontario and Quebec (Harker et al. 2004). Drainage accelerates discharge and flushes contaminants into receiving water bodies. However, controlled tile drainage uses water control structures at outlets to manage the water table beneath fields, allowing producers to optimize the level of water available for crops during the growing season and to manage the flow of water and nutrients leaving the field (Sunohara et al. 2014).

Wetland drainage is extensive. Since the 1800s, approximately 20 million ha (or 1/7) of Canada's total wetland area has been drained including more than 60 % in Southern Ontario and over half of the prairie potholes in Western Canada. Agriculture accounts for the majority of wetland loss (Environment Canada 1991; Rubec and Hanson 2009). Wetland degradation from agriculture also comes from location of farm infrastructure, the operation of farm equipment, livestock crossing, and intensive crop production in riparian areas. Wetlands are important for filtering nutrients and toxins, as well as slowing overland flows and reducing flood risk (Yang et al. 2010). Wetland drainage has contributed to changes in nutrient runoff and hydrologic connectivity with cumulative effects that are poorly understood (Pomeroy et al. 2010; Yang et al. 2010). In Southern Manitoba it is estimated that wetland drainage since 1968 has increased the area contributing runoff to Lake Winnipeg by 4518 km^2 and total phosphorous loads by 6 % (Yang et al. 2010).

21.2.3 Land Management

Land management practices which affect soil health and runoff include tillage, cultivar type and vegetation cover. The intensity of agricultural land use is increasing. Between 1971 and 2011 the area of cropland increased by 27 % and tame and seeded pasture increased by 34 %. At the same time the amount of summerfallow declined by 81 % and natural areas including pasture, woodland, and wetlands declined by 16 % (Statistics Canada 2014). Permanent and perennial cover crops reduce runoff as well as soil erosion. Riparian management, natural cover, grassed waterways and buffer strips are practices that increase water recharge and infiltration, reducing erosion and runoff near water bodies. In 2011, 54 % of farms maintained riparian buffer on waterways with the practice most common in Atlantic regions, and Quebec and Ontario (Statistics Canada 2013).

Climate, soils, and crop type influence tillage practice. Cereals, oilseeds, and bean crops are most amenable to conservation or no-till (the practice of leaving crop residue on the field after harvest), and the practice is widely adopted in the Prairies with adoption rates of 86 % (Statistics Canada 2014). The practice drops off significantly east of Saskatchewan as soil moisture increases. Conservation tillage and no-till slow runoff by trapping water and snow in residue, reducing evapotranspiration, and reducing soil compaction from machinery. However impacts on phosphorous are uncertain. Some studies show that decomposing organic matter from reduced-tillage can increase concentrations of soluble phosphorus in surface runoff (Harker et al. 2004). In the end, definitions of tillage systems may not be refined enough to validate the practices and understand biophysical processes, suggesting a need for better monitoring to understand water quality impacts from tillage (Lobb et al. 2007).

21.2.4 Livestock Management

Approximately 4 million beef cattle and 26 million pigs are raised in Canada each year (AAFC 2013). Over 50 % of manure is produced in the Prairies and the Great Lakes drainage regions of southern Ontario and the St. Lawrence (Statistics Canada 2014). Manure is used for fertilizing crops, but improper storage and application is a significant risk to water, both from introduction of nutrients as well as pathogens and endocrine disrupting hormones. Manure application is associated with high concentrations of nitrates in shallow ground water. Many farmers allow livestock to drink from surface water during at least part of the year, resulting in damage to riparian areas and increased contamination from manure (Statistics Canada 2014). Livestock grazing in riparian areas also contributes to increased runoff from soil compaction. Major effects of livestock grazing on stream and riparian ecosystems include changes in stream channel morphology, hydrology, riparian soil health, and instream and stream bank vegetation; these impacts manifest at local as well as watershed and regional scales (Belsky et al. 1999).

21.2.5 Nutrient and Pesticide Management

Fertilizer is necessary to optimize plant growth, but excessive nutrient application leads to increased phosphorous and nitrates in soil and is eventually carried through underground percolation or overland flows into rivers, lakes and estuaries. Rates of phosphorous application have increased over time due to an increase in the amount of farm land area treated with fertilizer. Surface runoff combined with soil erosion is the most important factor for nutrient contamination; however, atmospheric transport and groundwater leaching are regionally significant. Between 2001 and 2011, the total area in Canada treated with fertilizers increased by 4 %; similarly the area treated with herbicides, pesticides and fungicides increased by 3 %, 42 %, and 114 % respectively (Statistics Canada 2014). These trends are thought to be related to adaptation to climate change, the introduction of new genetically engineered crops that are tolerant to certain chemicals, and the adoption of other BMPs such as conservation tillage (Statistics Canada 2014). Crop rotation reduces the need for pesticides and is a form of pest control. In terms of nutrient management, soil testing and precision agriculture maximize the efficiency of application of manure and commercial fertilizers. Nutrient testing is done annually on about 20 % of farms while 13 % do not do nutrient testing (Statistics Canada 2014). Precision technologies that allow farmers to obtain irrigation scheduling data from local weather stations can also be used to reduce chemical and fertilizer applications (Nicol et al. 2010). The challenge remains to have the technology adopted by the majority of crop producers in order that the efficiencies gained become fully realized (Yang 2016).

21.2.6 Tradeoffs and Uncertainties

There is significant scientific uncertainty on the effectiveness of agricultural BMPs due to complex interactions between land management and nutrient transport, as well as uncertainties about the impacts of BMPs on crop demands for water, nutrients and pesticides. Most BMP studies focus on specific practices and combinations of practices that are not replicable or generalizable. Evidence is mixed on the effectiveness of BMPs with benefits dependent on local soils and climate conditions as well as how they interact with other management practices (CCA 2013). Little is known about the relationship between field level practice change and large scale cumulative effects (AARD 2014). Evaluating impacts at sub-basin and basin scales is a challenge because hydrologic and ecological processes involve many contributing factors that are hard to control for.

There are also field scale tradeoffs. For example, more efficient water management from conservation tillage can lead to more intensive land use as it allows for extended crop rotations and reduced summerfallow. Some BMPs may simply redistribute the movement of nutrients between surface and sub-surface pathways. For example, minimum tillage may reduce losses of water and some pollutants to surface drainage, but may also increase infiltration into the soil and leaching to groundwater (Harker et al. 2004). Predicting BMP effects requires understanding runoff and soil saturation, as well as predictions of nutrient reductions. Even where it is possible to understand the spatial distribution of runoff producing areas, dissolved phosphorous reductions from different BMPs are uncertain (Rao et al. 2009).

21.3 Agriculture and Water Policy

Water governance in Canada is highly decentralized with important implications for agricultural water management. A key characteristic of decentralized governance is delegation of responsibility and decentralization of authority leading to fragmentation and spillovers in decision making (Dunn et al. 2014). Canada is a federation with a national government as well as ten provincial and three territorial governments. The Canadian Constitution outlines the division of responsibilities and authorities between the Federal, Provincial and Territorial jurisdictions. The Federal government has responsibility for federal lands and international waters, as well as several sectors, including agriculture, that have an interest in or impact on water. Federal responsibility for water is fragmented across 19 different departments which have some degree of responsibility for water (Corkal et al. 2007). The departments that directly affect agriculture are Environment Canada, Health Canada, and Agriculture and Agri-Food Canada. These departments share responsibilities for health, environment and agriculture with the provinces. In areas of shared responsibility the typical role of the Federal government is to set standards, and leave implementation to the Provinces (Klimas and Weersink 2006). The management and allocation of land and water resources is the responsibility of the Provinces and Territories. Within Provinces and Territories much of the responsibility for water supply and treatment is delegated to municipalities and regional authorities often with insufficient budget and authority (Dunn et al. 2015). Operationally, the safeguarding of water resources is delivered by municipalities who are responsible for land use zoning.

Water has traditionally been managed as an input into different uses such as agriculture, or municipal uses. Regulation of water, in terms of quality and quantity is usually through permitting individual uses or projects. Water quantity and quality challenges have highlighted governance gaps at watershed scales (e.g., Dunn et al. 2014). Recently there has been a movement towards shared governance at a watershed scale through integrated water resource management, but integration of institutional mandates remains a challenge (Nowlan and Bakker 2007). Overlapping mandates and governance gaps have resulted in lack of policy harmonization with implications for data collection and management of cross-boundary issues (Dunn et al. 2014; Bakker and Cook 2011).

Source water protection is challenged by jurisdictional fragmentation between land and water authorities (Dunn et al. 2015). Health Canada sets guidelines for drinking water quality while responsibility for safe drinking water rests with the provinces, territories and municipalities. Standards are not binding and tend to be lower than in other jurisdictions (Dunn et al. 2015). Provincial responsibilities for water allocation and permitting of water treatment facilities and industrial point sources are largely within the purview of environment ministries, while agricultural and natural resource ministries and municipalities are responsible for land use. The results have been lethal. In May of 2000, 2300 individuals in Walkerton Ontario became sick and seven died when heavy rains following manure application on farmland flushed pathogens into community wells. The contamination occurred even though proper manure practices were being followed at the time. Since then, a multi-barrier approach has been adopted for source water protection, however, outbreaks of illness are still common (CCA 2013).

Regulation of nutrients and pesticides is primarily done through application standards. For example, the Ontario Water Resources Act and the Alberta Agricultural Operation Practices Act set manure management standards and practices for the application, handling and storage of nutrients and pesticides. However, they do not address land management practices. Provincial water and environmental legislation (including legislation triggering Environmental Impact Assessments for point sources such as intensive livestock operations) contain standards and regulations to protect water quality through set-backs, water crossing guidelines and nutrient and pesticide storage and handling procedures. Water quality guidelines have not been established for the majority of pesticides used in Canadian agriculture, nor are there guidelines or standards for emerging risks from endocrine disrupting substances in pharmaceuticals and pesticides. Bureaucratic fragmentation has allowed different levels of government to offload and delegate fiscal and regulatory responsibilities for water management resulting in reduced fiscal and administrative capacity for national monitoring to detect emerging risks from non-regulated sources (e.g., Bakker and Cook 2011).

Because of the diffuse nature of non-point sources the focus for on-farm water quality management has been on extension and incentives for voluntary adoption of BMPs. The Federal Government, through Agriculture and Agri-Food Canada (AAFC), influences farm practices through Growing Forward, a 5-year policy framework for the agricultural and agri-food sector. Renewed every 5 years Growing Forward is implemented through joint agreements between federal, provincial and territorial governments and is the foundation for jointly delivered agricultural programs and services including stewardship payments to improve the environmental performance of the agriculture and agri-food sector.

To access funds, producers are required to complete an Environmental Farm Plan (EFP) which identifies environmental risks, and develop action plans to mitigate these risks. Farm plans are confidential and farmers do not have to report baselines. Thus it is nearly impossible to evaluate the performance of the Growing Forward program (Vercammen 2011). Numerous studies highlight the importance of spatially targeting BMPs (e.g., Yang and Weersink 2004). For example, in the U.S. agri-environmental indices are used to allocate funds for the U.S. Conservation Reserve Program to target the most effective practices, locations, and issues. In Canada agri-environmental indices have been developed in Manitoba and Ontario, but they have been developed for different program objectives with little standardization making it difficult to make inter-program or inter-regional comparisons of investment efficiency (Hajkowicz et al. 2009).

The focus on voluntary incentives for BMP adoption in Canada mirrors the experience of other jurisdictions where the tradition is that regulated point sources pay agricultural non-point sources to reduce pollution (Shortle 2013). Perhaps the most significant factor favoring voluntary incentives is historic precedent and the assumption that regulation is a restriction on private landowner rights (Cortus et al. 2011). Farmers oppose regulation for water quality (Filson et al. 2009). However, taxes and command and control approaches, such as fertilizer standards and nitrate zoning limits, could be more effective (Tanaka and Wu 2004; Ribaudo et al. 2001; Worrall et al. 2009). Canadian experience in regulating agricultural land is limited. In 1999 Prince Edward Island used legislation to mandate BMPs in response to agricultural contamination of its main aquifer and drinking water supply. The legislation mandated buffer zones and crop rotation, but these policies were eventually abandoned in favor of stewardship payments due to the impossibility of monitoring and enforcement of field practices, as well as push back from producers (CCA 2013).

21.3.1 Integrated Water Resource Management

Integrated Water Resource Management (IWRM) brings together government and non-government decision makers and stakeholders with a role in water management to develop coordinated strategies to manage water and land resources (e.g., Roy et al. 2009; Morin and Cantin 2009). IWRM provides the coordination to address cross-sectoral challenges in water management and provides a means to address agricultural contributions. Roy et al. (2009) identified at least 119 non-government organizations and regional watershed authorities promoting water conservation in agriculture and involved in implementation of IWRM.

IWRM is based on partnership and collaborative governance. However, there are key differences across provinces in terms of how much support is received from different levels of government. In B.C., IWRM is driven by municipal interests coming together on shared issues and working through collaboration to achieve common objectives, primarily related to municipal development of land and green infrastructure (Roy et al. 2009). Alberta has Basin Wide Watershed Planning and Advisory Councils which receive technical and funding support from government for watershed planning and basin reporting. Sub-basin stewardship groups are also involved in implementation of IWRM but both Councils and stewardship groups lack funding for implementation. In Saskatchewan, IWRM is carried out by the Saskatchewan Watershed Authority with local Watershed Advisory Committees which consist of municipal government partners and community stakeholders. Manitoba Conservation Districts, Ontario Conservation Authorities, and in Quebec, Organisations de Bassin Versant, have a similar structure with combined municipal-provincial governance and funding. These organizations are co-funded by municipalities and their boards consist of elected municipal councillors who are tied to the agricultural community through rate payers and the local tax base. The committees receive technical support from Federal and Provincial staff. In some cases, the government authorities have also coordinated environmental group farm planning to leverage BMP funds from Growing Forward as well as from NGOs such as Ducks Unlimited who are also important funders of IWRM (Roy et al. 2009).

Challenges associated with implementing IWRM include integrating the mandates of different organizations and government departments, and developing appropriate financing strategies to address water issues at the right scale (e.g., Morin and Cantin 2009). All groups lack adequate funds to implement plans. Problems in the Great Lakes and Lake Winnipeg require management strategies to be developed at a large basin scale, while IWRM tends to target sub-basins which lack capacity as well as normative values for effective on the ground management of non-point source agricultural pollution (e.g., Cohen and Bakker 2010). The delegation of watershed planning to local and regional authorities assumes that local agencies are in the best position to deliver IWRM, but capacity varies. Local authorities are more likely to represent local interests at the expense of downstream basin wide interests, particularly when outcomes from non-point source controls are long term and uncertain and it is necessary to show demonstrable local benefits to keep rate-payers happy. One of the biggest hurdles for non-point sources management through IWRM is that specific costs are borne by landowners and municipalities while benefits are diffuse and difficult to attribute to individual actions. Thus IWRM, in its current form and practice throughout Canada, is unlikely to address large scale challenges such as eutrophication. There is an opportunity for the Federal government to improve IWRM by funding science and coordinating the development of indicators, particularly where there are cross boundary issues (e.g., Morin and Cantin 2009; Dunn et al. 2015) and tie Growing Forward payments to IWRM plans that address significant water quality challenges.

21.4 BMP Programs

21.4.1 Factors Affecting BMP Adoption

Adoption of BMPs is motivated by stewardship and environmental factors as well as on-farm benefits. In Canada the level of environmental farm planning and adoption of BMPs is mixed. In 2011 35 % of Canadian farms had EFPs. Of these, 95 % had at least partially implemented recommended practices. There is significant variation in EFP and BMP adoption rates across provinces, with farm planning and BMP adoption more likely in the East, particularly in the Atlantic Provinces and Quebec (Statistics Canada 2013), possibly because of more stringent regulation for nutrient and manure management than in the Prairies and more acute water quality issues.

Several studies have been carried out in Canada on factors affecting adoption of BMPs. Significant factors include: education, farm size, interaction with extension, enterprise type, debt level, farm diversification, age, and income. Biophysical characteristics such as type of land and elevation, and proximity to water bodies are significant (Kim et al. 2004). Social factors such as participation in environmental organizations and contact with extensionists also have a positive effect (Ghazalian et al. 2009; Kim et al. 2004; Paudel et al. 2008; Tamini et al. 2012; Nicol et al. 2010; Kutz et al. 2014; Hadrich 2012). Trust in government is an important factor in participation in government supported BMP programs (e.g., Kehrig 2002; Wang et al. 2015) as are attitudes and world views about the environment (Parker et al. 2007; Mitchell 2005). Barriers to BMP adoption include lack of awareness, lack of understanding of the feasibility and the costs of BMP adoption, and lack of funding (Amy et al. 2012; Ghazalian et al. 2009; Van Winkle and Hadrich 2011). Vercammen (2011) observes that while these results are not surprising, the influence of individual variables can be inconsistent from study to study and there is no theoretical framework for understanding which factors are most important for adoption. In a recent meta-analysis of BMP adoption Baumgart-Getz et al. (2012) identify 31 independent variables, many of which have only small effects individually. On this evidence it is hard to prioritize strategies to encourage adoption.

The greatest barrier to BMP adoption is cost (Statistics Canada 2013). Payments under Growing Forward are on a cost-share basis, but typically fall short of adoption costs for most BMPs. BMPs often have private benefits due to increased efficiency of inputs, as well as improved soil productivity and drought resilience. As technologies have improved and costs of water have increased there has been widespread adoption of BMPs which have private benefits. Nutrients are expensive and nutrient management BMPs can be profitable on average (e.g., Valentin et al. 2004). Similarly, zero till and conservation till are on average profitable (Sparling and Brethour 2007). On the other hand, BMPs to protect riparian areas are relatively high cost because they involve land use change and the reduction/removal of land from crop production (e.g. Jeffrey et al. 2014). For practices that do not have private benefits there has been little uptake even though in many cases the social benefits outweigh private costs and justify subsidization (Boxall et al. 2013; Cortus et al. 2011; Amy et al. 2012; Jeffrey et al. 2014).

21.4.2 *Contract Design*

The participation of producers in BMP programs depends on contract terms and their interactions with business risk management programs. Risks from BMP adoption include: production risk due to weather, pests and disease; price risk due to changes in prices for crops such as oilseeds; technological risk from not understanding the feasibility of practices; and institutional risk from program failure and regulatory change. Changing business risk management programs such as crop insurance and income support programs could increase adoption (Mitchell 2005). For example, Prince Edward Island has reduced insurance rates for crops that use nutrient management plans (CCA 2013).

The literature on BMP contract design is primarily concerned with producer preferences for contract length. However, there is more scope to understand the influence of business risk management on producer decisions to adopt BMPs. Major issues which must be addressed through contract design include high up-front costs, long time periods with no revenue, and high project risk due to long time horizons and uncertainty in realizing improvements in water quality (Goldstein et al. 2006). There are tradeoffs since fixed up-front payments result in moral hazard with overcompensation and underperformance. Long term agreements require premiums for loss of option value and may not compare favorable to short term agreements from a cost perspective. Lennox and Armsworth (2011) show how the choice between short and long contracts is affected by certainty about the future availability of alternatives. Understanding risk perspectives of producers is also important for understanding leakage and unanticipated consequences. For example reducing one input such as water might result in farmers applying higher rates of other inputs such as fertilizer and pesticides to reduce risk (Vercammen 2011). These interactions highlight the need for cross-compliance and a whole-farm approach in designing effective BMP programs.

The first-come-first-serve model for allocating Growing Forward funds has undoubtedly reduced program effectiveness, attracting producers and practices with low opportunity cost (Boxall et al. 2013). There is evidence of weak correlation between low cost practices and BMP effectiveness (Ribaudo et al. 2010; Boxall et al. 2013). Asymmetric information from land owners knowing more about their private costs and benefits than funding agencies results in adverse selection, with low cost low value contracts crowding out higher cost higher quality contracts (Wu and Babcock 1995).

Procurement (reverse) auctions for water management actions can be used to reveal costs and benefits of practices and to allocate funds more efficiently. Auctions are standard practice in other jurisdictions – for example they are used in the U.S. Conservation Reserve Program (Claassen et al. 2008). Properly designed auctions can increase producer participation and reduce the problem of adverse selection by targeting high benefit practices. Auctions include a number of design features such as the payment format, information about the budget, and the benefits of management practices that affect efficiency and participation rates. Unfortunately, there are few generalizable rules to guide the optimal design of auctions for BMPs (Latacz-Lohmann and Van der Hamsvoort 1998). There is evidence that over time producers learn about prices which reduces the competitiveness of auctions. Furthermore, indices to score and rank environmental benefits can lead to distributional consequences that must be considered in program design (Claassen et al. 2008; Rolfe et al. 2009). Nonetheless, overall the evidence seems to suggest auctions out-perform fixed price schemes.

Unlike other jurisdictions, Canada has been slow to use auctions to allocate budgets for procuring BMPs. There are notable exceptions. For example, Ducks Unlimited Canada and the Saskatchewan Watershed Authority used a reverse auction to procure wetland restoration in Saskatchewan's Assiniboine Watershed. In Manitoba Conservation Districts are using reverse auctions to allocate funds for IWRM. The auctions help to identify willing participants and practices, and the Conservation Districts have developed an Environmental Benefits Index to support water management objectives in Manitoba's IWRM plans. This information has been helpful for leveraging funds from Growing Forward, and other non-government agencies, which is a key to success when budgets are insufficient to fully implement programs.

21.4.3 Water Quality Trading

Limited budgets for the environment raise the difficult question of how to finance watershed restoration and who should pay for pollution reductions. Water quality trading is seen as a way to bring non-point source agricultural pollution under the regulatory umbrella (Shortle 2013; Shortle and Horan 2008). Water quality trading involves the trade of nutrient reductions between point and non-point sources and can be viewed as an innovative financing mechanism for non-point source reductions. The most common type of trading program involves an offset agreement between a regulated point source with specific emission limits – such as a waste water treatment plant – and other point or non-point sources. The U.S. has several such trading programs to meet requirements for permitted facilities under the National Pollution Discharge Elimination System. Over the last decade several multi-source trading programs have been established to meet Total Maximum Daily Load (TMDL) requirements under the U.S. Clean Water Act. This type of program involves trading between multiple point and non-point sources to collectively achieve a joint load limit or ambient target.

Water quality trading for agriculture poses unique challenges because of uncertainties in BMP effectiveness and difficulties monitoring non-point sources. However, there are increasing examples of water quality trading in agriculture as programs are being developed to meet TMDL requirements for large drainages such as Chesapeake Bay and the Gulf of Mexico. Two of the more significant programs in terms of number of participants and expected cost savings are the Pennsylvania Nutrient Credit Trading Program, which addresses the flow of nutrients from point and nonpoint sources in Pennsylvania to Chesapeake Bay, and the Ohio River Interstate Trading Program launched in March 2014. The Ohio River Basin covers 14 states and drains into the Mississippi River and eventually the Gulf of Mexico. The current program involves three states, Ohio, Indiana, and Kentucky and relies on all states operating under the same rules so that nutrient reduction credits can be traded between states. At full scale the project is expected to include eight states, with up to 230,000 farmers creating credits for 46 power plants and thousands of other industrial and municipal point sources (EPRI 2014).

Non-point to non-point trading programs are rare, though there are examples including the California Grassland Areas Program, which caps agricultural sources, as well as the Lake Taupo Nitrogen Trading Program in New Zealand, which has capped nitrogen loads for agriculture with landowners receiving allowances based on historical land uses (Selman et al. 2009; Shortle 2013). The California Grassland Areas Program operates like a point source program since it involves trading collected drainage water between irrigation districts (Shortle 2013). Both programs operate like cap and trade programs with the Lake Taupo program using public funds to purchase a 20 % permanent reduction in nitrogen. Both programs are notable for overcoming the political hurdle of imposing environmental regulations on the agricultural sector (Shortle 2013). Monitoring non-point sources in the Lake Taupo program is an ongoing challenge and the Lake Taupo Protection Trust, which administers the program, is currently exploring methods for farm self-monitoring and reporting through the use of Water Quality Management Plans. Water Quality Management Plans are used by the Environmental Protection Agency (EPA) for state and facility wide compliance. Their use for non-point sources from individual agricultural lands is evolving as a means of documenting compliance for individual operations.

One of the most important barriers to agricultural participation in water quality trading is onerous eligibility requirements and baselines. Eligibility requirements state which practices must be undertaken in order to create a credit. Baselines establish what practices are considered "additional" to business as usual and eligible for nutrient reduction offsets or credits. Programs can use current practice as the baseline or require a higher standard, such as an improved or best practice baseline. Controlled tile drainage is a potentially important practice for Ontario and Quebec, and thus the eligibility of this practice under EPA programs could be significant for any trading program addressing transboundary pollution in the Great Lakes. The US Department of Agriculture (USDA) and EPA have been examining whether the benefits of controlled tile drainage can be sold as water quality credits under EPA water quality trading programs (e.g., Skaggs and Youssef 2009). To date, EPA has not made a decision; however, the fact that controlled drainage is financially beneficial on average begs the question of whether this practice meets the test of financial additionality and requires additional incentives. Interestingly, controlled tile drainage may also be an effective way to develop a cap and trade program for agriculture, since the drainage outlets effectively become point sources.

The economic benefits of water quality trading arise from transferring high cost load reductions to low cost load reductions. This usually means rewarding "bad" actors who can make significant water quality improvements by undertaking relatively low cost BMPs and penalizing "good" actors who have already voluntarily adopted the low hanging fruit with further nutrient reductions only feasible through higher cost practices. This approach is often perceived as unpalatable by the public and seen as a way of rewarding polluters (Shortle 2013; O'Grady 2011). Furthermore, regulators are worried about paying for practices that are not financially additional since in theory the practice should be adopted without payment under business as usual. However, high baselines reduce participation and increase the cost of credits, ultimately reducing the abatement cost savings that can be achieved through trading between point and non-point sources (Shortle 2013).

21.5 Opportunities for Canada

In Canada there are no strong legislative barriers to water quality trading. Instead, barriers are related to lack of understanding of the specific form of pollution being addressed, concerns about hot spots, and developing the information systems and models as well as monitoring programs to support trading (Cantin 2006). The South Nation Conservation Authority Clean Water Program in Ontario is one of the first trading programs developed in North America. In this program point sources purchase offsets by funding BMPs in the agriculture sector. The program is interesting because the program is peer led – farmer to farmer – with the Conservation Authority acting as an intermediary between the buyers and the producers. South Nation bases nutrient reduction requirements for permitted entities on coefficients for BMPs derived from the literature and expert opinion. High trading ratios are then used to address uncertainties in the coefficients and ensure nutrient reductions. Agreements for nutrient reductions are between the point sources and the Conservation Authority which is liable for the nutrient reductions. From the farmer's perspective, the program is a BMP program and not a water quality trading program. In 2014, the Lake Simcoe Conservation Authority in Ontario launched an urban storm water Phosphorous Offset Program with a similar structure to offset new urban development. The program is administered by the Conservation Authority and will fund existing BMP programs run by the authority, as well as deliver specific protocols and mechanisms for procuring offsets for new development as demand emerges.

There are a number of opportunities to develop broader water quality trading programs to address some of Canada's urgent priorities around restoration of the Great Lakes and Lake Winnipeg Basins. In addition, there are opportunities to further develop smaller programs similar to the South Nation and Lake Simcoe programs where municipal waste treatment plants are facing the need to upgrade, or where there are local water quality challenges such as in the Bow River Basin in Alberta. Under the Canada-U.S. Great Lakes Water Quality Agreement new programs and approaches are required to reduce phosphorous loadings from urban, rural, industrial and agricultural sources in order to meet load reduction targets for phosphorous concentrations in Lake Erie (Environment Canada 2013; Goucher and Maas 2014).

Lake Erie is the third largest lake in North America. The Lake's water quality is very poor, with agricultural non-point sources blamed for eutrophication and a massive algal bloom which cut off water supply in Toledo Ohio for 3 days in 2014 (Goucher and Maas 2014; Carter 2014). Market based approaches have been recommended to address non-point source pollution from agriculture. With a surface area of 25,667 km^2 Lake Erie is bounded by Ontario to the North, Michigan to the West, and Ohio, Pennsylvania, and New York to the South and East. The inlet is the Detroit River which divides Canada and the U.S. and has a drainage of 1813 km^2. With several major cities including Detroit MI, Windsor ON, Toledo OH, Cleveland OH and Buffalo NY, it would be possible to develop a point-non-point trading program; the question is whether, similar to the Ohio

River interstate trading program, it would be possible to develop a program that could cross both international and state boundaries. At the least, Environment Canada, the Province of Ontario, and the EPA would have to harmonize rules for water quality protection and establish common protocols and indicators for BMPs. Increased education and trust building with farmers will likely be required; concerns include how reducing fertilizer might affect returns, especially when commodity prices are strong, and whether practices like no-till are effective or feasible for crops like corn (Carter 2014).

In June 2011, the Province of Manitoba passed the Save Lake Winnipeg Act included a number of initiatives and regulations to reduce the phosphorus load to Lake Winnipeg by 50 % to pre-1990 levels. The Canada-Manitoba Memorandum of Understanding "Respecting Lake Winnipeg and the Lake Winnipeg Basin" provides financial and technical support from both the Federal and Provincial Government to the Lake Winnipeg Basin Stewardship Fund, to reduce nutrient loads throughout the Lake Winnipeg Basin and its sub-watersheds. Similar to Lake Erie, Lake Winnipeg drains an enormous inter-jurisdictional basin covering approximately 1 million km^2, and encompassing parts of Alberta, Saskatchewan, Manitoba, Ontario, North and South Dakota and Montana. The basin contains 90 % of the Canadian Prairie's agricultural land and serves over 6 million people (Voora et al. 2009). The lake is one of the most eutrophic lakes in the world, and most loads come from non-point sources. Currently there are no efforts to address non-point sources through trading programs. In any case, it is not clear that demand from point sources would be sufficient to reduce phosphorous problems in the Lake. In order to seriously address the problem, given its scope, agriculture will have to face regulation making the basin a candidate for testing inter-jurisdiction trading between non-point sources.

Although there are no legal barriers to water quality trading in Canada, there are institutional ones. In 2006 the Policy Research Initiative engaged a group of experts to identify conditions that would have to be in place for a trading program to be successful (Cantin 2006). These included: the existence of a clearly documented problem, well-developed BMPs and the ability to quantify pollution reductions; an understanding of pollutant behavior and watershed dynamics for determining critical load and trading ratios; and a watershed that is well understood and well monitored (Cantin 2006). Canada would fail to meet most of these criteria. However, as the South Nation example illustrates they are overly stringent. Moreover, trading can provide a driver for filling in some of the gaps as market requirements emerge, particularly for coordinated science and monitoring and baseline data collection. Cantin (2006) also found a lack of flexibility on the part of regulators to relax regulatory standards for permitted sources. The expansion of programs in the U.S. and the urgent need to develop new programs for nutrient reductions in Canada may improve the appetite for risk taking.

21.6 Conclusions

Expansion and intensification of agriculture has remained possible, even with water constraints, due to better tillage practices and increased efficiencies in farm technologies and adoption of BMPs (Harker et al. 2004; CCA 2013). However, Canada's largest water bodies are showing stresses from agricultural impacts. The sustainability of both agriculture and water depend on addressing the impacts of agriculture on water quality. The need to act is urgent, however uncertainties, concerns about who should pay, and fragmented governance hinder action. Federal-Provincial and international agreements to address water quality in Lakes Erie and Winnipeg should encourage risk taking and experimentation. Building off a decade of BMP incentive programs, the time is ripe for coordinated effort between the Provinces and the Federal government to synthesize lessons learned, deepen investments in science and monitoring, and develop pilot projects in a coordinated fashion over large drainages so that initiatives can be knit together and rolled up into meaningful scale action.

Several opportunities to improve the effectiveness of agricultural water management have been identified. First, the Federal government can use its funding to link IWRM processes throughout the Provinces to provincial and national scale challenges related to eutrophication of major water bodies. Secondly, development of standardized monitoring and indicators across the provinces can help identify the contributions of BMPs from different sources to downstream water quality improvements, and can facilitate inter-jurisdictional program development. A combination of local, regional, and provincial water quality initiatives is necessary for managing drinking water as well as ensuring sustainable aquatic ecosystems.

Significant education and awareness building is required to engage the agricultural sector, in order to ensure that programs are designed to address norms, and that monitoring and enforcement of agreements is feasible. New monitoring strategies such as Water Quality Management Plans could be built off of Environmental Farm Plans and lessons can be learned from New Zealand and other jurisdictions that are testing these for farm level monitoring.

The Canadian decentralization experience can be compared to that of the United States where the Clean Water Act (1972) clearly outlines lines of authority and responsibility for water quality, and where decisions about water quality management are buffered from local interest through Federal control. In the US, Federal responsibility for water quality has led to standardization of monitoring and development of science and protocols for nutrient management and trading. The EPA provides a national regulatory backstop for water quality management with authority delegated to States, and USDA provides a national coordination role on private land efforts to meet water quality objectives. There is a need for the Federal Government in Canada to overcome bureaucratic fragmentation through multi-jurisdictional agreements with the Provinces and sufficient funding to implement programs at scale. Cross-ministry coordination is required and existing bodies such as the Canadian Council for Ministers of the Environment need to work more with their agricultural counterparts in developing joint agreements.

A tentative approach to agricultural water management will not reduce uncertainty, nor is it feasible to rely on other sectors to finance and address water challenges from agriculture. Canadian governments overall are risk averse, and Canada is a persistent laggard in innovative environmental management, often following the lead of other jurisdictions before developing its own programs. In the case of water management, programs in other jurisdictions provide a rich foundation of lessons and initiatives from which to build.

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